

Beyond Reading Media and Interaction Behavior: Cognitive Implications of Digitized Reading Patterns

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Abstract

This paper examines the reading and navigation behaviour when interacting with paper and digital tablet media. An experiment of reading a newspaper in spreadsheet format was conducted. The interaction with the newspaper in the paper and digital setups was video-recorded. Qualitative, visual inspection of the interaction behaviour enabled identification of reading and navigation patterns specific to the reading media. The patterns were quantified as duration to assess the amount of time dedicated for reading in contrast to navigation. The findings show that, in paper reading condition, reading time is higher when compared to tablet condition. On the other hand, the navigation time was generally higher in the tablet than in the paper condition, with possible consequences on the cognitive load. The paper discusses the findings in light of the limited capacity of mediated message processing model and derives implications to the design of digital reading interfaces.

Keywords: Reading behavior, newspaper reading, digital reading, cognitive processing, limited capacity model of mediated message processing

1. Introduction

The morning newspaper, a bundle of newsprint paper smelling of freshly printed ink, has been an integral part of the morning routine of many since 17th century, becoming an institution of its own right, with its established design, development, and content providing traditions and ways of reading. The term newspaper itself points to a collection of news that has been printed on a paper. However, the emergence of digital online newspapers on computers in 1980s and 1990s and on mobile devices in 2000s has challenged this status quo. On the other hand, the printed newspaper is not disappearing any time fast, since studies have shown that newspaper readers perceive print and digital newspapers as complementary to each other and are not ready to choose one over the other [9,10]. Nevertheless, the existing newspaper design traditions of printed newspapers cannot be transferred as such into the digital newspapers read on mobile devices, which creates a challenge to designers, developers, content providers, and readers of digital newspapers.

Despite there exist numerous isolated studies comparing digital and traditional reading, most of them focus on comparing performance such as reading speed (e.g., [33]), as well as high-level information processing like recall, comprehension, and creativity (e.g., [35]). The findings are often controversial showing contradictory findings (cf. [4], [8], [35]), while the topic lacks a systematic approach on causes or implications in relation to human information processing. In contrast, most of the studies are limited to identifying differences in effects rather than pointing out behavior that leads to those effects. As such, there are still gaps in the research comparing printed and digital newspapers and reading on paper and reading on a digital device in general, especially concerning the fundamental reading behaviors and patterns such as user actions, as well as identifying the implications in a systematic way.

In this paper, the differences between the two media, print paper and a tablet computer, are examined with respect to the reader's interaction behavior. Reading and navigation patterns during newspaper reading are derived and identified. The research question guiding this study is: *What differences are there between tablet and paper media in terms of reading and navigation patterns?* An experiment was conducted in which the

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participants read the largest Finnish newspaper in two conditions: the traditional paper version and digital tablet version. Each participant took part in the study individually and read/browsed the newspaper of the day for 15 min in each condition. The data analyzed in this paper consists of video-recorded user actions during the two reading sessions. Based on the collected data, two findings are observed: 1) effective reading time on tablet was lower than on paper; and 2) navigation time and navigation-tasks diversity were higher on tablet than on paper.

These findings indicate that the two media inherently may facilitate two kinds of reading behavior: traditional paper enables better sustained reading as compared to digital reading; on the other hand, digital reading requires the user to allocate more time and resources on navigation when compared to the traditional reading medium. However, these implications should be explored in further research. As a step in this direction, the paper examines the findings in light of the model of limited capacity of mediated message processing (see Lang [20]) as an approach to frame the implications of media-specific reading behaviors on the actual processing of information displayed on digital media. In turn, this fact has implications and challenges on how to design mobile reading interfaces that are optimal for the intended purpose.

The paper is structured as follows. Section 2 summarizes the existing research on comparing digital and paper reading. Section 3 briefly describes the limited capacity model of mediated message processing. Sections 4 and 5 describe the methods and the results, respectively. The last sections discuss the results and their implications to design and conclude the paper.

