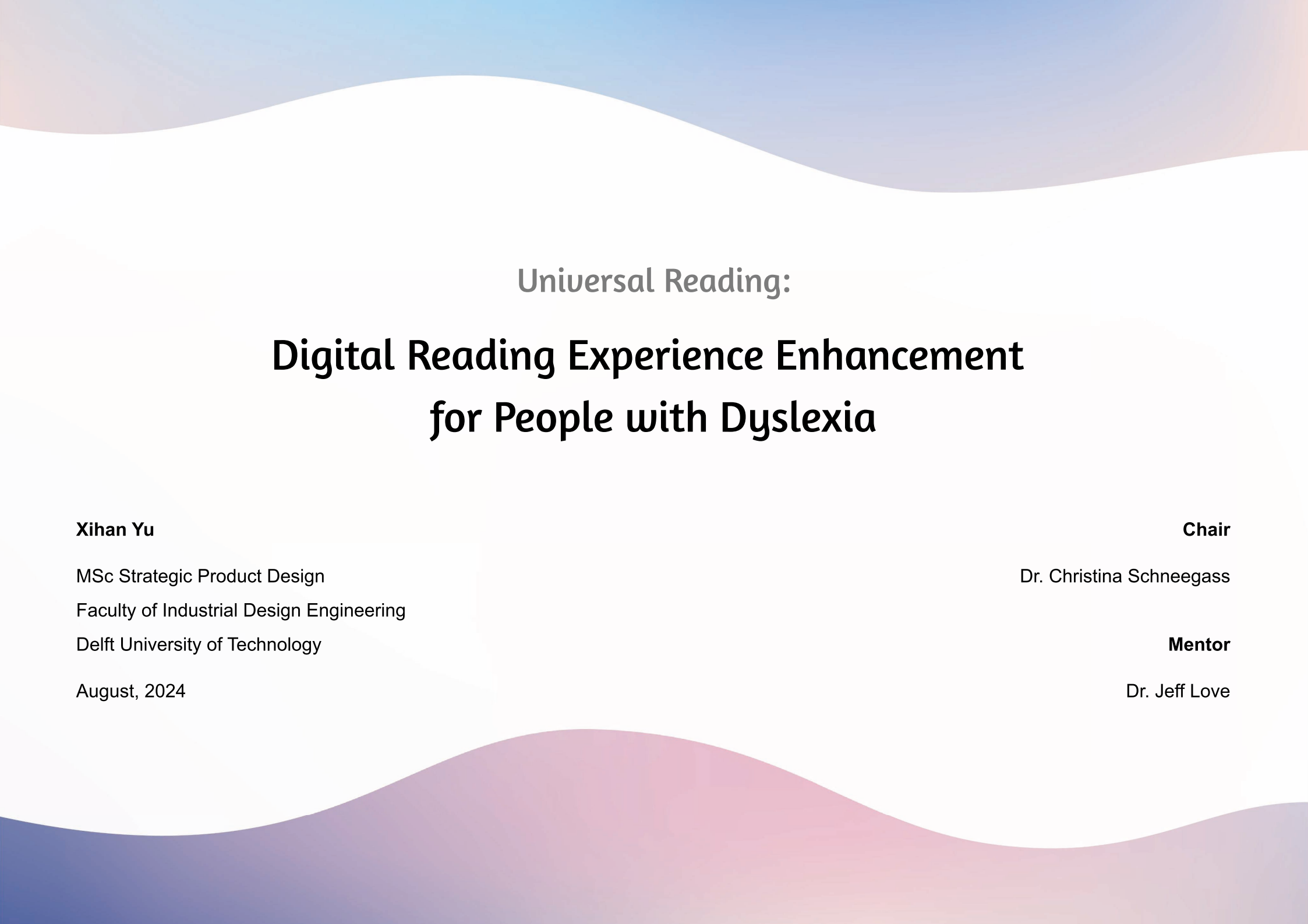




Universal Reading: Digital Reading Experience Enhancement for People with Dyslexia

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1 Abstract

This report outlines the design of an interactive reading assistance system aimed at enhancing reading efficiency and experience for individuals with dyslexia.

The design process is divided into four phases: Discover, Define, Develop, and Deliver.

The Discover phase includes literature and technical research. To achieve the design goal, eye-tracking technology combined with AI generation was identified as an ideal combination for intuitive information exchange and analysis during the research.

After finishing the design definition, the research involved a comprehensive iterative design process, incorporating insights from functional tests, user interviews, an expert interview, and a technical focus group. A notable innovation is the use of reading data from eye movements, integrated with AI to provide real-time personalized reading assistance. The powerful capabilities of AI bring unlimited possibilities for the system's flexibility. To this end, a comprehensive strategic roadmap and system map were also designed to ensure the feasibility of the project.

Despite its innovative approach, the project faced challenges, including workload constraints and technical hurdles, which affected the thoroughness of verification and validation. These limitations highlight areas for further development and refinement. By addressing the challenges, this project has the potential to influence broader accessibility practices in digital reading.

2 Introduction

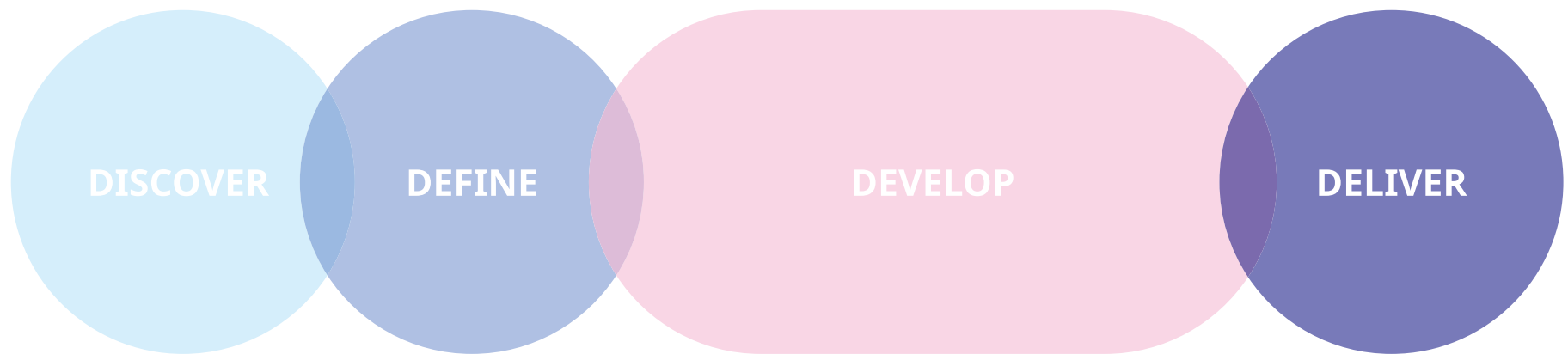
Dyslexia, also regarded as reading difficulty, is a result of specific differences in the way the brain processes written words and text. Dyslexia is characterized by poor spelling, pronunciation, reading fluency, comprehension, and writing (Boets et al., 2013). It is described as a long-lasting deficit that can manifest as early as preschool and persist into adulthood (Martins et al., 2010). Dyslexia does not naturally resolve with age. Research from the British Dyslexia Association¹ indicates that as people age, some may adapt to their reading ability and style, or use compensatory neural mechanisms to mitigate their reading difficulties. This is why dyslexia is often perceived as a condition primarily affecting children, with less attention paid to adults. Consequently, existing support and training programs primarily target children, leaving a gap in systematic assistance for adults. Nevertheless, this does not mean that adults with dyslexia do not suffer from the pain that dyslexia brings to the reading experience.

Various tools are available to assist individuals with dyslexia in improving their reading experience, which includes physical aids like reading cards or rulers, as well as digital interfaces such as software, website plug-ins, and specialized fonts. On the other hand, organizations like the British Dyslexia Association have developed design guidelines for designers, working up specifications such as appropriate fonts, weight, line height, color, and information capacity. Innovative practices with new technologies, such as multimodal approaches and eye-tracking, have also emerged from research. There are corresponding quantitative analysis studies to determine the usability of several kinds of assist tools. Research has shown that specific types of reading rulers can significantly enhance reading performance for individuals with dyslexia (Niklaus et al., 2023).

However, digital reading rulers are not widely adopted, and existing implementations vary significantly without a common standard. Additionally, studies by Luz Rello and Ricardo Baeza-Yates have demonstrated that readability for dyslexic individuals improves with larger font sizes, increased character spacing, and certain color combinations. These studies have primarily focused on investigating single variables, but there remains a lack of comprehensive guidelines for optimizing digital reading tools for dyslexia. Therefore, building upon previous research, integrating appropriate technological aids and human-computer interaction experience design to achieve comprehensive optimization of design solutions represents a highly promising direction.

In this design project, I aim to explore interactive strategies for improving the reading experience of individuals with dyslexia through an iterative design process. Research and design is assumed to be synthesized based on extensive literature and case studies, and combined with in-depth engagement with individuals with dyslexia. This study aims to derive systematic and feasible approaches from existing research on reading assistance methods for individuals with dyslexia, and to integrate eye-tracking and AI technology to enhance the reading experience across all age groups. In addition, based on the inspiration of universal design principles, this project is also expected to benefit the general population who are not with dyslexia.

3 Design Thinking Process



- *Literature Review*
- *Pre-research*

- *Design Definition*

- *Functional Test 1&2*
- *Expert Interview*
- *Technical Focus Group*

- *Strategic Roadmap*
- *User Experience Design*
- *Interaction Design*

4 Literature Review

In design research focused on assistive strategies for dyslexic individuals, the classification and comparison of various factors of text presentation can provide valuable insights for clear design directions. This section describes the various factors affecting the reading experience of individuals with dyslexia, categorizing them based on their impact and scope. Then, through literature review and research, the existing design schemes and products for the target group are listed. These design cases are examined to substantiate the efficacy of combining solutions to address these distinct factors, thereby enhancing the reading experience.

4.1 What is Dyslexia?

In our progressively digital world, where information is efficiently conveyed through text, a distinctive group encounters unique challenges. Individuals with dyslexia, who grapple with impediments in text reading, face difficulties in maintaining the necessary focus to comprehend written content. Dyslexia is characterized by challenges in spelling, rapid reading, writing, mentally “sounding out” words, pronouncing words when reading aloud, and comprehending written text. Dyslexia is classified into developmental and acquired forms. The etiology of dyslexia involves a complex interplay of genetic and environmental factors, with some cases exhibiting familial patterns. In contrast to developmental dyslexia, which emerges early in life, acquired dyslexia can result from neurological incidents such as traumatic brain injury, stroke, or dementia. Dyslexia is the most prevalent learning disability worldwide. According to the International Dyslexia Association, 15–20% of the population show some signs of dyslexia.¹

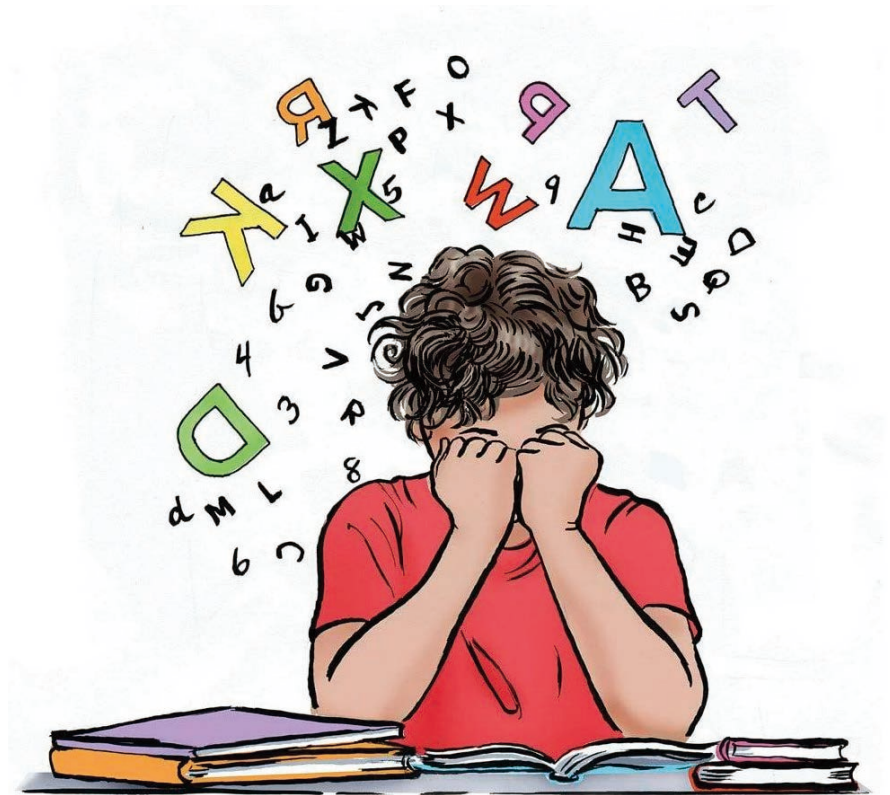


Figure 1: Individual with dyslexia

¹ <https://dyslexiaida.org/dyslexia-basics/>, last accessed August 1st, 2024

4.2 Text Presentation Factors

The presentational feature associated with dyslexia involves difficulty in accurately and swiftly identifying text content, leading to comprehension challenges. Therefore, improving the accessibility of text content for individuals with dyslexia becomes a fundamental strategy to enhance their reading experience. It is obvious that visual accessibility accounts for a considerable weight. Luz Rello conducted research on Text Presentation in 2015, aiming to identify the text presentation factors impacting the reading performance of individuals with and without dyslexia. Rello classifies influence factors into text presentation and text content. Under the part of the text presentation, factors are divided into “font size,” “font type,” “colors,” and “character spacing”. In this report, for better organization and alignment with forthcoming sections, I reorganize these factors into three parts: fonts, layouts (colors, sizes, spacing), and highlights. Differing from Rello's classification, I propose “highlights” as an independent category due to its adaptable and reversible visual properties. This section will dive into the analysis and interpretation of corresponding assistive tools for each factor, including physical reading rulers, font packages, software, and more. In addition to various visual factors, text-to-speech will also be mentioned as an auxiliary way to present multimodal information.

4.2.1 Layouts

In this part, the general basic visual styling structure of the texts which may affect the reading experience would be discussed. Specifically, the “layouts” here address variations in text presentation such as spacing, size, and color. Professionals across different disciplines, including psychologists, NGOs, and UX designers, have contributed valuable insights into optimizing text layouts for individuals with dyslexia. For instance, the British

Dyslexia Association annually releases the Dyslexia Friendly Style Guide¹, offering recommendations on font, size, spacing, color contrast, and writing style tailored to this audience. Noteworthy layout suggestions from the guide include:

- *Font size should be 12-14 point or equivalent;*
- *Larger inter-letter / character spacing, ideally around 35% of the average letter width;*
- *Inter-word spacing should be at least 3.5 times the inter-letter spacing;*
- *Some dyslexic people find that larger line spacing improves readability;*
- *Add extra space around headings and between paragraphs;*
- *Use sufficient contrast levels between background and text, and use dark coloured text on a light (not white) background;*
- *Left align text;*
- *Write short simple sentences: 60 to 70 characters is optimal.*

While these guidelines obviously enhance text clarity and organization, they often lack robust experimental validation and rely primarily on empirical evidence.

Research conducted by Luz Rello aimed to identify layouts that facilitate easier reading for individuals with dyslexia. The study involved 46 dyslexic participants and analyzed eight parameters related to dyslexic reading using a within-subjects design. Key findings indicated that font size, character spacing, text and background color, and text grayscale significantly affect reading performance. In contrast, paragraph spacing, background grayscale, line spacing, and column width have a lesser impact. Based on these results, it is recommended to use font size of 12 or larger, slightly increase word and character spacing, and avoid pure black text. Instead, softer color palettes like muted green, brown, blue, and cream should be chosen to reduce contrast and improve readability for individuals with dyslexia.

