Is Pagination Better than Scrolling when Reading on a Phone?

Nikhita Joshi
nvjoshi@uwaterloo.ca
Cheriton School of Computer Science
University of Waterloo
Waterloo, Canada

Géry Casiez* †
gery.casiez@univ-lille.fr
Univ. Lille, CNRS, Inria, Centrale Lille
UMR 9189 CRIStAL
Lille, France

Daniel Vogel
dvogel@uwaterloo.ca
Cheriton School of Computer Science
University of Waterloo
Waterloo, Canada

ABSTRACT

Scrolling and paginating can both be used to read documents on smartphones. Prior work mainly suggests that pagination leads to higher reading comprehension, but these studies have either focused on desktop environments, are over 10 years old, or lack ecological validity. Therefore, we replicate these experiments to better understand the differences between scrolling and pagination. Through a large-scale, between-subjects online study, participants read a short story using either pagination or scrolling, and answered multiple-choice questions. Our results found no significant differences between these two techniques for reading comprehension, duration, and task workload, which differs from findings presented in prior work.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

reading, controlled experiments

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1 INTRODUCTION

The fundamental interactions to navigate documents longer than a single device screen are *pagination* and *scrolling*. Pagination separates a document into discrete pre-defined chunks ("pages") mimicking the structured experience of reading a physical document. Usually, a single tap on a button or screen location moves to the next or previous page. Scrolling uses the metaphor of sliding the document under a screen-sized viewport (or the complementary metaphor of sliding a viewport over the document). A vertical drag on the touch screen moves the document up or down (or a scrollbar is used to move the viewport position in the document).

*Also with Institut Universitaire de France.
†Also with Cheriton School of Computer Science, University of Waterloo.

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Clearly, these two techniques use very different interaction mechanics, and that changes how people read a document. Readers have complete control over how they view a document when scrolling since they decide how much the document advances, for example, by a few paragraphs or a few lines. Research has found this is beneficial for certain reading goals, like skimming a document [11]. However, several studies suggest that the structure imposed by pagination leads to better reading comprehension [3, 9, 11]. The theory is that the discretization of a document into pre-defined pages makes it easier for readers to build "a better mental representation of the text," which subsequently makes it easier for readers to relocate information and remember details [9]. Perhaps for this reason, popular smartphone reading apps like iOS Books use pagination.

Yet, all of the studies above are more than 10 years old or were conducted on desktop computers. Today, smartphones are truly ubiquitous and so is scrolling, not just for many reading experiences like online articles, but for many other types of interactions like viewing social media posts. Unlike desktop systems, touchscreen scrolling on a phone uses direct manipulation of the relative document position, which has highly desirable instrumental interaction properties: no spatial indirection, high compatibility, and high integration [2]. These interaction mechanics and prolific use of smartphones could mean that people have become better at reading by scrolling and therefore better at remembering what they read. The benefits associated with the imposed structure of pagination may no longer apply. A 2022 study that tested smartphones claims some "marginal" overall benefit to pagination [5], but this may be lacking in ecological validity as all participants were recruited from education programs at a university and participants had to use a provided device rather than their own device. We argue that there is a need to revisit this fundamental question in the context of modern smartphone users to answer the research question: *does pagination still lead to better reading comprehension than scrolling?*

We conducted a highly-controlled yet ecologically valid between-subjects experiment where 100 participants, who were recruited from the general public using a crowdsourcing service, were given a short story to read on their own smartphone using only scrolling or pagination. We recorded how long they spent reading, examined their reading comprehension using a standard objective time-limited test, and collected responses to NASA-TLX-inspired questions. Our findings found no significant differences between scrolling and pagination, which is an important contribution as it challenges a long-held assumption about the benefits of different reading techniques.

Table 1: Demographic information for participants.

Gender		Age		Education		Handedness	
Man	58	18-24	6	Less than High School	3	Right	87
Woman	36	25-34	42	High School Diploma	13	Left	11
Non-Binary	4	35-44	35	Some University (no credit)	19	Ambidextrous	2
Unknown	2	45-54	10	Technical School	8		
		55-64	3	Bachelor's Degree	46		
		65-74	4	Professional Degree Beyond Bachelor's Degree	3		
				Master's Degree	6		
				Doctorate	2		

2 BACKGROUND AND RELATED WORK

The differences between scrolling and pagination for reading comprehension have long been studied in desktop environments. In 2009, Sanchez and Wiley [11] were the first to find statistically significant differences between scrolling and pagination. In a between-subjects experiment, 40 participants read informational text on a desktop by scrolling or paginating and then wrote an essay to demonstrate reading comprehension. Their results showed that pagination led to statistically higher essay scores ($p < 0.01$). One possible explanation offered by the authors is working memory capacity: "the ability to process and store information simultaneously." Specifically, readers with a lower working memory capacity may not be able to simultaneously process and reveal new information when scrolling and relate it to existing relationships in the text. In fact, their results showed that participants with a lower working memory capacity were more negatively impacted by scrolling than those with a higher working memory capacity ($p < 0.05$).