2. Related work

Print paper and digital media have been empirically compared since the introduction of personal computers in work and everyday tasks, namely since 1980s. Whereas in early comparisons, the paper medium showed some sort of advantages over the screen, nowadays, with the advances in technology and computer literacy, these differences blur [19], [27,28], [33]. However, one can still argue that each medium has its own strengths. The strengths of the print paper are natural/quick navigation, flexibility of the spatial layout (e.g., unfolding the papers), serial presentation and, not less important, the subjective preference of the readers. The benefits of digital reading include the automatic search, updating of content, hyper-linking, multimedia, accessibility, colors, and the fact that people have become more computer literate [7], [29,30], [33]. In addition, the size and weight of computer tablets and the improvement in screen quality make reading from mobile devices increasingly acceptable, especially in conditions where a paper version is not convenient [9], [33]. In the following, two types of related work are summarized: 1) reading behaviors from various perspectives especially oculomotor activity and reading styles, and 2) cognitive processing implications of differences in reading media.

2.1. Reading Behaviors Associated with Digital and Paper Media

Liu [24] investigated the reading behavior in digital environment and examined the evolution of reading behaviors. The findings showed that electronic reading involved more browsing and scanning, keyword spotting, selective reading, and that people spent less time in concentrated reading when compared to paper reading. Moreover, reading on digital media came with a loss of reader attention. Liu pointed out that some differences in reading behavior between paper and tablet might be explained by the fact that the paper medium is associated with thorough reading (of, for example, books), while electronic reading is often “for fun” and, thus, more selective and less concentrated. Hillesund [12] examined the way in which proficient readers handle print paper and digital texts and explained the concepts of continuous and discontinuous reading, and the combination of those two. Chen et al. [3] found that navigation patterns specific in digital and paper reading do not affect reading comprehension; however, navigation style was the main factor affecting the process of reading.

In a study on news reading on a screen versus paper, Holmqvist et al. [13] employed eye-tracking and found that online news readers scanned more and read less than the traditional newspaper readers. That is, readers of online newspapers spent more fixation time on the link lists (scanning) than on the article areas (reading). On the other hand, a more recent eye-tracking study [36] found no significant differences between reading on the mobile devices and paper in terms of oculomotor behavior, though when comparing computer displays with tablets and other e-readers, the mean fixation duration was significantly longer in reading on the computer screen. Another study [17], based on data about reading patterns collected in 2013 from a readership study and automatic logs of a Swedish newspaper, found that print readers and online readers differ in the articles and pages they select for reading, but the amount of time spent on each article becomes closer in the two reading conditions.

2.2. Cognitive and Emotional Implications of Digital and Paper Reading

Reading comprehension is extensively studied in comparisons of digital and paper reading, and majority of the studies report better performance associated with paper medium than with screen (see [26], [35]). However, some studies report equal performance on reading comprehension ([4], [8]), which may also be due to the increasing familiarity with the digital medium (see [3]). Among the research showing superior reading comprehension when using paper compared with a computer screen, [35] also showed that levels of stress and tiredness were higher for the participants in the computer-screen condition. The authors' explanation emphasized the difference of text configuration in the two media, which makes the acquisition of information to proceed slowly in the case of the screen presentation compared with the paper. For the screen presentation, the authors argue, that more cognitive resources are invested due to the deficiency of the information presentation. In addition, in the case of reading from a screen, there is higher workload due to both reading itself and operating the computer. Chen et al. [3] compared tablet, computer, and paper reading and found that reading comprehension is also affected by the familiarity with the medium, as people with a higher level of tablet familiarity had better deep level comprehension than the ones with lower tablet familiarity.