¹ <https://www.bdadyslexia.org.uk/advice/employers/creating-a-dyslexia-friendly-workplace/dyslexia-friendly-style-guide>, last accessed August 1st, 2024

4.2.2 Fonts

Research indicates that the optimal fonts for dyslexia and other learning disorders share common characteristics. The British Dyslexia Association suggests that sans-serif fonts (fonts that don't have extending features called "serifs" at the end of strokes) enhance text legibility. Sharon Lockley emphasizes the preference for non-italic and non-oblique fonts among individuals with dyslexia. Additionally, some research advocates for monospace fonts, where each letter occupies equal horizontal space on a line, as being more reader-friendly.



Figure 2: Serif vs. sans serif fonts — which one is better for dyslexic people?
www.designhill.com

Following these guidelines, fonts recommended for dyslexia are typically categorized into two groups: standard fonts and specially designed fonts. To prioritize universality, pre-installed or widely used fonts are initially recommended. Wilkins, Smith and colleagues (2007) believe that serifs are like extra strokes on letters. Just like their point of view, most mentioned fonts are certainly sans-serif fonts. The British Dyslexia Association recommends to use Arial, Comic Sans or, as alternatives to these, Verdana, Tahoma, Century Gothic, and Trebuchet. At the same time, there's an argument that certain serif fonts perform well in aiding reading. The International Dyslexia Centre, for example, is an advocate of the sans serif Times New Roman. Courier, which is also sans serif, performs even better than Times New Roman in a way because it is monospaced.

Specialized fonts designed for individuals with dyslexia form another significant category. The most reputable font designed for people with reading disabilities is Open Dyslexic. With this font, letters have heavy weighted bottoms to indicate direction. From the description from the official introduction, "Consistently weighted bottoms can also help reinforce the line of text; The unique shapes of each letter can help prevent confusion through flipping and swapping." Other fonts like Dylexiad, Dyslexie, and Read Regular have also been invented to help with dyslexia. However, while specially designed fonts may reduce the likelihood of letter misidentification, studies indicate limited improvement in overall reading speed and accuracy.

OpenDyslexic

Free and Open Source Dyslexia Typeface

OpenDyslexic is a new open sourced font created to increase readability for readers with dyslexia. The typeface includes regular, bold, italic, and bold-italic styles. It is being updated continually and improved based on input from dyslexic users. There are no restrictions on using OpenDyslexic outside of attribution.

Figure 3: Font Open Dyslexic

4.2.3 Highlight tools

If layouts and fonts are more considered by content creators within digital interfaces, “highlights” are more like a way for individuals with dyslexia to take initiative. Through observation of individuals with dyslexia, there’s evidence that using reading rulers is a highly recommended physical assistive measure. Social media posts from individuals with dyslexia affirm that reading rulers aid in focusing on the text being read, with some expressing preferences for specific types and colors of rulers. Commercially available products in this category, including color overlays, underlines, and highlighting, prioritize physical emphasis to guide readers and minimize distraction caused by difficulty in tracking their position. Among these, the color overlay and the underline overlay are more productive options – these products can be easily accessed from webshops. Additionally, some dyslexic people mention employing homemade tools, such as using a blank paper to cover already read texts. Furthermore, digital reading ruler tools, equipped with features like layout adjustment, font modification, and text-to-speech capabilities, have been developed, expanding the accessibility of assistive aids within digital interfaces. The coming part of Currently Available Digital Tools includes more introduction of such kinds of digital tools.

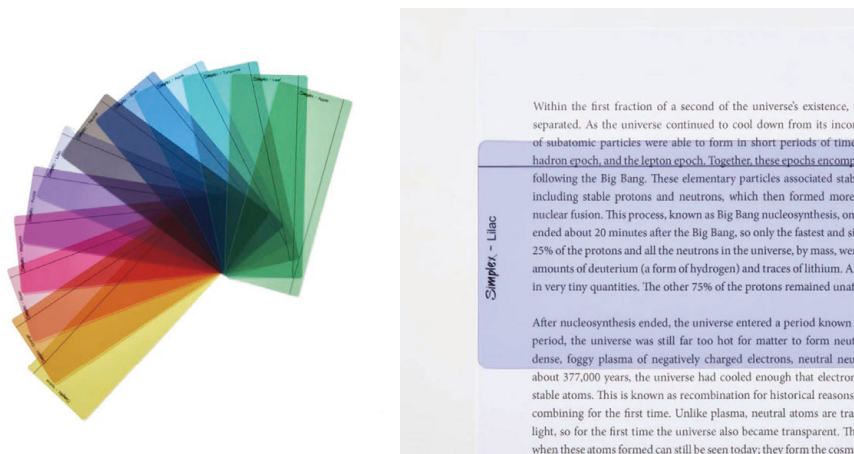


Figure 4: Dyslexia reading rulers

In a research done by Niklaus et al. in 2023, highlights on text can be divided into color overlay, shadow, underline, and lightbox. They conducted a quantitative analysis of the reading speed, degree of Comprehension, and helpfulness with 4 different digital reading rulers. From the study, the reading speed statistically significantly increases when testers use the gray bar rulers, followed by the shade, and the underline rulers; The lightbox ruler is the most preferred over all other rulers; None of the rulers had a significant effect on comprehension for participants with dyslexia. These research results help to prove that highlight rulers can play an obvious role in helping individuals with dyslexia in the digital interface, and they are also easy to be emotionally accepted by making them feel helped.

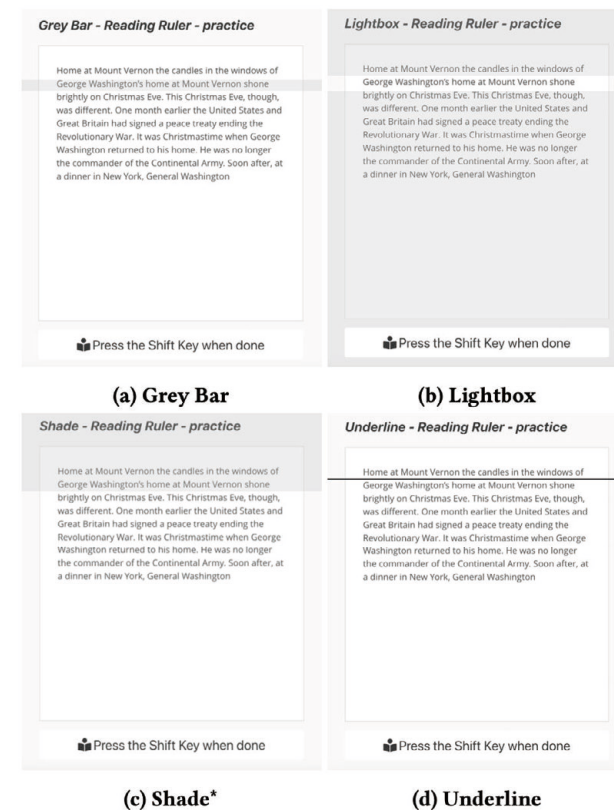


Figure 5: Digital reading ruler design categories (Niklaus et al., 2023)

4.2.4 Text-to-Speech

Dyslexics are encouraged to use different technologies to help with reading. Alongside visual adjustments, multisensory compensation is a commonly employed method. Nowadays, Text-to-Speech (TTS) technology has emerged as a widely used multisensory tool due to its low installation and usage threshold. Text-to-Speech can be easily accessed through common browser plug-ins and audiobook software in everyday life. There is evidence that properly used Text-to-Speech technology can not only improve the efficiency of information input, but also improve the level of information understanding. Fidler and Everatt (2012) suggest that to improve learning situations for students with dyslexia, one could increase comprehension by means of supportive technology. Students with dyslexia may need to rely more on their listening comprehension skills to understand information. In Draffan's (2002) chapter 2 on assistive technologies in supporting students' learning, he argues that listening to written text helps students with dyslexia in their reading tasks. This added audio is often faster than students' own reading pace, and it may aid understanding. Audio-support lowers the necessity to decode every single word and thus more attention can be given to understanding the content and building an integrative model (Schnotz, 2005). As computer technology has significantly improved, the number of tools of this type that are of good quality and easily accessible is significantly increasing (e.g., Kurzweil 3000, MWSReader). As a multisensory reading paradigm, sound-based reading assistance not only aids dyslexics through Text-to-Speech but also provides systematic reading support to visually impaired individuals in the form of audiobooks, thereby embodying an inclusive design approach.

Despite the positive impact of speech-based reading assistance on reading and comprehension, current Text-to-Speech tools on the market still have limitations. First of all, the speech speed of Text-to-Speech tools is hard to be consistent with the reading speed of dyslexics. Although many tools offer adjustable reading speeds, dyslexia's nature makes it difficult for users to maintain a constant reading pace, resulting in speed mismatch. Secondly, re-reading is a common characteristic of dyslexia, and achieving adaptability often requires manual adjustment of playback positions, which

can pose additional difficulties for dyslexic individuals. But there is no denying that Text-to-Speech technology has brought a good option for the empowerment of dyslexic reading. And we are pleased to see that many digital reading tools are now incorporating the Text-to-Speech function, and more effort is put into managing it to become more customized and flexible.

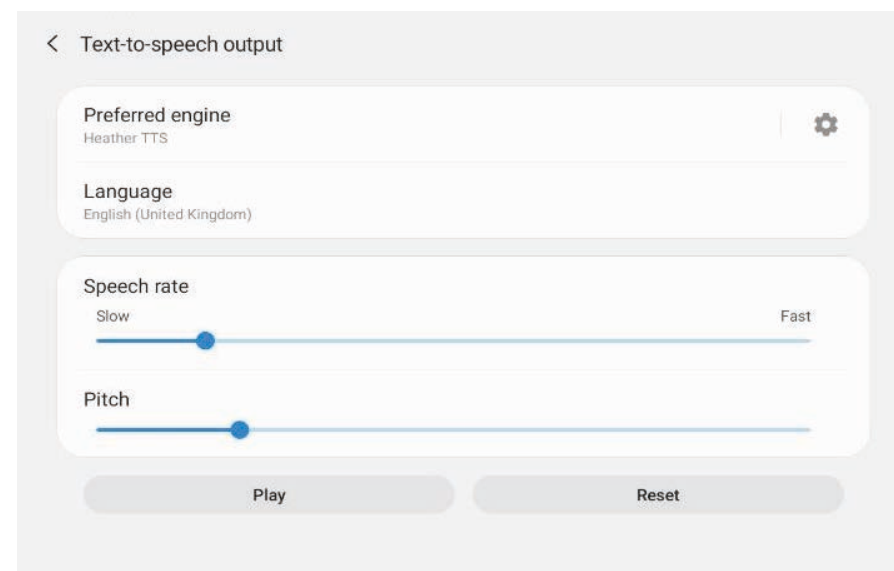


Figure 6: Common text-to-speech features include adjustable voice pitch and speed

4.3 Digital Enhancement

In the content above, we discussed the factors that contribute to the presentation of texts in dyslexia reading. Here, we delve into the practical application of these factors. Certain software, plug-ins, and browser extensions integrate various factors, including layouts, fonts, highlights, and text-to-speech functionality. Based on the expansion of the highlight tools, some researchers have chosen the eye-tracker as an input device to replace the role of the mouse. This innovation proves particularly advantageous for individuals with dyslexia, enabling them to maintain focus on the text being read. Moreover, the British Dyslexia Association advocates for consideration of writing style to enhance the reading experience, emphasizing the importance of employing simple language and expressions; Certain digital tools now incorporate features for explaining content, aligning with this recommendation. AI could be a powerful tool in this context.

4.3.1 Currently Available Digital Tools

Integrated digital tools are mostly in the form of browser extensions and desktop applications. In order to meet the reading habits of individuals with dyslexia, these tools often undergo simplification adjustments to their interfaces. This typically involves the removal of advertisements, plugins, intricate layouts, and decorative elements. Essential functionalities include the ability to adjust layout aspects such as background color, text color, font style, font size, and spacing. Presently, nearly all such digital tools are equipped with text-to-speech capabilities to accommodate multisensory reading needs. Moreover, some applications offer additional features like highlighting, directional search, translation, and even note-taking functionalities.

Take Reader Mode as an example, which is a Chrome reading extension and web app. In addition to making it easy to customize the reading interface and take notes, the digital reader has a special emphasis on support for dyslexia. It comes with a variety of mainstream dyslexia friendly fonts on the market. Users can also turn to the inserted text-to-speech function. Reading ruler is another signature feature of this tool. “Read the articles at your own pace by using the Dyslexia Ruler as guidance. Easily configure the ruler's size, color and position to your liking,” which is described by the website of Reader Mode.

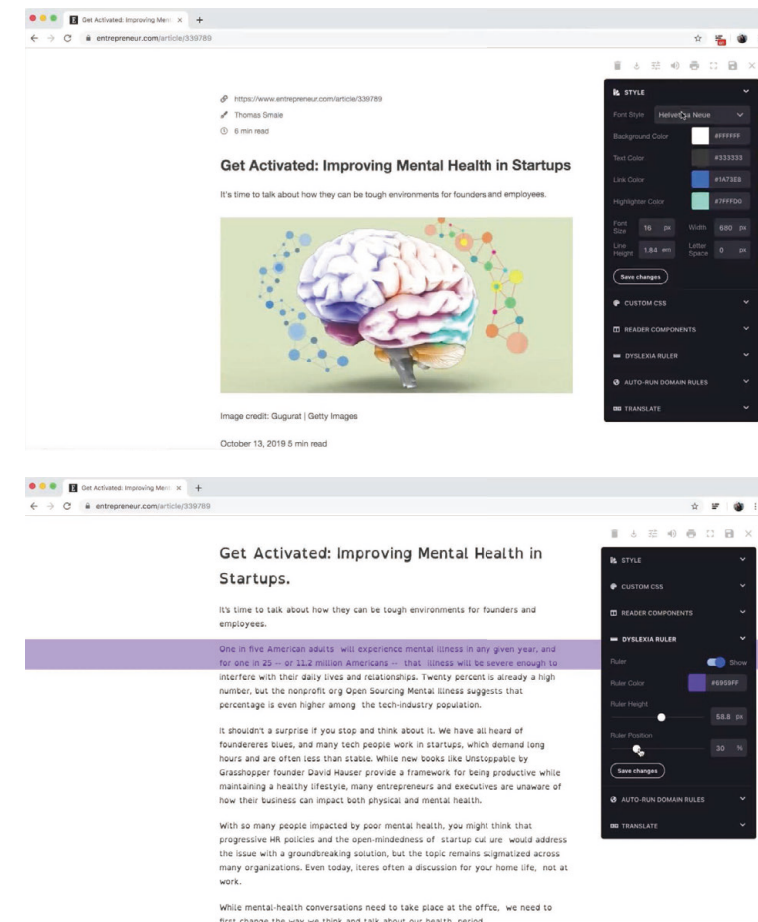


Figure 7: Reader Mode: Customize reading experience for dyslexia support

4.3.2 Eye Gaze & Reading

During the whole process of collecting and processing text information for humans, the first and foremost step is to use the eyes to see the text. In most cases of normal reading, the eyes move fluently at a certain speed, while the reader finds it difficult to understand the text, such smooth eye movements may be disrupted. Okoso et al. tried to figure out the relationship between eye gaze features and the difficulty of understanding a paragraph, sentence or word in 2015. According to the experiment, when a problem for word comprehension occurs, a fixation duration is proved to be longer. Long fixations (longer than 0.7 sec.) are associated with difficult words, whereas lower levels of difficulty cost medium-length durations (about 0.4 - 0.7). Ahn et al. collected eye moving data of 95 participants to decode a reader's eye movements to predict their level of text

comprehension and related states in 2020. They found that people who rated the passage as difficult tended to read more slowly and carefully, producing fixations having longer durations and saccades having smaller amplitudes.

