Color-coded Document Catcher: Interface for Reading Online Documents Using the Psychological Effects of Color

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Abstract

Online documents have two major advantages over paper documents: hypertext and a larger volume of data space in which online reference is possible. However, compared with paper media, electronic media are not necessarily the best in all circumstances. Many people print an online document on paper and then read it. Here we attempt to create an online document interface to support this reading. Having analyzed cue information used to accelerate reading of online documents, how the system should present the documents, and how the documents should be operated by users, we proposed an online document interface that removes hindrances to reading and supports active reading. We also employ the psychological effects of color in order to realize this interface. Moreover, we confirmed the effectiveness of the proposed color interface by comparing it with both a randomly colored interface and a colorless interface.

1 Introduction

The advantages of online documents are its hierarchical text structure (hypertext), which cannot be realized on paper, and the larger volume of data space in which online reference is possible. The use of online documents have spread in people's daily lives not only at companies but also at schools and homes. Therefore, the intellectual activity of reading is changing from being on paper to being on a computer.

However, compared with paper media, electronic media are not necessarily the best in all circumstances. Many people still print an online document out on paper and then read it. A computer user must pay attention to small details like how to move the mouse pointer toward the small slider on the right side of the screen when using a scroll bar, or finding it difficult to follow a display when moving a mouse wheel too much. Consequently, these extra computer tasks make it difficult for users to concentrate on the original task of reading.

If the interface can remove hindrances to reading and support active reading, we believe the interface will further the user's reading comprehension (Ichino et al., 2004 & 2005). The purpose of our study is to activate users' thinking activities of reading by analyzing both the obstruction factor and the furtherance factor of a user's reading.

In the following section, we analyze cue information used to accelerate reading of online documents, how the system should present the documents, and how the documents should be operated by users. In section 3, we study an online document interface for reading support and demonstrate the interface. In section 4, we demonstrate the effectiveness of the interface method compared with a general interface. In the last section we provide a summary of our findings.

2 Text Representation of Online Documents

This analysis studied the reading of online documents. Our study focused on the function of browsing the text displayed on one page in a Web browser. Considering existing circumstances and earlier studies about online documents, we first asked the following questions:

- What are the elements of cue information for accelerating active reading?
- How should a document and its cue information be represented in order to support active reading but not prevent reading?

- How should a document and its cue information be operated by a user in a limited space in order not to hinder reading?

Section 2.1, 2.2, and 2.3 describe each.

2.1 Cue Information for Active Reading

We classified the cue information for accelerating active reading into three types: text structure, intention of the writer, and text message, and then analyzed each piece of information. We also considered mechanical extraction of the information as the application possibility to a user interface.

Text structure

A text consists of sentences located one-dimensionally in a line. Generally, a person's reading process of a text follows a set pattern. First, a person takes in information one after another from some text. Then, he/she attaches a relationship to them. Finally, he/she creates a structure summarized semantically from the text read. By applying the method of calculating a similarity between texts currently used practical in the field of information retrieval, the relation between texts can be extracted somewhat mechanically. In our study, the relevance between partial units of a text is expressed as a text structure.

Intention of the writer

Text can also be regarded as a medium of information exchange between a writer and reader. For example, with an exam prep book, an author often expresses parts to emphasize to the reader by underlining text or changing the text color. Information can be expressed on multiple layers by using such expression methods. While various viewpoints can be considered as intention information from the writer, we adopted the concept of often-used important sentences based on the field of Automatic Summarization (Mani, 2001). In our study, a part that the writer or readers consider to be important for understanding the contents is expressed as an intention of the writer.

Text message

A text can be divided into two parts: the part to which a writer expresses his/her opinion subjectively, and the part that he/she describes objectively using concrete examples. The latter is information that can be imagined and judged easily from everyday experience. If we read a text after guessing what contents are being treated, then understanding will progress (Hisahara, 1980). By specifying parts with high concreteness in a text, we believe that the user's understanding would be promoted. Moreover, at the sentence level, this information can be evaluated somewhat formally (Minami, 1998).