Regarding emotions and motivation, earlier and recent studies (e.g., [7], [16]) pointed out that people prefer the print medium and feel more familiar with it. A national survey on the newspaper reading trends in Finland [9] showed that media consumers are still committed to printed newspapers and magazines and they want to read both electronic and print media, rather than choosing one of them. Flavian and Gurrea [10] have studied the motivations behind reading newspapers online vs. print and if the two media can be seen as substitute products. They showed that both formats are considered as information conduits and not as substitutive products. However, motivations that could be satisfied by both media positively affect the level of perceived substitutability between the reading media in contrast to the motivations driven by the differential attributes of each medium.

Noyes and Garland [29] pointed out that the physical nature of a computer screen also evokes additional processing during task execution compared with a paper condition, which in turn leads to greater perceived and actual workload. Moreover, the differences in the way information is retrieved on screen and paper has been found to result in differences in memory due to the nature of visual input [29]. D'Haenens and Heuvelman [5], in an experiment on how readers consume and recall news presented in online and paper versions of two Dutch newspapers, showed that the news consumption was not influenced by the news format, but rather by the news category or reader's characteristics. However, no systematic differences were found to distinguish between the readers of the print paper and digital formats. The only difference found was that the participants reading printed newspapers recalled the news better. Mangen and Kuiken [25] studied narrative engagement when reading on booklet and tablet and found that level of experience with digital reading did not affect reading engagement. Tablet reading was found generally generating lower engagement with the text and handling of the medium. On the other hand, booklet readers reported better transportation and empathy than tablet readers.

Hou et al. [14] compared recently paper and digital reading of a comic book and found that reading comprehension, fatigue, and immersion were similar in the two conditions if the digital reading was not disruptive. The methodology used in their study enabled them to conclude that the reading outcome is not influenced by the materiality of the presentation medium (e.g., screen vs. paper, or tactile dimensions of the medium), but rather by the way the text is presented and facilitates the reader to construct cognitive maps of the text structure. The cognitive map mechanism is also found useful to explain why paper books are better for readers to form a coherent cognitive map of the text than digital texts [15] which have consequences on increased reading outcomes and performance [14].

Despite the many benefits of digital reading such as providing different levels of navigation support for the manipulation of the digital text, and presenting capabilities for analytic reading (e.g., annotation, highlighting, indexing), Brown [2] acknowledges that the paper medium is more suitable for sustained reading. However, Brown also posits that the reading habits change with the development and pervasiveness of reading technology, and that reading is a multidimensional act that involves many strategies depending on the goals of reading such as pleasure and enjoyment, information and learning. Moreover, it is recognized that in paper reading, readers feel omnipotent, they dominate text, and they have a feel of orientation given the physical and tactile properties of the medium [2]. This natural navigation is not encountered when using digital reading media and the loss of context may hinder the motivation and attention. Thus, the navigation in digital reading media is essential for creating a positive reading experience and Brown points out that software development in this direction is a promising research area which has also implications in creating new habits of reading.

3. Limited Capacity Model of Processing Information

The limited capacity model of information processing developed by Lang [20] is founded on the assumption that the ability of people to process information is limited (see also [1], [11]). Accordingly, the cognitive resources (for attending the different stimuli from the environment, encoding new information into the working memory, and/or performing other cognitive processes) are limited and compete for different processing tasks [20]. The model is useful to explain and understand how mediated messages are processed and has been applied in media and communication research, for example in the context of television viewing [20] and communication (see e.g., [21]).

The model of limited capacity of information processing or limited capacity of mediated message processing (LCMMP henceforth) turns the focus from behavior to information processing (see [18]), following the paradigm shift in psychology started in the late 70's (see [23]). Accordingly, media in the term "mediated messages" is conceptualized as a complex set of stimuli characterized by multiple variables that are psychologically relevant and continuously change in time such as attention, encoding, storage, resource allocation, effort, and elaboration [23]. The LCMMP model can thus provide a sound theoretical basis to the information systems (IS) and human-computer interaction (HCI) research to explain and understand implications of digital media design for reading on both the design of better interfaces and optimal human information processing. Currently, the model is not applied as such in IS and HCI communities.

