Readability and Optimal Text Settings

-Taryn Bipat

Annotated Bibliography
Study Comparison Table
Contents

Part 1: Introduction 4
   Who reads and what do they read online? 5
      Foreign Language Users 6
      Users with Reading Difficulties 7
   Reading and Scanning 8
      Defining Readability 8
      Defining Scanning 9
      What are the optimal text settings for reading and scanning online? 9
   This Literature Review 10
   Scope 10
      Process 11
      Literature on Readability on Wikipedia 11

Part 2: Methodologies 13
   Eye-tracking studies 13
   Usability Methods 14
      Empirical Observations or Usability Testing Methods 15
   Building Web Usability Guidelines 16
   Literature Reviews 17

Part 3: Understanding the web text factors that impact reading and scanning 18
   Line spacing 19
   Font Size 20
   Font Type 21
   Word Style - Italics vs. Plain 22
   White space on page 23
   Line length 24
Optimal Text Settings

Color Contrast 26
Are web factors dependent on each other? 26

Part 4: Scanning 28

Part 5: Screen Size 31
Reading on Mobile Devices 32
Language and Screen Size 33
Reading on Tablets 34

Part 6: Accessibility Research 36
Individuals with Dyslexia 36
Individuals with low or loss of vision 37

Part 7: Reading and Scanning in Foreign Languages 40
Chinese Language 41
Arabic Language 41
Research in other Languages 42
Second Language Learning 43

Part 8: Conclusion 45
Future Research Needs 45
Expanding the scope of the Literature Review 47
Conclusion and Limitations 47

Bibliography 49
Section 1: Introduction

With the development of the web and new technological hardware, the spread of information is boundless and instantaneous. It has now become easier than ever for anyone to gather digital content. There now exists a large body of information accessible at your fingertips and you can gain new information faster than ever. Wikipedia's considered one of the more text-heavy webpages, where users can read information on just about any subject. Furthermore, that information can be gathered on so many different devices from handheld devices to laptops to larger screens computers, monitors and tablets. The expansion of information has led to new questions about how humans can easily access digital information on different types of digital devices through scanning and reading digital text (Singer and Alexander, 2017; Moran, 2020).

With new technology and new ways of using this technology, good usability becomes key to making systems easy to use. These devices need to be efficient, effective and satisfactory for the users (Nielsen, 1994). Due to so many people currently using electronic information on the web, it is critical to make sure we have good Web Usability; the web should be easy to use, to learn and ultimately, to read. (Bhatia, 2011).

One of the easiest ways to improve web usability is through readability (Hussain et al., 2011). Reading remains one of the primary ways that people interact with their devices. Based on web usability guidelines, if we can improve how users read on screens and in web browsers, we can make it easier for people to gather information.

Information is valuable only if one can understand it. Therefore readability is one of the important aspects of web usability. Readability is the property which makes any writing easy or hard to read, understand and memorize.  
----------(Hussain et al., 2011)

More recently, there has been an increase in research to better understand how user’s are reading online. Research has shown that reading on screen versus reading on print is not the same (Holmqvist et al., 2003; Kurniawan et al., 2001). Online information is often formatted in a similar fashion to printed information but the way we process that information is different.

Kurniawan et al. (2001) demonstrated that reading on paper was 10–30% faster than

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1 https://en.wikipedia.org/wiki/Main_Page
Optimal Text Settings

reading online. This demonstrates that being able to read but also comprehend text on the web requires different, and possibly novel, techniques. However, it is important for us to find ways to make reading on paper and online similar processes or at least processes that are efficient, satisfying and effective for all users.

Moreover, the web has become accessible to so many different types of people from all corners of the world. Wikipedia, specifically, is a platform in over 290 different language editions used by people all over the world (Lemmerich et al., 2019). The population of users that read on the internet is extremely diverse so it is important to understand how we can create universal web readability guidelines.

There has been over 100 years of research on reading online. Thus, the research scope has become extremely widespread. To better scope this literature review, in the following part, I am going to briefly introduce some of the key topics presented in this literature review. While I began with the initial idea of understanding readability on Wikipedia. I quickly spread beyond Wikipedia to generally understand text setting across different types of literature. I explain in more detail at the end of this first part about why that decision was made.

To summarize, Wikipedia is currently set up with typical online features - images, text blocks and lists. Broadly, the literature covered in this literature review covers content that will be applicable to Wikipedia.

In the following subsections, I will outline the web user segments represented in this research and the key behaviors explored, reading and scanning. I then wrap up this section by explaining how this literature review was developed over the course of March, 2022.

Who reads and what do they read online?

Before diving into optimal text settings in the literature, it is first important to understand the users that this literature deep-dive impacts. In this section, I quickly recap the diverse population web readability impacts and some content on what they read. Across the literature, there are many different content types that people read; health related information (Daraz et al., 2018; Mcinnes & Haglund, 2011), encyclopedias like Wikipedia (Lemmerich et al., 2019), blogs (Johnson et al., 2021), journalism (Holmqvist et al., 2003), and online shopping reviews (Hu et al., 2012). There are different purposes such as online learning (Sokmen, 2003), to make decisions for buying items (Hu et al., 2012) or keeping up to date with current...
Optimal Text Settings

events (Yadamsuren and Erdelez, 2011). There is also content people do not like to read online such as reading contracts and terms and agreements (Robillard et al., 2019) or privacy notices (Milne et al., 2006).

There is research that characterizes who reads online (Menadue and Jacups, 2018). Menadue and Jacobs characterized online readers based on demographics and also based on individuals’ reading habits offline. In particular, Wikipedia is an interesting research site to better understand readership because it brings so many readers with a diversity of demographics (Johnson et al., 2020). Johnson et al. (2020) demonstrated the gender differences in Wikipedia readership showing that women are underrepresented among readers of Wikipedia and typically view fewer pages per reading session than men do.

On Wikipedia, page views and other metadata such as time spent on a given page (dwell time) help better understand how content is consumed. TeBlunthius et al. (2019) conducted a study to better understand how patterns in reading time vary between global contexts. Their research demonstrated that across the globe, people read differently. Global South readers spend more time per page view and that this difference is amplified on desktop devices, which are thought to be better suited for in-depth information seeking tasks (TeBlunthius et al., 2019).

They ultimately show that reading and scanning of text happens on Wikipedia.

In another study, readers of various Wikipedia language editions demonstrated that readers in countries with a lower human development index (HDI) were more likely to read for in-depth understanding compared to readers in high-HDI countries (Lemmerich et al., 2019).

The findings from this study demonstrate that so many different people read but also that they read in different ways. Thus, attempting to understand readability helps identify various pathways towards making digital information gathering equitable across different populations, especially those that may speak different languages and may be culturally different.

Foreign Language Users

Across my search into the literature, most of the research to understand the optimal text settings for reading and scanning takes an anglo-centric perspective. There is sparse literature in other languages; it became difficult to find and much of this literature was in different languages making it difficult to interpret. However, readability is important across all languages and it is important to take a global view on this research subject.

Other languages have very unique text considerations such as different
characters and ways of reading such as Farsi being read from right to left (Bipat et al., 2020). In this review, I highlight research around Chinese (Huang et al., 2019), Arabic (Abubakar and Lu, 2012), Korean (Kim et al., 2016), Spanish (Rello and Marcos, 2012) and Malay (Ali et al., 2013) in part 7. However, one important gap is filling in this currently anglo-centric literature.

Furthermore, one of the most common situations where users have to read online is for learning (Reiber-Kuijpers et al., 2021). Foreign language learners can now use the web as a place to learn their language as there are typically a lot of texts in the language they are currently learning. Being able to learn a second language has become much easier because we have access to the internet but it also demonstrates another reason that web readability is something we need to keep working on.

Researchers have noted that having so much online information to learn from can now lead to additional demands for comprehension, reading ability and for critically analyzing and synthesizing information from across many different sources and mediums (Britt et al., 2018). Web pages hold text but also headings, images, hyperlinks and much more.

Moreover, as learners from paper to digital it is important to understand how their reading ability changes. Prior research has shown that there is a small difference reading digitally versus paper in their native language. The research shows a small negative effect on reading comprehension of these foreign language texts (Delgado et al., 2018). New technologies bring new challenges for those that might be using digital means to learn a different foreign language. Currently, a lot of research only focuses on reading in a user’s native language (Reiber-Kuijpers et al., 2021; Singer and Alexander 2017). In this literature review, I do not delve very far into second language learning, however, in part 7, I note the importance of second language learning on platforms such as Wikipedia and research that has been done on specifically improving readability for second language learners reading online.

Users with Reading Difficulties

“High readability becomes a necessity for the users with reading difficulties.”
-------------(Miniukovich et al., 2017)

As noted earlier, there are so many people around the globe that benefit from reading on digital devices. However, a large piece of that includes individuals that might struggle reading online due to literacy difficulties. According to Miniukovich et al. (2017), there are few websites designed for high readability and typically they are under-investigated
when thinking about web usability (Miniukovich et al. 2017).

For users with literacy difficulties, reading and understanding text require more time and effort than for regular users. Unless website designers are ready to neglect them - which many government and non-profit websites are forbidden to do - they should design for high readability.

One example of this group are individuals with Dyslexia. A lot of the research centered around reading on screen is devoted to Dyslexics (Rello et al., 2016). Furthermore, there is a body of research that focuses on users with low vision (Legge, 2016). In part 6, I delve further into accessibility research that focuses on understanding optimal text settings for each of these types of participants.

Currently, the research covered in this literature review demonstrates that a wide variety of users with different reading needs use the web to consume content. Thus, as researchers and practitioners it is important for us to look further into this work.

