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The influence of text visualization on the screen on eye movements and information processing

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Abstract
Since the last decade Internet has become a rapidly growing source of professional and scientific information. This trend necessitates defining new standards for presenting sophisticated texts to facilitate their efficient processing. The experiment involving 40 participants presented in this paper investigates the influence of text visualization on text recall. We contrasted text scrolling versus dividing paragraphs into separate screens and additionally provided drop-in quotes for both conditions. The dependent variables were derived from a text recall test conducted at the end of the experiment combined with eye tracking data regarding average fixation and dwell time. Sensory processing was tested using word recognition tasks, whereas the semantic level was examined using synonyms and multiple-choice questions. Based on the results, we argue that text visualization techniques are likely to facilitate information processing on the sensory and semantic level. Eye tracking data shows differences in reading efficiency; it was observed that scrolling required more processing time comparing to reading text divided into screens, while the results from a recall test remained almost identical. More specifically, participants from the latter group memorized more words that had never appeared in the original text. In addition, we observed significant differences in eye movements for middle paragraphs.

Keywords

eye movements, text processing, text visualization

Introduction and related work

During the last decade Internet has grown as a major source of scientific information for both researchers and science passionates. There are many guidelines regarding publishing non-scientific texts on the Web [1,2], however, such guidelines might not be equally useful for scientific material, as they concern publishing texts for commercial purposes or news websites. The question posited in this article regardswhether manipulation of the text visualization could facilitate more effective processing which would allow publishing of scientific texts in an unchanged form. This study combines knowledge from the domains of design, in particular from typography, and cognitive psychology.

In the research on eye movement analysis two major lines of studies are distinguished. The first one concerns research on reading processes taking place on basic level of text perception, such as the influence of semantic content or word frequency on eye movements (for a review, see [3]). The second line of studies investigates text perception in a complex environment, where it is surrounded by other elements such as graphics or other verbal stimuli. Such experiments were conducted in a natural setting – participants were asked to read a newspaper [4,5] or perform a task on a website while their eye movements were recorded [6,7,8,9]. In this type of research, results are interpreted in the context of interaction between particular visual elements, such as headlines, information graphics, photographs, or quotes and their relative attractiveness in the context of visual attention [10,11].

Displaying texts on a computer screen is limited by technical possibilities of equipment, such as screen resolution and pixel size. In recent design research [12,13], particular attention has been paid to the global design factors, such as the sanserif typeface appropriate for screen displaying, characterized by suitable x-height and intraglyph space, as well as proper type size proportional to the screen size and the distance between the user and the screen. On the other hand, literature from the field of psychology and human factors brought interesting results in reference to the length of text recommended for a single screen display. For example, it is known from previous research [14] that dividing text into separate screens might influence text processing, also when it comes to user's preferences. More recent studies yield interesting, yet confusing results. Sanchez and Wiley [15] observed no significant differences in reading time between groups that read the same text presented on one versus few separate screens without taking into account individual differences; on the other hand, Baker's [16] data suggests that dividing text into separate screens elongates mean reading time. However, none of these studies used eye movements data as a dependent variable.

In the study by Holmqvist and Wartenberg [5], participants were asked to read a newspaper while their eye movements were measured using a head-mounted eye tracker. In such awaythe influence of local design factors, such as size, information graphics, color, fact boxes, or drop-in quotes on eye movements was investigated. Results showed that, while most design elements influenced text perception, this effect was different for attracting attention and for sustaining it. Interestingly, call-outs positioned inside the text and fact boxes on the margins seemed to be facilitating both types of attentional processing. Experimental data suggests that

standards used for text display on a computer screen may have an influence on its processing and further recall [1]. Possibly, it is particularly important to follow certain standards in case of sophisticated text, which requires more attention from users, such as, e.g. scientific articles. According to previous research [5], elements that might facilitate both early processing and sustained attention include, but are not limited to, side notes/call-outs, drop-in quotes with additional facts or quotes from the main body of the text. As far as layout design is concerned, separating text into several screens has been previously discussed [14, 15, 16] as a possible factor; however, reported results are ambiguous and worth further investigation. In this view, the present studycombines methods from cognitive psychology and design to provide a unique insight into cognitive processes mediating text processing and recall [10].