According to the LCMMP, three elements are interacting in mediated message processing: *the viewer, the medium, and the message or information* (see [22]). The viewer (user in computer science) is the information processor; his/her ability to process information is limited. The medium is seen as a set of structural features used to present audio or visual information. The message is characterized by different attributes such as the topic, genre, and information contained in a message. Media use (as well as computer use) can be defined as the "allocation of a limited pool of processing resources to the cognitive processes required for viewers to make sense of a message" [22]. Moreover, processing a message "includes (but is not limited to) the parallel cognitive subprocesses (or tasks) of encoding, storage, and retrieval" [22]. The subprocesses occur simultaneously while the user attends different stimuli contained in the message as well as in the medium.

The user selects (on a conscious or sub-conscious basis) which information in the message to encode and store, because it is not possible to encode and store all the information. The selection is based on the amount of resources available for processing (encoding, storing, and retrieving), and these resources in turn are affected by all elements involved: the user, the message, and the medium. Thus, besides the user's interest and familiarity, and the message contents characteristics, the presentation medium itself plays a crucial role in information processing.

The LCMMP facilitates the understanding of how users of digital reading interfaces successfully attend the relevant information, encode it, store it, and comprehend it, and enables the operationalization of the challenges faced by digital readers in terms of cognitive processing. If too many resources are allocated for automatic processing and/or for controlling/operating the interface, there can be left insufficient resources for encoding, storing, and retrieving the relevant information, with negative consequences on comprehension and other higher-level cognitive tasks. In addition, controlling/operating the interface affects the perceived ease of use, tiredness, and stress experienced by readers. Therefore, this model provides a theoretical basis to IS and HCI research for the design of reading systems and interfaces that compensate the effort to manipulate the interface and bound the unnecessary orienting responses that distract readers' attention from the relevant information presented on the digital medium.

4. Methods

A laboratory experiment was conducted during February-April 2012 with participants individually reading a newspaper on a digital tablet and a traditional print paper. The participants were recruited via email by sending invitation letters to student mailing lists. The incentive to participate in the experiment was three movie tickets. The experiment was conducted by employing the ethical principles stated in the Declaration of Helsinki regarding human research subjects; written consent was collected from all the participants.

4.1. Participants

All participants, but one, were students within the age range of 19-40 ($M_{age} = 24$, $SD = 4.2$). The sample size was 29, where 8 were men and 21, women. Most of the participants (96.6%) had reported no experience to little experience with a digital tablet or a similar gadget; thus, this sample represents rather novice users of a tablet computer. Fourteen participants (44.8%) were at the moment of the experiment subscribed to the newspaper. Of all selected participants, 19 (65.5%) reported themselves as regular readers.

4.2. Study Design, Materials, Task

The design of the experiment was within-subjects¹. Each participant was exposed to two conditions; reading the print version of the largest newspaper in Finland, Helsingin Sanomat, and reading the digital version of the same newspaper. An iPad 2 tablet, which supported a dedicated iPad application of the newspaper, was utilized as the digital platform. The order of the conditions was counterbalanced. Each reading session lasted 15 minutes. The participants were free to select for reading in each condition the news articles they wished. The contents of the articles were not controlled; instead a fresh issue of the newspaper was provided for reading in the experiment day, resulting in 23 different issues being used in the experiments (one or two experiments were carried out per day).

The arrangement was planned such that to provide a laboratory setting that resembles natural reading in an everyday situation. For this reason, also the digital reading on the tablet was set up by utilizing the online version of the newspaper, with all inherent connection and live events that may occur when using an online system. Participants were

¹ During the experiment psychophysiological data were also recorded, and, because individual differences affect the psychophysiological values, it is recommended to use a within-subjects study design (see [32]). The collection and analysis of psychophysiological data are reported in [31].

instructed to skip reading the ads and the weather. The reading behavior was video-recorded; for the tablet also screen capture was recorded.