Hienert et al. developed EyeMetricsLive, a browser plugin that uses live eye-tracking data to generate visual stimuli. total fixation duration, number of fixations, timestamp of the first fixation, time to first fixation, first fixation duration, and average fixation duration. For each saccade, it stores the timestamps of the entry- and exit saccade, its sequential index, its duration, its length, its amplitude, its peak velocity, and its 2-dimensional direction vector. The intensity of reading a word can be shown directly by a heat map on the fly. The system visualizes reading intensity with a real-time heat map, providing immediate feedback to enhance user experience and comprehension.

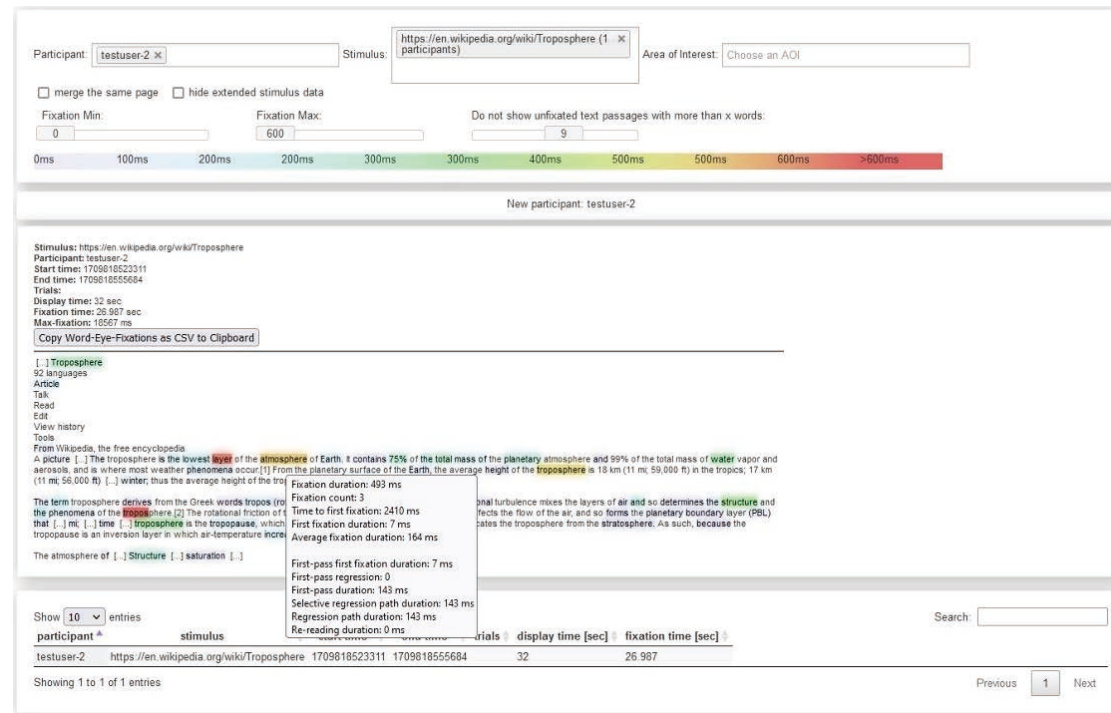


Figure 8: EyeLiveMetric's user interface

4.3.3 GARY: Eye-tracker Implement

Numerous research shows a firm link between eye movement and dyslexia. Rayner contends that eye movement serves as a barometer of cognitive engagement during reading, with fluent and swift eye movements indicative of higher levels of comprehension, while prolonged fixations and erratic eye movements may signal difficulties in understanding. In several cases, researchers used eye-tracking tests as evidence of dyslexia. The eye movements of readers with dyslexia are different from regular readers. Specifically, individuals with dyslexia exhibit longer fixations, more frequent fixations, shorter saccades, and increased regressions during reading (Rello, 2014).

In addition to being an indicator of dyslexia, eye movement and eye-tracking also has potential as a reading assistance. One of the limits of existing tools is that they lack the capability to synchronize visual processing with auditory output, potentially leading to discrepancies between the text read and heard (Schiavo et al., 2021). In a study by Niklaus et al. (2023), a focus group discussion among individuals with dyslexia identified eye-tracking as a potential alternative input method to conventional mouse and keyboard controls. Participants expressed interest in a reading aid that would dynamically adjust based on their eye movements, alleviating the need for manual input.

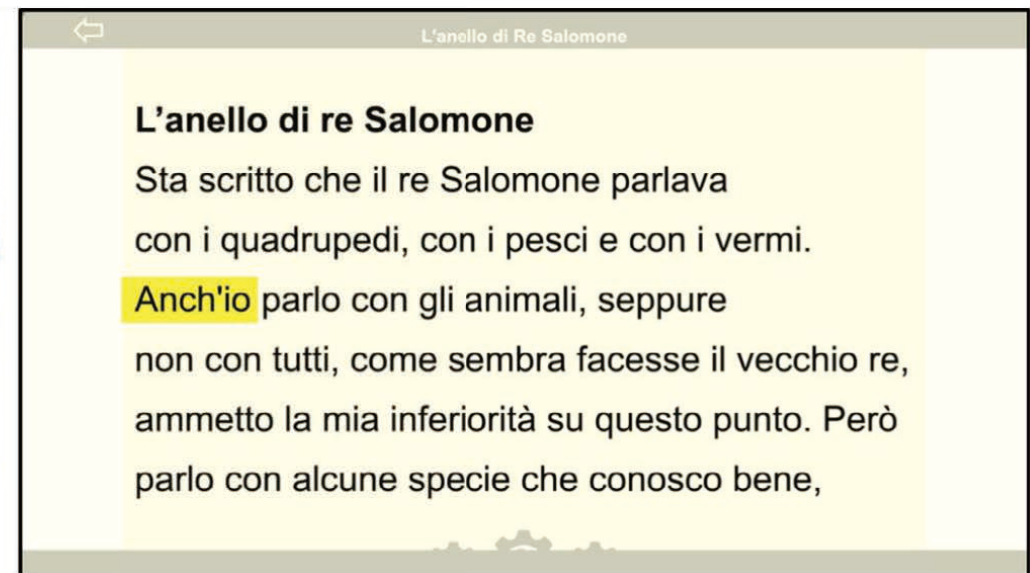
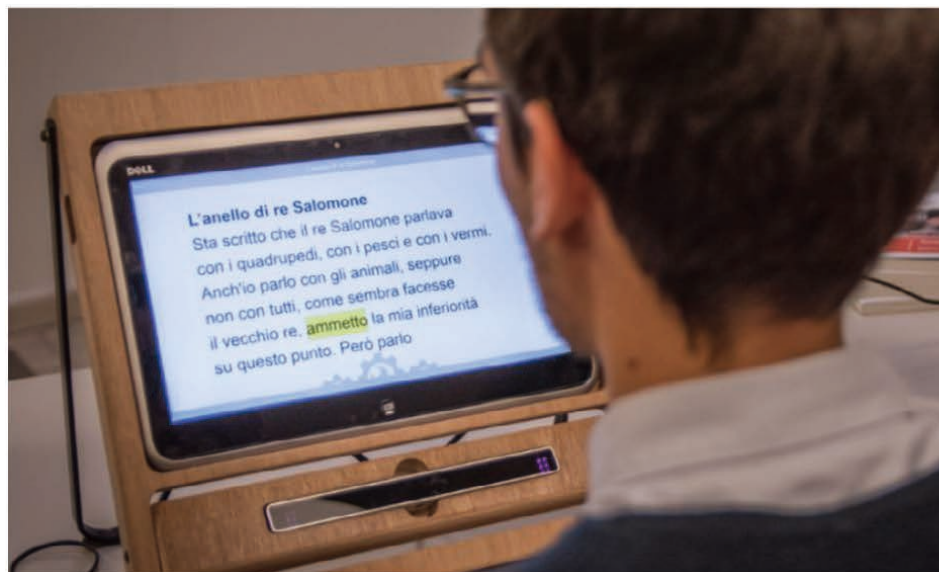


Figure 9: GARY and its display

In practice, eye-tracking technology has been integrated into the development of reading assistance tools for individuals with dyslexia. Notably, the GARY (Gaze and Read it by Yourself) application combines text-to-speech synthesis with eye-tracking technology to facilitate reading. A distinguishing feature of GARY is that the audio speed is automatically adjusted to keep up with the reading speed of the user, and therefore driven by the user's attention to the text. It ensures the interaction between the reading and listening processes, and the control of the readers' attention. What's more, combining with the benefits mentioned above in the part of Highlight Tools, eye-tracking can provide an effect of a digital reading ruler which is real-time moving with eye movement. Schiavo et al. (2020) conducted a validation experiment to assess the efficacy of GARY in improving reading comprehension among individuals with dyslexia. Results demonstrated that participants exhibited higher comprehension scores when using GARY compared to traditional read-aloud tools, providing compelling evidence for the beneficial impact of eye-tracking technology on the reading behavior of individuals with dyslexia. While the GARY introduces an innovative concept of using eye-tracking technology for input, from a HCI perspective, GARY lacks validated usability. It is worth considering further exploration from the perspectives of interaction and communication design, to optimize the application of eye-tracking technology in enhancing the reading experience.

4.3.4 Content Processing

Dyslexia, characterized by difficulties in word recognition, spelling, and content decoding, is exacerbated by complex grammar structures and lengthy, intricate sentences. Recognizing this challenge, the British Dyslexia Association introduced Dyslexia Style 2023, advocating for writing styles that employ active voice, concise paragraphs, straightforward language with everyday vocabulary, and the use of bullet points and numbering to facilitate comprehension among dyslexic individuals. At the same time, there are also some more associations and researchers pointing out the significance of content simplification for people with dyslexia. However, different authors show different writing styles, in that tailoring text to meet these guidelines can be a labor-intensive task, especially on a large scale.

The emergence of artificial intelligence and machine learning presents a promising solution to this dilemma. Transfer learning is a technique used in machine learning to address the challenge of obtaining accurate training data that matches the feature space and data distribution of the test data. Developing tailored written material for individuals with dyslexia can be a resource-intensive process. Alternatively, text style transfer technology can be utilized to automatically convert standard written material into a more dyslexia-friendly format, providing a potential solution to this challenge. There's potential of transfer learning and text style transfer technology to automatically convert standard written material into a more readable format for individuals with dyslexia. (Madjidi et al., 2023) Given the popularity of AI technology, the barrier to using AI tools for simplifying text content to meet specific needs is sharply diminishing, allowing for implementation on various platforms including basic webpages and software.

4.4 Universal Design

Optimization measures for dyslexia hold universal significance and are deeply rooted in social relevance. By focusing on textual accessibility for users with dyslexia, we can derive broader benefits for all users. This approach aligns with the principles of universal design, which seeks to create inclusive and accessible environments for diverse user groups.

4.4.1 Generalized Audience: Design for all visual readers

Our primary target users are individuals with dyslexia. Dyslexia is a common condition, making those affected a significant user group. Addressing their needs directly impacts a considerable portion of the population. However, the benefits of designing for dyslexic users extend beyond this group to include all visual readers. Improving accessibility practices for dyslexic users can help alleviate common difficulties faced by all Internet users, including those with other disabilities.

The enhancements made for dyslexic readers, such as improving web readability and providing multimodal documents, inherently benefit general readers. Pollak's research revealed that both students with and without dyslexia benefit from these improvements, demonstrating that accessibility practices can improve the reading experience for all users. This dual benefit underscores the universal value of such design practices.

Furthermore, in interviews with experts from the library field, the potential for visual reading methods that combine eye-tracking technology and artificial intelligence to assist visually impaired or low vision individuals was highlighted. These innovative approaches show promise in making reading more accessible to a broader audience, including those with low vision, thereby reinforcing the broader applicability of our design principles. You can see this expert interview in section 6.3.

4.4.2 Reasons and Principles

There are two primary reasons that contribute to universal design. Firstly, the definition of dyslexia is often flexible and vague. Most diagnoses rely on assessments of personal reading abilities, indicating that dyslexia does not have clear diagnostic criteria that distinctly separate patients from non-patients. Dixon's research in 2007 on educational software for both dyslexic and non-dyslexic readers supports this view, suggesting that dyslexia symptoms are present to varying degrees among most people. Therefore, targeting dyslexic users effectively addresses a broader spectrum of reading difficulties encountered by many individuals. The second reason is, accessibility practices designed for dyslexic users offer substantial benefits to all readers. By improving web readability and reducing reading difficulties for dyslexic readers, general users also experience enhanced reading comfort and comprehension. This dual benefit is supported by Pollak's findings, which show that multimodal documents designed for dyslexics can help all students, regardless of whether they have dyslexia. These improvements make digital content more accessible and enjoyable for a diverse audience, reinforcing the principles of universal design.

According to Follette et al.'s Universal Design File, several principles can be applied to enhance the practical value of universal design. Firstly, the design should be useful and marketable to people with diverse abilities, ensuring broad accessibility and inclusivity. Secondly, it should accommodate a wide range of individual preferences and abilities, offering flexibility that allows users to customize their experience based on unique needs. Lastly, the design must be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. By adhering to these principles, the design becomes intuitive and user-friendly, reducing cognitive load and facilitating seamless interaction.

In conclusion, focusing on the needs of dyslexic users through universal design principles not only addresses a significant user group but also creates a more inclusive environment for all readers. The principles of universal design ensure that the benefits extend beyond the primary target audience, enhancing accessibility and usability for everyone.

5 Pre-research

The Pre-research section serves as a foundational preparation for the ensuing design process, and also a clarification for the design scope and direction. The primary aim of this phase is to achieve a comprehension of target users, including their categorization, preferences, and habits. To achieve it, a target user selection and a pre-interview were conducted. The valuable insights gained from this interview were analyzed and formulated into a "How Might We?" question, guiding the subsequent design definition. This process of analysis also helped in creating a clearer picture of typical users, which is the target user definition. Design tools such as personas and user journeys were used to aid in understanding the general actions and moods of this user group.

5.1 User Research

This user research marks the initial contact with potential target users. The first step involved deciding on a method for selecting participants. At the beginning, I assumed there would be an established official medical judgment method. However, upon investigation, it was found that such criteria were lacking. Therefore, questionnaires from various research organizations were accepted as a selection judgment method. Participants were recruited through TU Delft Library, Rotterdam Public Library, online contacts, and other channels. 6 participants, who indicated the possibility of dyslexia through the questionnaires, were subsequently interviewed. The interview transcripts were then analyzed, resulting in valuable insights.

5.1.1 Target Objects Selection

Dyslexia studies are mostly focused on children or students, rather than adults. This neglect may stem from the assumption that adults have the ability to adapt to their reading difficulties or employ compensatory measures. However, dyslexia does not diminish or heal naturally with age, which still affects 1 in 10 individuals at all ages. (Bowman, 2010) In this study, the initial step involves identifying the research participants. Given the lack of precise medical diagnostic methods tailored specifically for adults, I turned to use assessment screeners provided by research organizations specializing in dyslexia.

This Revised Adult Dyslexia Organization Screening by Adult Dyslexia¹ Organization was developed by Professor Tim Miles and Dr Ross Cooper. The checklist is organized around some of the key difficulties experienced by people with dyslexia in terms of reading, spelling, memory, organization and sequencing. Each question offers a "yes" or "no" response, which is then tallied and converted into a score to assess the likelihood of dyslexia. The Adult Reading History Questionnaire by British Dyslexia Organization² is a self-report screening tool designed to measure risk of reading disability in adults (Lefly & Pennington, 2000), which asks adults about their own reading history and current reading habits in order to estimate the risk that they may have a reading disability. For each question, the testers were asked to select options from 0 to 4 according to the degree of light to heavy, and then obtained the total score according to the corresponding data of the options.

