The effects of text spacing on screen reading time and comprehension

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Abstract:

As computers continue to become pervasive, learners spend more and more time reading and learning in front of the screen. In view of this, there is an increased need to rethink text layout on-screen for optimal readability and performance. The present study investigated the effects of spacing after the period on on-screen reading time and comprehension among college students. The results showed that there is insufficient evidence to support the claim that a significant performance difference exists, in an on-screen reading task, between text formatting using single space, double space, or triple space in sentence separation. The study suggested that the difference on reading time is more correlated to individual psychological factors such as age and reading strategy.

Keywords: Text Spacing, Readability, Reading time, Reading comprehension

Full Text:

INTRODUCTION

As technology-based learning environments have become pervasive, learners are spending more and more time working in front of the screen. Accompanied by this trend, enormous amounts of reading texts and tests, such as GRE and TOFEL, are designed as computer-based or web-based. While on-screen reading has become a common task for current learners, very few empirical research studies have been conducted to inquire about how on-screen text layouts influence reading tasks.

The present study explored the effects of spacing after the period on on-screen reading tasks through two dependent variables, reading time and reading comprehension. Specifically, it is a follow-up study intended to refine the design and measurement of our previous studies (Loh, Branch, Shewanown, & Ali, 2002; Clinton, Branch, Holschuh, & Shewanown, 2003). We anticipated that the results of this study would shed light on future screen design, Web-based testing, on-line publication, e-learning, and other on-screen document formats.

RATIONALE

Focus of Study

We focused our study on spacing after the period for sentence separation because of the following concerns: it was believed that optimum word spacing in a text would increase reading speed and permit more rapid copying (Saenger, 1982). In addition, conventional practice in typing was to use double spacing after the period, however, today's most popular word processing software, as well as newer versions of APA format, seems to contradict this tradition by putting

just one space at the end of the sentence (Loh, Branch, Shewanown, & Ali, 2002). A review of literature had shown that the design guidelines for on-screen display are different from those for print and therefore these guidelines might not be generalized to on-screen text design (Dillon, 1992; Kingery & Furuta, 1997; Geske, 1997; Juola, 1998). Further, a literature review of typography showed that most of the studies concerning spacing are about spacing between words or between letters. Study about spacing between sentences, however, is extremely limited. To bridge this gap, the researchers had conducted studies about sentence spacing summarized as follows.

Previous Studies

Two studies (Loh et al. 2002; Clinton, et al. 2003) were conducted to measure the effects of spacing after the period on reading time. Participants were all college students. The number of participants in the first study was 66 and that of the follow-up study was 82. Demographic data, such as gender, age, race, language, and hours spent reading on-screen each week, were also collected.

The experiment instruments consisted of passages adopted from GRE practice tests and followed by several multiple-choice comprehensive questions after each passage. These passages were reformatted into two versions in the first study: single space and double spaces after the period, while in the second study there were three versions: single, double and triple spaces. The different versions of texts were randomly assigned to an individual participant during the test. The layout was processed with Macromedia Flash and Microsoft Internet Explorer to simulate an actual on-line GRE test. Scripting technology was also applied to stamp the reading time. Before the test, a practice passage was presented to allow participants to become familiar with the interface.

Descriptive statistics and a two-tailed t-test were carried out using SPSS in the first study to compare reading time between the single space version and double space version of a certain passage, while one-way ANOVA was applied in the second study to compare mean total reading time among three conditions of passages (i.e., single, double and triple spaces).

Neither study provided evidence that there were statistically significant differences between reading time of single space and double space passages (and triple space in the second study). Specifically, in the second study, even after eliminating outliers such as impossibly short reading time, large amount of variation within groups still existed and could not lead to a different result.

The Present Study

As mentioned, we did not achieve satisfactory results in our previous studies. Data collected in the previous studies contained too much within-group variance to detect a statistically significant impact and to elucidate the research questions. Therefore, the main task in this study was to reduce within-group variance and to attack more significant factors impacting reading tasks.

First, we assumed that reading passages of GRE tests may have been too difficult for the participants at undergraduate level and nine passages seemed too long for participants to voluntarily accomplish. If a passage is difficult, the participant may be blocked by some individual words or sentences. If a reading task is long, the participant may become psychologically tired before he or she finishes the task. Both situations will greatly introduce variance. Thus, in this study, we changed the reading materials to an easier level suitable for undergraduate students and reduced the number of passages to three.