4.3. Data Analysis

Video coding and coding schemes

Visual inspection of the interaction behavior with the two reading media was conducted using Noldus Observer XT. Two coding schemes of events and behaviors were produced in an iterative manner, one for each reading condition. The coding schemes for the two media have also been matched so that the findings could be compared across the media. The scrolling behavior in the digital reading condition has been coded so that to distinguish between scrolling that disrupts reading and scrolling during which reading is possible. The reason was to obtain a measure of the time during which the subject actually reads the articles of the newspaper. The final coding schemes are shown in Table 1. Three types of behaviors were identified: 1) mutually exclusive events or states (at a time, only one of them can occur); 2) mutually exclusive behavior with no match with other media (e.g., events or states specific to one media); and 3) external behavior (behavior that can occur simultaneously with mutually exclusive states or events). Concurrent behavior in Table 1 defines behavior occurring simultaneously with reading or navigation and not affecting those in a disruptive way.

Table 1. Coding schemes for paper and tablet reading

Paper reading	Type	Tablet reading	Type
<i>Mutually exclusive Behavior</i>		<i>Mutually exclusive Behavior</i>	
Open newspaper	Start event	Open newspaper	Start event
Turn page	Navigation	Transition event	Navigation
		Select event	Navigation
Front page	Reading	Front page view	Reading
Spread open	Reading	Article view	Reading
		Section view	Reading
Disruptive distraction	Disruption	Disruptive distraction	Disruption
<i>Mutually exclusive event with no match on tablet media</i>		<i>Mutually exclusive event with no match on paper media</i>	
Revisit spread	Reading	Menu view	Navigation
		Error	Disruption
		Advert	Disruption
		Comic view	Reading
<i>External behavior</i>		<i>External behavior</i>	
Non-interruptive distraction	Concurrent behavior	Non-interruptive distraction	Concurrent behavior
Hand movement	Concurrent behavior	Holding tablet in hand(s)	Concurrent behavior
Small adjustment of the paper	Concurrent behavior	Additional content view	Concurrent behavior
		Picture view	Concurrent behavior
		Slow loading	Disruption
		No content	Disruption
		Point scroll	Reading
		State scroll	Navigation

Coding accuracy, data cleaning and pre-processing

The coding was conducted as accurately as possible by three research assistants in a cooperative manner, under close supervision by the author. Most of the coding relied on visual inspection in Noldus Observer XT, and whenever needed frame-by-frame inspection was employed to achieve the greatest accuracy. The timestamps in the logs were reported with millisecond accuracy. During the experiment, there have occurred a few Internet connection errors, downloading errors, and unresponsiveness of the software. For two participants, these errors caused a relatively large disruption time, and therefore data from 2 subjects were discarded. Thus, 27 participants were retained for further analysis.

The behavioral analysis and the coding scheme were used to quantify the reading and navigation behaviors in terms of number of pages (spreads vs. views) visited, total and average duration of visits per reading session, number of navigation events (page turns vs. view and menu transitions and selections), and total and average duration of navigation events.

5. Results

5.1. Media Differences

In the tablet application of the newspaper, the articles were organized in sections named similarly as in the traditional paper. However, each section was displayed on a separate page, and the articles were displayed on the page by headlines and a short excerpt from the article. Different types of views (pages) where reading occurred have been distinguished in tablet reading such as front-page view, section views (including comics), and article views. These views accounted for the reading behavior in the tablet reading condition (see Table 1). Other views in the tablet condition included menu, adverts, as well as popups; these were not included as reading to ensure the match between the contents of the two experimental reading conditions.

The reading patterns associated with the two media appeared to display several differences. In a paper version of the newspaper, the subject had a lot of information visible at once in one spread. Reading on paper was identified when participants were viewing the front page, had a spread open, or revisited a spread (see Table 1). In contrast, in the tablet version there is only a limited amount of text visible at any given time. Thus, the digital version of the newspaper triggers several user actions for the navigation, not only between sections and articles, but also for scrolling inside articles to advance text. One clear difference between the two media was that the number and diversity of the events and behaviors in tablet reading were larger than in the paper version (see Table 1). Two types of strategies for advancing text were observed using scrolling: 1) to enable reading at the same time (coded as point scroll), 2) fast scrolling to the extent that it is not possible to read (state scroll). This kind of fast scrolling has been coded as disrupting reading and the time allocated for this action was subtracted from reading time. Other events that have been found to disrupt reading were social media popups for sharing the article, popups regarding the wireless connection, notifications of updates for the software. These events were excluded from both the reading time and the navigation time.