A related concept to working memory capacity is mental workload. In 2008, Wästlund et al. [12] conducted two between-subjects experiments on a desktop with 40 participants each where participants read a document (the type of document was not specified) and simultaneously responded to dialog boxes that appeared on the screen. The time taken to close these pop-ups was used to measure mental workload. After reading, participants answered 4-6 multiple-choice questions to measure reading comprehension. Their results showed that scrolling induces more mental workload than pagination ($p = 0.02$ for Experiment 1; $p = 0.002$ for Experiment 2), but they did not find any differences in reading comprehension ($p = 0.79$ for Experiment 1; $p = 0.38$ for Experiment 2). However, they note a possible floor effect due to the low number of questions.

In 1997, Piolat et al. [9] conducted a between-subjects experiment, where 26 participants read informational text on a desktop by scrolling or paginating and wrote summaries of it. They claimed that participants who navigated the document with pagination tended to receive higher grades ($p = 0.18$) and included more details in their summaries ($p = 0.06$) due to marginal statistical significance (i.e., $0.05 < p < 0.1$). They did not observe any significant differences nor any trends for reading duration.

Since these initial explorations on desktops, more recent work has compared scrolling and pagination on smartphones, yet they also only report marginal significance. Fukaya et al. [3] conducted a within-subjects experiment in 2011, where 12 participants read narrative and procedural texts by paginating or scrolling on a smartphone. The two text types were used to examine different metrics. Reading comprehension was evaluated using narrative texts, and participants answered fill-in-the-blank questions. Pagination led to marginally significant improvements in reading comprehension ($0.05 < p < 0.1$, exact values not given). "Operation time" was evaluated using the procedural texts. Specifically, these texts contained instructions for a virtual console shown on a desktop, so participants read the text while simultaneously interacting with the virtual console. Overall, there were no significant differences in operation time, but participants who preferred scrolling were marginally faster than those who preferred paginating ($0.05 < p < 0.1$). Task workload for reading the procedural test was quantified using a NASA-TLX, and they found that scrolling led to lower mental load than paginating, which contrasts Wästlund et al.'s findings [12].

A more recent 2022 between-subjects study by Haverkamp et al. [5] examined the effect of both device size and technique on text understanding. 145 participants read a scientific document by scrolling or paginating on a smartphone or tablet (32-39 participants per condition) and before answering a long-answer question about the document. They did not find any significant interaction effects ($p = 0.7$), suggesting that there were no differences between the two techniques when reading on a smartphone. Yet they conclude that overall, pagination tends to result in better understanding of the text due to marginally significant main effect of technique ($p = 0.07$).

To summarize, prior work examining both desktops and smartphones largely suggests that pagination may lead to improved reading comprehension over scrolling. However, most studies, including both studies that used smartphones, merely show 'trends,' rather than conclusive and significant statistical findings. As such, the validity of these claims is unclear. Furthermore, with the exception of Haverkamp et al.'s work [5], all of these studies are over 10 years old, and people may have become better at reading by scrolling due to several years of additional practice scrolling on smartphones. Even the recent study by Haverhamp et al. may be lacking in ecological validity as all participants were recruited from education programs at a university and participants did not use their own personal devices that they would be most comfortable with. For these reasons, we believe it is important to replicate these experiments.

3 EXPERIMENT

The goal of this experiment is to examine the effect of document navigation techniques on reading comprehension. Participants read short stories and answered questions about it, before answering questions about their overall experience. Our hypothesis was that

Table 2: Statistical test results for all metrics.

Metric	U	p
Reading Comprehension	1262	0.93
Reading Duration	1022	0.12
Test Duration	1094	0.28
Mental Demand	1137	0.43
Physical Demand	1349	0.39
Temporal Demand	1273	0.87
Effort	1111	0.34
Performance	1279	0.83
Frustration	1186	0.61

pagination would lead to higher reading comprehension scores, given the promising results from prior work.