2.2 Intelligible Representation of the Document

A person who is solving a problem uses not only the internal knowledge about it but also the external knowledge such as a figure or a color (Zhang & Norman, 1994). It means that presenting some elements of information about a certain object using an external representation must be helpful to enhance problem solving in combination with the internal knowledge. The information in a text is represented as streams of characters, which have one-dimensional structure. Our idea is that we help readers to reconstruct text information in their mind by presenting some elements of cue information of the text in an external representation (Figure 1).

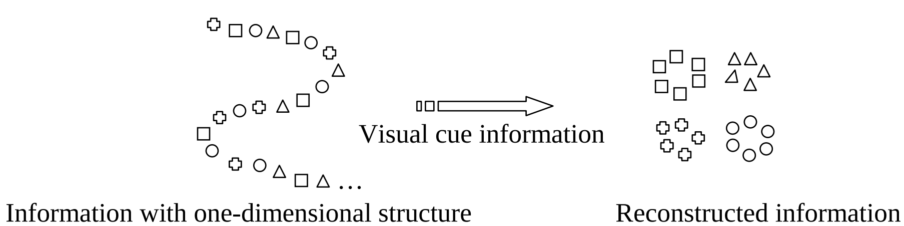


Figure 1: Reconstruction of text information

A user needs to learn how to match the visual information shown with the cue information. If the visual information is complicated, it could burden the user's memory because the user would have to keep it in mind, such as "this visual information corresponded with the cue information for XXX." Therefore, the most suitable presentation method is also one that associates certain semantic relationships between visual information and cue information.

Furthermore, to be able to perceive cue information while following the character of a document, high visibility of the cue information is important. However, when the presentation of the information is highly stimulating, such as being extremely remarkable or dynamically changing, the reader may slip out of reflective thinking. In this case, the most suitable presentation method is one that can be perceived easily but that does not divert a user's attention too much.
In summary, the requirements for cue information are: visual information, easiness to interpret of the information, and perceptibility to a level that does not divert attention too much.

For a document, we consider it important that a reader interprets the contents actively, which is why we present a document as it is, without processing the text. When reading a document on a display, it is known that the effective divisional unit of a document is a segment unit (Pynte & Noizet, 1980). When reading on paper, a reader will often return and reread a preceding page, especially a topic is divided from one page to another. In a book, a page often changes where a chapter or a paragraph changes. Therefore, we divided a document into paragraphs and indicate this.

2.3 Operation Not to Prevent Reading

The basic operation in the reading activity studied here comprises four phases. For each phase, we arranged three existing interface elements—a scroll bar, a wheel mouse, and an overview+detail interface for immediately moving to a part being read—using Donald Norman's 7-stage model, and analyzed what user difficulties might occur. Based on these elements, we extracted the following as requirements for designing the operation to not prevent reading.

Check of the present reading position
When a user thinks "I want to read around XXX," the user will first check where they are presently located in the whole text. A user must be able to easily perceive an object that shows the present location amid the whole and that easily specifies the present position.

Guess of the position of a movement location
After checking the present position, the user next tries to guess where the place is that they want to read in the whole text. A user remembers roughly the location where he/she wants to read. Then he/she plans how to operate a movement object and whether it changes from one state to another. The mark function makes it easy to quickly remember where the contents read are at the same time making it easy for the user to perceive.

Operation for move operation
The user next tries to touch an object to change the contents of a screen display. To make it easy for the user to reach an object to be moved, the user must be able to easily perceive the intended area to select.

Move operation
After a user touches a object to move, he/she moves it and actually changes the contents of a screen display. The user needs to gaze at a text during operation of the object. The user therefore needs to operate an object without having to look at it.

3 Color-coded Document Catcher

3.1 Psychological Effects of Color

Color not only has the effect of giving the user a favorable impression but also offers various psychological effects as well. We used the literature (Yamanaka 1997) about the psychological effects of color. The main effects we used are summarized below.

Sensory effects of color
These effects involve discrimination of colors first, after physical colors stimulate the eyes. Humans can visually discriminate about 7.5 million colors. Furthermore, a color can be described in three ways: hue, saturation, and lightness, which humans can recognize intuitively. Hue, saturation, and lightness express the basic quality of the color such as red or blue, the lightness of the color, and the strength of the color, respectively. We focused highly on this capability for humans to discriminate colors.

Perceptual effects of color

These effects occur in response to the influence of the stimulus of neighboring colors spatially or in time. We observed one of these effects, the feature in which a color with a high saturation is especially noticeable compared with surrounding colors.