The above two scales are the binary scale and the Likert scale. Among these two kinds of scales, the Likert scale is generally favored for its ability to capture subtle nuances in respondents' attitudes or opinions. In contrast, binary scales offer limited flexibility and may oversimplify complex responses. Given the considerations of statistical accuracy and objectivity, the latter scale was chosen as the selection tool for participant classification in this survey.

¹ <https://outsidersoftware.co.uk/wp-content/uploads/2012/11/RevisedADOScreening.pdf>, last accessed August 1st, 2024

² <https://dyslexiaida.org/screening-for-dyslexia/dyslexia-screener-for-adults/>, last accessed August 1st, 2024

Revised Adult Dyslexia Organisation screening

Please answer Yes or No. Do not miss any questions out. If you are in any doubt, answer whichever feels like the truer answer.

1	When using the telephone, do you get the numbers mixed up when you dial?	YES	NO
2	Is your spelling poor?	YES	NO
3	When writing down the date, do you often make mistakes?	YES	NO
4	Do you mix up dates and times and miss appointments?	YES	NO
5	Do you find forms difficult and confusing?	YES	NO
6	Do you find it difficult to take messages on the phone and pass them on correctly?	YES	NO
7	Do you mix up bus numbers like 35 and 53?	YES	NO
8	Do you find it difficult to say the months of the year forwards in a fluent manner?	YES	NO
9	When you were at school, did you find it hard to learn the multiplication or times tables?	YES	NO
10	Do you take longer than you should to read a page of a book?	YES	NO
11	Do you find difficulty in telling left from right?	YES	NO
12	Did you find it difficult to decide how to answer these questions?	YES	NO

This checklist was developed in conjunction with Professor Tim Miles OBE of Bangor University following empirical research by Dr Ross Cooper of LLU+, London South Bank University.

This checklist does not attempt to record the talents, skills or potential linked with dyslexia. The checklist is organised around some of the key difficulties experienced by people with dyslexia in terms of reading, spelling, memory, organisation and sequencing. A more formal assessment may confirm the presence of dyslexia, see Chapter 1: Identification of Dyslexia.

APPENDIX Adult Reading History Questionnaire

PLEASE NOTE: This reading history questionnaire applies to **you**, and **not** to your children.

Please circle the number of the response that most nearly describes your attitude or experience for each of the following questions or statements. If you think your response would be between numbers, place an "X" where you think it should be.

- Which of the following most nearly describes *your* attitude toward school when you were a child:

Loved school; favorite activity	0	1	2	3	4	Hated school; tried to get out of going
---------------------------------------	---	---	---	---	---	---
- How much difficulty did you have *learning to read* in elementary school?

None	0	1	2	3	4	A great deal
------	---	---	---	---	---	--------------
- How much extra help did you need when learning to read in elementary school?

Help from: No help	0	1	2	3	4	Tutors or special class 1 year	Tutors or special class 2 or more years
-----------------------	---	---	---	---	---	--------------------------------------	---
- Did you ever reverse the order of letters or numbers when you were a child?

No	0	1	2	3	4	A great deal
----	---	---	---	---	---	--------------
- Did you have difficulty learning letter and/or color names when you were a child?

No	0	1	2	3	4	A great deal
----	---	---	---	---	---	--------------
- How would you compare your reading skill to that of others in your elementary classes?

Above average	0	1	2	3	4	Average	Below average
---------------	---	---	---	---	---	---------	---------------
- All students struggle from time to time in school. In comparison to others in your classes, how much did you struggle to complete your work?

Not at all	0	1	2	3	4	Less than most	About the same	More than most	Much more than most
------------	---	---	---	---	---	----------------	----------------	----------------	---------------------
- Did you experience difficulty in high school or college English classes?

No; enjoyed and did well	0	1	2	3	4	Some	A great deal; did poorly
-----------------------------	---	---	---	---	---	------	-----------------------------
- What is your current attitude toward reading?

Very positive	0	1	2	3	4	Very negative
---------------	---	---	---	---	---	---------------
- How much reading do you do for pleasure?

A great deal	0	1	2	3	4	Some	None
--------------	---	---	---	---	---	------	------

(appendix continues)

Figure 10: Two types of questionnaires to identify dyslexia (excerpt)

5.1.2 Pre-interviews

Through the questionnaire screening, potential interviewees can be found. For the selected participants, I first conducted a pre-interview. For this interview, a semi-structured interview script was prepared. The purpose of this interview was to help me get in touch with the participants for the first time about their level of dyslexia, specific manifestations and feelings in their lives, their reactions and strategies, and their psychology. So that, the semi-structured script is divided into 3 parts:

Experience

- How did you become aware of your own reading disability?
- Compared to others, what characteristics or signs do you believe you exhibit?
- What are your typical thoughts or feelings when reading?
- How long can you usually read before feeling unable to continue?
- Do the people around you know about your reading disability? How does this affect your social life?

Strategies

- Have you tried any methods to alleviate your reading disability, such as annotating, using highlighters, underlining, summarizing, using overlays, intentionally enlarging content, or printing it out?
- Have these methods been effective? Which one has been most effective for you? What method have you used most recently?

Psychological

- Have you ever felt anxiety, sadness, or self-deprecation due to your reading disability?
- Have these experiences led to feelings of inferiority?
- Have you ever avoided reading as a result? If so, what alternative or compensatory methods do you employ?
- Do you believe your reading disability has had any positive effects in certain aspects of your life?

So far, six individuals with dyslexia have participated in the interviews. Among them:

A was a Chinese student in her twenties, studying at TU Delft. She reported symptoms such as a lack of patience for reading long and serious content and being easily distracted by the environment. She scored a **Moderate Risk** on the Adult Reading History Questionnaire.

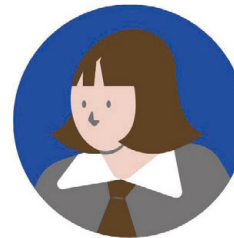
B is a Romanian intern in his twenties, working in Eindhoven. He found reading large blocks of text irritating and said he would avoid it if there was an alternative. His questionnaire indicated a **Significant Risk**.

C was a Dutch student, around twenty, interviewed at the TU Delft Library. He reported having ADHD and self-suspected some dyslexic tendencies. His main symptom is need to spend extra effort to force himself to concentrate on reading. He concluded with a **Moderate Risk** after the questionnaire.

D is a Chinese researcher at Amsterdam University, found through a social media post about dyslexia. He described having dyslexia for many years and had tried various reading assistance methods, including specialized fonts and ChatGPT. He was ranked at **Significant Risk** on the questionnaire.

E was a Dutch office worker in her thirties, based in Rotterdam. She describes herself as not good at reading. The most reading scene for her is at work. She used structural tools for better understanding. She scored a **Moderate Risk**.

F was a Chinese student in his twenties at TU Delft. He believes that his dyslexia mainly occurs when reading non-native language material, which exacerbates his reading difficulties. He mentioned that fluency helps improve reading performance and was ranked at **Significant Risk** for the questionnaire.



A, Student, Chinese

"Prefer quick and short reading stimulation."



B, Intern, Romania

"Easy to distractions and skipping lines."



C, Student, Dutch

"Someone like to read with music, but not me."



D, Researcher, Chinese

"AI is a good helper for efficient reading."



E, Office worker, Dutch

"I was introduced to structured literacy."



F, Student, Chinese

"I prefer reading with a mouse or a pen to track."

5.1.3 Interview Results

Symptoms

- Experiences visual fatigue (A, C)
- Struggles with dense text (content and layout) (C)
- Fear of large blocks of text (C, D, F)
- Often loses place while reading (B)
- Eyes move, but focus wanes (A, B, E)
- Frequently misses information (C, D, E, F)
- Slow reading speed (B, F)
- Short attention span (A)
- Distracted by external noises (A, C, D)

Autonomous actions

- Prefer less content on the screen (B, E)
- Use mouses to track reading position (B, D)
- Makes notes (E, F)
- Underlines and highlights (A, B, C, E)
- Color overlays and homemade tools (D)
- Audio books and text-to-speech software (A, E)
- Compensatory ways of reading (B, D)
- Tree structures or mind maps for information organization (A, B)
- Manual segmentation and structuralization (A)
- Use AI tools to summarize text (A, B, C, D, E, F)

Psychological feelings

- Feels frustrated and impatient (A)
- Linear reading leads to fatigue (B, F)
- Forced reading exacerbates dyslexia (C)
- Prefers brief, engaging reading experiences (A)
- Occasional states of “flow” (F)

* A to E represents the interviewees.

The interview results revealed a certain levels of information: During the interviews, interviewees often proactively shared the autonomous strategies they used to cope with reading difficulties. Despite this, the conflict between their desire to read and their actual reading ability remained starkly evident. Through discussions with them, we reached a consensus that some technologies identified in the literature review, such as eye-tracking and AI-generated content, could empower reading experience to some extent. However, it must be noted that the additional time and effort required to use these technologies, and the frequent switching between different software can easily divert the reader's attention and increase their burden. This led us to pose the question: Is there an integrative interaction design solution that can make the reading assistance both simple and useful? How might we simplify the interaction while ensuring a diverse range of customizable features to create natural reading experience?

See the next page for a detailed infographic on the derivation process of “How Might We?”.

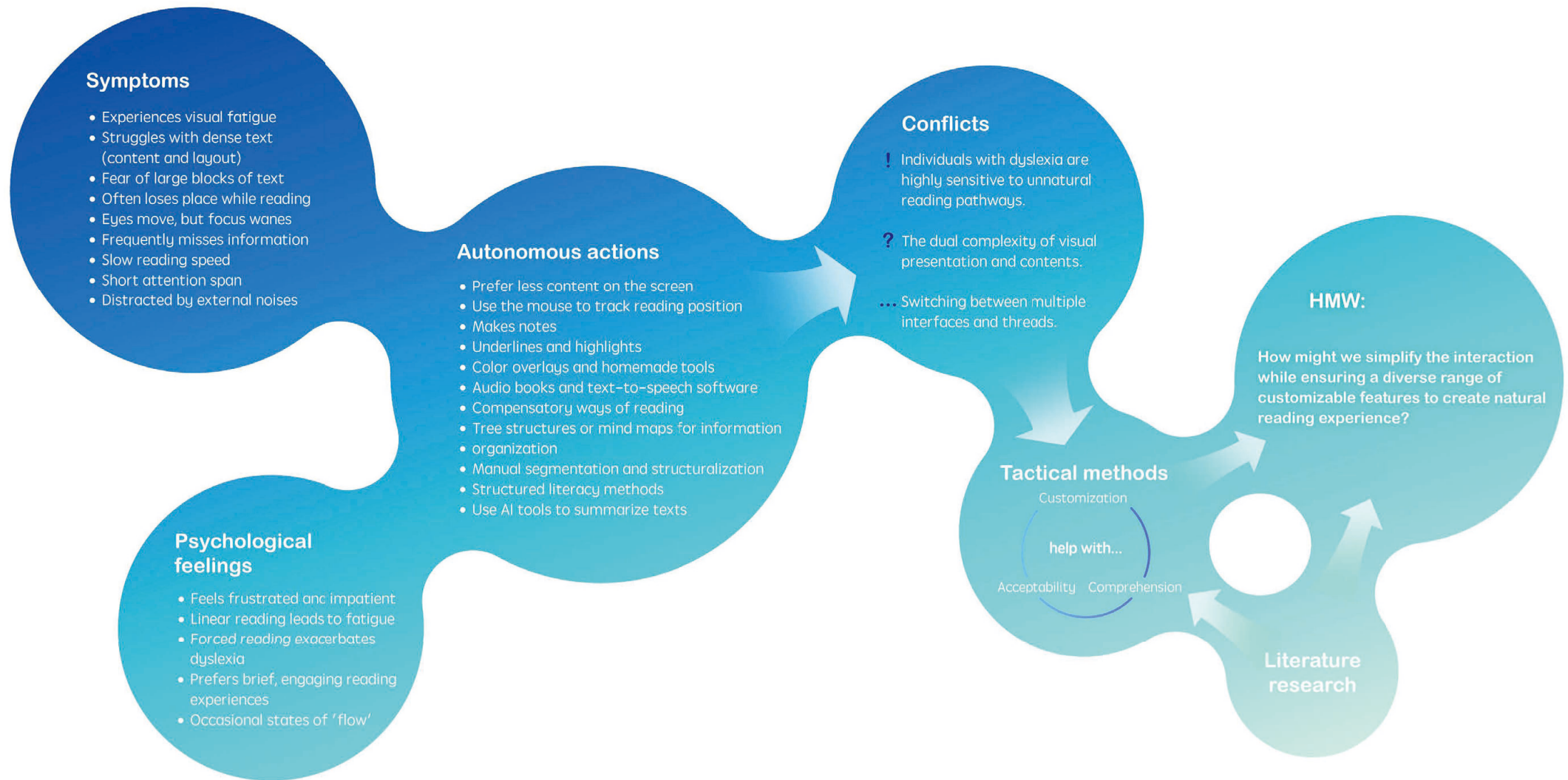


Figure 11: From the pre-interview to How Might We?

5.2 Target User Definition

The main target users of this project are individuals with dyslexia. However, as a result of applying universal design principles, the project also aims to benefit all visual readers. There are two key reasons for defining the target users this way. First, the definition of dyslexia is often flexible and vague. Most diagnoses are based on assessments of personal reading abilities, indicating that dyslexia does not have clear diagnostic criteria separating patients from non-patients. Dixon's test on educational software applying for both dyslexic and non-dyslexic readers supports this, suggesting that dyslexia symptoms are common to varying degrees among most people. Second, improving web readability to reduce reading difficulties for dyslexic readers will also benefit general readers. Pollak's research revealed that both students with and without dyslexia benefit from using multimodal documents designed for dyslexics. Therefore, the target users of this design project are finally defined as: mainly designed for individuals with dyslexia, while benefiting all general visual readers.

5.2.1 Persona

Based on the research and the target user definition, a rich portrait of the crowd unfolds towards us. As we still focus on finding solutions for individuals with dyslexia while the benefits to universal groups are added, the typical personas will still be dyslexic people. Following the pre-interview with participants, different people have chances to read different types of writing, and their feelings and reactions also markedly vary according to different kinds of reading materials. Therefore, I designed two typical personas here, and the following design development will be based on these settings.

5.2.2 User Journey

After the two personas, a general user journey of dyslexic reading is formed. This map incorporates multiple detailed behavioral and psychological changes in academic reading, work reading, and entertainment reading. The fluctuation of the emotional line shows the tension, confusion, anxiety and uncertainty of the dyslexic in the face of reading, and the sense of accomplishment after finishing reading.

From this user journey map, we can see great needs of efficient and effortless reading from the target group, while they have to face the unusual difficulty of capturing and understanding content information. This leads to the opportunity of building a service system design that meets the complex needs of individuals with dyslexia in terms of functionality and comprehension.



Persona 1

Name / Federico

Age / 23

Occupation / CS Student

Location / The Netherlands

Language / Mother tongue & English

About

Despite being a non-native speaker, Federico has been learning English since childhood and uses it fluently in his academic and social life. However, his dyslexia introduces significant challenges, particularly with English reading. His dyslexia often causes him to misread words, lose his place in texts, and read at a slower pace, which hinders his academic performance.

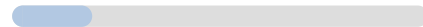
To cope, Federico employs various compensatory techniques, such as highlighting text, enlarging pages, and using tools like Chat GPT for summarization, though these methods have limited efficacy.