To quantify the navigation, for the paper session, the main events considered were the page turns, irrespective of direction or number of pages turned at once. In tablet session, the interaction behaviors coded as navigation were the following: 1) transitions between articles, between sections, and between articles and section views; 2) menu views. Thus, the events defining the navigation behavior on the tablet newspaper comprise the transition events, select events, and menu views. The reason of including menu views into navigation and not into reading was that, typically, the menu is a means of selecting the desired options or contents; thus, it is typically employed when readers wish to change the current view.

5.2. Within-Subject Reading Behavior

Overall, across the 27 participants, the time allocated for reading in the paper reading condition was higher than in the tablet reading session. When **comparing the reading times** in the two experimental conditions, overall, the time spent on reading on paper is higher than the time spent on reading on tablet ($M_{\text{paper}} = 841.6$; $M_{\text{tablet}} = 793.2$), and this difference is statistically significant according to the Wilcoxon signed rank test ($Z = -3.15$; $p = 0.02$).

In the **paper reading sessions**, overall, the time spent on reading (namely, the time spent on open spreads) was representing 93.5% of total session time and the average variation was about 40 s (4.4%). The participants spending the least amount of time having their spreads open for reading spent a fair amount of time turning pages, 196 s and 118 s, respectively, meaning that they have used about 20% and 13% of their reading time, respectively, for browsing. On an average a subject spent 78.7 s ($SD = 46.7$ s) on a spread, including the revisited spreads.

In the **tablet reading sessions**, on an average a subject read a fairly large amount of time representing about 88.1% of all reading session with a variation among participants representing 6.2% of total reading time.

To account for **both the order of session and the reading medium**, a linear mixed methods analysis was employed. The duration of reading was significantly affected by the reading medium ($t = -2.67$; $p = 0.01$; $b_{\text{Tablet}} = -49.8$). Neither the order of the session nor the interaction medium \times session did affect the total duration. Thus, in the paper reading session, participants generally spent a longer time on reading as compared with the tablet reading session, regardless of the order of the sessions. When evaluating the reading duration, the subject operationalized as the intercept in the regression line was not found a contributing factor and thus was not introduced as random effect.

5.3. Within-Subject Navigation Behavior

Generally, across the 27 participants, the time spent for navigation was higher in the tablet reading condition. In the **paper reading sessions**, across the sample, the average number of page turns was 14.6 per session. The average duration of all page turns was 52.8 s per session, representing 5.9% of total session time. In the **tablet reading sessions**, across the sample, the average number of navigation events was 44.0 per session. The average duration of the navigation events was 59.0 s, accounting for 6.55% of the session duration.

When **comparing the duration of navigation events between the two media**, the difference was not found statistically significant according to Wilcoxon signed rank test ($Z = -1.55$; $p = 0.12$). However, when examining the data more closely, it was found an outlier that had both on paper and on tablet extreme durations for the navigation (i.e., 42 page turns per session and 111 navigation events on the tablet). Removing this outlier from the analysis provided evidence that generally the duration of navigation time was higher in the tablet condition than in paper reading condition ($Z = -1.98$; $p = 0.048$; $N = 26$).