Second, important indices on reading tasks should include reading comprehension as well as reading time. Analysis of reading time only, rather than reading comprehension, may limit the applicability of the study to real-life reading tasks. Further, we also assumed that these two indices might be correlated; therefore, it was considered desirable to do multivariate analysis.

Each measure by itself reflects a small effect of the intervention, but neither is sufficient to conclude an intervention effect using a univariate test. Conducting multivariate analysis and including both of the effects might yield more precise and convincible results in terms of the intervention effects. Third, we postulated that some confounding variables contribute to the great variance. Those latent variables pivotal to reading time and comprehension may have been contributive to the great within-group variance and may have confounded the research results. As a way to control such variance, we decided to identify and employ these variables in the present study.

A literature review below showed that that reading strategies may be a confounding variable that had contributed to the great variance within experimental groups in our previous studies. As a way to statistically control such variance, we decided to include reading strategies as a variable in our study. The following passages depict the rationale and procedures we employed on this issue.

Including Reading Strategy as a Variable

Studies show that the use of reading strategies could evidently affect reading speed and reading comprehension. For instance, Dreyer & Nel (2003) outlined the format and structure of a strategic reading instruction component of an English for Professional Purposes course offered within a technology-enhanced environment. The results indicated that students who received strategic reading instruction in this environment received both statistically and practically significant higher marks on three reading comprehension measures than did the students in the control group. On the other hand, a review of literature also shows that reading strategies greatly differ between skilled readers and unskilled readers. Paris and Jacobs (1987) provided an illustration of the difference between the two types of groups:

Skilled readers often engage in deliberate activities that require planful thinking, flexible strategies, and periodic self-monitoring. They think about the topic, look forward and backward in the passage, and check their own understanding as they read. Beginning readers or poor readers do not recruit and use these skills. Indeed, novice readers often seem obvious to these strategies and the need to use them (Paris & Jacobs, 1987, p.270).

In view of the great potential of reading strategies to affect reading speed and reading comprehension, as well as great individual differences existing among readers, we regard reading strategies as a confounding variable that may affect the validity of the experimental variable, and therefore we have incorporated it into the experiment as a means of increased statistical control.

Measurement of Reading Strategy

There are several instruments that have been used to measure reading strategies. For example, Jacobs and Paris (1987) developed the 22-items Index of Reading Awareness to measure four aspects of strategies in reading: evaluation, planning, regulation, and conditional knowledge. Pereira-Laird and Deane (1997) developed a self-report Reading Strategy Use (RSU) to assess adolescent students' strategies when reading narrative and expository texts. However, most of these instruments either have questionable reliability and validity or lacks psychometric properties and would be difficult to use in research.

Mokhtari and Reichard (2002) developed the Metacognitive Awareness of Reading Strategy Inventory (MARSI) to measure adolescent and adult readers' metacognitive awareness and perceived use of reading strategies while reading academic and school-related materials. The Inventory comprises a total of 30 items and includes three subscales: Global Reading Strategies (13 items), Problem-solving Strategies (8 items), and Support Reading Strategies (9 items). The MARSI has been carefully tested and has good reliability and validity. The scoring method is simple: the subscale item scores are added up to get a subscale score; and then all three subscales scores are added together to obtain a total score. In this study, we refer to reduced and modified items from MARSI as the blueprint for measuring reading strategies. A total of ten items,

including five global reading strategy items and five problem-solving strategy items, were administered AFTER participants had completed all of the reading comprehension questions and guided them to RECALL what strategies they had just used. In order to be more suitable for the study, some items unrelated to the study were removed. The participants were then classified in groups with different levels of reading strategy: High and Low (Or High, Medium, Low), using the percentile as the dividing points. By including reading strategies as a controlled variable, we anticipated that the within group variance would be significantly reduced and thus more precise and accurate statistic results could be attained.

RESEARCH QUESTION

The research question of this study is: "What is the effect of text spacing on reading time and comprehension?", or "Does the space after the period affect reading time and comprehension?" The results from this study may provide implications for more effective on-screen message design.