Method

The experiment took places as a part of a Brain Weekend organized by SWPS. The goal of this event is to propagate knowledge regarding different types of research work related to brain to the wide non-scientific audience. The event was visited by approximately 200 people. Study participants were randomly recruited from arriving visitors.A total of 40 participants with normal or corrected-to-normal vision volunteered to participate in the experiment. Each session lasted on average approximately 10 minutes. After giving their informed consent and eye-tracker calibration participants were required to read a text of popular-scientific nature consisting of 400 words on 22-inch monitor while their eye movements were measured. The presented text was extracted from the autobiography of Maria Skłodowaska Curie [18] and regarded her research advances in the field of chemistry.

In the *pagination* condition, participants were asked to navigate between screens using arrows, whereas in the *scrolling* condition they could use a mouse to scroll up and down.

After reading the text and performing a 2-minutevisual task, participants were asked to complete a questionnaire, which consisted ofmultiple-choice questions and a list of words.

Apparatus and Materials

Eye tracker

To measure eye movements, table-mounted eye tracking system with 120Hz sampling rate and consisting of a 22'' monitor with integrated infrared camera was used (SensoMotoric Instruments, Berlin, Germany).

Text

Text used in the study came from Maria Skłodowska-Curie's autobiography [18], and pertained discovery of radium and its most popular applications. It was described by participants as moderately challenging due to largenumber of scientific terms.

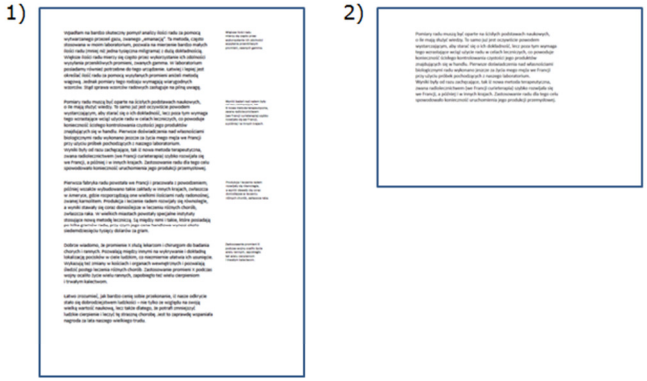

Figure 1. Stimuli used for scrolling condition with callouts (1) and pagination condition without callouts (2).

Questionnaire:

There were twelve questions (two per each paragraph - one of them was related to the text contained in side notes/call-outs and one was not), and the subjectcould choose answers among these three options. The list consisted of 24 words, from which the subjects had to point out those that appeared in the text. The words were divided into four categories: words which appeared in the original text, words which sounded similar to the words from the text, synonyms to words from the text and finally words which were not connected with words from the text in any way.

Variables

Dependent Variables (DV):

Eye Tracking Data:

- *dwell time*- the sum of all fixations and saccades made in aparticular area. In this experiment, it was interpreted in terms of the length of the reading time both for each individual paragraph and for the entire text.
- *average fixation time* –an average length of a fixation made in a particular area of interest.
- *fixation count* –a sum of all fixations made by a participant in a particular area.

Independent Variables (IV):

1. *scrolling* versus *pagination*
2. presence versus absence of *call-outs*

Results

Eye Tracking Results:

With respect to the reading of the entire text, a significant increase in both average fixation duration (Fig.2) and dwell time (Fig.3) was observed in the scrolling condition $t(18.08)=1,914$; $p=.072$. Equal variances were not assumed. Further analysis revealed that those differences were particularly strong for middle paragraphs (Fig. 4 shows

significant differences, p<.05). Analysis of fixation count for *scrolling* and *pagination* showed no significant differences between the two conditions.

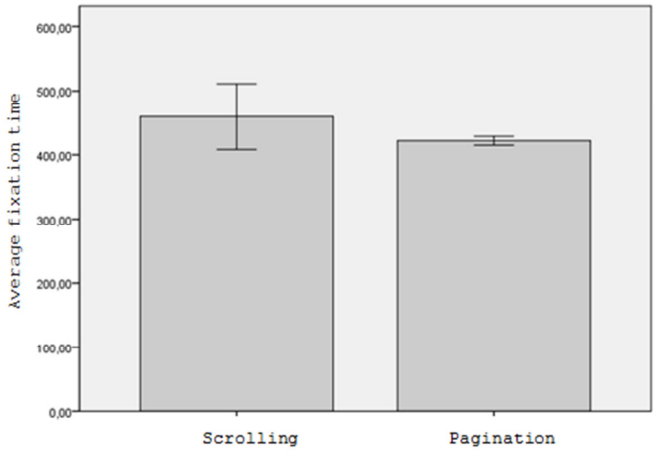

Figure 2. Average fixation time for *scrolling* (*M*=248,92ms; *SE*=55,04ms) and *pagination* (*M*=217,83ms; *SE*=8,01ms) conditions.

