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# Impact of Screen Aspect Ratio on Reading Electronic Material*

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The major question addressed in this paper is influence of different screen aspect ratios on reading electronic material. In order to examine differences, we performed a research that included two of most popular aspect ratios: 4:3 and 16:9. Both aspect ratios were represented in desktop and handheld variant. The research referred to engineering students as readers. Engineering students were very interesting population for this research due to the fact that they spend most of their time reading electronic materials, during their education. Logically, it is necessary to measure how effective this way of reading educational material is. The general hypothesis of this study was that there is difference in usage of electronic reading material on screens with different aspect ratios, and that the current hype for widescreen displays is unjustified when it comes to reading electronic material. Reading time, amount of interactions and knowledge test scores were used as measures in experiment. Our results speak in favor of the hypothesis and suggest why proposed screen aspect ratio is the most suitable for reading electronic materials.

**Keywords:** screen aspect ratio; electronic reading material; engineering education; Human Computer Interaction (HCI); usability testing

## 1. Introduction

Progress of civilization relies on the distribution of knowledge mainly through written word. Large amount of knowledge we gather during our lifetime is done by reading. Throughout our education we are directed towards written materials as a source of information. This is also true when lifelong learning is concerned. We read as a part of our everyday activities, in our workplace, in commute and in the comfort of our home. Advances in technology influenced a major shift of this reading process from paper sources towards digital material. Large amount of reading is done using electronic devices, such as desktop computers, notebooks and also using handheld devices such as phones and tablets.

Using electronic reading material carries many benefits. First of all storing and management of documents is much easier. Flexible nature of digital material provides simple ways of editing text. They become more accessible thanks to web and cloud services. Exchange of electronic documents is just few clicks away. Also, it is important to state that use of electronic reading material significantly benefits the environment, since it influences the production and spending of paper. Disposing of electronic material is much easier and leaves no consequences to environment than those in paper form.

General popularity of electronic reading material is obvious in educational area as well as in consumer sector. In addition, the 2011 Horizon Report [1] states that in following years the usage of electronic books will have great influence on higher education. The content of electronic books and the social activities they enable, rather than the device used to access them, are the keys to their popularity; nearly everyone carries some device that can function as an electronic reader, and more people are engaging with electronic books than ever before.

With the rise in processing capabilities, especially in computer graphics, electronic devices provided a new use in using multimedia content. This caused the development of wide screen with different aspect ratios out of which mostly used is 16:9. Playing movies on computers is one of the main driving forces of this trend. Even movies are recorded differently to provide better viewing experience using wide screen aspect ratio. Before movies were mostly founded on close ups and dialogues and today they shifted towards wide scenes with lots of action. This trend was so intense that wide screens took over the market in 2012 as reported by StatCounter [16]. This means that even office computers and computers used for studying now use wide screens, disregarding the fact that probably the least amount of time they are actually used for watching movies. They are actually mostly used for work and reading. The question is how this shift to wide aspect ratio affects frequent daily activities such as reading electronic material? Mostly used paper formats actually have completely opposite aspect ratios from wide screens.

Evolution of operating systems and application failed to properly acknowledge the shift to wide screen aspect ratio. Screen layouts have undergone



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none or minimal changes. Most operating systems and applications still provide interfaces that are best suited to 4:3 aspect ratio.

In this paper we will interrogate what effect different screen aspect ratios have on reading electronic material. In particular, our study is based on reading material for engineering education.

We organize the paper as follows. First, in introduction, we briefly explained the need for examination of screen aspect ratios influence on reading electronic material. In second section overview of current researches and experiments on this subject is provided. Third section states the issue this paper focuses on. In following section we described settings of our study, as well as methodology used for conducting this experiment. Afterwards, results of our study were presented, followed by a discussion. Last section consists of conclusions that we have drawn based on analyzed data and obtained results.

## 2. State of the art

When talking about reading digital texts, we can distinguish between two opinions. In one opinion, digital texts will never replace those that are written on paper. Second opinion strongly favors digital material, and states that in near future we will all be reading digital material. Ted Nelson [2] said, ''the question is not can we do everything on screens, but when will we, how will we and how can we make it great?''