Reading and Scanning

Now that I have discussed a little about the importance of reading and the diverse population of readers. It is important to dive into how content is consumed online. The Nielsen Norman group has been doing research on this for over 20 years and has consistently shown that people rarely read online. Users tend to scan text online rather than paying attention to each individual word (Moran, 2020).

Defining Readability

According to Rello et al. (2016), “readability refers to the ease at which a reader can read and understand the written text” (Rello et al., 2016). In this paper, they also discuss subjective versus objective readability. Readability based on hard evidence such as saccades or reading speed are objective. Users' perceptions of reading and their preferences is subjective. In many studies presented in this review, authors explore both of these facets of readability.

Typically, when users actually read they spend time reading each individual word to better comprehend the text. For users, with additional needs for reading and writing, being able to have high readability allows them reduces users' frustration and time wasting (Miniukovich et al., 2017).

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2 The Nielsen Norman group has been doing research on web readability for over 20 years. In 1997, Jakob Nielsen posted a report that discussed how users read on the web. This data was recently updated in 2020 by Kate Moran from the Nielsen Norman group. I use this data as a foundation for a lot of this literature review.
Defining Scanning

However, what is scanning and how is it different from reading? Scanning is reading rapidly in order to find specific facts. While skimming tells you what general information is within a section, scanning helps you locate a particular fact. Just generally, it was difficult to find a specific description of what scanning actually is because there are many different forms of this presented in part 4.

In one study by Holmqvist et al. (2003), they demonstrated that users reading digital papers scan more and read less than traditional newspaper readers. They also further explain reasons for why this may be true. According to Homqvist et al. (2003), “traditional printed media exist in parallel to the new media. Reading traditional newspapers implies looking for headlines, briefs, photos, and drop quotes. On the one hand, the new media differ considerably from the traditional printed media. Online readers read from a computer screen and move around by clicking on links and menu buttons.” (Holmqvist et al., 2003). Essentially, these new types of features of a web page such as buttons, hyperlinks, headers and more lead to users jumping around a page.

Furthermore, readers themselves reported that reading on paper “is something they do with pleasure and, if possible, in a situation that allows distraction (along with breakfast, in a coffee break after lunch, on the train, or in the subway). It is a relaxing activity to traverse through the folds and it usually takes quite a long time” (Holmqvist et al., 2003). With web news, people usually read when they have much less breaks. They can easily get to the media online whenever they have a quick moment (Holmqvist et al., 2003). It is also important to note that user’s self-reported feelings also demonstrate why it is important for users to need high readability; so they can quickly scan and comprehend online news when they have a quick break in their daily lives.

One of my own observations in this literature review is that online researchers typically conflate the words scanning and reading. In this paper, I try to distinguish reading that specifically focuses on reading and specifically scanning but many papers do not actually go into this type of detail. In parts 3 and 4 of this review, you can find more about research that focuses on reading and scanning.

What are the optimal text settings for reading and scanning online?

This literature review demonstrates that there could never possibly be one single answer to this question. Since user’s read differently on the web versus with traditional media, we can also assume that the same text factors or settings from print do not work in the web context. According to Dyson and Kipping, 1998,
they noted that optimal line and font setting for print materials are not optimal for screen reading (Dyson and Kipping, 1998).

In the literature, I focus on 7 different web factors commonly researched to better understand web readability: font size, font type, text type (italics vs. plain), white space, line length and color contrast.

More details and research about each one of these can be found in part 3.

This Literature Review

This literature review focuses on digital reading on the web. The goal of this literature review was to gather available and relevant research to give an overview of topics that are commonly explored around web readability and optimal font settings. Research on reading focuses more on different reading contexts, different user populations or specific web factors making it difficult to come to specific conclusions about what exactly are the guidelines for good readability and the chosen web factors that will bring high readability to all. In each part, I will give an overview of findings that help better respond to the following research questions. The specific research questions that guided this work:

**R1:** How do variables such as line length, font-size, line height and surrounding whitespace affect the practice of in-depth reading on Wikipedia?

**R2:** How do variables such as line length, font-size, line height and surrounding whitespace affect the practice of scanning on Wikipedia?

**R3:** How do these effects differ across languages and scripts, and which languages and scripts have been previously studied?

**R4:** How do these effects interact with screen size?

**R5:** How have previous researchers measured and tested these questions?

In the final part I will additionally make some recommendations for future research that can help us better understand the scope of this literature review. In the following part, I explore some of the most common methodologies to understand optimal text settings: eye-tracking, experimental design and surveys.

Scope

This paper reviews current literature around readability on the web. This review spanned the month of March, 2022. Methodologically, I spent time reviewing the literature in the project scope document and then branched off into related readings. Through uncovering new literature, I started to weave together my own findings about these papers presented in the conclusion.
Optimal Text Settings

Typically, other literature reviews scope the literature based on specific and more recent years to be able to understand the ever constantly changing nature of technology and online behavior. However, this research was not relevant as the idea of this literature review was really broad and hard to scope. A lot of findings about things that happened 20-30 years ago are still relevant because those current fonts, font sizes and web layouts are typically the same as they are not. Moran (2020) did note that some formats of web technology have changed leading to new eye movements such as different scrolling patterns and configurations for pages but these changes are not major enough to lead to a paradigm shift in this field.

Process

In a month’s time it is just not feasible to cover the entirety of the type of research that is there. A quick Google Scholar search of “text readability online” presents 173,000 hits with topics ranging across many different disciplines.

To better scope this study within a months time frame, I began with the literature presented in the project scope and worked outwards. I began to see many papers cross-sited across papers and ones that showed up repeatedly. Those are the papers that I focused on for this literature review. For the first 2 weeks of the project, I compiled a list of 47 papers presented in the annotated bibliography then I worked to expand on those as I wrote this literature analysis.

Literature on Readability on Wikipedia

Furthermore, looking specifically at Wikipedia, only 2 studies were found related specifically to web readability or usability. One by Rello et al. (2016), that suggested the best font sizes for high readability. Another by TeBlunthius et al., (2019) that suggests that Wikipedia readers scan and read text online.

A couple sample searches on Google Scholar for “Wikipedia text”, “Wikipedia reading”, “Wikipedia text settings” or “Wikipedia font” brought up about 100,000 hits for each search. Out of these 100,000, I reviewed the top 10 and none of those hits were related to the research questions except for the Rello et al. (2016) paper that showed up within the top 10 of “Wikipedia font”.

One of the more interesting search criteria for “Wikipedia readability” does have some familiar literature but most of this reading focuses more on the language used on Wikipedia. Some of the Wikipedia content may be hard for users to understand because the jargon is too
Optimal Text Settings

complicated, but this is not necessarily related to text settings or formatting (Lucassen et al., 2012; Suwannakhan et al., 2020). Lucassen et al. (2012) focused mostly on sentence length and word length but to show complexity of the language not to show usability of the platform.

For these reasons, this review goes way beyond the literature on just Wikipedia. The format of Wikipedia is similar to other web pages that use different fonts, font sizes, whitespace, etc… so the recommendations from this literature can still support the readability of Wikipedia.
Part 2: Methodologies

In this section, I describe the experiments performed to test the effects of web factors that affect the usability of the content on a webpage. In the literature review, there were four main methodologies that were present; eye tracking studies (Rello et al., 2016), usability methods (Bhatia et al., 2011), guideline formation (Miniukovich et al., 2017) and literature reviews (Hussain et al., 2011). In this part, I further discuss the use of these methodologies and some of the limitations.

Eye-tracking studies

Eye-tracking technology has become an important tool in conducting usability studies. Eye-tracking allows usability researchers to record and analyze a person’s eye movements. These systems typically capture a person’s fixations, saccades and scanpaths (Tobii, 2022\textsuperscript{3}; Nielsen & Pernice, 2009; Holmqvist, 2011).

These systems include specialized cameras that can monitor every movement of a person’s eye and record quantitative data of that specific movement. This allows researchers to discover eye movement patterns and make claims about how participants look or read a particular artifact (Moran, 2020).

Moran, 2020 noted that eye-tracking studies are valuable for gathering both quantitative and qualitative data. Quantitative eye-tracking studies were more common in the literature that I reviewed. Researchers gather reading time, fixation duration and more then aggregate that data across a large sample size. Researchers can then create heatmap visualizations or gaze metrics for future references. Additionally, researchers supplement this quantitative data with qualitative data taken from participant feedback and surveys. In qualitative eye-tracking studies, researchers analyze individual users’ viewing behaviors through gazeplots and gaze replays (Moran, 2020).

In this literature review, a majority of the studies leveraged eye-tracking technology either through eye-tracking headsets or devices attached to screens. For example, Rello and Baeza-Yates (2016) used eye-tracking to measure fixation duration and number of fixations. Participants were asked to read 12 different passages in different fonts while using the eye-tracking device. In this study, they used the Tobii 1750 eye-tracker and had to calibrate the device for each participant.

\textsuperscript{3} Tobii eye-tracking software and hardware were used in most eye-tracking studies in this literature review. Their technology has been around for over 20 years and gives researchers easy access to eye movement data. https://www.tobii.com/
Participants all were placed at a similar distance from the eye-tracking devices and the angle to the screen was controlled by using a fixed chair. The authors also controlled the light position in the room to make sure the environment was consistent for each participant (Rello and Baeza Yates, 2016).

Burmistrov et al., 2016, used eye-tracking to understand the legibility of light and ultra light fonts. They used an infrared-video-based eye tracker (SMI iView-X Hi-Speed 1250) at a sampling rate of 500 Hz and an instrument spatial resolution of 0.01 degrees. The authors used the eye-tracking device to calculate search time, duration of fixations and saccadic amplitude.