RESEARCH DESIGN

Researchers were interested in characterizing differences among groups of students who were randomly assigned the same reading materials with different spacing after the period. The grouping variable is spacing after the period: one space, two spaces, and three spaces. The covariate variable is reading strategy, a total score of Global Reading Strategies and Problem-solving Strategies. The two main outcome variables are reading time and reading comprehension.

The text passages used in the experimental instrument were formatted with the spacing after the period of one space, two spaces, and three spaces. Each participant was assigned to only one of the three treatment conditions. Each participant read all three passages and was prompted to reply to all of the test items associated with the corresponding passage. The computer automatically records the time between when the participant received the screen with the passage and when the participant moved away from the screen.

A reading strategy questionnaire was also included after the reading passages. The reading strategy score includes the score of Global Reading Strategies, which represents a set of reading strategies oriented toward a global analysis of text, and the score of Problem-Solving Strategies, which represents the localized strategies for solving problems when text becomes difficult to read. We also designed items to collect other information, including demographic information, online reading frequency, confidence about on-screen reading, and information on the computer used by the participant during the study. Also, at the end of the experiment, we provided a text area for participants to express their experience, comments, or questions regarding this research.

DATA COLLECTION AND ANALYSIS

This study was conducted entirely in an electronic format with delivery through the Web. College students (n=63) in teacher preparation participated in the study. Permission was obtained from the Institutional Review Board for Human Subjects of the University. The participants consisted of a total of 48 females and 15 males, age ranging from 18 to 42 (mean= 21.3, standard deviation=3.83). All reported that English is their first language. Around 90% of the participants reported that they feel comfortable with online reading. About 10% of the participants reported that they spent more than 10 hours per week in reading both paper-based and online print materials.

Participants were initially directed to the web address (http://..../) for the study by their class instructors. The online consent form was presented to the participants before the reading task. The participant then completed a short demographic survey, including age, gender, how often he/she reads text on screen, and native language. Then, upon clicking a button to begin reading a passage, participants were randomly assigned to either the 'single space', 'double space, or 'triple

space' group. After they finished reading each passage they could click another button to move on to a page with comprehension questions. On that page, after selecting answers, participants could then click on a button to "proceed to the next reading task." There were a total of three passages. Each text passage would normally require no more than ten minutes. After having finished the third passage, participants were asked to fill out an online questionnaire with ten items regarding reading strategies. At the bottom of questionnaire, there was a button to "end." This would complete the activity and each participant was thanked for participating in the study via a "Thank You" page. The information regarding the computer where a participant worked was also automatically submitted along with experimental data.

A descriptive analysis was first conducted after completion of data collection, and then a series of analyses of variance (MANOVA and ANOVA) and correlation analysis were conducted to examine main effects. Table I presents the means and standard deviations of each outcome variable for each group. The data of four samples were excluded because of missing data.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR THREE CONDITIONS OF SPACING

Spacing	Mean		Standard deviation		Sample
	Time	Comprehension	Time	Comprehension	Size
One-space	302.40	7.20	100.244	2.526	20
Double-space	327.04	7.88	126.996	2.383	24
Triple-space	319.87	7.40	122.270	3.158	15

Then, a multivariate omnibus analysis of variance was conducted to determine the effect of the three types of text spacing (one space, double space, and triple space) on the two dependent variables, reading time and reading comprehension. Significant differences were not found among the three spacing conditions on the dependent measures, Wilks' A = .982, F(4, 110)= .249 . The p value for this statistic is .91. The MANOVA omnibus effects are not generalizable. Based on this result, we conclude that there is no sufficient evidence to reject the hypothesis that groups differ and conclude that the three group centroids are identical.

Analyses of variance (ANOVA) on each dependent variable were conducted as follow-up tests to the MANOVA. The univariate omnibus analyses gave significance levels of time and comprehension as .483 and .687 respectively. Table 2 presents the one-way ANOVA results from SPSS. We concluded that there was not enough evidence to suggest that a significance difference exists in on-screen reading tasks, between text formatting using single space, double space or triple space in sentence separation. The conclusion is similar to those from previous studies (see Loh et al., 2002; Clinton et al., 2003).