Motivation

Academic



Business

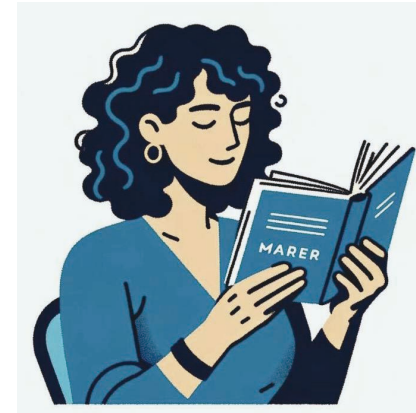


Entertainment



Frustration

- Although he is proficient in English, the academic content frequently involves difficult words and phrases.
- His dyslexia makes him often miss the track, resulting in a slow reading speed.
- Chat gpt's summary inevitably leaves out interesting details.



Persona 2

Name / Emma

Age / 30

Occupation / Marketing Manager in a Global Company

Location / The Netherlands

Language / English

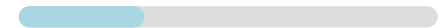
About

Emma, a marketing manager, has a penchant for fiction and storybooks. Despite her enthusiasm for reading, Emma's dyslexia poses significant obstacles, making it challenging for her to engage with text-based materials as effortlessly as she would like. To manage her condition, Emma utilizes audiobooks. She also uses text-to-speech tools, helping her improve comprehension.

For work reading, Emma often relies on summarization tools and note-taking apps. These tools enable her to quickly grasp the main points of lengthy documents and manage her professional responsibilities effectively.

Motivation

Academic



Business



Entertainment



Frustration

- Audio is hard to adjust. When she wants to rewind a few seconds, The precision of the interaction is not good.
- In her business reading, to maintain her focus, she has to switch back and forth between readers and other note-taking software.

User Journey

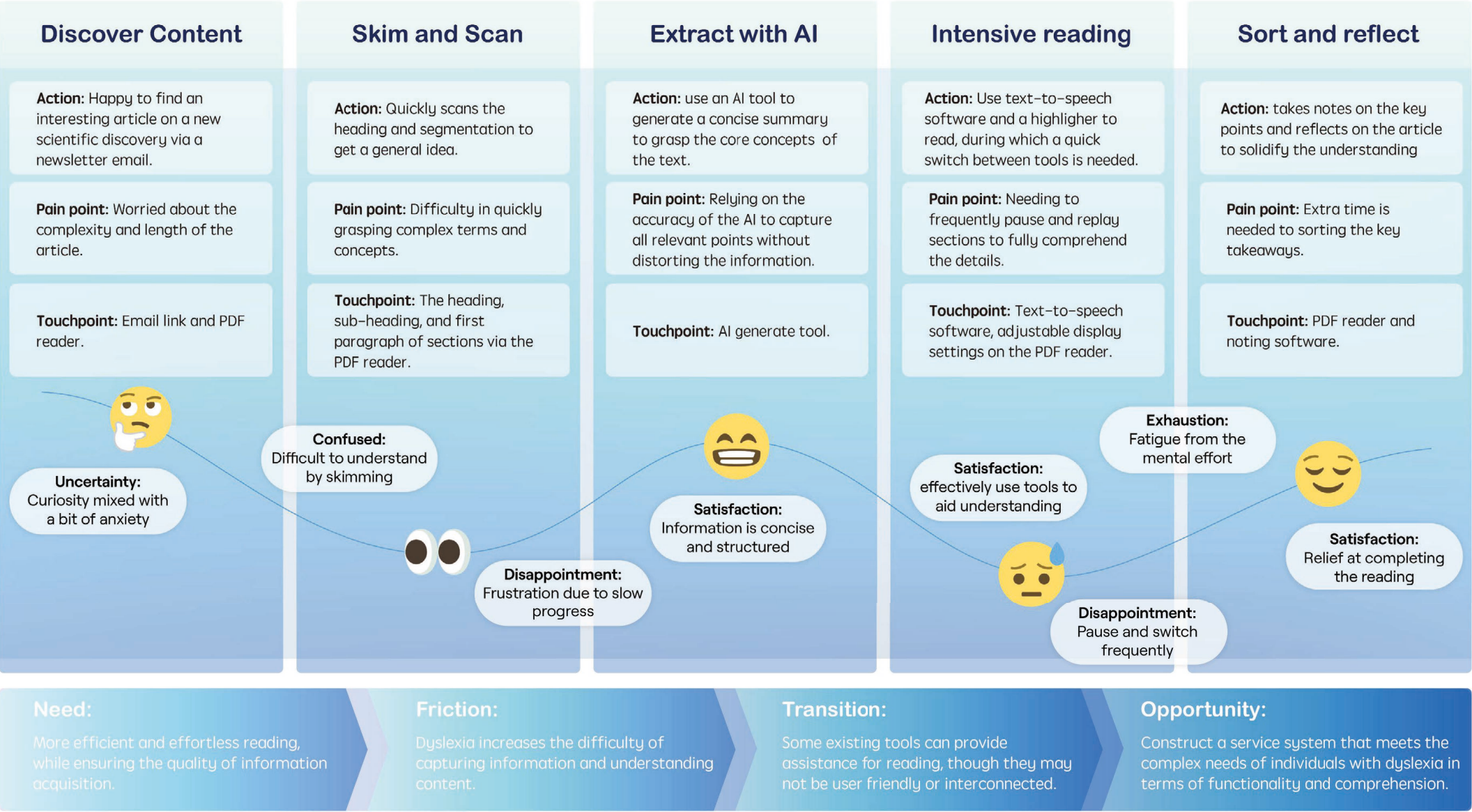
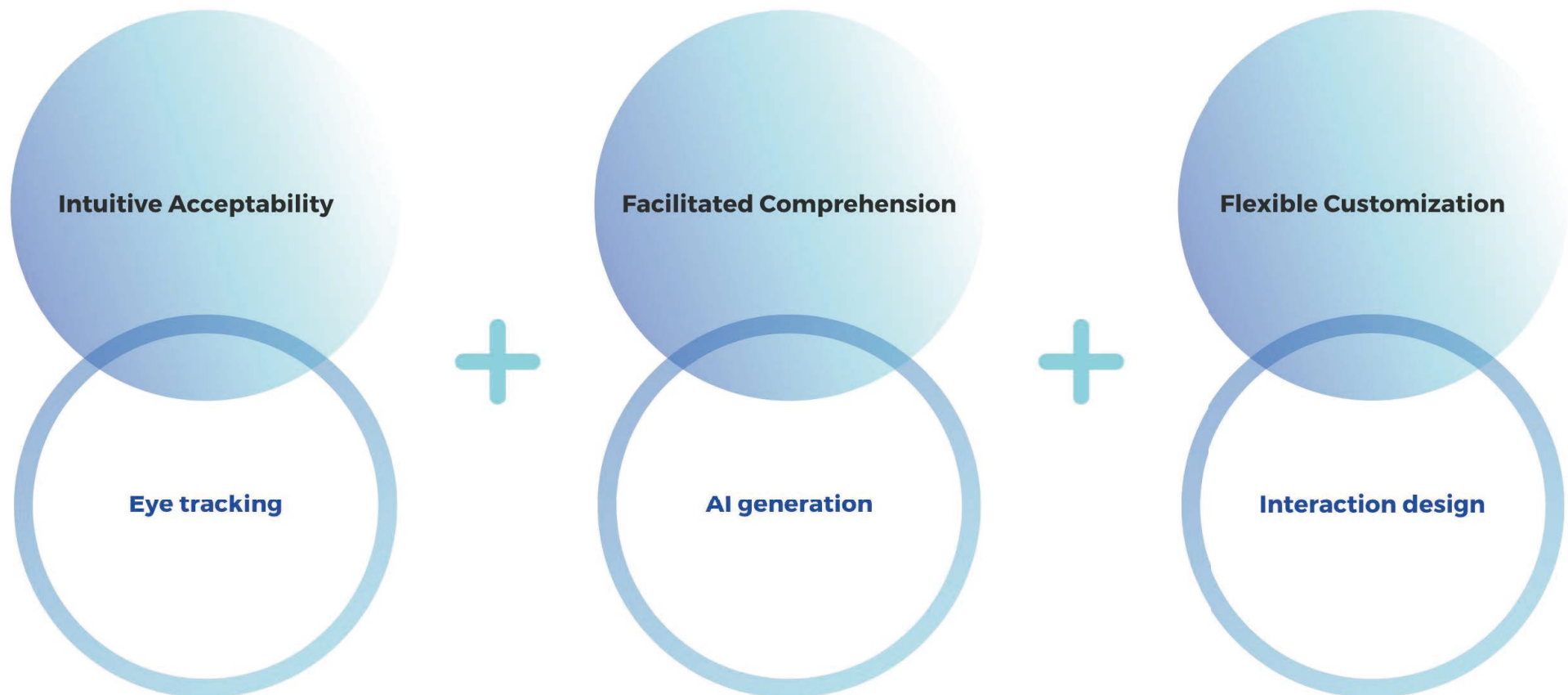


Figure 12: User journey map

6 Design Definition

Based on the comprehensive review of literature and research, I have gained a relatively comprehensive understanding of dyslexia, the situations of individuals with dyslexia, as well as existing strategies and solutions for addressing these challenges. It is evident that this condition is often overlooked, with individuals frequently resorting to subjective initiatives to find compensatory measures. While research on this topic is relatively extensive, systematic and up-to-date solutions are limited. The majority of existing solutions consist of traditional fonts, layouts, and text-to-speech tools. GARY, which integrates eye-tracking technology, offers strong interactivity but lacks emphasis on overall user experience. Additionally, emerging technologies like AICG show great potential in enhancing content processing capabilities. It is also a promising direction to use AI tools to simplify the generation of text content that is more suitable for individuals with dyslexia.

Therefore, the definition of the design project is to develop a system that optimizes the interactive reading experience for individuals with dyslexia by leveraging eye-tracking technology and AI content generation. In the following sections, both Research through Design and Iterative testing methods would be used as main design methods. By prototyping and iterative optimization based on participant feedback, I aim to achieve a comprehensive and user-centric design for interactive reading experiences.



7 Iterative Testing

Iterative testing involves making incremental changes to a product or business process based on diverse insights, ranging from testing results to overall user feedback. These changes are evaluated against predefined metrics, making iterative testing a common practice in user experience and interface design for software and applications. The iterative testing method is mostly used in the stage of experience design and prototyping.

At this stage of my project, I have established a preliminary design definition and gained a general understanding of the technology and the actions between potential design elements. The design goal is to create an interactive interface to assist dyslexic reading, which could be a webpage platform that leverages eye-tracking technology for reading assistance. However, the exact final implementation remains uncertain, and the method of combining digital reading with eye-tracking technology is disappointingly conventional, adhering too similar to existing designs. Therefore, the iterative design process to gain opinions close to real scenarios is crucial for pointing out an optimal design direction and differentiating this project from existing products.

The iterative design process for this project involves several key steps, each contributing to the overall design and functionality of the platform. These steps include: functional test (the reading page), functional test (the framing), expert interviews, and technical focus groups. By incorporating these steps into the iterative testing process, I aim to continuously refine the design based on real-time feedback and insights. This approach fosters a flexible and responsive design process, ultimately leading to a more user-friendly and effective reading assistance platform.

In this chapter, I will provide a detailed overview of the iterative design process. The final design specifics will be further elaborated in Section 7.3 Prototype.

Functional Test 1: Reading Page

Interactive interface



Functional Test 2: Framing

Platform design



Expert Interview

System feasibility



Technical Focus Group

Technical feasibility

Functional Test 1

At this step, a basic interactive prototype was built, allowing users to control the cursor and activate interactions by eye gaze. The purpose of the first round of test was to **explore user preferences for potential interaction methods of the reading page** derived from literature and user research, and to evaluate the value and benefits these methods provide based on user feedback.

To achieve this, two different versions of the reading page interface were developed with Processing and HTML, each featuring contrasting interaction styles. These versions aimed to simulate the authentic experience of web browsing.



Identify the Interaction

Functional Test 2

In this round, I conducted a second test of the updated reading page, collected opinions on the workflow, and **verified the feasibility of the system wireframes**. This complemented the first round of reading page interface design testing. Participants were asked to experience the reading page again and share their feelings. Additionally, I explained the workflow logic of the platform to them using diagram demos.

After this round, the interaction details of the reading interface began to take shape, and the web architecture was presented in the form of wireframes.



Verify the Wireframes

Expert Interview

Before the third round of iterative test, the fundamental design of the platform had already been established. But the opinions came only from the user's side. Therefore, seeking external authoritative feedback became particularly valuable for determining the future direction.

In this expert interview, I particularly wanted to **gain specialists' opinions and suggestions especially on how the stakeholders interact at the organizational level**, to make my system design more complete and trustworthy. Additionally, experts provided sharp opinions on the system's trustworthiness based on their experience.



Clarify the Structure

Technical Focus Group

After the initial development of the prototype, a technical focus group was conducted. A distinctive aspect of this session was the inclusion of two researchers with master's degrees in computer AI and linguistics, in addition to general participants.

The objective of this focus group was to gather feedback on the prototype's performance from both individuals with and without dyslexia and to **gain insights into the technical feasibility and potential improvements from a professional perspective**. This was the first time conducting a group test, so more diverse information was obtained.



Validate the Technology

7.1 Functional Test: Reading Page

7.1.1 Preparation

Questions

During this round of testing, we aim to address the following questions:

1. What are the users' likes and dislikes about the web reader?
2. How do users perceive the interest, richness, and dynamic aspects of the visual & interaction style?
3. Which format of the digital reading ruler is most preferred as a reading position reminder?
4. Are the adjustable formatting and font features attractive to users?
5. What are the users' expectations for features triggered by eye movement during the reading process?
6. What feedback and suggestions do users have after initially trying the first version of the reading page prototype?

Materials

Two versions of the reading page were prepared for the functional test. I attempted to emulate GARY's visual logic by converting eye gaze into coordinates that highlight the word being read. This feature includes the added value of changing background color, text color, highlight color, and focus color, thus representing the concept of a "customizable layout." Especially, to explore different interaction forms, two distinct approaches were developed. One approach used a simple rectangular highlight to mark the word being read, while the other created an engaging bubble effect through visual interaction. Additionally, images of four different forms of an electronic reading ruler were prepared to explore potential future directions. These included a gray bar, a light box, a shade, and an underline.

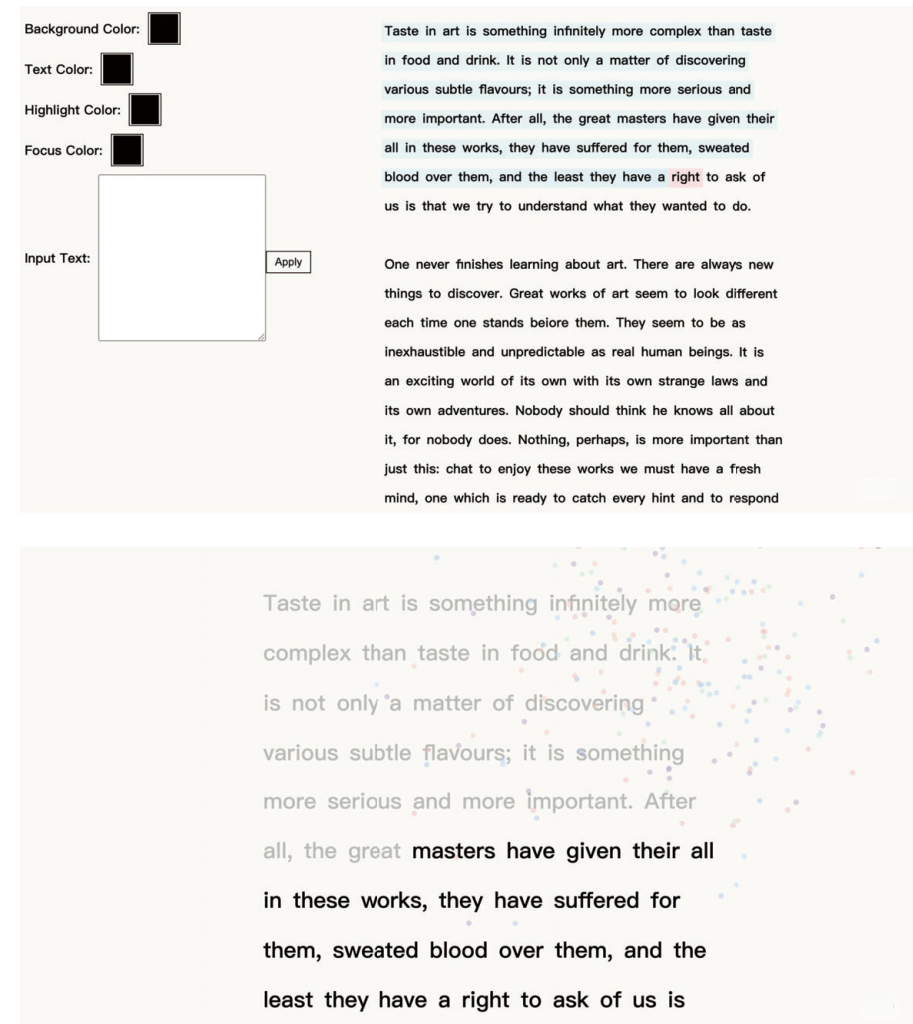


Figure 13: Two styles of the Reading Page of functional test 1. The upper version is with words turning highlighted; The lower version's words faded with bubble animation.