Feeling effects of color

These effects are classified into perceptual-feeling effects and emotional-feeling effects. Perceptual-feeling effects are based on the inherent characteristics of a person's vision system. Emotional-feeling effects are effects that are uniquely possessed by an individual. We observed one perceptual-feeling effect, a feeling of hard and soft where the lower (higher) the lightness, the harder (softer) the person can feel.

Using colors carefully can become a very powerful means to bring a user's attention to important points, summarize information, and classify information. It is not easy to create such effects except by using color. We believe that the readability of a document can be improved by using the above-mentioned effects.

3.2 User Interface Design

Based on the analysis of the previous section, we designed the user interface. In this research, the operation design performed satisfies the requirements described in section 2.3 by applying and improving the overview+detail type interface said to be most suitable for electronic documents (Hornbæk & Frøkjær, 2003).

3.2.1 Presentation of the Document and Cue Information

To display a document organized into paragraphs, we enclosed each paragraph in a Web page with a colored border expressing the three above-mentioned items of cue information (the detail frame, Figure 2, left). To the right of the detail frame we displayed the overview frame, reduced to a size that could display the entire document. The same colors used as borders for each paragraph in the detail frame were used for background colors in the overview frame (Figure 2, right).

We produced the following information displayed as cue information for reading awareness:

- *Relevance between paragraphs*: Which paragraph is related to which other paragraph?
- *Importance of a paragraph*: Where is the paragraph in which a writer's insistence especially appears?
- *Concreteness of a paragraph*: Where is the paragraph described more concretely?

To meet the requirement that the cue information be shown so it may be easy to perceive for a user while reading a document, however so a user's attention may not be called too much, we produced the cue information visually using colors. Moreover, to meet the requirement that cue information remind the user of the semantic content, we used the various effects of color mentioned in section 3.1 above. We made the three attributes of a color—hue, saturation, and lightness—correspond with the three elements of cue information—relevance, importance, and concreteness, respectively.

Figure 3 illustrates how one color can express the three elements of cue information simultaneously by comparison with surrounding colors. Since a user needs to recognize the distance between paragraphs, we made Relevance correspond to hue sentiently arranged at equal intervals. For example, a user can intuitively grasp that the Relevance of paragraphs shown in light blue and bluish green is high, while the Relevance of paragraphs shown in light blue and purple red is low (Figure 3, upper left). For Importance, saturation is most suitable since saturation and the degree of awareness are related. A paragraph with high Importance assigned a color with high saturation can attract a user's attention immediately (Figure 3, center left). For Concreteness, lightness is most suitable because it affects a feeling of hard and soft about a color. A particular concrete text has a soft impression. By assigning a color with high lightness to a paragraph with high Concreteness, a user can easily discriminate the concreteness of a paragraph (Figure 3, lower left).

3.2.2 Operation Not to Prevent Reading

Check of the present reading position: To make it easy to perceive the present reading position, we enclosed the paragraph of the overview frame currently being read with a gray-border (Figure 2, right). Moreover, after perceiving, for specifying where the present location is among the whole text, the feature of the overview+detail type interface can be used as it is.

Guess of the position of a movement location: Since a user can be reminded of the three elements of cue information from the color of a paragraph, this makes it easy to immediately identify one's location in the content being read.

Operation for move operation: To make it easy to perceive the area being pointed to at the time of movement, in the overview frame we made the whole paragraph the pointable area instead of an isolated character sequence—Conventional overview+detail. It then becomes even easier for the user to perceive the pointable area since it is not only large, but also separated from other areas by color (Figure 2, right).

Move operation: To operate without seeing the object to be moved, when the pointer enters anywhere within a paragraph in the overview, the paragraph in the detail frame is displayed in the center of the page (Figure 2, left).