In order to reduce the within group variation, we also used the variable of reading strategy as a covariate and conducted a one-way analysis of covariance (ANCOVA). Table 3 presents the results of the ANCOVA test. The ANCOVA was also not significant, F(2, 62)=.386, p= .68. Once again, we find that insufficient evidence to conclude that there is a statistically significant difference between uses of different spaces after the period in a passage, even when we controlled for the variable of reading strategy. However, the test of the relationship between the covariate of reading strategy and the outcome variable of reading time does show a strong relationship, F(1, 62)=5.13, p=.027. The results of this analysis confirmed the researchers' belief that reading strategy affects reading time.

Correlation coefficients were computed among age, reading time, reading comprehension and reading strategy. The results of the correlation analyses are presented in Table 4, which shows that, at the .05 significance level, the relationship between age and reading time, reading time and problem solving strategy, is large, .302 and .499, respectively. In general, the older a participant is, the more time he or she possibly spends on reading a passage. The higher problem solving

skill a participant has when text becomes difficult to read, the less time he or she possibly spends on reading a passage. However, reading comprehension does not correlate to either of those variables at the .05 significance level.

In addition, an independent-samples t-test was conducted to evaluate the hypothesis that participants who had been tested on different types of computer, Mac or PC, would need different reading time. If the text spacing after the period would make a difference, we could also ask

whether there would be a difference between working on Mac and PC. The test was not significant, t(61)=1.29, p= .228. Therefore, there is also no evidence that reading time on different types of machines would be different.

TABLE 2. ONE-WAY ANALYSIS OF VARIANCE FOR READING TIME AND COMPREHENSION

		Sum of Squares	Df	Mean Square	F	Sig
Time	Between Groups	21634.49	2	10817.24	.736	.483
	Within Groups	881966.50	60	14699.44		
	Total	903600.98	62			
Comprehension	Between Groups	5.29	2	2.64	.378	.687
	Within Groups	391.43	56	6.99		
	Total	396.71	58			

RESULTS, DISCUSSION, AND CONCLUSION

This study measured how screen layout, specifically spacing after the period, could possibly affect the time and comprehension on a reading task. Research results provided insufficient evidence that time and comprehension differ significantly among different conditions of spacing between sentences. Even when we included reading strategy as a covariance, the difference between text spacing was still not significant. However, the research does indicate that some individual factors, such as age and reading strategy, may significantly influence reading time.

TABLE 3. TESTS OF BETWEEN-SUBJECTS EFFECTS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	92892.618(a)	3	30964.206	2.229	.094
Intercept	35254.483	1	35254.483	2.537	.117
Strategy_total	71279.013	1	71279.013	5.130	.027
Text_spacing	10722.389	2	5361.194	.386	.682
Error	805868.350	58	13894.282		
Total	7442312.000	62			
Corrected Total	898760.968	61			

a R Squared = .1 03 (Adjusted R Squared = .057)

Moreover, the following issues were raised during data analysis and might be worth consideration for future research design and methodology regarding sensitive detection of effects such as that of text spacing.

a. Within Group Variance vs Between Group Variance

In the ANOVA analysis, we noticed that much more within group variance exists than between group variance. This phenomenon could occur for two possible reasons. One is that spacing actually does not impact reading time and comprehension, as in the case of other physical factors in our study, such as computer types. Another is that the effects of other latent factors that we have not controlled surpass the effects of text spacing. For example, most probably, the factor of

sample's off-task behavior could affect time and comprehension greatly. Since the measurement did not control for off-task behaviors, the research instrument may still not accurately measure the actual time students spent on reading. One of our participants expressed this observation: "Many students who chose to do this, may not have been into the material enough to want to answer the questions. So they just answer the questions to get it over with.' Without a strictly constrained psychological condition, like in an examination, off-task behaviors would be very hard to reduce and would be a main source of variance. Therefore, we have too much within group variance covering variance between groups and thus we could not detect the delicate effect of text spacing, if any exists.

b. Physical Factors vs Psychological Factors

Through this series of studies, we have realized that there are many latent and confounding factors that we cannot cope with. These factors can be divided into two major classes, physical factors and psychological factors. Physical factors here mainly refer to factors that allow participants to receive the same physical image of the reading passage. We may call these external factors, including text layout, screen size, background color, etc. These physical factors pose a difficulty regarding making sure two participants to receive the "same" image of a passage. For example, it is virtually impossible to have the text appear at exactly the same size on every monitor. The dot pitch of 96dpi on Windows versus 72dpi on some Macs, the resolution of the screen (I 024x768) vs (I 240x900)--all such factors will influence the actual size of the text on the screen, even if the text was formatted as a graphic, as was the case in the Loh et al. (2002) and Clinton et al. (2003) studies.