There are, however, some limitations to eye-tracking:

1. With eye-tracking it is important to track all eyes. Eyes are just as or more diverse as the type of people that exist around the globe. There are just generally limitations to what types of eyes and features of eyes can be tracked.
2. Eye-tracking studies also required considerable financial, time, and labor resources. Eye-tracking hardware and software costs range but can cost thousands of dollars.
3. Eye-tracking needs to be married to other qualitative methods since it only measures eye movement. However, eye movement may not always explain why something is occurring. In the studies mentioned above. Each of these studies also conducted pre- and post- surveys to test comprehension and collected qualitative feedback from the participants.

Usability Methods

Past researchers have shown that usability methods should combine both user testing methods and inspection methods (Bhatia et al., 2011; Katner and Rosenbaum, 1997). When evaluating digital texts, inspection methods such as heuristic evaluation and cognitive walkthroughs allow researchers and practitioners to uncover various usability problems. Typically, these inspection methods come earlier in the design process to make changes iteratively to the product (Nielsen and Phillips, 1993). In this literature review, some researchers deployed similar inspection methods.

Miniukovich et al., 2019 further discussed inspection based methods - typically in these methods experts review webpages and then recommend changes that will increase the readability. They also note

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4 The saccadic amplitude is the distance traveled by the eye between two fixation points.
that these types of design inspections are different from empirical observations that show users actually reading. Empirical studies show that the readability needs to be improved but it does not tell us how to improve it and typically an expert will still need to translate the findings to actionable recommendations. In their study, Miniukovich et al., 2019 uses guidelines created by experts to better evaluate different types of web pages.

In another study, prior to running an empirical study, Li et al., 2019 tested how often Reader View finds webpages transformable. Reader View changes the standard reading to web factors that are easier to read such as font size and white space. The authors did their own heuristic evaluation on 100 websites (Li et al., 2019)

Empirical Observations or Usability Testing Methods

Later on in the design process, researchers will employ user testing methods to collect data about specific population segments. In many of the studies that are part of this literature review, researchers set up an experimental study that allowed them to learn how users were reading, gain their likeability of the reading task and understand their comprehension of the task.

In the same study mentioned earlier by Li et al. (2019), after doing a heuristic evaluation of website reader view, the authors conducted a 10-minute within subjects study to better understand the two conditions of Standard Web Page vs. Reader View.

Participants were given the text in each condition then asked to read the webpage word by word and then respond to a few comprehension questions. After they finished reading the passages, the authors also presented users with a survey that had 7 readability questions, 9 user experiences questions and 1 RSD question for the last condition they read (Li et al., 2019).

In another study that used experimental observations, Ali et al., (2013), tested two different fonts, Georgia and Verdana to see how they impacted readability. In their methodology, they created reading passages or text blocks using those two fonts. The passages were the same size and approximately the same difficulty to read. They had each participant read both blocks of text and the participant could rest between each activity.

A research assistant recorded the time taken to read the text and the number of errors committed throughout the reading. The authors of this paper scored each of readings based on prior literature that demonstrated how many words and sentences can be detected by the reader.
Optimal Text Settings

and the clarity of vocabulary and grammar in words and verses (Brinck et al., 2002). The authors created a rubric to determine the accuracy and reading speed.

The sum of both scores was decided as the readability performance score. The following table, created by Ali et al. (2013) shows the seven steps used in the development of the rubric based on Mertler (2000) recommendation. Overall, the rubric developed was reviewed and validated by a Malay language specialist teacher.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Aims</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify the objectives to be achieved</td>
</tr>
<tr>
<td>2</td>
<td>Identify the specific criteria required</td>
</tr>
<tr>
<td>3</td>
<td>Identify the required level of scale breakdown</td>
</tr>
<tr>
<td>4</td>
<td>Determine the highest and lowest performance scale</td>
</tr>
<tr>
<td>5</td>
<td>Build rubrics</td>
</tr>
<tr>
<td>6</td>
<td>Obtain data</td>
</tr>
<tr>
<td>7</td>
<td>Revise the rubric, as necessary</td>
</tr>
</tbody>
</table>

Similar to Li et al. (2019) and Ali et al. (2013) study, many studies employ both qualitative and quantitative methods.

Other experimental design studies also focus on visual search tasks rather than just reading word for word (Ling and van Schaik, 2007). Interestingly, the visual search task reflects most closely to what we would consider scanning. In a visual search task, participants are asked to quickly browse an interface gathering key insights about features such as menu buttons, hyper texts and labels. Lastly, there are validated reading tests that have been used such as the Chapman-Cook Reading Speed Test that showed up in this literature search (Paterson and Tinker, 1929).

In my own review of the literature, I noted that there are limitations to experimental studies. First, there are so many different interactions of various web factors. It becomes difficult to disentangle the differences between web factors and the various differences between so many populations. Different reading tests and methodologies might not necessarily work for the entire population of web readers. Lastly, many of these studies are done under lab conditions, so having users read under the pressure of a lab might lead to biased effects.

Building Web Usability Guidelines

Another methodology, reviewed in the literature, was the formation of web usability guidelines. Experts in usability, practitioners and researchers came together using their own knowledge to build a set of guidelines to learn from (Miniukovic et al., 2017). Miniukovic et al. (2017) demonstrated this methodology to produce a set of 61 guidelines for dyslexic readers. They reviewed existing guidelines by hosting workshops with dyslexic experts and user interface experts.
They initially began with two researchers reviewing the entire corpus of guidelines and excluded those belonging to one of three categories. Then the experts were invited to resolve contradictions and review the validity of guidelines. Each guideline was printed on a card, they reviewed them individually and then discussed further.

Literature Reviews

Many authors have noted that for over 100 years, this type of research on readability on paper and web has been conducted (Nanavati and Bias, 2005). Thus, it is important to compile the necessary information. This research itself is really broad and thus many researchers have scoped it into specific topics and conducted systematic literature reviews around that topic. These literature reviews do not necessarily demonstrate how specific design decisions impact reading but rather sheds light on prior work that highlights why some design decisions have been made. These literature reviews, similar to this piece, demonstrate the synthesis and the broad amount of information across this field. In the following parts, I will further discuss the findings from these four methodologies.
Part 3: Understanding the web text factors that impact reading and scanning

Web factors include the information that web designers use to improve a website.

------------------(Bhatia et al., 2011)

Within the graphic interface of the web, users can find text, links and graphics. Together all of these features make up the content that people consume on the internet. There are different web factors or design decisions that impact the usability of the website.

Various researchers and designers have worked to categorize these different web factors. In an online article by Nyx Ditech⁵, they break down usability into 5 different categories:

1. Typography
2. Background
3. Whitespace
4. Visual Hierarchy
5. Writing

In their dissertation work, Ivory (2001) presents 157 highly-accurate, quantitative page-level and site-level measures. These are the factors that assess many aspects of Web interfaces, including the amount of text on a page, color usage, and consistency. Ivory (2001) additionally categorized these factors into different classes such as text elements, link elements, graphic elements, text formatting, link formatting, graphic formatting, page formatting, page function, and page performance.

Hussain et al. (2011) analyzed eight readability factors i.e. color contrast, white space, line spacing, font style, font size, text width, headings, graphics and animation. These eight factors are compared to understand their impact on different age group reading performance. The chosen eight factors were based on prior literature around online readability.

Similarly to Hussain et al. (2011), in the papers that were read for this literature review, I found 7 main web factors that were more commonly studied to understand reading and writing. In this section, I briefly outline a couple studies that better explain each of these factors and their impact on consuming online text.

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⁵ 5 Factors That Influence Readability and Legibility of a UI - Nyx Ditech
Optimal Text Settings

Line spacing

Rello et al. (2016) note that there really are not specific guidelines currently for line spacing. They did observe, however, browsers have a default line spacing relative to the font size. A spacing of 1.0 equates to 120% of the font size. In best-practice recommendations, this spacing of 1.0 is often listed as generally the most readable and does not require additional overhead to understand.

According to Rello et al. (2016), line spacing is defined as “the vertical distance between the baselines of two text lines. The concept is also known as leading from the days of hand-typesetting and line height in CSS. The bigger the line spacing, the further two sentences are apart vertically” (Rello et al., 2016). In their eye-tracking study, the findings show that line spacing had a small but significant effect on comprehension, suggesting that too small or too large spacings make it difficult for users to comprehend the online text. These findings show that websites with blocks of text need to have more vertical line spacing in between text (Rello et al., 2016).

More specifically, other researchers have narrowed down which line spacing leads to faster reading time (Paterson and Tinker, 1929). In their study, they wanted to better understand how line spacing in printed text impacts reading performance. They discovered that larger line spacings (1.2 and 1.4) lead to faster readings than smaller line spacings of 1.1. However, the authors do note that the faster reading time could be due to other web factors such as font size (Paterson and Tinker, 1929).

Ling and Shaik, 2007 also demonstrated that line spacing had a significant impact on task performance. Wider line spacing led to better comprehension accuracy and faster reading times. Their findings show that participants performed better with double line spacing than with 1.5 spacing, and better with 1.5 than single spacing (Ling and Shaik, 2007).

Dyson, 2004 additionally conducted a study to understand how line spacing impacts fast and normal reading. They collected comprehension, reading speed and scrolling patterns. Their findings suggest that spacing between the lines of a text, also impacts speed of reading on-screen (Dyson, 2004). Double spacing led to faster reading times than single spacing (Dyson, 2004).

