Can users read text on large displays?: Effects of Physical Display Size on Users' Reading Comprehension of Text

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ABSTRACT

Large displays are becoming prevalent, but little research has been conducted to quantify their effect on an individual user. We present an experiment in which users' reading comprehension of text displayed on physically large and small displays are compared through three types of tasks. By adjusting the viewing distance for both displays, we maintained a constant visual angle. This experiment demonstrated that differences in display size did not affect users' performance in brief reading comprehension tasks, that is, both search tasks involving small units such as characters or words and comprehension tasks involving larger units such as sentences or paragraphs. We found a large difference between the outcome of this experiment relating to text media and the results of previous research, which showed that for picture and video media, large displays bias users toward an egocentric perspective and small displays bias them toward an exocentric perspective.

CCS Concepts

• **Human-centered computing→User studies**

Keywords

Large display; display size; visual angle; field of view; reading task.

1. INTRODUCTION

It is possible to view various media content on devices such as smart phones, portable DVD players and electronic tablets, and viewing media using such small displays is now a widespread practice. In contrast, there is a tendency in offices and homes to choose large displays and televisions. Now that media is viewed by users on a diverse range of display sizes, the choice of places where media can be experienced is extensive.

However, little effort has been spent on understanding the design of the physical computer and its associated display devices [2]. Most work in this area has focused on pragmatic issues surrounding the changing form factors of displays, but few researchers have devoted much attention to understanding how physical affordances of these displays fundamentally affect human perception and thought. As such, design principles have been uniformly applied across a variety of display devices that offer different cognitive and social affordances.

In particular, limited research has been conducted focusing on the physical display size, an important display characteristic. While full-scale electronic publishing centering on text, such as newspapers and novels, is expected to develop in the future, little research is being performed to systematically quantify the effects of the physical display size on users' reading comprehension of text.

In this paper, we present an experiment comparing users' reading comprehension of text presented on both small and large displays. To examine only the effects of physical display size, we maintained a constant visual angle for the two displays (i.e., the size of the field of view) by adjusting the viewing distances (Figure. 1). How will task performance under these two conditions differ when the information presented on both displays is identical? Because previous research has clarified that comprehension of pictures and videos differs depending on the physical display size, it is reasonable to expect similar differences for cases involving text. In this paper, we showed that contrary to expectations, physical display size has, at least for a brief reading comprehension task, no effect whatsoever on users' reading comprehension of text.

2. RELATED WORK

Much research [26, 6, 25, 8] has focused on collaborative work in which multiple users share a large display, but there is comparatively little research that objectively measures the effect of large displays on an individual user. Owing to space constraints, large displays are typically placed closer to users than small displays. In other words, large displays often present a larger retinal image (i.e., field of view (FOV)) to users. Some studies have examined the subjective effect of differences in FOV size on an individual user. They reported that when pictures or videos are viewed on a large display that offers a wide FOV, users have an increased sense of presence [3, 7], immersion [14, 22], vigilance [23], satisfaction [14], presence (i.e. sensation of being there) [9], and powerfulness [9] as well as a higher level of involvement [5] and simulator sickness (i.e. visually induced motion sickness) [14]. In addition, Reeves et al. [23] and Lin et al. [14] showed that as an objective performance indicator, a large FOV improves recall of presented information. These studies showed that when viewing distance is the same, sense of presence, immersion, and memory increases with a large FOV. However, because visual angle (that is, the size of the FOV) changes with viewing distance, physical display size and visual angle are not necessarily proportionate. Therefore, it is necessary to control visual angle by changing viewing distance and investigate whether the appearance of

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information changes with physical display size and viewing distance, even when visual angle is constant.

Few studies address this issue. Chapanis et al. [4] conducted an experiment comparing the readability of the degrees of a dial drawn on a board at five different viewing distances and sizes. In their experiment, viewing distance was adjusted in proportion to physical dial size in order to maintain a constant visual angle. The results showed that for large dials at a distance of 70 cm or more, it took less time to read the degrees on the dial. Patrick et al. [20] compared a desktop monitor, a large projection screen, and a head-mounted display (HMD) kept at identical visual angles and found that while users' memory and cognitive map building is less accurate when using a small desktop monitor, there is no difference between HMDs and large projection screens. Using the Simulator Sickness Questionnaire, which is a subjective assessment scale for simulator sickness, Shigemasu et al. [24] showed that even when visual angles are the same, physically large displays cause a higher degree of visually induced motion sickness. Human perception of space is broadly divided into egocentric coordinate systems, where the environment is positioned around one's self as the axis, and exocentric coordinate systems, where it is positioned in an external coordinate system outside of one's self [10]. Tan et al. [28] set a spatial orientation task using pictures and videos and found that even when visual angles are identical, large displays encourage users to select an egocentric coordinate system as a cognitive strategy, whereas small displays encourage the selection of an exocentric coordinate system. On the basis of this finding of Tan et al., Bao et al. [1] reasoned that if display size affects how pictures or videos are viewed, it will also affect the type of verbal expressions used when viewing pictures or videos. They had participants perform a task in which they were shown a video clip and asked to tell its story in words. The results showed that for participants viewing the clip on a large display, even when visual angles were identical, a higher percentage used local deixis expressions (e.g., *this*, *here*) than remote deixis expressions (e.g., *that*, *there*). These studies showed that even when the display's retinal image size is the same, the way an individual views picture or video media changes with physical display size.