TABLE 4. CORRELATIONS AMONG VARIABLES

		age	time	comprehension	Global strategy	Problem-solving strategy	Strategy total
age	Pearson Correlation	1	**.302(**)**	-.053	-.095	.059	-.024
	Sig. (2-tailed)		.044	.728	.538	.704	.879
	N		45	45	44	44	44
time	Pearson Correlation		1	.211	-.070	**.499(**)**	.296
	Sig. (2-tailed)			.164	.653	.001	.051
	N			45	44	44	44
comprehension	Pearson Correlation			1	-.057	.105	.033
	Sig. (2-tailed)				.712	.498	.830
	N				44	44	44
Global strategy	Pearson Correlation				1	.084	**.730(**)**
	Sig. (2-tailed)					.589	.000
	N					44	44
Problem-solving strategy	Pearson Correlation					1	**.742(**)**
	Sig. (2-tailed)						.000
	N						44

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Psychological factors refer to factors in which mental structure and processes affect the reading task. We may call these internal factors, such as reading habits, cognitive styles, problem solving skills, etc.. Through this study, we conclude that internal factors, such as reading strategy, are more significant factors influencing reading time and comprehension. The comments from our participants also support this conclusion. Several participants expressed that the topic of reading materials is more influential on their interest and therefore performance. As one participant said, "I

tended to read the articles that were more interesting more closely than the ones that did not interest me at all." Another participant stated, "I think I paid closer attention to the article about euthanasia [one of the reading passages] because I was more interested in that subject. I did not do this intentionally, but I just found myself paying closer attention to it possibly because it was easier to understands" Another expressed how reading style or habit impacts her reading performance: "I find it hard to read passages online because it hurts my eyes and causes a distraction. I'd rather print it out and read it." Since such internal factors seem more influential than external factors, like text spacing, will tend to increase within group variance and surpass the variance coming from effects of text spacing.

Moreover, a certain design of research instrument may favor participants differently through psychological factors, and therefore will also increase within group variance. In our study, in order to measure time accurately, passages were presented in such as way that a participant cannot go back once he or she starts to answer questions. However, this design is not beneficial for certain kinds of reading habits. Just as one of our participants, who likes to do reading back and forth, said, "I have always had a hard time reading and comprehending information, especially if I'm not allowed to go back and review over what I had just read." Therefore, the design of a more sound research instrument may be considered for future research.

In sum, this study was intended to use reading time and reading comprehension as indicators to investigate effects of spacing after the period. While we could not find sufficient evidence to support group separation, in the context of this study we conclude that reading time is more correlated to some individual psychological factors such as age and reading strategy.

From the view of research design, we also found that much more within-group variance than between-group variance exists in this kind of sensitive detection effort. This phenomenon indicates that more latent variables need to be controlled. Through the correlation analysis, we believe, if we want to detect the delicate effect of text spacing after the period, we first need to control or measure more influential psychological factors or internal factors.

RECOMMENDATIONS

Further study of effects of text spacing will require more accurate ways to measure a user's time and comprehension, and more control of latent variables in order to detect the small effect introduced by spacing. Among these variables, psychological factors exert a significant influence on reading tasks and, therefore, should be first controlled or measured. For example, we may create a real examination context so that the psychological state for the reading task would be in a stressful condition, or we may give a credit related to a course or give some incentives to participants so that they will be under mild stress, although these measures may introduce issues for getting IRB approval. Since reading time and achievement are more related to psychological factors, future research in the area of on-screen text could also look into the effects of text layout that may introduce certain psychological conditions.

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	N			45	44
compre hension	Pearson Correlation			1	-.057
	Sig. (2-tailed)				.712
	N				44
Global strategy	Pearson Correlation				1
	Sig. (2-tailed)				
	N				
Problem-solving strategy	Pearson Correlation				
	Sig. (2-tailed)				
	N				

		Problem-solving strategy	Strategy total
age	Pearson Correlation	.059	-.024
	Sig. (2-tailed)	.704	.879
	N	44	44
time	Pearson Correlation	.499(**)	.296
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	N	44	44
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