Rello and Marcos (2012) used eye-tracking to test four values for line spacing: 0.8, 1, 1.2 and 1.4 lines. Participants preferred 1.4 lines among lines. However, similarly to Paterson and Tinker (1929), Rello and Marcos (2012) note that there is no

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6 Line Spacing Guidelines: https://practicaltypography.com/line-spacing.html
concluding evidence for the interaction of other web factors. These authors propose a set of guidelines that will combine the data from different web factors to customize text for the best readability.

Similarly, Hojjati and Muniandy (2014), test whether font type and line spacing has an impact on reading. Their findings end up focusing much more on the readability of different findings rather than line spacing. Their results related to line spacing were inconclusive, partially because of the interaction between the two web factors of font type and line spacing (Hojjati and Muniandy, 2014).

Font Size

One of the most common web factors that was present in this literature review was font size. Various researchers have tested font sizes. Bernard et al. (2002) compared different fonts at the 10-, 12-, and 14-point sizes. They compared the most commonly used serif and san serif fonts to understand differences in “reading effectiveness, reading time, perceptions of font legibility, font attractiveness, and general preference” (Bernard et al., 2002). They had 60 volunteer participants with normal or corrected vision read twelve passages. For reading efficiency, they found no significant font size or type effects. Fonts at the 12-point size were read faster than fonts at the 10-point size. In addition, a font type x size interaction was found for the perception of font legibility. In general, however, Arial, Courier, and Georgia were perceived as the most legible.

Research has also shown that different populations benefit from different font sizes. Bernard et al., 2001 conducted a similar study with the older population. They tested a 12- and 14-point font for sans and serif fonts and found that a significant main effect of size was found for font legibility in that 14-point fonts were more legible to read than 12-point fonts. A marginal interaction was also found for reading time in that participants read 12-point serif fonts significantly slower than 14-point serif or sans serif fonts.

Font size has also been tested on different screen sizes: monitors and smaller screens such as mobile devices. Darroch et al. (2005) tested font size on small screens of handheld computers. They tested font sizes between 2- and 16-point for both older and younger participants. Their findings show that on handheld devices that about 6-point there is typically not much difference in reading performance. However, participants themselves noted that they had a preference for fonts in the middle range. The authors suggested that 8-12 point on handheld devices is a good range for good readability (Darroch et al., 2005).
In general most of the findings from studies in this literature review, show that larger text sizes are more readable than smaller sizes (Bhatia et al., 2011). According to Rello et al., 2016, font size had significant and large effects on readability and comprehension. In their study, they used a range of font sizes to show that reading and comprehension significantly improve with font sizes until 18-/22- points. This is interesting due to the fact that typically a font of 12-/14- is recommended. Rello et al. (2016) recommend 18- points font size to optimize readability and comprehension of web text content. They do note that the default line spacing is necessary to show the impact of font size.

In almost all of the studies that analyzed the effects of font size on reading, the findings show that font size is also highly dependent on the font type that is being used (Beymer et al., 2008; Banerjee et al., 2011; Chapman, 2016).

In a study by Banerjee et al. (2011), they test various fonts and sizes to find the optimal combination for onscreen reading. Two types of fonts were used, serif fonts: Times New Roman, Georgia and Courier New and the Sans serif fonts included Arial, Verdana and Tahoma. These fonts were presented in 10-, 12- and 14- point sizes. Their findings highlighted that serif fonts were better for readability compared to sans serif. They recommended 14- point font size for onscreen reading and Courier New for the fastest reading time. Verdana was recommended based on subjects’ ranking and mental workload scoring (Banarjee et al., 2011).

Font Type

Similar to Banerjee et al., (2011), other researchers investigated the difference between font types. In particular, researchers analyzed the impact of san serif and serif font types (Josephson, 2008). According to Karen Mitchell (2019), font is “a set of letterings that are printed or shown in a particular style and size”. Times New Roman is the most common default font type for word processing packages and thus people are more familiar with this font.

Many web designers say that san serif fonts, such as Arial or Verdana, have a better screen readability especially at small sizes than other serif fonts (Peck, 2003). However, this fact is not that surprising as sans Serif and serif were intended for two different purposes. Verdana was created to improve readability on a computer and Times New Roman was created specifically to improve reading on traditional paper (Hojjati and Muniandy, 2014).

In their study, Hojjati and Muniandy (2014) ask student participants to read four passages of similar length and
difficulty, with different font types and different spacing. They gathered the reading time to identify which font type (Times New Roman (serif) and Verdana (san serif) by which spacing is easier and faster to read. They additionally gave a comprehension quiz to understand how legible the content was. Overall, the results showed that there was a significant difference between the readability of serif and san serif font type. Similarly to other studies presented in this part, the research findings suggest Verdana font type as a better choice in displaying long text for on-screen display (Hojjati and Muniandy, 2014).

Ali et al. (2013) additionally tested four fonts, Georgia (serif) and Verdana (sans serif) for the first respondents and Times New Roman (serif) and Arial (sans serif) for the second respondents. Georgia and Verdana were designed for computer screens. Unlike the other authors, the findings from this study showed that there was no significant difference between the readability between serif and sans serif font of both screen display category and print display category. However, the findings do show that Verdana was the best choice for websites with long text. Since there was no significant difference in readability, Ali et al. (2013) suggest that both sans serif and serif fonts are options for web usage (Ali et al., 2013).

Bernard et al. (2002) also showed that Times New Roman and Arial supported faster readability than Courier, Schoolbook and Georgia. However, in this study, they also asked participants about their overall choices for font type based on attractiveness and preference for reading. According to participants, Georgia was the most attractive font of those tested. This contrasts participants’ preference for Verdana. Georgia and Times were the most attractive and generally less preferred. Of all of the fonts presented in this study, the findings show that Verdana was the overall best choice as it was the most preferred and still had good readability and legibility. This is consistent with other research studies in this literature review.

Word Style - *Italics* vs. Plain

In online text, users typically have to change the word style in text; they can choose between the plain text or an italicized version. Word style can change just about anywhere in text, an author can choose just to change the style on one word, sentence or an entire paragraph. In this literature review, I use italicized text to highlight quotes from the studies reviewed.

Some authors have done research to better understand readability and word style. Hill and Scharff, 1997 studied foreground/background color.
Optimal Text Settings

combinations, font types and word styles on the readability websites. In their study with 42 participants scanning a website for target words, they found that participants were quicker to respond to plain text than to italics.

Bhatia et al. (2011) tested italics by giving participants three web pages with no italics, moderated italics (web page with short phrases italicized) and high italics (web page with full italicized sentences). They found that italics did not have an effect on subjects’ performance of knowledge and comprehension tasks. Students viewing pages with no italics performed better than those viewing pages with moderate italics. In addition, students viewing pages with high italic performed better than the students viewing pages with moderate italics. Italics did not have a significant effect on students’ response times to the web page. Overall based on the likeability and ease of use self-reported scores, there was no significant effect of italicized test. Essentially, italics had no impact on efficiency and satisfaction but had an effect on effectiveness.

Furthermore, Ivory and Hearst inspected ‘good’ web pages and identified that they rarely contained italicized words (Ivory and Hearst, 2002). Similarly, Flanders and Willis (1998) conducted a web analysis literature review to better understand web usability. They explored “bad design” to better understand how to do good design. They found eight factors that are critical to good readability including font or text style. They noted that actually web pages that they defined as having good usability, typically do not have italicized words (Flanders and Willis, 1998). Lastly, Boyarski et al. (1998) studied plain Verdana font against Verdana Italic. They asked participants to complete a reading comprehension test with both of these font styles on a screen display. The findings from this study show that readers preferred regular Verdana and its overall better readability.

Holistically, all of these studies demonstrate that italics typically leads to poor readability and slower readability compared to regular text. In this literature review, I did not study bold fonts and it is recommended for future work.

White space on page

According to Adobe’s web usability principles, white space, also known as “negative space,” is empty space around the content and functional elements of a page.

Many researchers have noted the importance of white space on readability. For example, Flanders and Willis (1998) [https://xd.adobe.com/ideas/principles/web-design/what-is-white-space-in-design/](https://xd.adobe.com/ideas/principles/web-design/what-is-white-space-in-design/)
noted that white space is one of the factors critical to web usability. Friedman (2008) noted that white space helps web pages that are heavy in text and make it easier to read. According to Friedman (2008), "white space aids to balance large amounts of text and helps the user’s eyes drift over the content. It also offers parting among components in the layout, comprising visuals and text" (Friedman, 2008).

Hussain et al. (2011) also confirm that white space should be present for good readability for older people, teenagers and children. Similarly Nielson et al. show that white spaces are “essential to isolate text as well as visuals and vibrancies. With old age various problems such as eyesight, memory and many more rise so elderly people like websites that are clear and simple.” (Nielson, 2005). Yu et al also show that “white spaces are recommended between text and blocks of text” (Yu, 2010). According to the National Cancer Institute (2003), white space changes the layout of the page and is recommended for high readability. Typically, this white space should be around headers, embedded figures, and paragraphs.

However, research has also shown that too much white space can have an impact on readability. Chaparro et al. (2004) demonstrated that a good amount of white space between headings and text led to better comprehension of text but it actually led to slower reading times for users (Chaparro et al., 2004). Similarly, based on user preference, white space is preferred but did not result in performance differences compared to low and high amounts of white space in visual search tasks (Chaparro & Bernard, 2011).

Consistently, Chapparo et al., (2005) conducted a study that additionally showed that whitespace does not typically lead to better reading times and comprehension. Participants were given an “enhanced” page layout that included headers, indentation, and figure placement and a normal layout. The findings showed that reading and comprehension was not impacted by the layout. However, participants preferred the “enhanced” format as it made it easier and more comfortable to read.