As described above, although there has been some research into how physical display size affects the way an individual views picture or video media, no research has examined how it affects the way text media are read. Text is the most basic medium of transferring information. Therefore, we investigated how an individual's reading comprehension of text is affected by physical display size at a constant visual angle. We based our study on the findings presented by Tan et al. and Bao et al. We predicted that if the fact that when information is presented as pictures or videos, large displays encourage the user to use an egocentric perspective and local deixis expressions and small displays encourage the use of an exocentric perspective and remote deixis expressions holds true, then for information presented as text, large displays should encourage users to read text from a local perspective, whereas small displays should encourage reading from a global perspective.

3. EVALUATING READING COMPREHENSION OF TEXT DISPLAYED ON AN ELECTRONIC DISPLAY

In this section, we examine the methods of evaluating reading comprehension of text shown on a display.

The process of reading comprehension of text involves two types of processing: bottom-up processing, in which meaning is construed in some way from individual characters to words, from the meaning of words to phrases and sentences, and from the meaning of sentences to paragraphs and whole texts, and top-down processing, where on the basis of pre-existing knowledge related to the text and activated by the reading part of the text, predictions and hypotheses held by the reader determine the input and prescribe the meaning of words and sentences [30, 19]. One way of evaluating the extent to which a user has read text on a display from a local or a global perspective is to measure the user's reading comprehension for each level of the text, that is, the words, phrases, sentences, and paragraphs processed in the bottom-up process.

Most research into reading comprehension of text on an electronic device has measured the impression at the point of reading comprehension by a subjective evaluation method [18, 17]. However, these studies have limitations such as repeatability or the fact that subtle psychological effects that the user cannot articulate cannot be investigated. In contrast, a few studies have objectively and quantitatively evaluated the effects on the user at the point of reading comprehension on a desktop monitor. For instance, Piolat et al. [21] experimentally tested the effect of two different user interfaces on a desktop monitor, employing either page-by-page presentation or page scrolling, on reading comprehension of text. They set three levels of text construction as processed from the bottom up at the point of reading comprehension, namely surface, cohesion, and coherence, and set a task where mistakes in the text that included errors on each level had to be detected and corrected. The distinguishing feature of their technique is the mistakes can be automatically generated because tasks can be generated by randomly sampling words, sentences, and paragraphs from a text. Similarly, Honda [11] examined the effects on reading comprehension of different presentation interfaces on a desktop monitor. Honda asked participants to select an explanatory text from a group of candidates that matched the content of the test text. Because problem selection and generation of the explanatory text was performed only manually in this technique, arbitrariness and tester's subjectivity are easily introduced.

As the evaluation technique of Piolat et al. uses tasks where arbitrariness does not play an obvious role, we concluded that it is suitable for testing the validity of our prediction, at the end of the previous section, that large displays encourage reading comprehension of text from a local perspective and small displays encourage reading comprehension from a global perspective. Accordingly, we set three different levels of text construction in our experiment, as in that of Piolat et al., and provided tasks for each level. We set the three levels to meet the following criteria:

(a) Level 1: surface

For readers to answer questions at this level, extremely local processing alone suffices, for instance, grasping the meaning of characters, words, and punctuation marks. They do not need to build a global representation of the text.

(b) Level 2: cohesion

Questions at this level affect the relationships between the constituents of a sentence or adjacent sentences. For readers to answer questions at this level, it suffices to grasp only the meaning of related parts of the text and does not necessitate an overall representation of the meaning of the text as a whole. Verbal expressions indicating cohesion [27] between constituents include reference, substitution, and conjunction expressions.

(c) Level 3: coherence

For readers to answer questions at this level, they need to have already built or have attempted to build a coherent representation of text content which linked different blocks of information together.

4. EXPERIMENTAL SETUP

4.1 Apparatus

For the small display, we used a 4.5" LCD (Sony VAIO VGN-UX90PS) and for the large display, we used a 65" plasma screen (Panasonic VIERA TH-65PX500) (Figure. 1).

The original display aspect ratio for both screens was 16:9, but to conduct the experiment at the standard ratio of 4:3, we did not use the left and right sides of the display area. The pixel count of the display area used in our experiment (hereafter, "used display area") for both displays was 800 × 600. The width of the used display area was 76.6 mm for the small display and 1,074 mm for the large display; thus, the physical size ratio of the used display area for the two screens was 1:14.

It is desirable that the displays' pixel size ratio is also equivalent to this physical size ratio (1:14). From the available products, we selected two displays in which physical size ratio and pixel size ratio are as similar as possible. The pixel sizes of the small and large displays we employed were 0.096 and 0.75 mm, respectively, which yielded a large display to small display ratio of 7.8:1. Because we know that viewing at a distance from which pixels can be perceived can affect vision, we asked all participants whether they could see the pixels or the pixel structure. Because none of them could see the pixels, we did not consider the effect on vision when pixels can be perceived in this experiment.

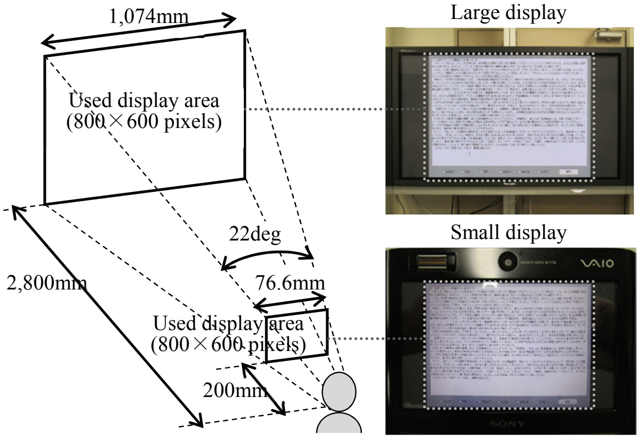
For both displays, we adjusted viewing distance so that visual angles (the sizes of the image projected onto the retina from a specific position in the room) were identical. In this study, we set the viewing distance for the small display at 200 mm and that for the large display at 2800 mm, whereas the horizontal visual angle for the used display areas of both devices was set to a unified 22 deg.