Equipment

A PC laptop and the Tobii Eye Tracker 5 were used for the test setup. The prototype was rendered as an HTML page in a web browser, ensuring that participants could interact with the reading interface in a realistic and familiar environment.



Figure 14: Tobii Eye Tracker 5

Procedure

The test was divided into three parts. First, participants were given a brief description of the project to provide context and explain the objectives of the reading interface. Next, they engaged in a guided tryout of the reading page, allowing them to become familiar with the features and interaction methods. Finally, an interview was conducted using questions above to gather their feedback and insights.

Participants

The test was conducted in person with three participants. Among them, two were dyslexic and one was non-dyslexic, providing a range of perspectives to ensure comprehensive feedback.

7.1.2 Excerpts

Needs and Pain Points:

- Preference for Digital Reading Ruler: Both Participant 1 and Participant 2 prefer **the shade style for the digital reading ruler** and find **adjustable formatting** necessary.
- Interface Simplicity: Participant 1 seeks **a simple and clear interface**, especially for serious texts.
- Distractive Interactions: Both Participant 1 and Participant 2 **dislike interactions that are distractive**. Participant 2 cannot tolerate dynamic effects unless they are exceptionally useful or aesthetically pleasing.
- Challenges in Navigation: Participant 1 faces challenges when trying to look back and find specific information in the text.
- Relevance of Interactions: Participant 3 finds it beneficial when **interactions promote reading** and are directly related to the text content, helping to sort out the outline and visualize key points.

Suggestions and Insights:

- Markable Content: Participant 1 suggests incorporating features that allow **marking or highlighting content** for easier reference. And Participant 3 also suggested that visual aids that highlight key content can significantly enhance comprehension and retention.
- Customization: Emphasizing the need for **customizable functions**, Participant 1 highlights changing background color, text color, highlight color, and focus color as necessary.
- Interactive Animations: While **interactive animations can enhance engagement**, Participant 1 notes that they should not be too distracting. Animations unrelated to the content might negatively impact the reading experience.
- Non-Linear + AI: Participant 2 suggests that incorporating **non-linear navigation and AI assistance** could enhance the reading experience, making it more intuitive and supportive.
- Visual Presentations: Participant 3 recommends that serious texts and entertainment texts should have distinct visual presentations. Entertainment texts could benefit from a more lively and engaging interface.

7.1.3 Insights

In analyzing the results of user tests and interviews, there are several key insights.

Participants emphasized the need for a simple and clear interface, particularly for serious texts. They need to find a balance between reducing cognitive load and maintaining user engagement. **The personalized and adjustable interface was well received.** The feedback revealed that while dynamic animations can enhance interest, they must be carefully designed to avoid causing distractions. One of the dyslexic participants emphasized that unrelated animations can negatively impact the reading experience, reinforcing the need for interactions that are directly related to the text content.

One of the core features identified through user feedback is the digital reading ruler, which uses a text fading effect to help users maintain focus on the current line of text. All respondents stated that they liked the effect of the shade style as a reading ruler. This tool addresses common pain points such as difficulty in reminding the reading position, which are prevalent among users with reading disabilities.

Another critical insight from the interviews is the potential for AI integration to enhance the understanding and the reading speed. Participants suggested that non-linear navigation, combined with AI-generated content for reading notes and hints, could provide personalized assistance and support, making the interface more helpful and intuitive.

In addition to content generation, AI has more possibilities combining with eye-tracking technology. One particularly intriguing insight is that all participants emphasized the importance of content understanding and summary. In their daily reading activities, they often rely on both AI and non-AI tools to achieve a structured understanding of the text. However, the introduction of an additional tool requires an extra user action, which can be distracting, especially for individuals with dyslexia. **Reflecting on telling the difference between the previous products, it became clear that integrating eye-tracking data as an AI-generable input could**

streamline this process. See section 3.2.4 Eye Gaze Data Processing for the theoretical basis in this regard. The competitive analysis reveals that existing products primarily focus on altering visual displays and adjusting tool parameters. However, they fall short in providing real-time feedback based on individual reading performance and do not adequately consider the specific needs of users with reading disabilities. This gap highlights the unique value proposition of our platform, which leverages eye-tracking technology not only as a visual aid but also as an input mechanism to record dynamic reading reactions and visualize them. By doing so, the platform can offer adaptive features that respond to the user's real-time needs, such as highlighting the current reading position and providing AI-generated summaries and insights.

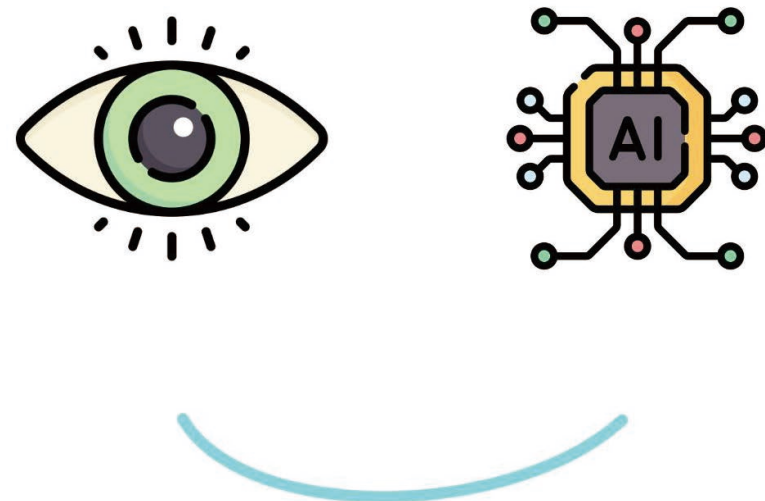


Figure 15: Combine eye-tracking with AI

7.2 Functional Test: Framing

7.2.1 Preparation

Questions

I aimed to collect feedback based on these questions:

1. How satisfied are you with the updated visual and interactive interface of the reading page?
2. After the introduction, is the mapping between reading data and the reading pattern clear enough?
3. In your opinion, what is the most convenient way to trigger features like AI hints, explanations, and summaries? For example, would you prefer extra buttons, long stare/blink, or automatic triggers based on reading behavior?
4. Do you find the overall workflow of the platform smooth? If not, which part do you find the most challenging or confusing?
5. Are there any features of the platform that you consider unnecessary or redundant?
6. What additional features would you like to see included in the system? Please provide specific examples.

Materials

After the first round of functional testing, a preliminary understanding of the target user's requirements for the reading page was established. To iterate upon these findings, I developed the page with a more useful format adjustment toolbar, implemented the shade style for the digital reading ruler, and integrated a background program to collect reading data. Additionally, I included a live reading pattern feature that maps the user's real-time reading data. A comprehensive set of platform wireframes was also designed, including the home page, the reading page, the personal profile, and the digital library.

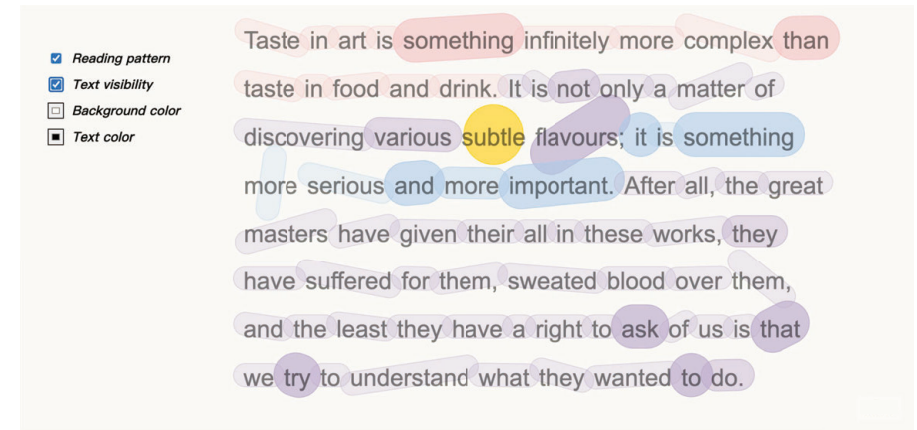


Figure 16: The reading page of functional test 2

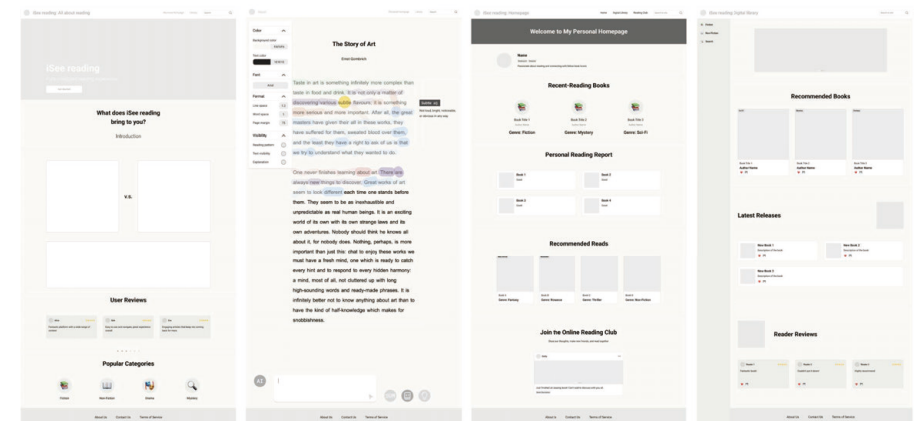


Figure 17: Website platform framework

Equipment

The equipment used for this test was the same as in the first round: a PC laptop and the Tobii Eye Tracker 5. The reading page was rendered as a functional interactive interface using HTML in the browser to ensure usability, while the web framework was created with Figma.

Procedure

The test procedure began with a brief introduction to the project, followed by sequential guidance for participants to try both the functional prototype of the reading page interface and the wireframe prototype of the entire platform. The system workflow was presented to participants as supplementary material. The test also concluded with an interview and feedback step.

Participants

In this round of functional testing, four participants were involved. Two of them, identified as Participant 3 and Participant 4 (with Participant 3 also having participated in the first round), reported symptoms of dyslexia. The other two participants, identified as Participant 5 and Participant 6, did not have dyslexia and served as general participants.

7.2.2 Excerpts

User Preferences and Needs:

- Visual Elements Connection: Participant 5 believed that **visual elements should have clear connections with reading data**.
- Selection Functions: Participant 6 desired **a translation function** and **a pop-up window to easily select from different functions** if the user give out a signal of visual fixation.
- Motivational Feedback: Participant 3 prefers **motivational feedback upon completion of reading**, such as motion effects. Reading reports and personal profiles are seen as encouraging.
- Different Feature Preferences: Participants 1 and 5 **value the digital library and co-reading features**, though Participant 3 found it not innovative enough. Participant 6 appreciated the format setting feature as it prepares the reader and allows different layout preferences for different articles but **disliked the co-reading feature** due to privacy concerns and the potential feeling of being monitored.

Confusions and Concerns:

- Highlight and Interaction Preferences: Participant 3 noted that **different users have varying preferences for highlights and interactive actions**, which could lead to error feedback. To address this, both **pre-setting and manual choices** are acceptable.
- Reading Parameters: Participant 5 was uncertain about the significance of parameters like reading speed and confused about which information would be provided in the report.
- Sensitive Content and Copyright: Participant 6 raised concerns about the suitability of **importing sensitive content and potential copyright issues**.
- Device Requirements: Participant 4 questioned whether users need to **purchase hardware devices** themselves to use the platform, highlighting a potential barrier to entry.

Suggestions for Improvement:

- Manual vs. Pre-setting Actions: Participant 3 **prefers manual actions during reading if there are not many functions**; otherwise, **an extra pre-setting before each reading session** is better. Participant 6 also suggested enabling or disabling automatic **pop-up prompts** in advance to avoid disrupting the reading flow.
- Machine Learning Component: Participant 5 suggested introducing **a machine learning component** where users can tag points of confusion, interest, or fatigue to help the system learn their reading preferences and patterns.
- Simplifying Text: Participant 5 recommended **automatic replacement** of unknown words with simpler synonyms and breaking complex sentences into simpler ones.
- AI Capabilities: Participant 4 highlighted the need for **AI capabilities for sentence explanation, simplifying complex expressions, difficult grammar, and translation**. Prefers these features to be activated with a single click or through a function bar with two clicks.
- Large Digital Library: Participant 4 expressed the need for **a large digital library** to access more books and articles.

7.2.3 Insights

After conducting two iterative tests, plenty of suggestions for improvement emerged, guiding the refinement of the system. I classified the insights into three big aspects and three small aspects: interaction, AI functions, emotional encouragement, copyright and privacy, hardware, and social extension.

Regarding interactions, the primary controversy is the correspondence between user input and the activation of functions, and how these functions should be activated when the correspondence is complex or unclear. The most frequently mentioned issue by participants is that slow reading and repeated reading might represent different situations: the reader might be confused, interested, or even tired. However, these psychological

fluctuations might appear the same to the system in the form of reading data. In this case, adding a real-time quick selection button for users to provide immediate feedback could be beneficial. Subsequently, introducing machine learning capabilities into the system to learn the user's habits and preferences would allow the system to make the most accurate judgments autonomously in the future. For the diverse AI-assisted functions, some participants expressed a desire to see translations and explanations in real-time. However, more participants reported that they do not want the smooth reading process to be interrupted. To address this, everyone agreed that adding a setting option before reading to decide whether to display real-time AI assistance would be beneficial. Additionally, users should have the option to activate certain features at any time during the reading process. It is evident that interaction feedback needs to precisely address user needs. A mismatch between user needs and machine responses can be disastrous for an interactive system. Therefore, it is necessary to conduct more tests on the interactive interface and interaction paths to achieve an intuitive, user-friendly, and highly adaptive design.

Behind the interactive interface, lies a complex AI mechanism. Participants universally feedback that AI assistance is one of the irreplaceable functions in this platform system, but the current AI feature list remains vague. In addition to the AI functionalities mentioned in the initial design, including real-time state reminders, personalized summaries based on reading data, and reading reports, participants also suggested features like translation and explanations, replacing uncommon words, breaking down long and complex sentences, and an excerpt function. Easy accessibility of AI functions is another priority. AI reminders, summaries, explanations, and replacement functions are features that can be updated in real-time during the reading process. Users can set whether to display these function modules before starting to read or simply activate them with a one-click action during reading. This ensures that users can quickly and effectively use these powerful tools without disrupting the smoothness of their reading experience. The excerpt and summary functions will be displayed at the end of the reading process. These contents can also be accessed later through the Personal Profile. Machine learning is another excellent insight from the participants. In the early stages of using this platform, pop-up windows will prompt users to select the needs corresponding to their

reading status. Later on, the system will be able to intelligently recognize their intentions.