To account for **both the order of sessions and the reading medium**, the linear mixed methods analysis showed that the duration of navigation events was not affected by the reading medium, but by the session order ($F(1,25) = 4.13$; $p = 0.05$). However, the estimate of the session order effect on navigation time was not found statistically significant. When removing the two outliers with the highest duration of page turns, the results showed that both the reading medium and the session order affected significantly the navigation duration model, but only the reading medium had a significant impact on the duration (i.e., reading on tablet was associated with an increase of navigation time by 21.18 s; $t = 2.13$; $p = 0.04$; $b_{\text{Session=1}} = 21.18$). The interaction effect between medium and order was not found significant either. However, in this case, there were observed individual differences between participants, and thus the subject operationalized as intercept in the regression line was introduced as random effect.

6. Discussion

This paper compared the reading and navigation behaviors when people interact with two essentially different media: traditional paper and digital tablet. The analysis relied on qualitative coding of the interactions of users with the digital and paper media while reading a newspaper. The reading and navigation behavior were quantified in terms of total and average duration of visits/views per reading session, and total and average duration of navigation events.

6.1. Differences between Reading Media

The findings showed the two reading media are essentially different in the way people navigate and select information. There is more information accessible at once in the paper reading; the tablet computer allows only a limited amount of information to be displayed at once. Moreover, there are more user actions and navigation possibilities in the tablet reading which require more cognitive resources to be allocated in the digital reading situation for non-reading tasks compared to the traditional paper medium (see also [29], [35]). Accordingly, our results indicate that the traditional paper medium facilitates sustained reading; there is more time allocated for effective reading in paper reading

compared to the tablet reading. This confirms earlier results and assumptions that paper is a more suitable medium for sustained reading [2], [7], [13].

The navigation time was also generally higher in the tablet reading condition than in the paper reading. However, this result was not as robust as in the case of reading time; both session order and some extreme user behavior affected the stability of this finding across the sample. Thus, one limitation of the present study can be regarded as being the relatively small sample size.

6.2. Cognitive implications

The findings related to reading behavior showed that –the paper medium elicited longer time spent on effective reading as compared to the tablet medium. In light of LCMMP model [20], it means that the paper reading condition favors the allocation of cognitive resources such as attention and memory (encoding, storing, retrieval) to processing content including news messages as well as headlines, pictures, and so forth. In contrast, the digital medium triggers a relatively smaller amount of resources to be allocated for effective reading. The duration per spread visit in the paper reading is more than double of the duration per view in the digital reading, telling that the attention of the reader is allocated a lot more to non-contents information and interface design elements. Thus, an increasing amount of resources is spent on the automatic or controlled processing of the information present in the interface that may also disrupt the reading. The consequence is that of the pool of available resources more of them are allocated to non-reading tasks in the digital reading when compared to traditional reading, with possible negative implications on higher-level cognitive tasks such as making sense of the information, comprehension, and recall. Furthermore, the necessary encoding, storing, and retrieval of information relevant for controlling the interaction and navigation make the experience of digital reading potentially more tiring and stressful especially for users who are not familiar with a specific interface. This in turn may have negative consequences in the ability to process further the news messages or to reflect and act upon the information.

These consequences are in line with the findings in earlier studies analyzing reading on the two media that showed decreased comprehension and increased level of stress and tiredness when reading from computer screen [35]. Wästlund et al. [35] argued that more cognitive resources are invested during reading in screen due to a deficiency of the information presentation and also due to a higher workload of reading itself and operating the computer. The navigation behavior observed in the two conditions supports the above predictions. There were observed more navigation events in the tablet reading, which according to the LCMMP model [20] would account for additional processing resources that would negatively influence the attention to news content and their processing. Moreover, the overall time spent on navigation and user actions to access content was generally higher in the tablet reading, strengthening the prediction that relatively more resources were employed for non-reading tasks in the digital reading.

6.3. Implications to Design

The analysis of the behavioral patterns showed that the paper medium proves to still have an advantage over the digital reading because of the natural navigation and focus on effective reading. This has implications on finding better solutions for the design of digital interfaces for reading to be as natural for the reader as the paper reading. Novel digital interfaces that are based on scrolling still lag behind paper media in performance and feeling of naturalness; scrolling can become frustrating when the pages are advancing too fast and there is no feeling of control over the content being browsed (see also [2]). On the other hand, interfaces that require clicks and selections require a lot of control from the user, who then allocates a lot of attentional resources on manipulating the interface, which may have negative effects on processing the relevant information.