Overall, whitespace helps the design of a page and users prefer the whitespace. However, in testing, more white space does not lead to better readability or faster times.

Line length

In conducting this literature review, line length impact on readability was a web factor that currently has been extensively studied for over 100 years (Nanavati and Bias, 2005). This research began in the...
1800s and 1900s, when recommendations were made for paper reading. Weber, 1881 suggested that 4 inches was typically a good line length. Tinker and Paterson (1929) confirmed that three and a half inches was a good length for faster reading times on paper (Tinker and Paterson, 1929).

Once computer reading became more popular, line length studies focused on understanding how line length impacted reading speed and comprehension on monitors that might be much bigger than paper. Most researchers found that longer line length on monitors resulted in faster reading times (Dyson and Kipping, 1998).

Nanavati and Bias (2005) conducted a literature review that encompasses more modern computer research. In this literature review, they attempt to answer two questions: what is the optimal reading length and how many columns should content be presented in for faster reading? Their findings on line length research showed that on computer monitors should not be more than 70 characters. If lines are not the appropriate length on digital screens, this could lead to different eye movement patterns that are not comfortable for users.

Additionally, in this literature review, the authors found that smaller screen sizes such as PDAs lead to different types of eye movements making it important for designers to find the appropriate line length for different screen times. I further discuss the impact of screen size in part 5.

In more recent literature, Bernard et al. (2003) investigated line length effects on reading time, reading efficiency and perceived reading efficiency for children and adults. In this study, the findings showed no significant differences for reading time or efficiency for either population. However, adult users preferred shorter line lengths rather than full-screen line lengths. Additionally, adults perceived that the full text lengths resulted in better scrolling amounts than narrower line lengths. The narrowest line length condition was perceived as promoting the highest amount of reader concentration, while the medium line-length condition was considered to be the most optimally presented length for reading. Unlike the adults, children had no significant difference in perceived readability (Bernard et al., 2003).

Similarly, in other studies, college-age students typically preferred either short or long lines but not the mid length (Shaikh, 2005). However, when given 4 different line lengths of 35, 55, 75 and 95 characters per line, 95 characters per line resulted in the fast reading speed (Shaikh, 2005).

While readers typically have preferences for short and long lines (Dyson and Haselgrove, 2001), research has been inconclusive about the optimal line length.
for faster reading. Dyson and Haselgrove (2001) investigated the impact of a fast and normal reading speed on different line lengths on comprehension, reading rate and scrolling patterns. Overall, their findings show that comprehension is reduced if reading fast. Additionally, A line length of 55 characters per line was the best length for both normal and fast reading. This medium length was the best for speed and comprehension. These findings demonstrate that the needs of the reading task (comprehension or speed) may lead to different needs for line length.

Overall, the literature again does not suggest one perfect line length. Researchers also suggest that other web factors such as font type, character spacing, page layout and more impact readability and in turn, impact line length. It is still important to understand the interaction of all of these factors.

Color Contrast

In my own experience, color contrast is an important factor when trying to read online. The color of the text on a specific color of a background needs to be legible. Research has also supported this fact that color contrast is important to readability (Hussain et al., 2011).

Even though color contrast is important, past research has shown the lack of usability guidelines for color contrast. Shumaila and Hussain (2012) noted that out of different web factors, color contrast has a large impact on efficiency of readability. Jang et al., 2007, combined some usability guidelines and proposed their own color contrast guideline that utilizes color temperature. They test their color contrast algorithm on normal adults and children that have sensitivities to color contrast (Jang et al., 2007).

Are web factors dependent on each other?

Typically none of these studies looked at just one web factor. Most studies that I presented in this literature review try to understand more than one factor together. It became difficult to differentiate between web factors when writing this part. Most studies that analyzed font size also looked at font type. Bhatia et al. (2011) looked at text style, font and color count, Bernard et al. (2003) also demonstrated that font type interacts with font size. Hussain et al. (2011) observed 8 prominent web factors and their impact on different age groups.

Many also found interactions between the various web factors (Tinker, 1963; Bernard et al., 2003). Bernard et al. (2003) showed that font type is interdependent with font size. Different combinations of font size with font type led to faster reading times. Contrarily, Beymer et al. (2008) actually show that there were no significant effects.
Optimal Text Settings

when comparing font size and font type. While using a smaller font size (10-point), fixation durations were significantly longer as compared to 14-point. Additionally, there were no significant differences in serif versus sans serif fonts.

The findings from all of the studies presented in this part show that there is no one magical combination of web factors that support the highest readability. However, it is important for designers and practitioners to find the interactions between web factors and understand how web factors might impact specific populations.

More specifically, web factors are highly dependent on different population segments. Hussain et al. (2011) conducted a literature review that focused on children, adults and older people. Bernard et al., (2001) analyzed which fonts children prefer to read online. There is also research that tries to better understand font type and font size specifically for students that are diagnosed with Dyslexia (Ismail and Jaafar, 2018).
Part 4: Scanning

As mentioned in the introduction, research has shown that just generally people scan large blocks of text such as newspapers online. This behavior is different from what people typically do when reading a paper offline (Holmqvist et al., 2003). Text online is in a different format with new features for users to interact with such as scrolling bars, buttons and links that can easily take you from one page to another. These new features lead to new methods of reading information online. For over 30 years, researchers have explored how users scan information on the web. In this section, I share a few of these studies but it is important to note that in most of the studies in this literature review, it becomes hard to differentiate between when researchers are focused on reading versus scanning. For that reason, this section should be read as more of a continuation from the prior part.

“They don’t. People rarely read Web Pages word by word; instead they scan the page, picking out individual words and sentences.” (Nielsen, 1997)

In 1997, Jakob Nielsen conducted an eye-tracking study that showed that 74% of participants scanned any new pages that they visited on the web. Thus, it is important that any web page must include scannable text to make it easier to read. Scannable text included highlighted keywords, meaningful subheadings, bulleted lists and more concise writing. The Nielsen Norman group more recently revisited the findings from 1997 and they show that even though the web continues to evolve, scanning behavior is similar (Moran, 2020). The eye-tracking studies done more recently still show that even when users scan, they quickly move from piece to piece on a web page and might even go back to similar pieces more than once.

Depending on what type of content, they’re reading. Scanning might also be different. Nielsen (2010) noted that scanning emails usually happens faster than scanning other types of web content.

In both of these eye-tracking studies done in 2006 and 2020, they also demonstrated various gaze patterns that are common for online use. These include:

- F-pattern: Eye-tracking technology has shown that users may scan a web page in an F-pattern, typically with two horizontal stripes followed by a longer vertical stripe (Pernice, 2019). Shreshta et al. (2007) conducted a study to better understand how users can text. Participants were asked to search
or browse either a text-based or image-based web page the authors found. The findings show a uniform scan path with longer fixations on the images Nielsen’s ‘F’ pattern (2006) was confirmed in both the text-browse and text-search tasks (Shreshta et al., 2007).

- Layer cake pattern: According to Pernice (2019), layer-cake scanning is when most fixations are typically made on the headings and subheadings. There are occasional eye movements on the body of text in-between the headings. Typically, on a heatmap, this would be horizontal lines across the page with space in between.

- Spotted pattern: The spotted scanning pattern involves fixating on specific words or chunks of words spread throughout the page. The user chooses words for one of two reasons. They may stand out in the text because they may be in a different font or because they are similar to a word that is similar to what they are looking for (Pernice, 2019).

- Commitment pattern leads to the best comprehension. This pattern of scanning is the same as traditional reading. In this pattern, users will read through every detail or as much as possible on the screen. This pattern is used when users are trying to learn the content or might be very interested in the overall understanding of the material (Pernice, 2019).

Other studies demonstrate features that are important to scanning. Authors have measured the effect of different web factors found in a web page layout on search time (Nygren and Allard, 1996). When a fixed layout happens, it is easy for users to scan because frequent users become familiar with effective scanning strategies. These strategies then become easily adaptable so a user can find the information they are looking for on the page (Nygren and Allard, 1996). Furthermore, scanning a horizontal list of items is slower than scanning a vertical list. Overall, the findings show that a fixed position of a webpage feature leads to faster scanning. If a user is able to learn the location of a feature and become familiar with a web page then they are more likely to scan the content rather than deep read. The authors also note there was no color, shade, space, size and slant differences in relation to scanning speed (Nygren and Allard, 1996).

There are also special instances where it is important for users to quickly scan but also deeply process (Salmeron et al., 2017). This may be on websites that users are not
so familiar with. For example, when students are doing a last minute homework assignment. In one study by Salmerón et al. (2017), they demonstrate how high school students articulate scanning and deeper processing of answering questions using a Wikipedia document, and how their reading comprehension skills and the question type interact with these processes. The authors found that scanning of information led to poor comprehension while deep processing allowed users to perform better. Scanning led to lower performance especially for those that are good comprehenders, while the positive effect of deep processing was independent of reading comprehension skills.