There are number of papers which focus on paper reading and digital reading comparison. Many authors from different research areas analyzed and discussed this issue. Schumacher and Waller [3] made a difference between outcome measures and process measures in reading behavior assessment. Outcome measures focus on what reader receives from text, while process measures indicate how the text is used. Reading speed, reading accuracy and reading comprehension are some popular outcome measures. On the other hand, most commonly discussed process measures are eye movement and manipulation.

Vast number of experiments [4–7] showed that silent reading from screen is somewhat slower than reading from paper, but this conclusion has to be taken with reserve, as there is a big difference in experimental procedures. Because of this, it is not yet known if same influences are responsible for slower reading on screens.

In addition, some studies [8, 9] revealed no significant difference in reading speed when text is presented on different medium.

Shepperd et al. [10] examined the perceptions and performance of students who used an electronic versus a traditional textbook. Experiment consisted of 392 students (98 male, 257 female and 37 unreported) which took the final exam of introductory psychology course. Only ten percent of participants used electronic version of textbook. Two outcome factors were measured: how much time students reported reading for the class; and what grade students achieved in the class. Results showed that there was no significant difference in final course grade, but electronic text somehow facilitated study and reduced number of study hours.

Mutter and Maurutto [9] also addressed the issue of reading comprehension. They asked participants to read a short story on paper and screen, and then answer several questions about the read story immediately after finishing the reading task. Again, no meaningful difference in reading comprehension was discovered between readers using either medium.

Gould et al [7] report an investigation of eye movement patterns when reading from either medium. Results show that when reading from screen readers made about 15% more fixations than when reading from paper. General conclusion was that eye movement patterns were similar when using both mediums. More recent authors [11] examined eye movement during silent reading of three eBooks and a printed book, while using three different devices: desktop PC, iPad tablet and Kindle eBook reader. Eye movement data gathered throughout the experiment suggest that reading behavior during reading an eBook is similar to reading from a printed book.

In terms of text manipulation Richardson et al., [12] report that experiment participants find on screen text manipulation awkward compared to paper. They state that by replacing direct manual interaction with an input device much feedback and control was lost.

As mentioned measures have not singled out elements that have impact on performance in reading from paper and screen, many researchers tried to isolate physical characteristics responsible for given differences. Within their research in 1980s, Gould and his colleagues observed orientation, visual angle, aspect ratio and display characteristics as possible impact factors on reading performance.

## 3. Problem statement

As we move towards paperless society, usage of electronic reading materials increasingly gains on popularity. The fact that people now read a lot on a computer encourages publishers to take advantage of this great new market. This leads to an increase in offer of electronic articles, journals and books. At the same time wide screens have established their position as most commonly used type of display.

The way of porting printed reading material to digital realm of wide screens is an issue needed to be discussed.

Electronic books are digital representation of the printed material. This means that the content is prepared and formatted to best fit the paper print. The problem is that there is a significant difference between aspect ratio of most paper formats and wide screens. It can be claimed that they are completely opposite. For instance all paper formats from A1 to A4 have 2:3 aspect ratio. This means that top and bottom edges of the paper are shorter than sides. Wide screens have smaller sides than top and bottom edges. This can cause a mismatch in the presentation of the content. The question is whether this mismatch in content presentation could be minimized by using screens that have aspect ratios closer to paper?

Influence of aspect ratio on reading electronic material is insufficiently explored in current research. There is a need to analyze how screen aspect ratio affects satisfaction of reading digital material and how it could be improved. Thus, we tried to further explore this issue by conducting a study. The study was based on reading electronic material for engineering education. Engineers were chosen as a target group because they often focus on electronic books and materials. Also, use of electronic materials is in accordance with their work, which is mostly performed on the computer. Storing and management of documents is much easier, modification of digital material is simple, papers are more accessible thanks to web and cloud services and exchange of electronic documents is much faster than in printed form.

One of the benefits of establishing what aspect ratio best fits reading process is the ability to maybe better adapt reading material to specific screen. This process can be done automatically according to screen limitations and preferences stated by knowledge creator. This can be done in development process or later using repurposing techniques [13].