The refresh rate was set to 60 Hz. To ensure identical color, brightness, and contrast of both displays, we adjusted these parameters on the basis of human observation.

To ensure unchanged viewing distances for both displays during the experiment, we asked participants to lean their backs and heads against the back of a chair or wall and to keep their head positions and viewing postures fixed. We adjusted chair height for each participant so that the distance from the floor to the center of the used display area and the floor–eye distance were equal.

Considering the possibility that the environment surrounding the displays might affect users, we did not make users move between two separate rooms but kept the surroundings constant by placing the displays in the same room. The room was a university lab room (24 m^2) without any natural light and was lit by eight 32 W fluorescent lamps. Because all university rooms are fitted according to the Standards for School Environmental Sanitation, we can say that this is an environment with standard lighting.

The mouse, mouse working velocity, and design of the mouse pointer used by the participants to input their answers were the same for both displays.



		Large display	Small display	Ratio
Display properties	Model	Panasonic VIERA TH-65PX500	SONY VAIO VGN-UX90PS	
	External dimensions	Width 1,754 mm Height 985 mm	Width 150 mm Height 95mm	
	Screen dimensions	Width 1,434 mm Height 806 mm	Width 98 mm Height 57.5 mm	
	Display panel (aspect ratio)	65" plasma screen (16:9)	4.5" LCD (16:9)	
	Pixel number (physical resolution)	horizontal 1,920 × vertical 1,080	horizontal 1,024 × vertical 600	
	Pixel dimensions	0.75mm	0.096 mm	7.8:1
Experimental condition	'Used display area' dimensions	Width 1,074 mm Height 806 mm	Width 76.6 mm Height 57.5 mm	14:1
	Viewing distance	2,800 mm	200 mm	14:1
	'Used display area' pixel number (display resolution)	800×600 *1	800×600 *2	
	Visual angle	22 deg		
	Refresh rate	60Hz		

*1 Display mode: normal (4:3), PC display resolution: 800×600

*2 Display mode: full (16:9), PC display resolution: 1,024×600, only used in 800x600 area of the test material presentation program

Figure 1. Display Properties and Experimental Conditions.

4.2 Keeping Color, Brightness, Contrast Constant

For this experiment, we needed to equate display characteristics such as color, brightness, and contrast across two displays.

To measure the spectral distribution of the light coming off the displays as well as the tristimulus values of this distribution when information is displayed, a spectral radiometer and a colorimeter can be used. MacIntyre et al. [15] proposed an approach to calculating luminance contrast on a CRT, however, this method is expensive, time-consuming, and laborious. This was especially true for our study, in which multiple displays needed to be calibrated. Calibration is further complicated by human visual phenomena such as light, dark, chromatic, and transient adaptations [16]. Furthermore, even when the parameters of different displays are matched perfectly using instruments, it is well known that humans will view the displays subjectively and not necessarily perceive them as matched.

In our study, when evaluating the effects of media on cognitive activity, we did not focus on the importance of matching the parameters of each device with an instrument. Instead, it was important that the displays "seemed identical" to the human eye. This approach also corresponds to Tjan's [29] view that "human observer is always needed to carry out a color matching experiment.” Based on this view, we calibrated color, luminance, and contrast in this study according to the following procedure. We asked an assessor group consisting of three people to compare the two displays. We asked, “Which one do you think is brighter?” and “Which do you think has better contrast?” and we calibrated all settings based on the answers. We repeated this process until the assessor group could not distinguish between the two displays. This method was also employed in the study by Tan et al. [28], mentioned in the related work section.

Nevertheless, it is difficult to perfectly match each parameter of the two displays with this technique. Therefore, using a similar technique, we obtained results approximately similar to those described in the results section in an experiment using large and small displays that were different from those in our experiment (see the section “Confirmation experiment”). From the results, we concluded that the method we employed in our study to calibrate color, luminance, and contrast based on human observation did not affect the results obtained in the results section.

5. EXPERIMENTAL METHOD

Building on the studies mentioned in the related work section, we formed the following hypothesis for this research and formulated three different tasks to test it.

Hypothesis: Physical display size affects performance in reading comprehension tasks. Large displays encourage users to read text information at the small-unit level of characters and words and small displays encourage reading of text information at the large-unit level of sentences and paragraphs.

5.1 Experimental conditions

We set two viewing conditions: far, in which a large display is viewed from a distance, and near, in which a small display is viewed from close-up (Figure 1). We used a within-subjects design. We presented text on the displays and compared the effects on reading comprehension.

The experimental setup and equipment are described in the previous section. We used standardized character size, number of characters per line, and line spacing for the text displayed on both displays.

5.2 Participants

Fourteen graduate students from an information science university participated in the experiment. They were 23–27 years of age. They all had Japanese as their mother tongue, and their vision or corrected vision was 1.0 or better. As a precaution, before the experiment, we presented a sample in the same manner under the same conditions to check for vision problems and eliminated participants who stated that the characters were difficult to read. One person was excluded on this basis; hence, the final number of participants was thirteen (three female).

5.3 Task and experimental material

As mentioned in the previous section, the text was divided into three different structural levels, and we created three kinds of tasks to evaluate reading comprehension at each level. Each participant performed all three kinds of tasks under both viewing conditions.