However, it was much harder to find literature around scanning. Some of my own assumptions of this is that it is harder to test scanning in usability tests. An ethnographic approach might be more useful to understand scanning rather than reading tasks that is common in studies that use usability methods (Huang et al., 2007). Researchers have leveraged visual searching tasks that more closely resemble scanning. Visual search tasks allow users to simulate the scenario of quick browsing (quickly moving around features) (Huang et al., 2007). Similar to Huang et al., (2007) that leveraged a visual search task, Hill (1997) analyzed readability for various web factor combinations of foreground/background color combinations, font styles and font types. They had participants scan simulated websites for a specific target word. Readability was based on reaction time. Their findings showed generally there was no one combination of foreground, background color, font or word style that leads to a fasted reaction time. Unlike most other readability studies, this methodology allowed researchers to specifically understand browsing or scanning the test (Hill, 1997). However, there is a big limitation of this scanning test; when users are put in the context of a laboratory setting, they may instead feel the need to deep read rather than just quickly browse when tested for comprehension.
Part 5: Screen Size

With the widespread use of digital devices (computers, tablet computers, and handheld devices) in our daily life, there is an ongoing transition of reading from paperbound to screen-based (Holmqvist et al., 2003). Digital Natives prefer to read via digital devices rather than paper. Typically, those defined as a Digital Native want the ability to gather information quickly and can process that information faster than before. They are more likely to get this information from technology, especially handheld devices with smaller screens that are always easily accessible (Dingli and Seychell, 2015).

Daroch et al. (2005) noted that there were many studies conducted to understand text display on monitors and only a few on smaller screens (Daroch et al., 2005). Similarly, most of the literature covered in this paper focuses on larger screen sizes -CRT and LED monitors.

Additionally, other researchers have noted that the web readability design guidelines are lacking for other screen sizes (Karkkainen & Laarni, 2002). Thus it is key to delve into research to understand technologies that have smaller screens but still allow users to consume information including mobile phones and tablets.

In general, we know that reading on screens leads to different behaviors. Shaikh and Chaparro (2004) found that screens typically used to consume different types of information than on paper. In their 2004 survey, their findings demonstrated that longer articles, such as technical reports and journal articles are typically read on paper. While, online news, newsletters and other types of shorter readings are preferred onscreen. Thus, to begin with, screens support different types of information but across screen sizes is there also a change?

In prior research, it has been shown that depending on the resolution of the screen, a font size might be a different height making it harder or easier to read. According to Bernard et al. (2003), font size 10 at a resolution of 640x480 is approximately the same height as font size 12 at a resolution of 1024x768 (Bernard et al., 2003) for the same screen. Thus content on a larger monitor will look differently on a smaller screen. For that reason, we can assume that different designs will be necessary across different screen sizes.

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9 A CRT (cathode-ray tube) monitor is an analog display device that creates a visible image on the screen by directing three electron beams over millions of phosphor dots to make them light up.
Reading on Mobile Devices

One of the more common types of smaller screen technologies are mobile phones. Similar to large screens, mobile phones are also a place where users can find so many different types of information. For example, mobile apps have been created to help share health information (Ayyaswami et al., 2019). Readability guidelines have shown that it is important to design for mobile first. If users can gain high readability on a smaller screen then there will be no doubt that they can also do it on larger screens.

Additionally, research has shown that currently content is not very mobile-friendly. Cheng and Dunn (2016), analyzed 270 mobile web pages with health information. The authors categorized these pages based on design and position of information display. They found that 71% of the pages were mobile-friendly but only 15% of those pages focused on specifically high readability with clean page format and queried information being displayed only when needed. Their findings demonstrate that just generally there are no specific guidelines on how to design health information mobile sites specifically for good readability so it should be a priority for designers and practitioners in the future. Mobile phones give people the ability to gather information at their fingertips and this is especially important for health-specific information (Chen and Dunny, 2016).

Past research has shown that reading on mobile phones is different from reading on regular screens and thus it is important to understand the type of web factors (listed in part 3) that impact reading (Darroch et al., 2005; Karkkainen and Laarni, 2002).

Darroch et al. (2005), found there is no one perfect font size on handheld devices. Their findings show that there was no significant difference in 6- to 16- point and scrolling behavior did not impact font size. However, older people did prefer larger size texts than younger people. They additionally tried to better understand the impact scrolling had one making font size more readable. They found that the amount of text presented did not make too much of a difference so scrolling did not really have an impact. They suggest to future designers that with a screen resolution of 640x480, there should be a range of 8-, 10- and 12- point fonts to make sure that older and younger people can easily read and comprehend text on a smaller device.

Öquist, 2006 produced their dissertation on evaluating readability on mobile devices. Through 5 different studies performed on mobile devices, they found that mobile phones led to a 10% decrease in reading speed compared to PDAs that have a 50% larger screen. In their research,
Optimal Text Settings

Öquist tested different types of text presentation types commonly found on mobile phones:

- Scrolling: Scrolling presentation is the type most familiar when using desktop screens and mobile screens. In scrolling displays, the text is presented but may not fit within the screen so a scroll bar is used to allow a user to move between pieces of information. A scroll bar can be either vertically or horizontally (Duchnicky and Kollers, 1983).

- Paging: In the Paging style, content is presented normally but divided into different pages that fit the size of the screen. A user can move between screens usually through a button, swiping or arrows. Page numbers are used to show the users where they are in the reading (Muter, 1996; Öquist, 2006).

- Leading: In the Leading presentation, text moves dynamically across the screen and it continuously moves. The user typically has the choice on how fast the text moves. Moving the text pixel by pixel is faster than character by character (Muter, 1996; Öquist, 2006).

- RSVP: Rapid serial visual presentation (RSVP) is a method for bypassing eye movements during reading. In RSVP, each word (or small group of words) appears in the same location, serially (Potter, 1984).

Öquist (2006) found that for longer texts, there were no significant differences in reading speed on mobile devices in the different formats. Thus, they proposed an Adaptive RSVP that performed better and reduced task load than the common Fixed RSVP described above (Öquist, 2006).

Language and Screen Size

Another finding from the literature is that text with different characters may be portrayed differently on different screen sizes. This is further explored in part 7 but it is important to note that the width of line strokes in various languages might be particularly harder to read on smaller screens.

Hasegawa et al. (2008) studied readability of English and Japanese text on mobile phones with liquid crystal displays. They conducted an experimental study and measured subjective evaluation, reading speed, number of errors and viewing distance. They tested English and Japanese settings on two different types of displays on different resolutions with various font sizes and fonts. Their results showed that readability was better when the resolution of the screen was higher. Additionally, as font size decreased on the screen, young subjects had to move the
screen closer to their faces to read. However, older subjects increased the viewing distance irrespective of the size of characters. Characters of 3-5 mm are appropriate for the young but inadequate for the elderly. Moreover, the readability of Japanese characters improved when they were vertically enlarged to approximately twice the width on a mobile phone (Hasewaga et al., 2008).

Similarly to Japanese characters, the readability and legibility of Korean letters may be impacted by screen size. In a study by Kim et al. (2016), they analyzed readability through reading time for three different display sizes and five different font sizes. Their findings show that there is a significant interaction effect between display size and font size. Additionally, on small and medium displays, reading time was shorter for the smaller font sizes. While, on a large display, the reading time was the shortest for a larger font size. This is due to the fact that there is necessary scrolling and unique eye movements needed for smaller screens (Kim et al., 2016).

Reading on Tablets

Most of the research presented in this section focused on very small screens - PDAs and mobile phones. The other commonly used technology are tablets. The size of tablets range dramatically so many findings from monitors to mobile settings may apply. A few studies have looked at the benefit of tablets (Chen et al., 2014; Werner et al., 2012). With the tablet, The resolution again changes and we need to design for a different type of resolution. Furthermore, having clear and concise content is important for smaller screen readability across tablets, mobile phones and other technology.

Čerepino (2017) studied readability on iPad text and compared their findings to readability on computer screens and paper. The authors found that sans serif font Gotham was more readable on the iPad than other fonts. However, when they presented fonts in larger text sizes, there was no significant difference between the fonts. Additionally, they found that two column text layouts were harder to read on the screen because of few characters per line leading to unusual eye-movements. The authors suggested layout of text with 79 characters or more characters per row are readable and legible enough for reading texts on iPad. These findings suggest that readability on an iPad can be just as good and easy as printed text.

Chen et al. (2014) found that familiarity with screen size is a factor that just generally influences how well someone can read from a particular screen size. I can hypothesize for someone that is a

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10 Readability Guidelines on Tablets; https://readabilityguidelines.co.uk/audiences-devices-channels/mobiles-and-tablets/
Digital Native and is familiar with smaller screens, readability will be higher.

Furthermore, some smaller screens such as tablets have been leveraged to help support others. Haji et al. (2015) showed that iPads can also act as a low vision aid for those. Additionally, Werner et al. (2012) have noted that technology usage can be difficult for older users because of technical barriers such as smaller screen sizes. However, their study shows that among older individuals iPads are highly accepted and useful for older individuals and researchers need to continue to understand usability on iPads for older individuals (Werner et al., 2012).
Part 6: Accessibility

Research

In this literature review, I have already incorporated many studies that focus on accessibility. For example, Rello et al. (2016) looked at font size but part of their objective was to understand high readability for users with Dyslexia. Understanding accessibility is important because it leads designs with high usability that guides users through the easiest route.

Readability online is difficult for some so it is important to have high readability whenever possible. This would also make it easier for those that may not have trouble with reading online. A lot of research on accessibility focuses on two different populations, individuals with Dyslexia and those with low vision.

Individuals with Dyslexia

According to the International Dyslexia Association\textsuperscript{11}, across the world, over 10% of the population has Dyslexia, a language-based learning disability. This neurological disability makes it difficult for a person to read and write. The eye movements of readers with dyslexia are different from regular readers. People with dyslexia, as well as beginner readers, make longer fixations and more fixations than normal readers. The main characteristic of Dyslexia is that users may see words as if they seem doubled, overlapped, irregular, moved, danced, faded, swirled, and even bounced or jumped out of the page which is termed as visual-perceptual distortion (Yoliando, 2020). If we can improve readability for users with Dyslexia, it will also be beneficial for those that do not have it.