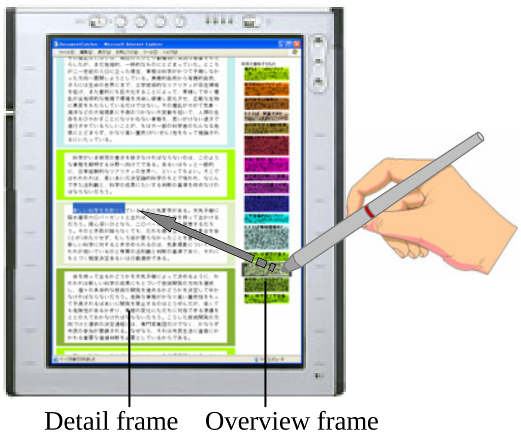


Figure 2: Color-coded document catcher

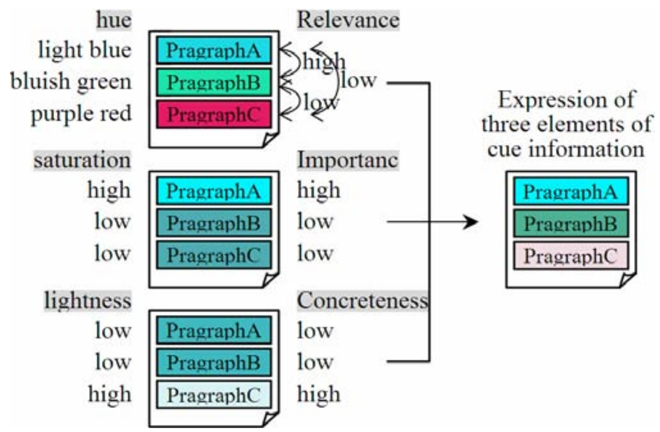


Figure 3: Expression of cue information using the psychological effects of color

4 Experiment

The aim of the present experiment is to determine whether or not an online document interface using the psychological effects of color is effective. Therefore, we designed our experiment based on the following two viewpoints.

Spatial encoding of text

One of the weak points of online document interfaces compared with paper documents is that it is difficult to grasp where the current reading location is (O'Hara & Sellen, 1997). A number of findings are consistent with the idea that spatial encoding of text in two dimensions is related to memory. For example, such spatial encoding can help improve readers' subsequent recall of information in long texts (Lovelace & Southall, 1983). This idea is considered to be useful to readers during the comprehension phase. Viewed in this light, many studies that compared the differences between interfaces on PCs (Piolat et al., 1997) and PDAs (O'Hara et al., 1999) ask readers the spatial position of text information. From a similar standpoint, we also investigated whether the proposed method has an effect on spatial encoding of text information. (Sentence-locating task)

Interface availability

Spatial encoding of text is intended to measure memory of the spatial position of the text. We also need to confirm whether spatial encoding is a cue to being able to recall text information, and whether such spatial encoding is immediately available on the proposed interface. In this experiment, we set up a task that asks the subject to insert some words in blank spaces from a reading text, and to analyze the time required and efficiency of pen operation to fill in the blanks. (Blank-completing task)

4.1 Method

4.1.1 Design

Three types of screen presentations (display modes) were used in this research:

(1) Proposed color mode: Participants read a document with colored paragraphs, the colors of which are determined based on the proposed technique.
(2) Random color mode: Participants read a document with colored paragraphs, whose colors are the same as those used for the Proposed color mode but randomly arranged.
(3) Colorless mode: Participants read a document without any colored paragraphs.

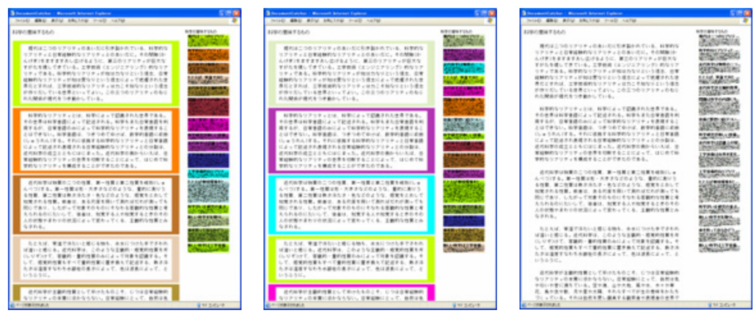
4.1.2 Participants

Sixteen men and women in their 20s and 30s participated in the experiment. All participants used a computer on a regular basis. All read a document in each of the above display modes, reading the document one time per display mode.