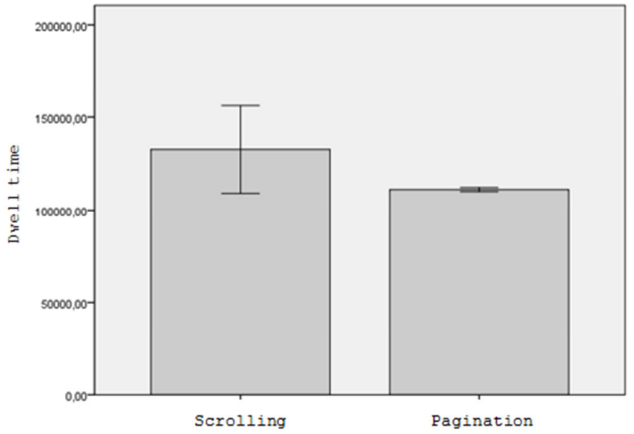

Figure 3. Dwell time values for *scrolling* (*M*=132,66 sec; *SE*=48,778 sec) and *pagination* (*M*=111,22 sec; *SE*=2,41 sec) condition.

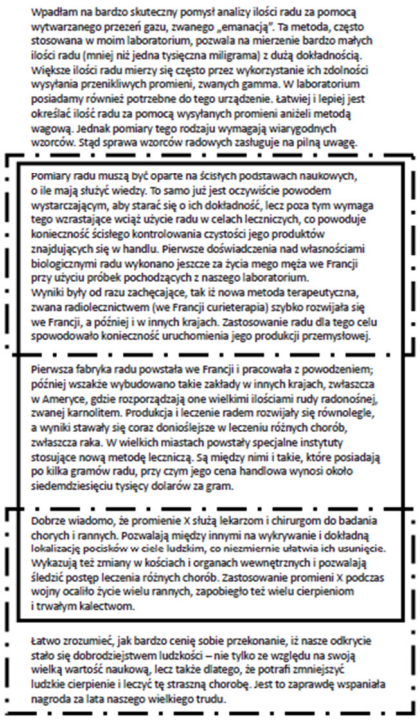

Figure 4. Significant differences (p<.05) in dwell time (—) and fixation duration (— · —) variables for the *scrolling* condition.

In the same time, no significant differences between the conditions with and without *callouts* were observed in eye tracking data (p>.05), with an exception of the fixation count variable. In the condition with callouts, significantly more fixations were observed in the whole text t(38)=2,17; p=.036 (equal variances assumed).

Recall Test Results:

The results showed no statistically significant differences in the efficacy of the recall between *scroll* vs. *pagination* conditions. Also, no influence of call-outs on the text recall was determined. The only significant difference was observed in the number of errors when it came to marking of the words unconnected with those from the original text in both conditions. In other words, users from the *pagination* condition claimed they had seen words in the text that had never been there.

Discussion and further research

The goal of this experiment was to investigate the influence of the selected visualization techniques, such as pagination and scrolling supported by call-outs on text recall. Results showed that, although users spent on average more time reading text displayed on one screen (scrolling condition), especially on middle and last paragraphs, it had almost no effect on later recall. In other words, separating text into several screens had a beneficial influence on reading efficacy. The fact that differences in mean reading time pertain especially middle and last paragraphs of the text might be explained by the fact that at the beginning all users viewed similar displays, with only first paragraphs visible. Discrepancies were observed in the eye tracking data after one group had to use scrolling in order to continue reading, which might suggest different processing of the subsequent paragraphs. Interestingly, previous research suggests that working memory capacity (WMC) might have an influence on reading efficacy [16]; namely, users with lower WMC in the scrolling condition had lower results on later recall. At the same time, WMC had no effect on participants who read text separated into several screens. Possibly, individual

differences might have an influence on reading sophisticated texts; however, this requires further research.

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