Research has been done to better understand how web factors might be impacted for users with Dyslexia. Rello and Baeza-Yates (2016) conducted a study to understand the effect of font type on screen reading performance. They tested 97 subjects (48 with dyslexia) with 12 different fonts. For the tested fonts, sans serif, monospaced, and roman font styles significantly improved the reading performance over serif, proportional, and italic fonts.

Rello and Baeza-Yates (2012) also tested how text and background colors can improve readability of people with dyslexia. They conducted an eye-tracking study and questionnaire to collect user preferences to answer their research question. They found that most individuals without dyslexia prefer black and white color combinations, while those with dyslexia only around 13% of the participants preferred them. Additionally, individuals with dyslexia have better readability when color pairs have lower

\textsuperscript{11} https://dyslexiaida.org/
Optimal Text Settings

contrasts. The color pair which was the fastest to read by the participants with dyslexia was black and cream.

Similarly, in another study by Rello and Bigham (2017), they measure the impact of background colors on screen readability. They conducted a large scale user study with 341 participants, 84 of those self-reported as having dyslexia. Their findings show that using certain background colors have a significant impact on people with and without dyslexia. Warm background colors (Peach, Orange and Yellow) significantly improved reading performance over cool background colors (Blue, Blue Grey and Green) (Rello and Bigham, 2017).

Furthermore, Miniukovich et al. (2017) leveraged dyslexia and design experts to develop a set of 61 readability guidelines. They found that typically guidelines for web usability did not focus on readability for accessibility and especially not for people with dyslexia. After developing the 61 guidelines, they conducted a usability test to narrow the list to 12 guidelines. They noted that a small list of guidelines will be easier to adapt and follow. Their final set of 12 guidelines focuses on using larger fonts, narrower content columns and no text styles such as italics and underlining (Miniukovich et al., 2017).

Li et al. (2019), tested the readability of Reader Views in Mozilla Firefox. Typically these Reader Views reduce the complexity of a web page by removing menus, images and content. They tested a Reader View web page with a normal web page with participants both with and without dyslexia. For both participants, the simple Reader View web page helped both populations increase their reading speed by 5%, and overall, users reported improved readability and visual attractiveness.

The findings from these studies show that certain web factors need to be adapted to support users with Dyslexia. Similarly, in the next subsection, I provide some context for users with low vision.

Individuals with low or loss of vision

Many of the studies that I described above studied how older individuals have different web factor needs such as specific fonts and larger font size. However, most of those studies primarily focused on individuals with normal to corrected vision. In the following section, I describe research that focuses primarily on those that need high web readability due to lower than normal vision.

Wu et al. (2020) conducted an online survey with 133 participants with low vision to better understand the history of those individuals' vision loss and how they use various assistive technologies.
Optimal Text Settings

Their survey demonstrates the diversity in the population of people with low vision. Their findings show that people with vision loss suffered from mainly three diseases: albinism, retinitis pigmentosa and glaucoma. Participants ranged from 18 to 98 years old. Each participant, additionally, reported using vision, audio or braille to read. Most users did 50% of their reading visually and most spent more time doing digital reading than paper reading. Most participants used at least one technology from each of our digital content magnifiers and hard-copy content magnifiers for visual reading.

Granquist et al. (2018) also conducted an online survey to understand user’s vision history and also acuity and magnification. Their findings demonstrate that people self-reported being engaged in digital reading and typically had to enlarge physical character size or reduce the viewing distance by putting their faces closer to the screen.

Prior research had delved into how current technology helps support users with low vision. Currently, digital documents allow users to change many features including font size, character and line spacing, font style, color contrast and page layout to meet any individualistic needs of a reader (Legge, 2016).

According to Legge, 2016, for users with low vision they typically need larger font sizes or screen sizes than those with normal vision. For those with loss of vision, magnification to over 20- points may be needed. Also, those with loss of vision need to bring the phone closer to their face or pinch-to-zoom.

Researchers have also focused on spacing for users of low vision because of the concept of crowding (Bouma, 1970). According to Bouma, 1970, “crowding is the interfering effects of one target on the identification of a nearby target in the visual field. The spatial extent of crowding increases in peripheral vision” (Bouma, 1970). Thus, content needs to be farther apart to be easily recognizable. Findings have shown that there is no significant difference for larger line separation but double spacing can have a small advantage (Calabrèse et al., 2010).

Legge, 2016 also noted that high contrast is often essential for those with low vision. Those with low vision have reduced contrast sensitivity, and need high-contrast text. Readability will be better on a brighter display, and from care in controlling ceiling light from external glare sources (Legge, 2016).

Technology helps low vision users be more efficient and effective when reading online. For example, Ardit and Lu. (2008) developed a technology called Basic LowBrowse View that will help users with low vision read web pages faster. Using principles and guidelines for low vision
Optimal Text Settings

people, their tool divides a web page into multiple frames. The top frame is for reading text, while the bottom frame has the entire web page with all the original content. The reading frame uses a single size font of the user’s choice, with configurable reading frame size, font size, colors, contrast and letter spacing. Their findings show that LowBrowse View significantly helped people with low vision with digital readability.

Additionally, another common technology used by people with low vision or no vision are screen readers. Research has shown that audio can help users consume content faster than visually reading\textsuperscript{12}.

\textsuperscript{12} American Association of the Blind: Screen readers. 
https://www.afb.org/blindness-and-low-vision
Part 7: Reading and Scanning in Foreign Languages

“Reading patterns, are very similar across languages and cultures, because they’re based on human behavior”  
(Moran, 2020)

The Nielsen Norman group noted that typically “behavior patterns, including reading patterns, are very similar across languages and cultures, because they're based on human behavior”. In their eye-tracking research they found that cultural differences typically occur when comparing American or European cultures to Asian cultures. In part 5, I listed a study by Hasagawa et al. (2008) that compared readability of English and Japanese text on mobile displays. The findings show that the readability of Japanese characters improved when they were vertically enlarged to approximately twice the width on a mobile phone.

Compared to the English text, Japanese needed different web factor changes for readability. In the other literature presented in this part, the different characters that are not similar to the roman alphabet typically require additional research to understand how we can better support digital readability. This conforms with Moran’s (2020) statement that cultural differences may be expected when comparing American or European experiences to Asian cultures.

However, it is still important to note that there still is a lack of research around usability in just about any language: European, American or Asian. Roig-Vila et al. (2014) analyzed web content accessibility on various Spanish education websites based on the guidelines set up by the World Web Consortium (W3C) and the Web Accessibility Initiative (WAI). They found that almost 98% of the websites analyzed did not comply with the technical accessibility requirements. This demonstrates the importance of understanding web accessibility and readability across all languages (Roig-Vila et al., 2014).

In this section, I focus on various languages and research conducted to better understand web factors that influence readability. It is important to note that an abundance of this research focused on Chinese and Arabic. My assumption is that a lot of this research is due to the fact that in both of these languages, they have different alphabet characters and additionally different methods of reading. Prior research has additionally confirmed this, Bipat et al. (2020) demonstrated that people behave and collaborate online in other languages especially languages such as Chinese have different ways of collaborating (Bipat et al., 2020). Due to these differences, the
Optimal Text Settings

way we think about web readability may lead to different guidelines for various web factors.

Chinese Language

A lot of research on readability has focused on the Chinese language. Moran (2020) noted that they conducted their qualitative portion of their famous readability eye-tracking study in Beijing to identify if there were any cultural differences between English and Chinese.

Chinese characters are significantly different from the roman alphabet. There are almost 3500 commonly used characters (Ministry of Education of the People’s Republic of China, 2013). Additionally, Chinese characters are composed of strokes and radicals. There are 32 basic stroke types that differ by shape, length, direction and location (Stallings, 1976). Due to these differences, it is important to understand how these linguistic features impact readability.

Liu et al. (2016) investigated font size, stroke width and character complexity. Character complexity is based on the number of strokes in the character. Their findings confirm that font size and character complexity had significant effects on legibility, while stroke width did not show any significant differences. However, the interactions between the different factors did show significant effects. Stroke width is critical to the legibility for characters with high-level complexity, whereas font size is the critical factor influencing the legibility for characters with low-level complexity. The combination of 12-point font size and 1:10 stroke width resulted in the best legibility for both character complexity levels.

These findings demonstrate the importance of understanding other web factors such as character complexity and stroke width that were not necessarily present in other studies in part 4.

Arabic Language

In my literature review, I additionally found a lot of Arabic literature. This may be due to the fact that Arabic has a different set of characters with a unique cursive font. Additionally, Arabic is written in a script from right to left and also read that way.

Abubakar and Lu (2012) focused on web factors such as font size, line length and font type in the Arabic language. In their study, they used two font types (Arabic Traditional and Simplified Arabic) in 10-,

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https://www.bbc.co.uk/languages/other/arabic/guide/alphabet
Optimal Text Settings

14-, 16- and 18- point fonts. They had participants read text blocks aloud. Then they measured reading errors and reading speed. Their findings focus on students and found that smaller sizes in any font type was not readable for 10-12 year olds. On the other hand, font sizes 16- and 18- are more readable than smaller fonts, the averages of error size 18 improve in all font types, while age has a significant impact on reading speed. Simplified Arabic font is reported as readable to students aged 10-12, especially in sizes 14- and 18-.

Interestingly, compared to the findings of studies presented about English in part 3, Arabic also needs to be presented in larger font sizes for good readability with younger and older people.