4.1.3 Interfaces

All display modes—Proposed color, Random color, and Colorless—were displayed using a pen tablet liquid crystal display. The display size, resolution, and brightness of the display window were identical among the three display modes. The working conditions of the stylus pens were also the same. We also prepared a notebook PC for explaining to participants the sentence-locating and blank-completing tasks to be conducted after the reading task.
The software for presenting the document was Microsoft Internet Explorer Ver. 6. The type of interface was overview+detail type in all display modes.
Images of the experiment and screenshots from Internet Explorer are shown in Figures 4 and 5, respectively.

Figure 4: The experiment in action



Proposed color mode Random color mode Colorless mode

Figure 5: Screenshots of display windows

4.1.4 Documents and Tasks

Documents. Three editorial articles were prepared, each of which consisted of about 3,500 to 3,800 characters and 16 to 18 paragraphs.

Coloring to the document. Before the experiment began, 12 persons who were not among the 16 subjects rated the relevance between paragraphs, the importance of each paragraph, and the concreteness of each paragraph in the document. Based on the grade decided by a majority vote, we fixed the color of each paragraph as the Proposed color mode.

Sentence-locating task. Participants were asked to indicate where a sentence was located in the previously read document. We chose 16 test sentences from each document. To determine whether the reader's ability to spatially encode text information relies on spatial cues of hue (relevance), saturation (importance), and lightness (concreteness), we classified the 16 sentences into four categories (Table 1). These 16 sentences were questioned in random order.

Blank-completing task. Participants were then asked to fill in blanks in sentence with some words in the previously read document. We chose 18 test sentences from each document. We classified the 18 sentences into two categories. Ten of the sentences were quoted directly from the document (hereinafter, "quotation sentences"), and the other eight sentences were related to two or three sentences quoted from the documents (hereinafter, "copulative sentences") (Table 2). To determine whether a reader's ability to recall text information relies on hue (relevance), we classified eight copulative sentences into four sub-categories. Quotation sentences were presented first, followed by copulative sentences. The presentation order in each category was random.

Table 1: Question composition of Sentence-locating task

Sentence in each category		Number of questions
Relevance (hue)	Nearby sentence where the relevance (hue) of neighboring paragraphs changes a lot	4
Importance (saturation)	Sentence in a paragraph with high importance (saturation)	4
Concreteness (lightness)	Sentence in a paragraph with high concreteness (lightness)	4
Other	Sentence applicable to none of the above	4
	Total	16

Table 2: Question composition of Blank-completing task

Sentence in each category		Number of questions
Quotation sentences	Sentence as quoted directly from the document	10
Copulative sentences	(a) Sentence connecting two or three sentences in two paragraphs whose relevance is high (hue is similar) and is neighboring	2
	(b) Sentence connecting two or three sentences in two paragraphs whose relevance is low (hue is not similar) and is neighboring	2
	(c) Sentence connecting two or three sentences in two paragraphs whose relevance is high and is not neighboring	2
	(d) Sentence connecting two or three sentences in two paragraphs whose relevance is low and is not neighboring	2
	Total	18

4.1.5 Procedures

Each subject conducted the experiment for an interval of 5 hours or more, and participated with all three display modes. A subject, a document, and a display mode were combined so that the number of subjects who assign each document and each display mode would cover all 16 sentence-locating tasks. The order the experiment was conducted was set up so that any effects of documents or display mode on the order would be balanced among the subjects.

Training. Before beginning the experiment, participants were taught the three display modes and how to use them. The subjects were then shown through example and operation the two kinds of tests to be performed after the reading task, and then actually practiced.

Reading task. Before reading the experimental document, participants were told that they would have to read a document and "read well enough to understand it and to be able to answer questions about it later." The time limit per reading was 40 minutes, and participants were free to use the overview+detail interface arrows as desired. Backtracking was allowed.

Sentence-locating task. After reading the document, participants had to locate each of the 16 test sentences in the response box that was a snapshot of the overview frame with which each document line was replaced with a straight line. The tool prepared for the sentence-locating task is shown in Figure 6. The test sentences were displayed one by one in a predefined random order in a box (Figure 6, left). Participants were told to use the mouse to indicate what they thought was the location of the sentences in the document, by clicking on a line in the response box (Figure 6, right). Before starting, the experimenter insisted that participants try to find the exact location of each sentence "right down to the very line" and to "think carefully before clicking because answers could not be changed." The test sentence box and response box were of the same size in all display modes. Once a subject had responded, the next sentence was written over the first in the test sentence box, and the response box no longer showed any signs of the previously chosen location. There was no overall time limit on the test.