Half of the participants mentioned that the reading platform could provide emotional encouragement. These views were particularly expressed by female participants. One highly praised the pre-reading format settings, stating that it not only offers a personalized interface design but also helps set a reading style that matches the content, thus fostering a positive and pleasant reading mindset. Another participant suggested a reading summary and motivation mechanism at the end of a reading process, such as displaying animations of coins falling into a treasure chest to visualize the amount of reading. She also mentioned that the reading report serves more as an emotional incentive than a practical report, as it helps note down how much content she has read and the reading quality. For users with dyslexia, positive psychological cues and encouragement will obviously motivate them to continue reading. Based on these, it is evident that emotional design plays an important role in this platform.

Copyright and privacy is about information security issues. Copyright will be the most sensitive and concerning issue for the digital library resource providers, and individual uploaders will also be worried about whether the text information they upload might be stolen. Additionally, the visibility of personal information on an open platform is closely related to user experience.

Hardware considerations must be addressed clearly. It's important to communicate hardware requirements effectively and explore integration options that minimize the need for users to purchase additional devices. Integrating eye-tracking capabilities into existing devices, similar to the technology used in Apple ID, could be a beneficial solution.

The digital library and co-reading functions are what I refer to as social extension. The strategic design aims to build a platform interconnected with various social resources and networks. Maintaining such a platform requires the full integration of these social resources. That's why these features are positioned in a long-term future vision. Participants had differing opinions on the co-reading function, which leads to careful further consideration.

In conclusion, this testing section takes a deep look at the entire platform system. The insights gain focus on the rationality of the working logic and the fluency of interactions. Throughout the testing process, technology and interaction frequently emerge as mutually reinforcing elements. Technologies such as machine learning offer solutions to the challenges of interaction design, while the hierarchical nature of interaction design enhances the accessibility of these technologies. Additionally, emotional design softens and enhances the platform's touchpoints, making them more perceptible and user-friendly. However, two aspects have yet to be proven: the feasibility verification at both the system and technical levels.

7.3 Expert Interview

7.3.1 Preparation

Interviewees

The expert interviewees two specialists in digital reading based at a research institution in the Netherlands. Expert 1 has expertise in the technology behind e-books and audiobooks and extensive experience managing relationships between libraries and publishers. Expert 2 specializes in accessibility and adapted reading, focusing on making reading materials accessible to individuals with reading disabilities. They provided valuable insights into the practical applications and challenges of the system design during the interview.

Procedure

At the request of the interviewees, this interview was conducted as an online meeting. To maintain a humble approach and obtain the most unbiased expert opinions, no predefined outline was set for the interview. The entire session consisted of a 20-minute project introduction and prototype showcase, followed by a 20-minute discussion.

Materials

At this stage, the functional prototype and system structure were roughly established, and the iteration following the second round of test was completed. However, all previous insights came from the users' perspective. Therefore, the test-iterated design materials were prepared for this expert interview, with the aim of gaining professional insights based on the existing design.

7.3.2 Excerpts

The initial discussion centered around the differences in individual preferences and ideas when it comes to using reading technologies. Currently, a play button is the primary interaction tool. E1 agreed that the implementation of eye-tracking offers a more customized and innovative way of reading; **while E2 reminded that the science endorsements behind eye-tracking should be found**, as it's a credible method for enhancing the reading experience.

One of the significant advantages of incorporating AI-generated reading reports was highlighted. I discussed that these reports not only aid in better understanding and recalling the content but also provide emotional encouragement to readers. **E1 saw great potential in integrating these capabilities into general-purpose applications such as online library platform**, but it also raises questions about **the hardware requirements**. The eye-tracker I used in this project is Tobii Eye Tracker 5, currently costing around 250 euros, which is almost the cheapest eye-tracker customers could find in the market and it's not very unaffordable. There is potential for future technical integration directly into PC cameras, similar to how Apple ID functions today.

Regarding the implementation of AI technology, they thought that **the publishing industry would be worried about AI and cloud services**. Publishers and authors are apprehensive about generative AI potentially misusing their content and mistakenly abusing their works into AI generation. To address these concerns, it was clarified that the AI in this context would only process personal reading data without adapting the actual content. A detailed declaration of privacy would be necessary to assure users and stakeholders of their data's security.

The discussion also touched upon **the potential benefits for visually impaired individuals**. For those with low vision, such as people who cannot see sharply in the middle, eye-tracking technology could still be beneficial. Combining eye-tracking with Text-to-Speech (TTS) could enhance the reading experience for blind and low-vision users by allowing them to utilize their remaining vision more effectively. This integration could

serve large group of people who struggle with traditional reading methods.

Moreover, the conversation explored **the cross-functional potential with virtual reality**. Integrating eye-tracking with VR could create immersive reading environments that make reading easier and more engaging. This approach could offer a tactile experience, where users interact with the text in a more dynamic and enjoyable manner, rather than just reading passively.

The interview with experts helped clarify the direction for the further iteration of the system design and provided insights for potential future developments.

7.3.3 Insights

The expert interview provided a wealth of systematic insights, particularly in the vertical direction. Firstly, as a socialized service system, acquiring more book resources is crucial for building a sustainable user base and operational community. However, as Expert 1 mentioned, the publishing industry is concerned about data privacy issues related to AI and cloud services. To address this, it is essential to study and implement transparent information security measures and corresponding technologies. Another point of discussion was the use of split eye-trackers, which increase hardware costs. To enhance the ease of promotion and accessibility, it would be beneficial to explore the use of built-in cameras on personal devices for eye-tracking from a technical standpoint.

From the perspective of universal design, experts offered some innovative suggestions. For individuals with visual impairments, eye trackers and AI-assisted reading can significantly reduce their reading burdens. In the future, this project could integrate Text-to-Speech (TTS) technology and other advanced features to create additional reading value for a broader audience. This would not only enhance accessibility but also expand the platform's usability across diverse user groups. Considering long-term development, integrating eye-tracking with VR could also empower the project due to its multi-sensory and immersive characteristics. This integration might offer enhanced reading experiences and open new avenues for user engagement and accessibility in the future.

7.4 Technical Focus Group

7.4.1 Preparation

Participants

In this focus group, 6 participants were invited. In order to tell the difference between the former participants in functional tests, we can name them as Participant A to F. They are all master graduates. Participant A and Participant B reported symptoms of dyslexia. Participants C to F are individuals with normal reading ability. Among them, Participant E is a PhD student majoring in Computer Science and Artificial Intelligence, while Participant F is a master graduate who studied linguistics. Prior to the focus group, Participant E and F were expected to provide professional insights in the process. (they did!)

Procedure

Since the primary goal of this focus group was to verify the feasibility of the workflow and to gather insights from different perspectives, conducting on-site testing experiments was not essential. Given that some of the participants were unable to gather in person, this focus group was conducted in the form of an online meeting. This focus was assumed as a semi-structured format. The whole process is divided into 6 steps: project introduction, prototype display, discussion of problems from user perspective, technical feasibility, suggestions, and conclusions. The duration is 1 hour. In order to have a better organization, and avoid missing key information, a question checklist is prepared, which includes 3 parts: discussion on interaction elements, rank the importance of basic functions, and technological improvement.

Questions

Discussion on Interaction Elements

- Is the interface and navigation intuitive?
- How do the reading assistance features compare to your usual reading experience?
- Did the prototype meet your expectations for a reading assistance platform?
- What improvements would you suggest for the prototype? What additional features would you like to see?
- How likely are you to use this platform regularly?
- How likely are you to recommend this platform to others?

Rank the Importance of Basic Functions

- Please rate the six main functions (customizable interface, real-time eye-tracking, AI assistant, personal profile records, online co-reading, library) on a scale from 1 to 10.
- Which features stand out the most?
- Which features are confusing or unnecessary?

Technological Improvement

- Are there any parts of the design that do not make technical sense?
- What are your thoughts on the integration of AI in the prototype?
- Which AI features are easy to implement? Which AI features present significant technical challenges?
- How scalable is the platform's architecture for handling large user bases?
- What additional AI capabilities could further enhance the platform?
- Do you know of any literature or projects focused on real-time reading monitoring that I could reference?
- What are the security implications of AI, cloud libraries, and the processing of book and document data?

Materials

This phase took place immediately after the expert interview. It to some extent has a similar significance to the expert interview, which is to look at the feasibility of the project from a different perspective. Therefore, the test-iterated design materials were prepared for this focus group, which was going to gain comprehensive feedbacks.

7.4.2 Excerpts

Interface and Navigation

- AI prompts are suggested to help users avoid skipping lines or missing content.
- Features like word explanations should not only provide definitions but also contextual information to aid memory retention.
- The platform should indicate the first appearance of chapters or sections to help users locate information.
- Voice assistance features would be beneficial.
- Participant F pointed out that **the system could generate scientific recommendations for reading time and break frequency** based on the user's reading state. **AI could summarize reading habits and offer suggestions**, such as skipping difficult words or providing reading tips.
- **A preliminary test to understand a user's reading habits and preferences** could be added at the beginning.
- There is a suggestion to make the platform a plugin for PDF readers to increase practicality.

Function Evaluation

- During the discussion of give rates to features, the **customizable interface** and **real-time eye-tracking** received the highest scores (10 out of 10). Participants felt these functions were essential for enhancing the reading experience by allowing for personal adjustments and providing seamless interaction.
- The **AI assistant** and **personal profile records** both scored 8 out of 10. Participants appreciated the AI assistant for its potential to provide real-time support and summaries, while personal profile records were valued for tracking reading progress and habits.
- The **digital library** scored 7 out of 10, indicating that while it is important, it is not as critical as the core interaction and support features.
- The **online co-reading** feature received the lowest score (5 out of 10). Participants viewed it as less innovative and potentially distracting, suggesting it may not be necessary.

Technological Improvement

- The integration of AI and eye-tracking presents significant technical challenges.
- The need for a separate eye-tracker could be cumbersome. **Integrating eye-tracking capabilities with mobile or computer built-in cameras could simplify usage.**
- **Listing specific items that reports should include is crucial**, letting AI handle the generation process, suggested by Participant E.
- Participant E also mentioned that, using a GPT interface poses risks of information leakage within the company's system. **Building a proprietary large language model** can mitigate privacy issues. Offline models are essential to avoid problems associated with online models.
- It is important to **assure stakeholders that the company will not excessively manipulate or distribute their data**, using edge inference for privacy.

7.4.3 Insights

The participant composition of this focus group was complex, including not only potential users but also researchers with backgrounds in AI and linguistics. This activity functioned both as a test and a co-creation workshop. As a result, the conclusions drawn have dual feasibility in terms of interaction design and technology.

The interaction-based insights emphasized the importance of further personalization, which covers aspects of the entire user experience. When a user first tries the platform, a preliminary test could be introduced to encourage an initial machine learning test by having users select their preferences. This would enable the system to automatically recommend a combination of custom features tailored to the user's habits. During reading, the platform could help users associate similar and related content in the background, aiding memory and recall. AI could generate scientific recommendations for reading time and break frequency based on the user's reading state. Additionally, after reading or in the reading report, the platform could provide personalized suggestions based on the user's reading habits.

Moreover, the focus group extensively discussed system architecture and privacy issues. Using external AI interfaces poses risks of leaking user information and book resources. Therefore, researchers suggested developing a proprietary large language model that operates offline on the user's device. It is also important to inform users about these privacy operations, to include a user consent step before utilizing personal information.

7.5 Key Takeaway

The around-one-month iterative design process was divided into four stages: The first two rounds focused on functional testing of the reading page and the platform system. Subsequent stages included an expert interview and a technical focus group, which analyzed system feasibility and technical viability. This iterative design process was expanded and refined in both breadth and depth. In terms of breadth, the design evolved from the core functionality of the reading page to a more comprehensive socialized system design, laying the groundwork for the coming section, 7.1 Strategic Roadmap. In terms of depth, each iteration involved in-depth discussions with potential users and researchers, garnering insights from various perspectives. This process not only helped to refine the functional details but also partially validated the feasibility of the design. The following first diagram summarizes this process of design scope expansion and deepening.

All the excerpts (participants' side) and insights (mainly from the author's side) from the four rounds of tests played a remarkable role in refining the functions of the system. Prior to this iterative testing phase, the design definition had already established three key elements: eye-tracking, interaction design, and intelligent assistance. The ideas and comments collected from the tests and interviews provided broad perspectives on how design could enhance reading. In each subsequent round, participants were asked for their perspectives on the previous iteration and their specific needs regarding interactive features. Thus, most features presented in final design are traceable. This process enriched the design features, detailing abstract concepts into actionable design elements. The coming second diagram is a Sankey diagram, illustrating the transformation from the initial design definition to concrete design elements over the course of the iterative tests. This diagram is firmly linked to the system design and interaction design, which will be discussed in detail in sections 7.2 and 7.3.