## 4. Empirical study

New trends in information technology spiked the production and use of wide screens. Although wide screens are suitable for playing video material there is a reasonable doubt that they can prove to be ineffective when reading electronic material is concerned. In order to interrogate the influence of wide screen on quality of reading we conducted a specific form of usability study. The specific objective of our experiment was to explore and describe screen aspect ratios influence on reading quality and readers satisfaction. Students that major in computer science and related areas tend to rely on electronic reading material, mostly due to the fact that this specific area is fast growing. As a turbulent area of study, prone to frequent advances in technology, fastest way of exchanging knowledge is by creating and distributing electronic material. For this purpose we focused on reading for the purpose of studying engineering subjects, specifically computer science related.

### *4.1 Experimental methodology*

The experiment was conducted in laboratory setting. The research took place in a laboratory without external disturbances. The main focus of the experiment was to provide participants with electronic reading material. For reading purposes they would use devices with most popular aspect ratios. In order to simulate home and office surrounding as well as reading while mobile, for instance in commute, we also used handheld tablet devices.

The devices used covered two of most popular aspect ratios: 4:3 and 16:9. Both aspect ratios were represented in desktop and handheld variant (Table 1).

In [17], Jacob Nielsen said: "To identify a design's most important usability problems, testing 5 users is typically enough." This study included ten participants, students in computer science engineering. Their ages ranged from twenty-three to twenty-six. Both genders were evenly distributed. All participants reported to use computers for reading on a daily basis.

Before start of the experiment, a short briefing was used for introducing participants with the research protocol.

Research was carried out in three stages through five rounds. In first stage each of the participants read a text on one of the devices, in order to simulate the learning process. Texts were prepared for this purpose. They had equal number of words and they were presented in one column layout. Each text was displayed on three pages and contained one image in the beginning of the text. Every reading session was recorded with camera positioned over the participant's shoulder. Interactions with the device (click/scroll/tap/pinch) were logged by screen recording software. After reading, participant was asked to

**Table 1.** Devices used in experiment

| Device | Aspect ratio |
|---|---|
| **Desktop** | |
| IBM ThinkVision L180p monitor | 4:3 |
| Samsung SyncMaster 203B monitor | 16:9 |
| Samsung SyncMaster 203B monitor | 9:16 (16:9 in portrait mode) |
| **Handheld** | |
| Apple iPad 3 tablet | 4:3 or 3:4 users choice |
| Asus Slider tablet | 16:9 or 9:16 users choice |

take a knowledge test covering the information that was presented in the reading material. Test consisted out of twenty multiple choice questions. Upon completion of knowledge test a guided interview with participant was conducted in order to interrogate participant's impressions on reading process. Interview included nine questions, eight open-ended and one question with closed construction, whose purpose was to state the overall impression with reading on the given device, based on the principle of Likert scale [14]. Questionnaire used for the interview is provided in Appendix 1 of the paper. After finishing one round participant starts new round on next device. By doing this, each participant completed these three steps for each screen through five sessions.

### *4.2 Experiment results*

Processing of the collected data was done as a sheet based comparison of results for every tested display. Measures that were taken for analysis are reading time, number of interactions, score on knowledge test and subjective reading experience. Subjective reading experience includes numerical representation of satisfaction (Likert scale), as well as participants' comments that were given during the interview. Reading time is the number of seconds needed to read the text. Interactions are represented with events which occur when participant interacts with the screen by clicking, scrolling, tapping or pinching. Each separate interaction was counted during the process of reading. As for the knowledge test, correct answers were graded with 2 points each while every incorrect answer brought –1 point. Questions with no answer were not taken into account.

In our analysis of results, we used mean values of reading time, number of interactions and knowledge test points for each display. On Figs. 1 and 2 average reading time and average number of interactions were presented respectively. Fig. 1 reports highest reading time for 16:9 in portrait mode with