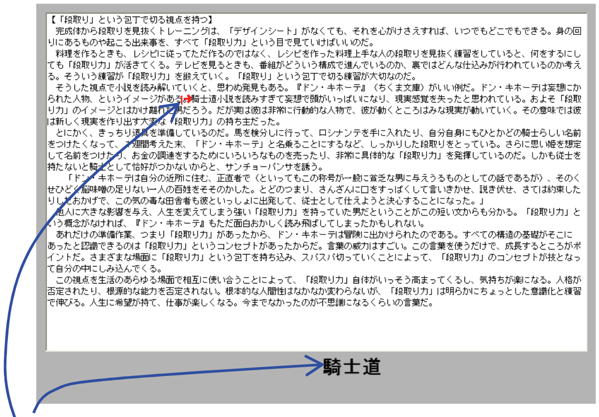
For the experiment, we chose articles from the same author, Takashi Saito, in order to preserve homogeneity; we used his book “Dandori Ryoku” (published by Chikumashobo). Our reasoning was that as Saito Takashi’s books have a reputation for readability, participant-specific effects could be minimized.

The text shown for each problem was set at 1300–1500 characters comprising seven to eight paragraphs, an amount that can be comfortably presented on a screen without the need for scrolling.

5.3.1 Surface task

For the surface task meeting the level 1 standard described above, participants were asked to search words in the text. Piolat et al. asked participants to detect and correct spelling mistakes or inappropriate words in the text, but we chose a word search task for our experiment. We reasoned that this corresponds to real usage situations as users frequently search for specific words, for example, when using displays to read television program information or websites.

To select words, we used a program to randomly sample nouns from the text with an appearance frequency of 1. At the start of the task, a word was shown at the bottom of the screen. The participant searched for that word in the text shown at the top of the screen and clicked on it with the mouse to respond. The word was then marked in red. This corresponds to one question; participants replied to six questions for the same text. Figure 2 shows an example.



【「段取り」という包丁で切る視点を持つ】

完成体から段取りを見抜くトレーニングは、「デザインシート」がなくても、それを心がけさえすれば、いつでもどこでもできる。身の回りにあるものや起こる出来事を、すべて「段取り力」という目で見ていけばいいのだ。

料理を作るときも、レシピに従ってただ作るのではなく、レシピを作った料理上手な人の段取りを見抜く練習をしていると、何をするにしても「段取り力」が活きてくる。テレビを見るときも、番組がどういう構成で進んでいるのか、裏ではどんな仕込みが行われているのか考える。そういう練習が「段取り力」を鍛えていく。「段取り」という包丁で切る練習が大切なのだ。

そうした視点で小説を読み解いていくと、思わぬ発見もある。『ドン・キホーテ』（ちくま文庫）がいい例だ。ドン・キホーテは妄想にかられた人物、というイメージがある。騎士道小説を読みすぎて妄想で頭がいっぱいになり、現実感覚を失ったと思われている。およそ「段取り力」のイメージとはかけ離れた男だろう。だが実は彼は非常に行動的な人物で、彼が動くところはみな現実が動いていく。その意味では彼は新しく現実を作り出す大変な「段取り力」の持ち主だった。

とにかく、きっちり道具を準備しているのだ。馬を検分しに行って、ロシナンテを手に入れたり、自分自身にもひとかどの騎士らしい名前をつけたくなって、一週間考えた末、「ドン・キホーテ」と名乗ることにするなど、しっかりした段取りをとっている。さらに思い姫を想定して名前をつけたり、お金の調達をするためにいろいろなものを売ったり、非常に具体的な「段取り力」を発揮しているのだ。しかも従士を持たないと騎士として恰好がつかないからと、サンチョ・パンサを誘う。

「ドン・キホーテは自分の近所に住む、正直者で（といってもこの称号が一般に貧乏な男に与えうるものとしての話であるが）、そのくせひどく脳味噌の足りない一人の百姓をそそのかした。とどのつまり、さんざんに口をすっぱくして言いきかせ、説き伏せ、さては約束したりしたおかげで、この気の毒な田舎者も彼といっしょに出発して、従士として仕えようと決心することになった。」

他人に大きな影響を与え、人生を変えてしまう強い「段取り力」を持っていた男だということがこの短い文からも分かる。「段取り力」という概念がなければ、『ドン・キホーテ』もただ面白おかしく読み飛ばしてしまったかもしれない。

あれだけの準備作業、つまり「段取り力」があったから、ドン・キホーテは冒険に出かけられたのである。すべての構造の基礎がそこにあったと認識できるのは「段取り力」というコンセプトがあったからだ。言葉の威力はすごい。この言葉を使うだけで、成長するところがポイントだ。さまざまな場面に「段取り力」という包丁を持ち込み、スパスパ切っていくことによって、「段取り力」のコンセプトが技となって自分の中にしみ込んでくる。

この視点を生活のあらゆる場面で相互に使い合うことによって、「段取り力」自体がいっそう高まってくるし、気持ちが楽になる。人格が否定されたり、根源的な能力を否定されない。根本的な人間性はなかなか変わらないが、「段取り力」は明らかにちょっとした意識化と練習で伸びる。人生に希望が持て、仕事が楽しくなる。今までなかったのが不思議になるくらいの言葉だ。

騎士道

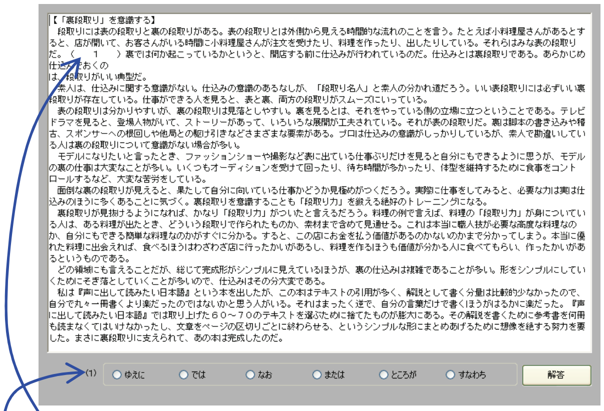
1) Word is displayed at the bottom of the screen.
2) When searching the displayed word in the text and clicking on it, it is marked in red.