3.1 Participants

Prior work mostly recruited participants from universities, specifically, psychology courses. To increase the diversity of participants, we recruited 114 participants through the online crowdsourcing platform, Prolific.[1] The task was restricted to the United States and Canada, those who had completed at least 1,000 tasks on the platform, and those whose approval rating was greater than 98%. Crowdsourced experiments have an increased risk of fraudulent responses, so we manually examined all open-ended responses to identify fraudulent responses (i.e., very short responses like "nice" and "good") [10], but only 1 participant was omitted for this reason. We also removed 13 participants who experienced technical difficulties with our interface. In total, 14 were omitted from analyses, leaving 100 valid responses (Table 1). All self-reported being proficient at reading in English (all ≥ 5 on a 1-7 point scale). On average, participants reported spending 4.8 hours on their phones (SD = 3.3), and 1.8 hours reading on their phones (SD = 1.8) daily. Upon completing the experiment, participants were remunerated $7.50. For each condition, participants who scored within the top 25% for reading comprehension received an additional $3 bonus as additional incentive to do well on the test.

3.2 Reading Comprehension Task

For increased ecological validity, participants read one of ten short stories (~1,500 words each) from easyCBM [1]. easyCBM is a system developed by the University of Oregon that provides teachers with standardized benchmark assessments for a variety of subjects.[2] We selected stories from the 8th grade reading level and used the accompanying 20-question multiple-choice tests to evaluate reading comprehension. An 8th grade reading level is representative of documents and websites targeted for the general public [8].

3.3 Apparatus

The experimental software was a React web application. The reading interface displayed the short story and was styled to resemble a Medium article.[3] Participants could navigate through the story by scrolling (i.e., they used their finger to move the text) or by paginating. Pagination was designed to mimic the mechanics of reading on a Kindle: participants could touch the left and right of the screen to move to the previous and next page respectively, and a thin 5 pixel progress bar at the top of the screen indicated where they were in the document. The supplementary video figure demonstrates the two techniques.

The test interface displayed 20 multiple-choice questions, which were navigated through by scrolling. A toolbar at the top of the screen indicated how many questions the participant had answered and the remaining time.

3.4 Procedure

Participants received a link to the experimental software through the Prolific system. The task was restricted to smartphones. First, they answered questions about demographic information and read instructions. Second, they performed a basic system calibration, where they rotated their phones to be in landscape and portrait mode and the system automatically captured device information, screen size, and logged a photo of how the story was rendered on the device for debugging purposes. For participants assigned to the pagination condition, the calibration phase was also used to split the story into pages that were adapted to the device screen size and orientation. Upon completing this calibration, they read the story. There was no time limit for the reading phase, but after reading the story, they completed the multiple-choice reading comprehension test, which had a 5 minute time limit. This was selected based on Joshi and Vogel's experiment [6], which used the same set of stories. Participants could finish the test early if they answered all questions, otherwise, the test would automatically end after 5 minutes. Finally, they answered questions about their overall experience.

3.5 Design

This is a between-subjects experiment with one independent variable, TECHNIQUE, with two levels: SCROLL (n=51) and PAGE (n=49). All participants read one of 10 short stories. The story and TECHNIQUE were both randomly assigned. The primary measures computed from logs were *Reading Comprehension*, representing the number of questions correctly answered on the reading comprehension test (0-20 range); *Reading Duration*, the time taken to read the story in minutes; and *Test Duration*, the time taken to complete the test in minutes. We also collected subjective measures about task workload using similar wording as the NASA-TLX: *Mental Demand*, *Physical Demand*, *Temporal Demand*, *Effort*, *Performance*, and *Frustration*. All were interval data on a 1-7 numerical scale, and *Performance* was reversed (i.e., $8 - x$) to align numeric scores and valence.

3.6 Results

For all metrics, we analyzed the distribution and homogeneity of the data using a Shapiro-Wilks test and a Levene's test. While the data for SCROLL and PAGE had similar variances, none of the metrics followed a normal distribution. Therefore, we use Mann-Whitney U tests in the analysis to follow. However, as a quick test, we also tried using independent samples t-tests as they are generally robust to non-normal distributions with large sample sizes and have more

[1] https://www.prolific.com
[2] We contacted the researchers via email and received special permission to use these stories.
[3] https://medium.com

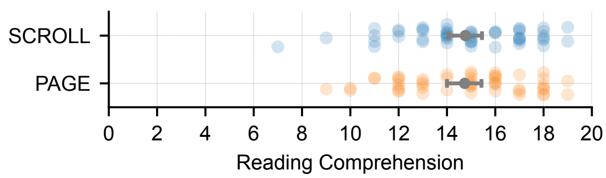

Figure 1: *Reading Comprehension* for SCROLL and PAGE.

statistical power, yet we received similar results. All graphs show 95% confidence intervals, bootstrapped with 10,000 re-samples, and individual data points. The supplementary materials contain all experimental data, and Table 2 shows detailed statistical test results.