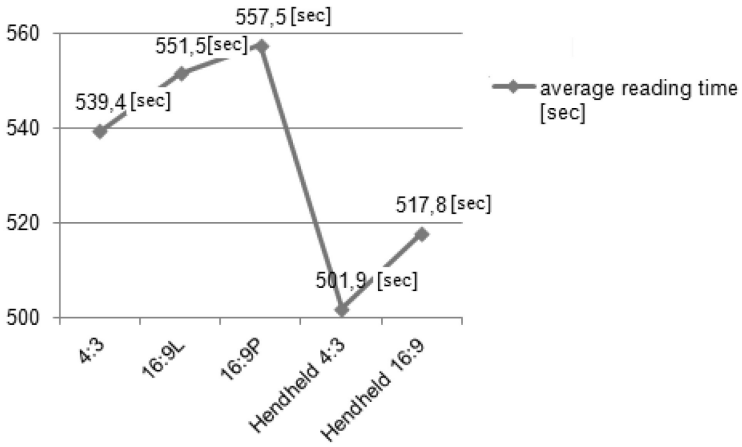


**Fig. 1.** Average reading time.

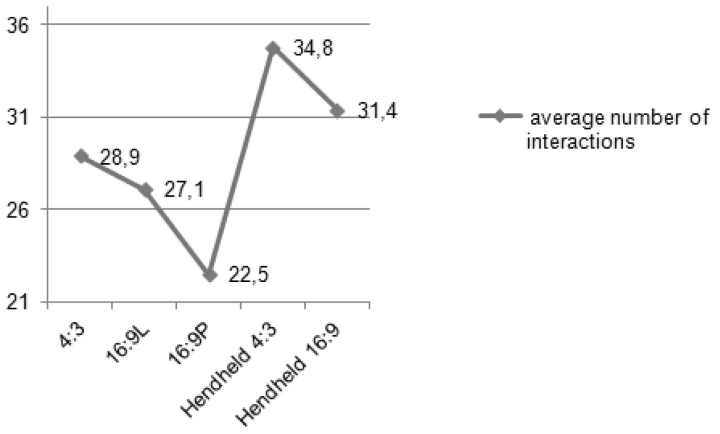


**Fig. 2.** Average number of interactions.

value of 557.5 seconds in average, while with handheld 4:3 display participants needed an average of 501.9 seconds to read the text, which is the lowest average time of all tested displays. It could be assumed that 16:9 in portrait mode will require minimum number of interactions, given that it reveals more contents than other screens. This is exactly what is shown on Fig. 2, where 16:9 display in portrait mode has an average of 22.5 interactions. On the other hand, handheld 4:3 display needs 34.8 interactions in average, which is a maximum average result.

Participants scored highest number of points on knowledge test based on text that they read on 4:3 display. Handheld 16:9 display is positioned on last place. It is interesting that 16:9 aspect ratio monitor has the same average knowledge test result for both landscape and portrait mode, which equals to 11.2 points. As shown on Fig. 3, this is just 0.6 points less from highest average score.

In order to collect and analyze data about reading experience, on devices with different screen aspect ratio, we used a Likert scale. Respondents expressed their satisfaction with the range of values from zero to seven. Fig. 4 shows average values of responses about interaction with devices, obtained by using Likert scale. Meanings of corresponding values are also given in Fig. 4.

## 5. Discussion

The main goal of this paper was to examine which type of display is most suitable for the process of reading electronic material. Specifically, we wanted to focus on readers' satisfaction and quality of reading. Our assumption was that 16:9 display in portrait mode offers conditions most similar to paper, to which we are already accustomed.

Texts used in the research, were prepared specially for this purpose. Topics covered in texts were adapted to engineering students. We have compared most frequently used desktop displays with 4:3 and 16:9 aspect ratios, as well as increasingly popular tablet devices (Android Slider tablet and Apple iPad