In a similar study with students, Ramadan (2011) tested student preferences for font type, font size, page layout and foreground/background color combinations in Arabic. Participants were asked to select their preferred font type from all the Arabic font styles on Windows. Then they selected between typeface style (Simplified, Traditional, Kofi and Nassekh) and font size (10-, 12-, and 14-point). They were then asked to read a passage in the font type and typeface chosen in one- or two- column formats with four different color combinations. The authors then conducted a comprehension test on the text read. They found that participants preferred 170 different font styles across 877 different participants. Additionally, size 14-pt in Simplified Arabic was the most readable and preferred font for users. During the reading part of the study, participants preferred to read Arabic materials in one column with a black and white color combination. The authors use these findings to create a set of guidelines for creating e-learning text for students (Ramadan, 2011).

Research in other Languages

Ali et al. (2013) conducted research on reading in the Malay language. They evaluate both serif and sans serif fonts. Malay is also written in the roman alphabet so these findings similarly match studies conducted in English. The authors tested four fonts namely Georgia (serif) and Verdana (san serif) for the first respondents and Times New Roman (serif) and Arial (san serif) for the second respondents. A readability test on a computer screen was conducted on 48 undergraduates. Overall, the results showed that there was no significant difference between the readability of serif and san serif font of both screen display categories. Accordingly, the research findings and the literature overview, suggest that Verdana and followed by Georgia as the better choice in displaying long text on websites.
Hasagawa et al. (2008) also tested the Japanese language, similar to Chinese, Japanese also has its own unique characters. These characters are shaped and written in different ways than in other languages so it's important to understand the readability on different mobile screens.

Second Language Learning

A large portion of the literature presented in this review is centered around second language learning. I felt that it was important to take some time to dive into this work as Wikipedia is also a platform where second language learning is part of the way the system works and how users collaborate to read and consume content.

On Wikipedia, users may need to switch between language editions. The requirement of switching between languages especially if a user switches into their second language might lead to a complexity barrier - unfamiliar topics might be too complex for non-native speakers. Multilingual users might be less likely to contribute in their second language especially on more complex topics or in unfamiliar situations (Kim et al., 2016).

Additionally, on Wikipedia about a quarter of multilingual users always edit the same articles in multiple languages, while just over 40% of multilingual users edit different articles in different languages (Hale, 2014). When non-English users do edit a second language edition that edition is most frequently English (Hale, 2014). Editing in multilingual contexts can sometimes hinder the collaboration that occurs on Wikipedia. Contributors who are not native speakers of the common language in a multilingual context may find it hard to interact informally (Kim et al., 2016). Various researchers have begun to understand ways to improve readability for second language learners (Wang et al., 2016).

Reiber-Kuijpers et al. (2021) demonstrated the importance of reading for second language learners through a systematic literature review that noted several characteristics of second language digital reading environments, tasks, and readers. One type of characteristics they focused on were format and layout of online text for second language learners. There is research currently on this topic that shows how web factors need to be designed for high readability for second language learners. Some of the key points in the literature review include that integrated formats allowed for better online comprehension. In integrated formats all content is in one page versus split-attention formats where the content is split up across different web pages (Al-Shehri and Gitsaki, 2010). Gilbert (2017) demonstrated that sometimes web factors like text color, fonts and images
can be helpful but additionally the overuse of these web factors can make it difficult to read and can be distracting to second language learners. Lück (2008) demonstrated that there are different ways to make it easier for second language learners to scan, especially using nonlinear texts. Overall, visual elements of digital pages multi-media appeared to enhance motivation and participation (Lück, 2008).

Univerally, digital screen reading is becoming more prominent and important for those learning a second language. For students, not only do they read but they also have to consume text when doing other things like collaborating and school activities (Chou, 2012). Additionally, it may lead to users having to switch between their native tongue and a second language they are learning. This is similar to Wikipedia where you may use other places to communicate such as the talk page or the sandbox.

In one study, specifically focused on graduate ESL students, Kong (2021) focused on understanding ESL graduate students’ frequency and perception of RS and reading-English-on-screen (RES). The findings showed participants spent more time reading on screen. Moreover, the interviewees’ perceptions of RS and RES appeared to mainly be affected by factors such as their familiarity with technology (sometimes relative to what they wanted to achieve when reading on screen) and their perceived difficulty of reading tasks in terms of content and language (sometimes relative to what they want to do for RS).
Part 8: Conclusion

Online users spend a large amount of time interacting with visual display terminals (Darroch et al., 2005). For that reason, it is extremely important to understand how we can comply with guidelines to make text legible and readable. The key findings of this literature review are as follows:

1. Top three methodologies are eye-tracking, experimental design and building web usability guidelines.
2. Web factors are interdependent on each other. Having good web readability means finding the right web factor combination.
3. Different screen sizes lead to different types of behaviors because you may need to consume a smaller amount of information on one screen.
4. A lot of research done on Arabic and Chinese. My hypothesis is because Chinese and Arabic have different characters and also because reading style is different. There is still a lack of research on different global languages.
5. Second language learners spend a lot of time reading information and learning using digital texts.
6. Most people scan, they don’t read when they are visually looking at something.
7. Accessibility is important when we think about readability. Especially, when we are looking at people with dyslexia or low vision.

This is a literature review that can be segmented in so many different ways. To sum this up, Web usability is so important across different types of people (neurodiversity) and then also across languages and cultures. However, my overview of the literature does demonstrate that there is definitely space for more work.

Future Research Needs

Through this research journey, I observed that there were a few topics currently missing from this literature review. First, there is a limited number of studies around optimal text settings in other languages. Most of this work additionally is hard to access and may be in different languages. There are also other things that influence language online such as translation work.

One of the topics that did not fit within the scope of this literature review was how readability may be impacted with text that is translated from one language to another. In a study by Choi, 2016 they focused on demonstrating the differences of reading behaviors across different participants with different occupations.
They hypothesize that users with different occupations will have different purposes of reading. They test this hypothesis by testing participants that are professional readers for their occupation such as translators, editors and proofreaders and a recreational reading group such as chefs, engineers and military professionals. Participants were asked to read four different types of text: 1) without a specific goal, 2) to study the topic, 3) to obtain information, and 4) to share information. Each of the texts were translated from English to Korean. Additionally, in each of the texts a few translational errors were inserted. The authors found their hypothesis to be true, different occupations read differently. Those that read professionally, meticulously read through each line. While the recreational reading group did not read as linearly. In relation to the translation errors, the different populations also perceived them differently. In relation to the errors, they were also perceived differently by each group. The professional readers were more likely to catch the errors. They also were more likely to tolerate the problems. They did not get as frustrated by the errors in translation.

This is just one example of a study that demonstrates that depending on how the text is presented, in this case translations and the type of person reading, requires specific attention and research. Currently, the literature does not typically cover all these specific situations and additionally, not across various languages and cultures.

A second topic that is not covered in this literature is that just generally technology is changing. Currently, the way we view the web still remains mostly through content displayed on the screen. However, with the development of new AR/VR technology that is most likely going to change in the future. Currently there are few studies that focus on how readability may be impacted.

Büttner et al. 2020 conducted a study to understand how font, text rotation and distance might impact legibility in the virtual reality space. Their findings show that there is a minimum required font size but also that we need to think about font size in angular unit dmm. Furthermore, text rotated 60° or more requires a much larger text size to be legible regardless of the distance of the text to the viewer and font.

Along these same lines, few studies in this literature review focus on technology used to improve readability. In one study described, Li et al. (2019) analyze “Reader View” technology. This is typically in the form of a web browser extension that allows users to minimize the non-text content on a page and make the page more readable. Alongside their study, there should be more research on tools and technology that can help all different populations with readability.
Optimal Text Settings

Ansari et al. (2020) published a mobile game-based solution to help children with Dyslexia in their early reading ages. This is another form of technology that helps support students with Dyslexia reading digital texts. Currently, there is limited work on these various technologies that help support readability and overall, improve the design of web pages for accessibility needs.

Expanding the scope of the Literature Review

"Imagine a collaboratively developed, universal content style guide, based on usability evidence." Sarah Winters, project founder.

There were two topics that I additionally did not add to this literature review due to the fact that they were not scoped within the initial research questions. First, understanding the variety of readability guidelines that currently exist and their limitations. Prior research has shown that design guidelines are a way to tackle current Web accessibility issues (Miniukovich et al., 2017). However, there is currently a large set of guidelines that are public. Thus, compiling them and creating a universal guideline set is a really difficult thing to do. Thus, as researchers it is important to better understand how we can familiarize ourselves with research guidelines and how to use them.

In general, research guidelines have the power to not only increase usability but also help us better create readability across languages and cultures. Readability guidelines can be specific enough for different people in different contexts.

The second topic not covered in this work is understanding how to diagnose and predict readability online. There are currently different tools and algorithms built to predict readability. Understanding this space further will help designers know where to improve and when to improve. Universally, making the web more readable.

Conclusion and Limitations

This literature review covered over March, 2020 just scratches the surface of information centered on readability and text settings. Due to time constraints, this literature review was not done systematically but rather stemmed from the foundations given in the project proposal document.

Furthermore, this literature review did not solely focus on Wikipedia text settings. Rather it focused on text settings
across the web. Thus, it is important to find ways to adapt these findings to the Wikipedia platform and investigate how that might impact the readability and usability. Additionally, how it may impact a platform that covers 290+ languages and groups of worldwide editors.

Just generally, the design of the current Wikipedia platform can benefit from the research around white space, font type, style and page layout. With more time and a broader scope of a literature review, I could focus on applying this literature to Wikipedia.
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Optimal Text Settings


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