Figure 2. Example of Surface Task.

5.3.2 Cohesion task

For the cohesion task meeting the level 2 standard described above, participants were asked to select appropriate connectives and place them in blank spaces.

As the verbal expressions indicating cohesion, this task dealt with conjunctive expressions, which can easily be sampled automatically. The target conjunctives were randomly sampled from those in the text. At the beginning of the task, text with blank spaces was displayed and the available conjunctive choices were shown at the bottom of the screen. The participants responded by selecting the appropriate conjunctive. Each conjunctive corresponded to one question and the participants responded to three questions for the same text. Figure 3 shows an example.



【「裏段取り」を意識する】

段取りには表の段取りと裏の段取りがある。表の段取りとは外側から見える時間的な流れのことを言う。たとえば小料理屋さんがあるとすると、店が開いて、お客さんがいる時間に小料理屋さんが注文を受けたり、料理を作ったり、出したりしている。それらはみな表の段取りだ。（　１　）裏では何か起こっているかというと、開店する前に仕込みが行われているのだ。仕込みとは裏段取りである。あらかじめ仕込んでおくのは、段取りがいい典型だ。

素人は、仕込みに関する意識がない。仕込みの意識のあるなしが、「段取り名人」と素人の分かれ道だろう。いい表段取りには必ずいい裏段取りが存在している。仕事ができる人を見ると、表と裏、両方の段取りがスムーズにいっている。

表の段取りは分かりやすいが、裏の段取りは見落としやすい。裏を見るとは、それをやっている側の立場に立つということである。テレビドラマを見ると、登場人物がいて、ストーリーがあって、いろいろな展開が工夫されている。それが表の段取りだ。裏は脚本の書き込みや稽古、スポンサーへの根回しや他局との駆け引きなどさまざまな要素がある。プロは仕込みの意識がしっかりしているが、素人で勘違いしている人は裏の段取りについて意識がない場合が多い。

モデルになりたいと言ったとき、ファッションショーや撮影など表に出ている仕事ぶりだけを見ると自分にもできるように思うが、モデルの裏の仕事は大変なことが多い。いくつもオーディションを受けて回ったり、待ち時間が多かったり、体型を維持するために食事をコントロールするなど、大変な苦労をしている。

面倒な裏の段取りが見えると、果たして自分に向いている仕事かどうか見極めがつくだろう。実際に仕事をしてみると、必要な力は実は仕込みのほうに多くあることに気づく。裏段取りを意識することも「段取り力」を鍛える絶好のトレーニングになる。

裏段取りが見抜けるようになれば、かなり「段取り力」がついたと言えるだろう。料理の例で言えば、料理の「段取り力」が身についている人は、ある料理が出たとき、どういう段取りで作られたものか、素材まで含めて見通せる。これは本当に職人技が必要な高度な料理なのか、自分にもできる簡単な料理なのかがすぐに分かる。すると、この店にお金を払う価値があるのかないのかまで分かってしまう。本当に優れた料理に出会えれば、食べるほうはわざわざ店に行ったかいがあるし、料理を作るほうも価値が分かる人に食べてもらい、作ったかいがあるというものである。

どの領域にも言えることだが、総じて完成形がシンプルに見えているほうが、裏の仕込みは複雑であることが多い。形をシンプルにしていくためにそぎ落としていくことが多いので、仕込みはその分大変である。

私は『声に出して読みたい日本語』という本を出したが、この本はテキストの引用が多く、解説として書く分量は比較的少なかったので、自分で丸々一冊書くより楽だったのではないかと思う人がいる。それはまったく逆で、自分の言葉だけで書くほうがはるかに楽だった。『声に出して読みたい日本語』では取り上げた６０～７０のテキストを選ぶために捨てたものが膨大にある。その解説を書くために参考書を何冊も読まなくてはいけなかったし、文章をページの区切りごとに終わらせる、というシンプルな形にまとめあげるために想像を絶する努力を要した。まさに裏段取りに支えられて、あの本は完成したのだ。

(1) ○ ゆえに　○ では　○ なお　○ または　○ ところが　○ すなわち

1) Blank spaces are displayed throughout the text.
2) The conjunctive that fits in space 1) is selected from a group of conjunctive candidates.

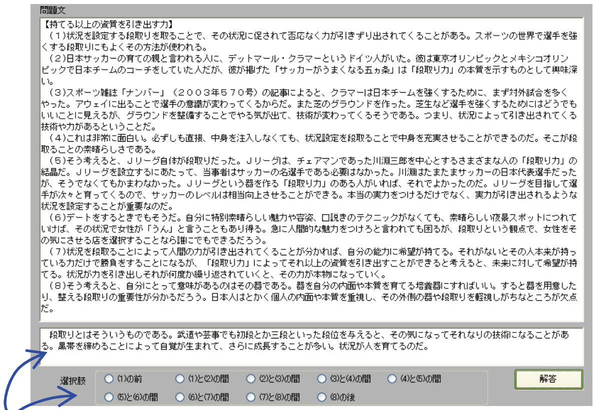
Figure 3. Example of Cohesion Task.

5.3.3 Coherence task

For the coherence task meeting the level 3 standard described above, the participants were asked for the original order of a sequence of paragraphs.