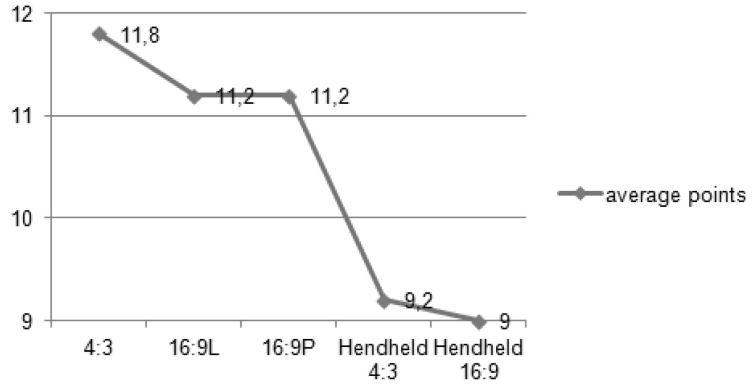


**Fig. 3.** Knowledge test average results.

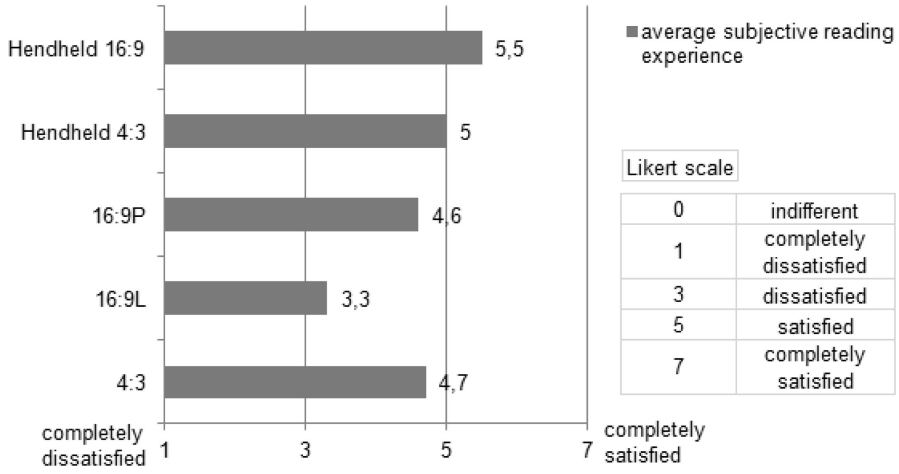


**Fig. 4.** Subjective reading experience.

3). In order to get quantitative results, we have used reading time, amount of interactions and knowledge test scores as measures. Subjective impressions are of great importance in making conclusions about quality and satisfaction of reading. Therefore, we also considered comments and opinions received from participants about tested displays.

Regarding to time of reading, displays were lined up in the following way. Handheld displays had best reading times with the average of 501.9 seconds on 4:3 aspect ratio and 517.8 seconds on 16:9 aspect ratio. Then follow desktop displays: 4:3, 16:9 in landscape mode and 16:9 in portrait mode with the average reading times of 539.4 seconds, 551.5 seconds and 557.5 seconds, respectively. The results showed that the maximum difference of mean reading times is less than 60 seconds. In accordance with these results, it can be argued that reading time is not a significant factor in examining the influence of different aspect ratios on reading electronic material. In addition, the fact that handhelds have the shortest reading time, in some part, can be explained by their good ergonomics and adjustability to body position of a reader. Actually, these characteristics of handheld devices are the most frequently mentioned positive comments of respondents, in the context of reading:

> "This device makes reading easy because of the possibility to set it where and how I want."

On the other hand, there is a big difference in results related to number of interactions for different screen aspect ratio devices. As can be seen on Fig. 3, average number of interactions needed for reading on 16:9 in portrait mode is 22.5. This is the lowest average number of interactions needed for participants to read the text on desktop devices. On the contrary to reading time results, handheld devices have not shown to be very good in terms of number of interactions needed to navigate through the text. Handheld display with 4:3 aspect ratio placed last with an average of 34.8 interactions, and for handheld display with 16:9 aspect ratio average number of interactions is 31.4. Obtained values can be explained by the fact that desktop widescreen display in portrait mode has the largest screen, which allows displaying greater part of text. That directly indicates the lower number of interactions needed on 16:9 display in portrait mode. Less favorable average results for handhelds are a consequence of smaller screen, but also of need for more interaction in order to position to a desired part of the text. These statements are supported by respondent's comments about interaction with devices.

For 16:9 in portrait mode:

> "Easy navigation through the text. No need for a lot of movement."

For handheld devices:

> "Positioning at the desired part of the text is difficult because of the way of scrolling and movement through text."