3.6.1 Reading Comprehension. As demonstrated in Figure 1, we did not observe any significant differences in *Reading Comprehension* between SCROLL (M = 14.8, SD = 2.6) and PAGE (M = 14.7, SD = 2.6). This finding differs from prior work [3, 5, 9, 11], but aligns with Wästlund et al.'s findings [12].

3.6.2 Duration. Similarly, as shown in Figure 2, we did not observe any significant differences between SCROLL (M = 7.3, SD = 3.8) and PAGE (M = 8.3, SD = 3.9) for *Reading Duration*. This finding differs from Fukaya et al. [3], who found that scrolling was marginally faster than pagination, but aligns with Piolat et al. [9] who did not find any significant differences. For *Test Duration*, we did not find any significant differences between SCROLL (M = 3.3, SD = 0.9) and PAGE (M = 3.5, SD = 0.9).

3.6.3 Task Workload. We did not observe any significant differences between SCROLL and PAGE for any task workload metrics (Figure 3). Notably, there were no significant differences between SCROLL (M = 3.6, SD = 1.6) and PAGE (M = 3.9, SD = 1.7) for *Mental Demand*, which differs from Wästlund et al. [12], who found that scrolling techniques led to higher mental workload than pagination, and from Fukaya et al. [3] who found that scrolling leads to lower mental workload.

3.6.4 Screen Rotation, Zoom, and Pan. For increased ecological validity, participants could scroll in either landscape or portrait mode and could also zoom and pan across the screen. As a quick check to ensure that these interactions did not hinder internal validity, we also analyzed the above metrics using participants who only read in portrait mode and who did not zoom or pan. 26 were briefly omitted (n=42 for SCROLL; n=32 for PAGE), with most being from the PAGE condition. Even then, we did not observe any significant differences between SCROLL and PAGE.

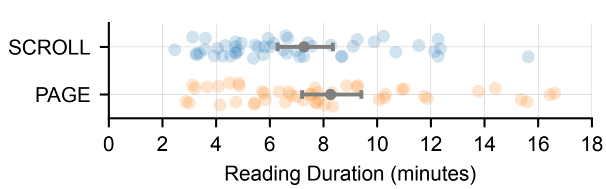

Figure 2: *Reading Duration* for SCROLL and PAGE.

3.6.5 Open-Ended Responses. We examined all free-form responses to better understand user experiences. As expected, most participants did not perceive any issues or differences when scrolling (e.g., *"being able to scroll while reading was effortless"* (P100)). However, P36 wished they *"did not have to scroll so much"* while reading and how this was cumbersome: *"I found myself wanting to read more of the story at once, without having to stop and scroll and re-find my position that I was reading."* This idea of navigation being difficult while scrolling has been demonstrated in prior work [9].

Pagination led to more varied opinions. Several participants noted how the design was similar to that of a Kindle or e-reader, so they did not experience any issues. Others enjoyed having the story split into multiple pages, as it was *"easier to read"* (P54), provided *"a sense of progression"* (P34), made *"the process less intimidating"* (P12) and *"the story more digestible"* (P43), and helped them *"focus even more"* (P32). Two participants noted how pagination made them *"forget things [like they were] different stories"* (P2) and that pagination *"made it even more difficult to keep track of everything"* (P5). These concerns may be related to working memory capacity, however, prior work suggests that this is typically associated with scrolling rather than paginating [11].

4 DISCUSSION

To summarize, our results did not find any significant differences in reading comprehension between scrolling and pagination when reading on a smartphone, which differs from findings presented in prior work. Participants took roughly the same amount of time to read the stories in both conditions, and there were no significant differences in perceived task workload.

These results differ from prior work, which has largely suggested that scrolling results in worse reading comprehension [3, 5, 9, 11]. We suspect that the ubiquity of smartphones, and subsequently scrolling, over the past several years has made it easier for people to create mental representations of the text they are reading, which is important for reading comprehension [9, 11].

Although we did not find significant differences between scrolling and paginating, the open-ended responses suggest that pagination strategies can still be desirable for readers and possibly improve things like focus and a sense of progression. As such, giving users the option to switch between pagination and scrolling modes when reading on a smartphone may further improve user experience.