The participants had to insert one paragraph that was shown independently of the text into the appropriate places.

The shown text consisted of a total of 7–8 paragraphs, and the paragraph extracted from the text and shown was randomly selected. At the beginning of the task, the separated one paragraph was shown at the bottom of the screen and the text without the paragraph appeared at the top. Each paragraph at the top of the screen was given a number, and the participants replied by indicating where the separated paragraph should be inserted. Figure 4 shows an example.



【持てる以上の資質を引き出す力】

（１)状況を設定する段取りを取ることで、その状況に促されて否応なく力が引きずり出されてくることがある。スポーツの世界で選手を強くする段取りにもよくその方法が使われる。

（２)日本サッカーの育ての親と言われる人に、デットマール・クラマーというドイツ人がいた。彼は東京オリンピックとメキシコオリンピックで日本チームのコーチをしていた人だが、彼が掲げた「サッカーがうまくなる五ヵ条」は「段取り力」の本質を示すものとして興味深い。

（３)スポーツ雑誌「ナンバー」（２００３年５７０号）の記事によると、クラマーは日本チームを強くするために、まず対外試合を多くやった。アウェイに出ることで選手の意識が変わってくるからだ。また芝のグラウンドを作った。芝生など選手を強くするためにはどうでもいいことに見えるが、グラウンドを整備することでやる気が出て、技術が変わってくるそうである。つまり、状況によって引き出されてくる技術や力があるということだ。

（４)これは非常に面白い。必ずしも直接、中身を注入しなくても、状況設定を段取ることで中身を充実させることができるのだ。そこが段取ることの素晴らしさである。

（５)そう考えると、Ｊリーグ自体が段取りだった。Ｊリーグは、チェアマンであった川淵三郎を中心とするさまざまな人の「段取り力」の結晶だ。Ｊリーグを設立するにあたって、当事者はサッカーの名選手である必要はなかった。川淵はたまたまサッカーの日本代表選手だったが、そうでなくてもかまわなかった。Ｊリーグという器を作る「段取り力」のある人がいれば、それでよかったのだ。Ｊリーグを目指して選手が次々と育ってくるので、サッカーのレベルは相当向上させることができる。本当の実力をつけるだけでなく、実力が引き出されるような状況を設定することが重要なのだ。

（６)デートをするときでもそうだ。自分に特別素晴らしい魅力や容姿、口説きのテクニックがなくても、素晴らしい夜景スポットにつれていけば、その状況で女性が「うん」と言うこともあり得る。急に人間的な魅力をつけろと言われても困るが、段取りという観点で、女性をその気にさせる店を選択することなら誰にでもできるだろう。

（７)状況を段取ることによって人間の力が引き出されてくることが分かれば、自分の能力に希望が持てる。それがないとその人本来が持っている力だけで勝負をすることになるが、「段取り力」によってそれ以上の資質を引き出すことができると考えると、未来に対して希望が持てる。状況が力を引き出しそれが何度か繰り返されていくと、その力が本物になっていく。

（８)そう考えると、自分にとって意味があるのはその器である。器を自分の内面や本質を育てる培養器にすればいい。すると器を用意したり、整える段取りの重要性が分かるだろう。日本人はとかく個人の内面や本質を重視し、その外側の器や段取りを軽視しがちなところが欠点だ。

段取りとはそういうものである。武道や芸事でも初段とか三段といった段位を与えると、その気になってそれなりの技術になることがある。黒帯を締めることによって自覚が生まれて、さらに成長することが多い。状況が人を育てるのだ。

選択肢
○ ⑴の前　○ ⑴と⑵の間　○ ⑵と⑶の間　○ ⑶と⑷の間　○ ⑷と⑸の間
○ ⑸と⑹の間　○ ⑹と⑺の間　○ ⑺と⑻の間　○ ⑻の後

1) Each paragraph is numbered, while at the same time a separated paragraph is shown at the bottom of the screen.
2) The place where the separated paragraph should be inserted is selected from a group of candidates.

Figure 4. Example of Coherence Task.

5.4 Experimental procedure

The experimental procedure is illustrated in Figure 5. The operating procedure and tasks were explained to the participants, who performed the tasks after a practice session. The participants were asked to answer as quickly as possible in all tasks. To ensure that the participants had the display surface in focus, they were asked to look at text that bore no relation to the problem text for 10 s before beginning each problem for each task.

The order of presentation of viewing conditions and text were counterbalanced between participants to avoid order effects. For instance, if one participant read text A under "near" conditions and text B under "far" conditions, a different participant would read text B under "near" conditions and text A under "far" conditions.

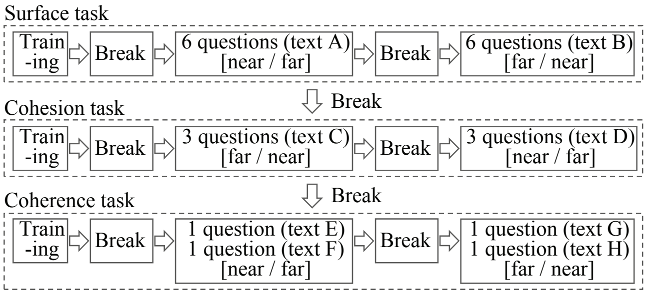


Figure 5. Experiment procedure.

6. RESULTS

6.1 Results

We measured the time needed to respond and accuracy rate for all three tasks.