Average knowledge test results presented on Fig. 4, show that desktop devices have the advantage over handhelds, when speaking of influence on readers' memory. There is a minor difference of 0.6 points between targeted display—16:9 in portrait mode and display which proved to be the best in this aspect of research—4:3 display. The difference in scored points could be attributed to difficulty of the text. Results for handhelds are significantly lower. Explanation can be found in their smaller screens, but also in the way of interacting with handheld devices. On these devices interaction includes fingers instead of a mouse. Furthermore, higher number of interactions is needed in order to position to the desired part of the text. These facts negatively affect monitoring, comprehension, focus and concentration of readers [15]. Last statement is substantiated by most frequent respondents' comment on handheld devices, about scrolling:

> "The navigation through text was very easy. But the main problem with navigation was that I had to scroll a lot. Every time I scrolled the text, my focus was disrupted."

Subjective reading experience data obtained from interviews unambiguously indicate that in most of the cases the respondents would choose handheld devices. Portable devices stand out as a logical choice, considering that they emulate reading from a book or paper the best and they allow reader to take a comfortable body position. However, according to analysis based on the test results, it is evident that when using handheld device, memorizing the facts from the text is on a low level.

In accordance with all presented results, we can conclude that if readers are sitting at the table, the most logical choice for reading is 16:9 display in portrait mode. Benefits of using this screen aspect ratio, confirmed by the results of the study presented in the paper, can be summarized in the following few sentences. 16:9 aspect ratio in portrait mode has lower number of interactions. Average knowledge test results show that desktop devices have the advantage over handhelds in examination of influence on readers memory. In addition, 4:3 display result is better than 16:9 in portrait mode just for 0.6 points. Higher grade of handheld devices in terms of reading time is already discussed. Their characteristics, such as good ergonomics and adjustability to body position of a reader are key factors that favor handheld devices. Nevertheless, these characteristics are not the subject of this study as they have no connection with screen aspect ratio.

## 6. Conclusions

By analyzing the results, we discovered that there is no significant difference in reading time between both modes (landscape and portrait) of widescreen display and traditional display with 4:3 aspect ratio. When it comes to reading on handheld devices participants managed to complete reading the text in a significantly smaller amount of time. This can be attributed to anatomical superiority of handheld devices, which in the best way emulate reading from books.

Even though handheld devices were superior in reading time, knowledge test actually stated their inferiority when it comes to memorising the content. This fact can probably be explained by rather small dimensions of the screen on such devices that uncover only a small portion of the text at a time. Larger desktop screens proved better for learning of the material where 4:3 aspect ratio proved to be slightly better than others.

However, analysis of the required number of interactions showed main advantage of 16:9 display in portrait mode probably due to its ability to show more content at a time. This advantage implies less need for scrolling, which reduces interruption of focus and concentration. Also, reader is able to see a more complete segment of the text or a whole image.

Finally, users decided to choose handheld devices as best for reading, following by 4:3 and 16:9 in portrait mode aspect ratios. Widescreen aspect ratio (16:9) was voted the last as it was expected by authors. Some of the participants opinions gathered through interview spoke in favor of 16:9 in portrait mode since it resembles reading of the paper. The main expectation was that new trend in using widescreens is not the best choice for reading. Our experiment spoke in favor of such assumptions.

In spite the favourable findings in this paper our approach indicated some downsides. Conducting of the experiment during one five round session proved tiresome for some participants and this might have affected their overall performance. Also the job of creating five different texts of same semantic value that carry equal amount of information proved as a difficult task.

In our future work we will focus on improving the experiment process in order to remove factors that can influence the final results. One of important aspects to be in focus is the specific profile and specific motivational factors of readers. Finally specific gestures and facial expressions of participants should be taken into account in order to better understand participants' emotions during the reading process.

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## Appendix 1: Questionnaire used for interview

**Appendix 1**

1. To what extent did reading of proposed text correspond to the experience of reading from paper?
2. What is your impression about interaction with the device during reading of given text?
3. Was it easy to navigate through the given text?
4. How much were you able to follow and understand the contents of the text?
5. Were you able to keep your concentration and focus while reading?
6. How interesting was the text?
7. Rate your experience of reading on offered device:
   1 completely dissatisfied
   3 dissatisfied
   5 satisfied
   7 completely satisfied
   0 indifferent
8. Which device you like the best for reading and why?
9. Open comment

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