4.1 Limitations

There are several experimental design factors that may have influenced the results. First, participants were reading with a clear goal in mind, which may have encouraged deep reading. However, there are other types of reading tasks, such as skimming, or reading without a particular goal, like when browsing through articles online. It is possible that scrolling and pagination may lead to more pronounced effects for different reading types.

Similarly, there are several different types of documents that are commonly read on a smartphone. We chose to focus on short stories at an 8th grade reading level as this does not require any background knowledge from participants and it represents the target reading level of websites [8]. Prior work primarily focused on non-fiction and scientific documents [5, 9, 11], so replicating this

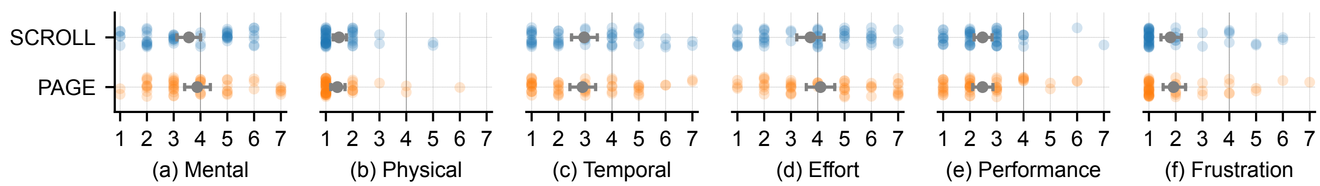

Figure 3: Additional task workload metrics for SCROLL and PAGE: (a) *Mental Demand*, (b) *Physical Demand*, (c) *Temporal Demand*, (d) *Effort*, (e) *Performance*, (f) *Frustration*.

with the same types of documents may reveal differences between the two techniques.

Another factor is when the the test took place. We administered the reading comprehension test immediately after the participants read the story. This, coupled with the document type, may have led to higher scores on the test. Repeating this experiment with a break in between the reading and testing phases [6] may allow us to more accurately determine whether these effects were determined by the reading technique or if they were a result of short-term memory. However, it should be noted that prior work also administered both phases within the same experimental session.

The nature of the test may have an effect as well. Wästund et al. [12] were the only others to find no differences in reading comprehension between scrolling and pagination and they also administered multiple-choice questions. Others relied on written responses [5, 9, 11] or fill-in-the-blank questions [3], so it is possible that scrolling and pagination may help readers do better on certain types of questions, which warrants additional research.

We estimated the power of our sample sizes using the standard deviation of all scores (SD = 2.6). We found that we could have detected medium to large effect sizes ($d = 0.57$), corresponding to ~1.5 point differences in scores (7.4%), which is slightly less than one letter grade of a difference. As such, we believe that our sample size is large enough to detect what we believe to be meaningful differences between the two conditions if they exist. However, it is still possible that smaller differences exist between the two techniques, which only would have become apparent with additional statistical power from a larger sample size.

Finally, Sanchez and Wiley [11] suggested that people with lower working memory capacity may be more negatively impacted by scrolling than those who have high working memory capacity. To keep the experiment duration short, we did not collect information about working memory capacity, however, we did recruit from a diverse population. Controlling for working memory capacity may reveal some differences between the two techniques.

4.2 Future Work

An important direction for future work is to investigate the effects of long-term use and to explore other metrics beyond reading comprehension. For example, the act of scrolling can cause readers to enter a flow state, which tempts them to keep scrolling even while they are engaged with and enjoying the displayed content. This can result in fragmented reading, which can be dangerous as it may impact how people interpret and understand media like the news [4]. Similarly, pagination could possibly reduce "mindless scrolling" tendencies on social media. It is possible that pagination may mitigate such risks in the long-term, but more work is needed to study this.

Our participants suggested that pagination helped improve focus, and studying this in more depth and across a wider variety of tasks would be beneficial. For example, in an information retrieval context, Kim et al. [7] found that participants found more relevant search results when paginating than when scrolling on a smartphone. To enable such investigations, an important technical contribution would be an app or browser extension that can turn any continuous scrolling webpage into a paginated version.

5 CONCLUSION

We investigate the effects of paginating and scrolling when reading on a smartphone. Our results indicated no significant differences between these two techniques for reading comprehension, duration, and task workload, which differs from prior work that has studied these effects on desktop and mobile devices. We believe that our findings are important as they challenge a long-held assumption about the pros and cons of different reading techniques, and they do so using a task with high ecological validity.

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