Blank-completing task. After having located the sentences, participants then had to fill in blank sections in sentences with some words from each of the 18 test sentences. The tool prepared for this task is shown in Figure 7. The two categories were shown in order of quotation sentences and copulative sentences, and test sentences were displayed one by one in a predefined random order in a box (Figure 7, top). Participants were told to use the keyboard to fill in the blank sections in the sentences with some words (Figure 7, bottom) while referring to the document on the tablet display. Before starting, the participants were told, “answer correctly and as quickly as possible.”

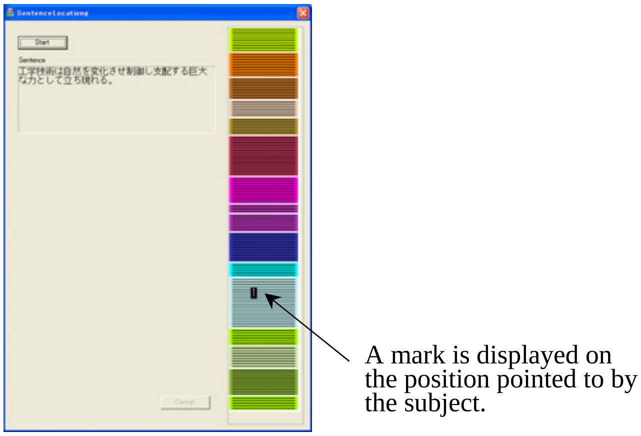


Figure 6: Sentence-locating task

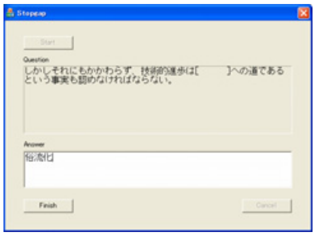


Figure 7: Blank-completing task

4.1.6 Measures

Pointing accuracy. For the sentence-locating task, pointing accuracy was measured by taking the mean difference (in number of lines) between the locations chosen in the response box and the real locations of the sentences in the document. When a reader pointed with the mouse to the estimated location of a sentence, the program displayed a mark on the position for which he/she pointed, and saved a snapshot of the picture.

Blank-completing time and pen operation. For the blank-completing task, the time taken to fill in the blanks was recorded for each subject for each test. Additionally, the number of taps and the move distance of the stylus pen produced by each subject while filling in the blanks were captured.

4.2 Results

4.2.1 Standardization and Multiple Comparison Test

Before comparing data among the display modes, it is necessary to absorb the difference between the three documents used in the experiment. For each document, a z-score (Yoshida, 1998) was calculated, which standardized the 16 participants’ data so that the average and standard deviation might be set to 0 and 1, respectively. Then, the derived z-scores were regrouped for all the display modes.
The Dunnet test (Nagata & Yoshida, 1997), used when comparing one contrast group with all other groups, was used for the multiple comparison test. The Proposed color mode was compared with the Random color mode and Colorless mode.

4.2.2 Pointing Accuracy

Regarding relevance, importance, and the whole, the Proposed color mode allowed participants to locate test sentences with a significantly higher degree of accuracy than Random color mode and Colorless mode. Regarding concreteness and other, the accuracy did not differ significantly between the three display modes (Figure 8).

4.2.3 Blank-completing Time and Pen Operation

Regarding pen operation, on the whole the Proposed color mode differs much more from Random color mode than from Colorless mode.

Time. For copulative sentences, the Proposed color mode allowed participants to fill in the blanks significantly faster than Random color mode. For quotation sentences, there was no significant difference between Proposed color mode and others. (Figure 9).

Number of taps. For copulative sentences and the whole, the Proposed color mode produced significantly fewer taps than Random color mode. For quotation sentences, there was no significant difference between Proposed color mode and others. (Figure 10).

Move distance of pen. For both quotation sentences and copulative sentences, the Proposed color mode produced significantly shorter pen distances than Random color mode. For quotation sentences, the Proposed color mode produced significantly shorter pen distances than Colorless mode (Figure 11).
Paying attention to the move distance of the pen, copulative sentences were compared for every sub-category, (a), (b), (c) and (d). For (c) and (d) which show sentences generated from paragraphs that were not neighboring, the subjects tended to move a shorter distance in Proposed color mode than in Random color mode or Colorless mode. For (c), which shows sentences generated from paragraphs with high relevance, the Proposed color mode produced significantly shorter pen distances than Random color mode and Colorless mode, in particular (Figure 12).