Figures 6, 7, and 8 show the measured values and z-scores[1] for the average completion time and average accuracy rate for each task. Because we counterbalanced the presented texts, as mentioned in the experimental procedure section, we cannot compare the measured values between viewing conditions. To compensate for the differences between the multiple texts used in this experiment, we therefore acquired the z-score of the participants' measured values for each text. We then conducted a two-way ANOVA for repeated measures ('viewing conditions' as one within-subjects factor × 'text' as one within-subjects factor) on those z-scores. There was no significant main effect of text and no significant interactions between viewing conditions and text. That is, we could verify that the differences among the texts used in this experiment had no effect on the reading comprehension performance. We then regrouped the z-scores for each participant for each viewing condition and compared them between viewing conditions. We used the significance test with the two-tailed paired *t*-test.

For the average completion time per question, no significant difference was found between the two viewing conditions at the 5% significance level for any of the three tasks: surface task (near: $M = -0.039$, $SD = 0.971$; far: $M = 0.039$, $SD = 0.961$; $t(77) = 0.547$, $p = 0.586$); cohesion task (near: $M = 0.202$, $SD = 0.972$; far: $M = -0.068$, $SD = 0.950$; $t(38) = 1.529$, $p = 0.135$); coherence task (near: $M = 0.025$, $SD = 0.979$; far: $M = 0.127$, $SD = 1.248$; $t(25) = 0.292$, $p = 0.772$).

Moreover, for the average accuracy rate, no significant difference was found between the two viewing conditions at the 5% significance level: surface task (near: $M = -3.99\text{E}{-17}$, $SD = 0.395$; far: $M = -3.99\text{E}{-17}$, $SD = 0.395$; $t(77) = 8.431\text{E}{-08}$, $p =$

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[1] The standardized score so that the mean value for each measured value is 0 and the standard deviation is 1

1.0), cohesion task (near: *M* = 0.026, *SD* = 0.698; far: *M* = 0.022, *SD* = 0.880; *t*(38) = 0.022, *p* = 0.982), coherence task (near: *M* = 0.088, *SD* = 1.032; far: *M* = 0.040, *SD* = 0.979, *t*(25) = 0.160, *p* = 0.874).

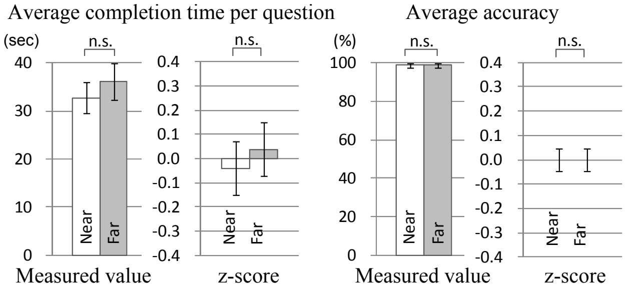

Figure 6. Completion time and accuracy for surface task.

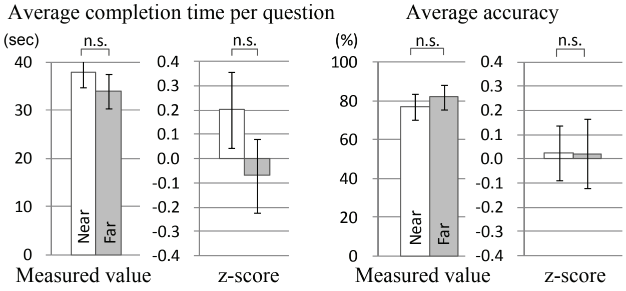

Figure 7. Completion time and accuracy for cohesion task.

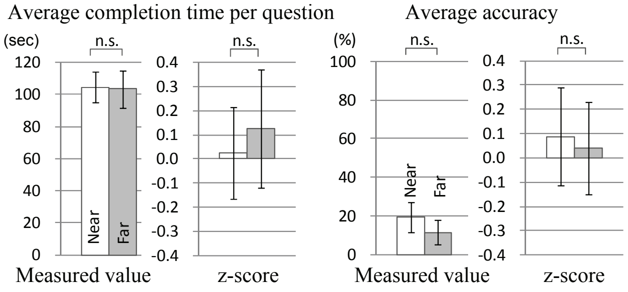

Figure 8. Completion time and accuracy for coherence task.

6.2 Confirmation experiment

The measurement results obtained in the results section were comparisons using one set consisting of small and large displays. With results from only one set, it is possible that a combination was selected that just happens not to produce any differences. Therefore, we conducted an additional experiment with a different display set to confirm the results reported in the results section.

For this experiment, we used the 5.6" LCD Fujitsu FMV-BIBLO LOOX U50WN for the small display and the 55 V plasma screen HITACHI W55-P5500 for the large display. Eight graduate students (two female) from information science universities participated in the experiment. They were 23–26 years in age. The adjustment methods for color, brightness, and contrast as well as the tasks, test material, and experimental procedure were as described in the previous sections.

For the average completion time per question, no significant difference was found between the two conditions for all three tasks: surface task (near: *M* = 0.051, *SD* = 0.954; far: *M* = −0.051, *SD* = 0.934; *t*(47) = 0.587, *p* = 0.560), cohesion task (near: *M* = 0.221, *SD* = 0.921; far: *M* = 0.028, *SD* = 0.962; *t*(23) = 0.933, *p* = 0.360), coherence task (near: *M* = 0.245, *SD* = 0.828; far: *M* = 0.097, *SD* = 1.386; *t*(15) = 0.326, *p* = 0.749). In addition, for the average accuracy rate, no significant difference was found between the two conditions for all tasks: surface task (near: *M* = −9.3E−18, *SD* = 0.386; far: *M* = −9.3E−18, *SD* = 0.386; *t*(47) = 5.96E−08, *p* = 1.0), cohesion task (near: *M* = 0.019, *SD* = 0.553; far: *M* = 0.059, *SD* = 0.777; *t*(23) = −0.208, *p* = 0.837), coherence task (near: *M* = −0.034, *SD* = 1.052; far: *M* = −0.193, *SD* = 0.579, *t*(15) = 0.563, *p* = 0.582).