Analyzing the effect that the order of the sessions has on reading and navigation behavior showed that in the digital reading, when the newspaper content is not completely

new, there are a lot of scanning and browsing events. This means for designers that the digital reading interface should be designed so that the content already seen is hidden from the reader so that the access to interesting and novel information is facilitated.

Our findings showed that disruptions such as slow loading, fast scrolling, pop-ups may occur in natural digital reading as opposed to traditional reading, and thus during digital reading there are challenges for designers and developers to provide disruption-free reading experiences to facilitate flow and to avoid fragmentation of reading. This is especially relevant in light of the study by Hou et al. [14] which showed that paper and digital reading are similar in terms of comprehension, fatigue, and immersion if the digital reading is not disruptive. In addition, designers should explore different solutions to make the information presentation easily accessible through different mechanisms that prove to be optimal to the intended purpose, for example to facilitate the creation of coherent cognitive maps of the text (see [15]).

The findings showed significant differences in navigation time and more diverse navigation strategies in the tablet reading, which diverge from the natural navigation encountered when interacting with the paper medium. Thus, designers should explore novel and innovative navigation paradigms for the digital reading as they are essential for creating a positive reading experience. Brown [2] pointed out that software development in this direction is a promising research area which has also implications in creating new habits of reading.

6.4. Future work

The present study showed also that individual differences play a role when comparing navigation behavior, but not reading behavior. The effect of certain user profiles has not been studied in detail here, however, there are studies that show that familiarity with the medium [3] influences the performance of readers such as in comprehending the text and that users' characteristics are associated with different patterns of news consumption [5]. Thus, additional research should also be conducted to study the effect of individual characteristics on both reading and navigation behavior. In this study, the random effect introduced in the linear mixed model analysis was found significant in modelling the navigation time; the individual characteristics reflected by the variable subject had a significant influence on the intercept in the regression lines, indicating that an amount of variation in the navigation time was due to individual characteristics. In addition, the analysis of the reading and navigation behavior based on partial correlation, when the effect of session order was controlled for, showed patterns that may reflect different styles of reading. As shown also in previous research, individual characteristics do influence reading behavior and preferences (see e.g., [3], [5], [16]), and research is needed in this area to profile the reading styles and readers typologies. In this respect, it has been shown that personality and approach motivation dispositions affect the physiological responses to reading on different media such as paper and tablet [31]. The present research could be extended by including in the model of reading and navigation the individual characteristics such as type of reading (systematic, focused), and preference of news categories (see [5]), as well as personality and motivational disposition (see [31]). Moreover, new studies should be conducted with different types of users with varying level of experience with a tablet computer. At the time of the experiment, the tablet computer was a relatively novel technology, the newspaper application was just launched, and the sample comprises mainly novice users of tablet. Reading and navigation behavior may be different when users are familiar with the device and/or newspaper application.

For future research, there is a need to study the way the navigation and interaction events, states, and actions affect the overall reading experience and cognitive load by utilizing the models of limited capacity of mediated message processing [20], as well as viewer engagement (see [6], [34]). These give a basis for studying further the interaction between user actions and behavior on the one hand, and cognitive and emotional processing on the other hand. Moreover, size of the display could also be a variable to further explore.

7. Conclusions

In summary, this paper shows that reading on paper elicit a longer time spent on effective reading tasks when compared with the tablet medium. Moreover, the navigation tasks are more frequent and consume more time and implicitly cognitive resources in the digital reading. This paper contributes to understanding the reading and navigation behavior in the light of the limited capacity of mediated message processing model and by this draws attention to designers to take into account not only the behavior, but also the internal processing of information and resource allocation for information processing when designing reading interfaces to ensure optimal user engagement and experience.

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