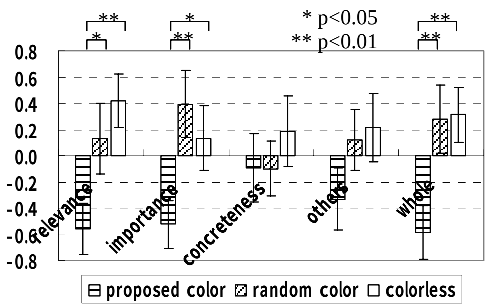


Figure 8: Mean difference between locations chosen in response box and real sentence locations

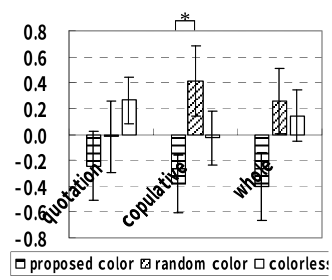


Figure 9: Time of blank-completing task

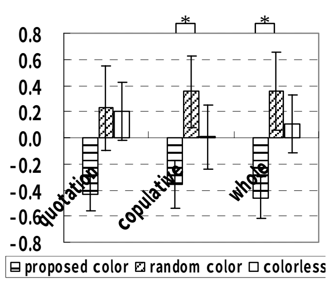


Figure 10: Number of taps in blank-completing task

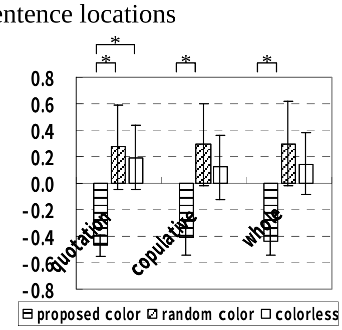


Figure 11: Move distance of pen in blank-completing task

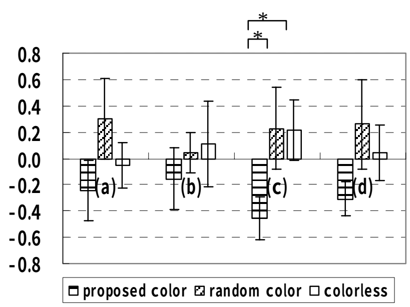


Figure 12: Move distance of pen in blank-completing task (copulative sentences)

4.3 Discussion

Data from the sentence-locating task showed that readers in the Proposed color mode environment located sentences better than those in the Random color mode or Colorless mode display environment. Results were especially good for sentences that were nearby where the relevance (hue) of neighboring paragraphs changed a lot and the sentence was located in a paragraph with high importance (saturation). This result indicates that the presentation of relevance (hue) and importance (saturation) has an effect on spatial encoding of a text. And, regarding concreteness (lightness), the Proposed color mode did not have the intended effect, producing almost the same results as Random color mode. It is necessary to reconsider the relations between concreteness and reading.
Data from the blank-completing task showed that readers in the Proposed color mode environment searched a specific part in less time and with fewer pen operations than parts in the Random color mode environment. This result shows that color can communicate information and improve the operation of an interface if using well-intended colors. Particularly in the test that asked readers to search for a sentence in paragraphs with high relevance but not neighboring, the move distance of the pen was small. This result shows that information about the relevance among the paragraphs presented as hue has an effect at the time of movement to some distant paragraphs. The

copulative-sentence test performed after that rather than the quotation-sentence test also has an effect. This gives the likelihood of a study effect.

5 Conclusion

The cue information for active reading, intelligible representation of a document, and operation not to prevent reading were analyzed. Based on our analysis, we proposed an online document interface that removes hindrances to reading and promotes active reading.

The effectiveness of the proposed color interface was confirmed by comparing it with both a randomly colored interface and a colorless interface. Our experiment ensured that spatial encoding of text and the operation of the interface improved by making colors (hue and saturation) correspond to features of the text (relevance and importance). In other words, we confirmed that progress was made in the readability of online documents by appropriately coloring using the psychological effects of color.

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