Thus, we confirmed the experimental result in the results section using this different set of displays: No difference in the completion time or accuracy rate of three different tasks appears in the measurements of reading comprehension of texts.

7. DISCUSSION

The purpose of this study was to investigate how display size affects an individual's reading comprehension of text when visual angle is constant. Building on the findings from previous studies, we hypothesized that large displays encourage users to read text information at the small-unit level of characters and words and small displays encourage reading of text information at the large-unit level of sentences and paragraphs.

However, the surface task showed that large displays do not encourage users to read text information at the small-unit level. Furthermore, the coherence task showed that small displays do not encourage users to read text information on the large-unit level.

These results clearly indicate that the hypothesis does not hold and when visual angle is constant, the affordances offered by two different size displays, one large and one small, do not affect user performance in brief reading comprehension tasks.

Our study suggests that physical display size is not an important factor in designing display systems for viewing text. Surprisingly, different display sizes did not produce any differences in all text information search tasks on the small-unit level or text information comprehension tasks on the large-unit level[2][3]. It is interesting that the results of previous research, which showed that for picture and video media, large displays bias users toward an egocentric perspective and small displays bias users toward an exocentric perspective, differ so greatly from the results of our experiment relating to text media.

We will discuss the main reasons for this difference. In the sense of recognizing objects distributed in the display space, the tasks using pictures and videos in previous research by Tan et al. and Bao et al. are similar to those using text in our research. However, in the former, the shape, orientation, and distribution of objects in

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[2] Note that the text tasks used in this study were also used in an experiment studying the differences between two different presentation media (paper and electronic media), which confirmed that these tasks exhibit significant differences in both completion time and accuracy rate.

[3] Note that both sets of large and small displays used in this study were also used in an experiment involving tasks related to images, which confirmed that they form a display condition that yields significant differences in completion time and accuracy rate [[12]].

the display space provide important clues to performing the task. In contrast, in the latter, the character size, character spacing, and line spacing appearing in the display space are all uniform, and therefore are not significant, whereas the understanding of chunks (words, phrases, sentences, and paragraphs) composed of multiple adjacent characters is important in performing the tasks. Once they are recognized as chunks and excluding factors such as the order of appearance of the chunks in the space or their relationships with the preceding and following chunks, their physical position as objects in the space does not have the same important meaning as in the former case. It can be speculated whether for this experiment where text was displayed, the degree of immersion of the user in the display space was weak, and therefore, no difference could be seen between the large and small displays. However, this must naturally be investigated for each task because these findings cannot be applied universally to diverse tasks in picture, video, and text media.

Whether text is displayed on small display or on large display does not affect users' reading comprehension. The results of our study should provide motivation and ideas to content providers for electronic displays, interface designers, software developers, and display device developers. For instance, this can provide information that increases the number of options for those who propose new lifestyles or workstyles, such as individual browsing or reading of newspaper articles or novels on a screen projected on a wall or large display and not on a small handheld PC or electronic paper.

After the experiment, we attempted a magnitude estimation consisting of a subjective evaluation with open-ended questions and interviews. The magnitude estimation results showed no difference between large and small displays for the following questions: "Did you feel the text as a whole was easy to grasp?" and "Did you feel that more than the text as a whole, a particular section of the text was easy to grasp?" This agrees with the experimental results in the results section. In contrast, it was clear from the open-ended questions and interviews that participants preferred reading text on a small display over reading on a large display. One possible reason for this may be the effect of fatigue or the degree of readability, both of which are difficult to measure in short tasks such as the ones in our experiment. One important issue for future study is the design of environments for experiments of longer duration or under circumstances closely reflecting real usage and objective and quantitative measurements of indices that were out of scope of this experiment, such as fatigue and readability.

Furthermore, our experiment did not evaluate questions regarding user behavior, such as how users behave or what types of cognitive strategies they employ when executing a task involving reading comprehension of text on a display. In the interviews we conducted in our experiment, we asked participants about strategies they employed in performing a task, but it became clear that it is difficult to gain any meaningful information or insights from participants' own explanations about the cognitive strategies they used. We expect that analysis of gaze movement patterns during reading comprehension of text using gaze behavior measuring equipment or analysis of operation patterns for a mouse or pen that substitute for gaze behavior will provide a deeper understanding of user reading comprehension on displays.

8. CONCLUSION

In this paper, we showed that difference in display size does not affect an individual's performance in brief reading comprehension tasks including text information search tasks on the small-unit level or text information comprehension tasks on the large-unit level.

The results of our experiment simply showed that differences in display size do not affect users' brief reading comprehension of articles. To design display systems that make optimum use of displays with different physical sizes, we must have a clear understanding of the interaction between display size and other factors such as the types of displayed text or users' postures during reading text. Further research in this field is necessary because existing findings [13, 17] indicate that there are specific differences in reading comprehension and degree of readability corresponding to differences in the format in which text is displayed on identical display devices, for instance, font, type size, and line spacing.

Our findings could be used to design electronic media space. However, especially today, when electronic media space often does not contain text alone but is commonly a multimedia space combining several types of media such as photos, illustrations, and video, we need to consider user cognitive properties with respect to these media and employ a comprehensive approach to display system design. For this reason, more empirical research is needed. It also could be useful in further research to observe and interview real users before the experiments are set, so to include relevant aspects of user experience like emotions, motivations, meaningful activities which affect users performance in reading in real situations.

9. ACKNOWLEDGMENTS

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