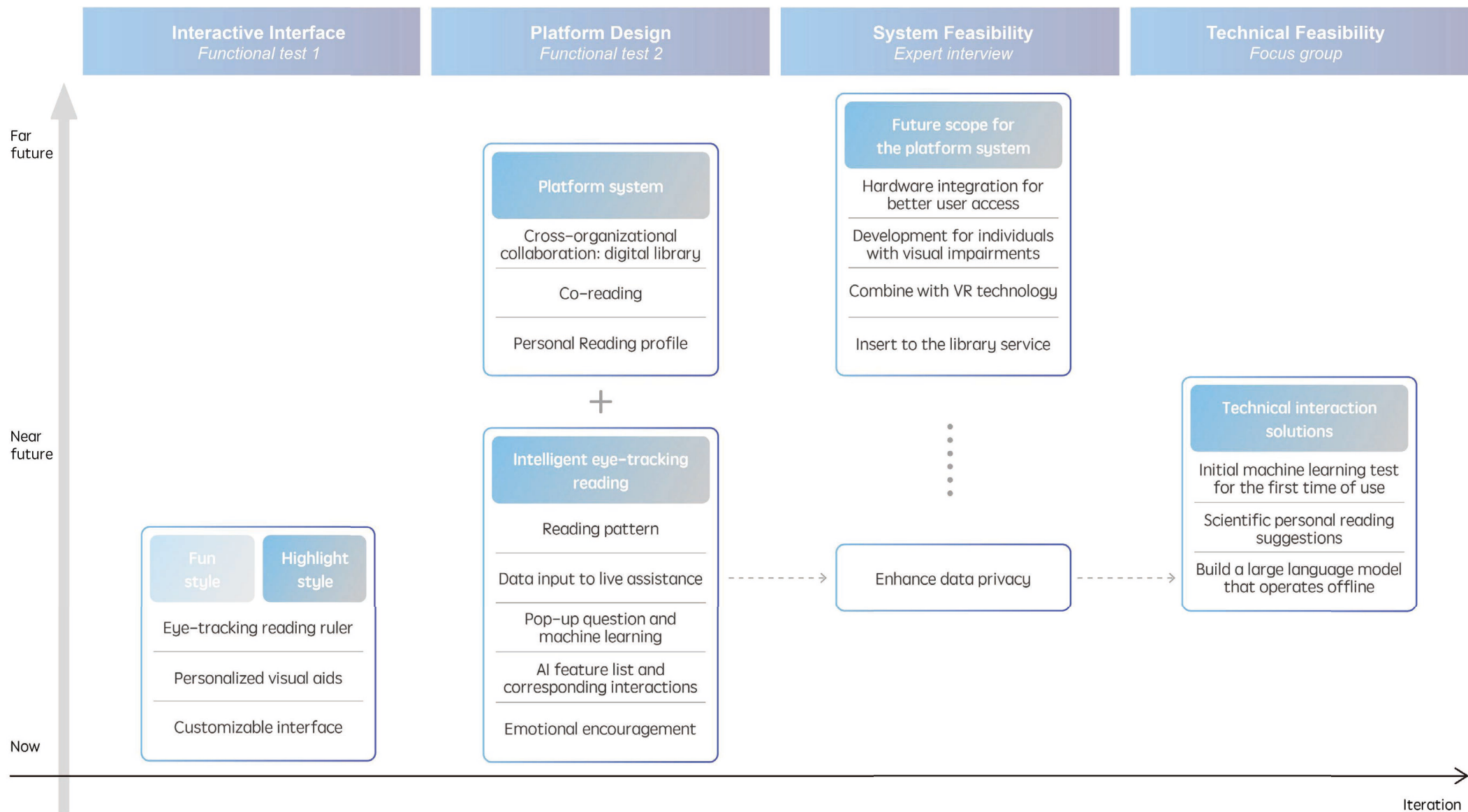


Figure 18: Relationship diagram about the scope of the tests

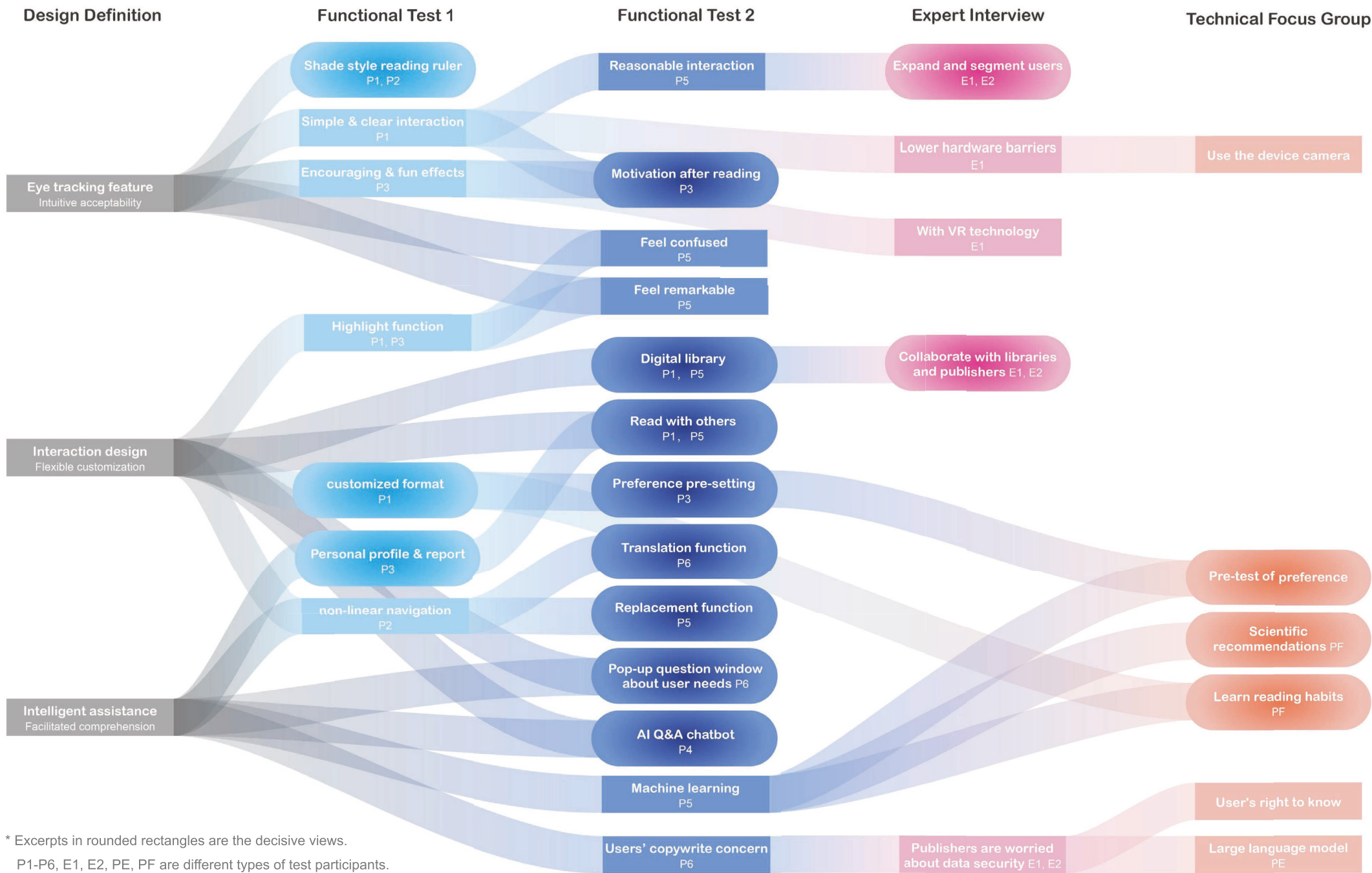


Figure 19: From tests to inspiration

8 Strategic Experience Design

8.1 Strategic Roadmap

Previously discussed as the “How Might We?” part, the core question now is, “How might we simplify the interaction while ensuring a diverse range of customizable features to create a natural reading experience?” Additionally, it is essential to ensure Intuitive Acceptability, Facilitated Comprehension, and Flexible Customization. Answering this question involves taking numerous future steps to ensure a seamless and engaging reading platform for all users. Before diving into detailed design, it is necessary to establish an overall, visible, and achievable roadmap. This roadmap is significant for several reasons. First, it provides a clear vision and strategic direction, ensuring that every development phase aligns with our ultimate goals. Second, it helps identify potential challenges early on and allows for efficient resource allocation. Lastly, it creates a coherent structure that guides the project from concept to implementation, making the entire process more manageable and focused. The envisioned interaction system is an online platform that offers universal reading assistance for all visual reading groups, particularly individuals with dyslexia. It also aims to engage various stakeholders, including educators, technology experts, and content creators, to organize resources and gain technological support. This collaborative approach ensures the platform is robust and comprehensive.

In this section, I will first introduce a bright future vision as a guiding principle, setting the stage for what we aim to achieve. Following this, the second step will detail how the digital platform will grow and evolve through the Three Horizons framework, gradually becoming more established and well-equipped to meet user needs. A key component of the roadmap is the Stakeholders Ecosystem Map, which will introduce different stakeholders and illustrate the flow of materials, information, and currencies, all contributing to a holistic system map.

8.1.1 Future Vision

The platform is defined as an experience enhancement design, which is a product service system. This system provides seamless and friendly interaction with users while running a complex service system in the background. All elements within the system work towards a series of common visions. The first and foremost principle is user-centric design. This means aligning user needs with our design objectives. From the user analysis conducted earlier, we identified several key requirements: a friendly and adjustable interface, agile real-time reading assistance, intelligent reading comprehension and summarization, and an emotional value and incentive mechanism.

To address these needs, the following future vision has been articulated:

Create an inclusive, intuitive, and intelligent digital reading environment that empowers all visual readers, especially those with dyslexia, to read effortlessly with greater comprehension and motivation.

This vision encompasses several aspects shown in the next page. By adhering to these principles, the platform aims to transform the digital reading experience for all visual readers, particularly those with dyslexia. The goal is to create a supportive and empowering environment that not only meets but exceeds user expectations, making reading more accessible, enjoyable, and effective.

This future vision guides all subsequent development stages, ensuring that each step taken aligns with our overarching objective of enhancing the reading experience for a diverse user base.

Inclusive Accessibility

Design the platform to be easily accessible to all users, regardless of their technical proficiency. This includes providing interfaces that can be customized to individual preferences, allowing users to adjust layout and typography to suit their reading needs.

Seamless Interaction

Ensure that the platform offers a smooth and intuitive user experience. By incorporating eye-tracking technology, the platform can display real-time reading progress, making the interaction feel natural and minimizing any friction that users might encounter.

Intelligent Assistance

Implement advanced features such as AI-assisted tools that intelligently record and analyze reading data. These tools provide personalized recommendations to enhance comprehension and retention, summarizing key points and offering insights tailored to the user's reading patterns.

Emotional Engagement

Foster an environment that motivates and emotionally engages users. By visualizing reading progress through the formation of reading patterns, the platform can create a sense of achievement and encourage continuous improvement.

8.1.2 Three Horizons

The Three Horizons model provides an overall framework for future storytelling, which is a valuable tool for understanding the different phases of product development. This model includes three parallel scenarios at various stages of the product's life cycle. The first horizon focuses on the current and near-future business landscape, using existing marketing strategies and technologies. It ensures that the immediate needs of the business are met while maintaining stability and growth. The second horizon acts as a bridge, exploring new user value segments, adapting to emerging technology applications, and conducting iterative user tests. This phase sets the foundation for future advancements. The third horizon envisions new value propositions that drive value enhancement for both users and the business. It aims to identify and implement groundbreaking changes that can transform the market and create long-term success. These three horizons outline an ideal growth tracking and transition, forming a comprehensive strategic vision for the future.

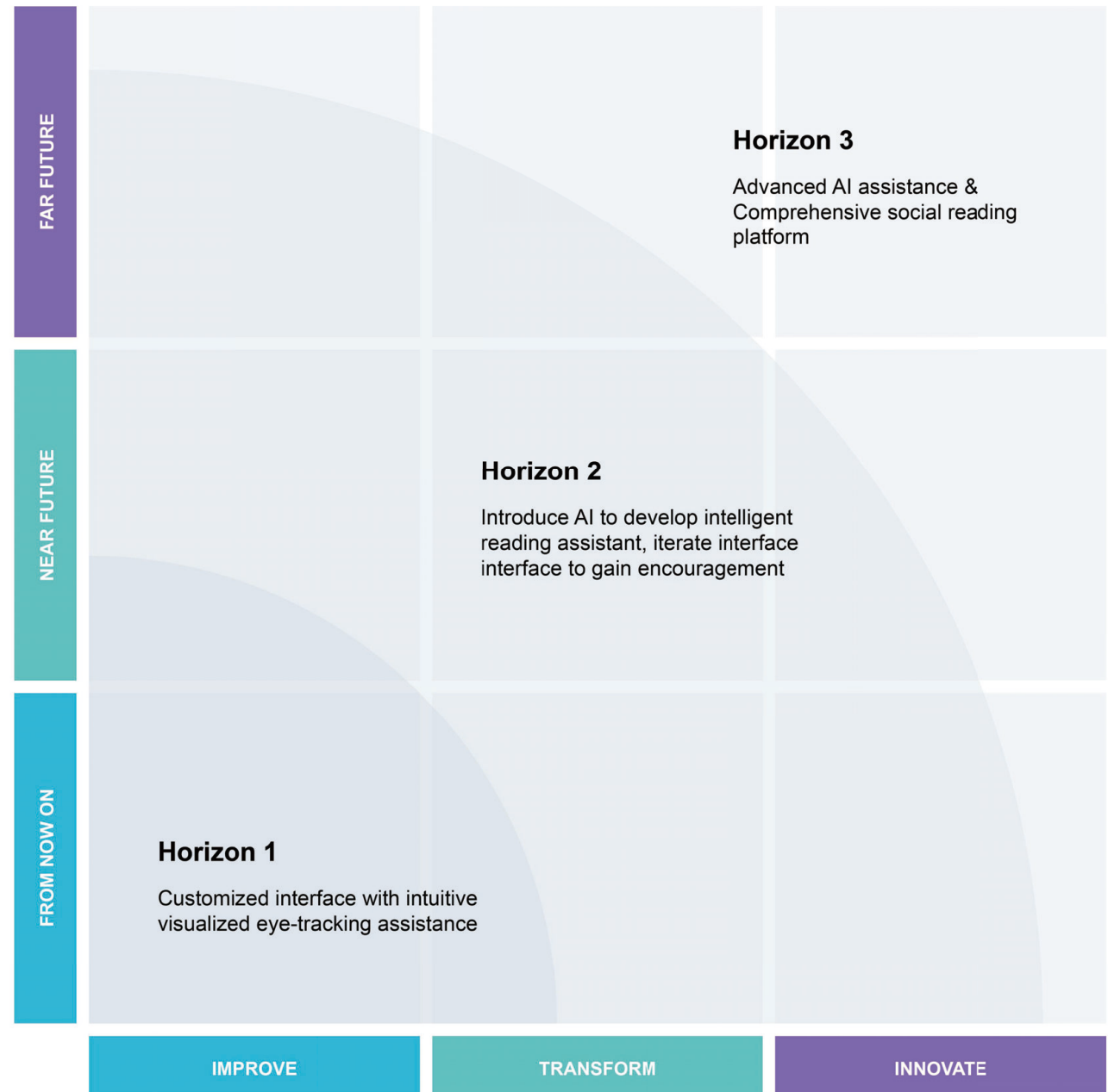


Figure 20: Three Horizons

Horizon 1: Inclusive Accessibility & Seamless Interaction

In the first horizon, eye-tracking technology is introduced as a pivotal component of the reading enhancement system. This method provides a seamless and intuitive interaction between users and the digital reader, typically a computer. Eye-tracking allows eye movements to serve as coordinate input, effectively substituting for the mouse in certain operations. This integration transforms reading and interface navigation into a single, fluid action, eliminating intermediate steps and making the interaction more direct and intuitive.

However, it is important to acknowledge that eye-tracking input has limitations in terms of precision and operational complexity, meaning it cannot fully replace the mouse. Therefore, during operations requiring precision, cursor movement will still primarily depend on the mouse. The most significant value of eye-tracking input in Horizon 1 is its ability to provide real-time reading position display, acting as a reminder for readers. This function also detects behaviors such as long staring, repeated reading, and speed changes, displaying appropriate reading assistance tags.

Alongside the eye-tracking as input, our platform features a well-designed interface that offers extensive customization options. Users can tailor the interfaces to their preferences, enhancing accessibility and usability.

Horizon 2: Intelligent Assistance & Emotional Engagement

In this stage, the customized and adjustable interface is further enhanced. Eye-tracking input evolves from merely providing real-time feedback to functioning as a comprehensive user data recorder. AI technology analyzes data such as prolonged staring, repeated reading, and speed changes, combining these insights with pre-generated summaries and textual insights to create a series of personal memos and a detailed reading report.

These memos can be displayed next to the text, serving dual purposes: offering phased summaries to aid comprehension and marking reading nodes for easier navigation during review or subsequent reading sessions. Users have the option to hide these memos if they find the interface too cluttered. The platform also introduces more visual engagement through dynamic reading patterns generated by eye-tracking input, reflecting

reading speed and frequency. This visualization acts as both a progress tracker and a motivational tool, encouraging users to continue reading.

Horizon 3: Optimization of AI Mechanisms & Multi-Platform Cooperation

The third horizon emphasizes not only further customization and intelligence but also the expansion of the platform's ecosystem. This stage involves integrating more advanced and agile external AI technologies to enhance the reading experience, making it smoother and more intuitive. The focus shifts towards transforming the platform from a simple reading tool into an integrated reading ecosystem.

To achieve this transformation, cross-industry cooperation becomes crucial. Our growing reputation enables us to collaborate with governments, libraries, and nonprofit organizations. These partners provide a wealth of books and articles, while we offer them valuable insights into user engagement and access to extensive reading data. This mutually beneficial relationship helps to broaden the platform's content and reach.

Moreover, the creation of online reading communities is planned, where users can choose to share their reading data and learn from others' experience. This aspect adds a social dimension to the platform, fostering a sense of belonging and shared progress among users. By building this ecosystem, the platform not only enhances individual reading experiences but also contributes to a network of knowledge and engagement.

At the level of universal design, multi-sensory communication and virtual reality technology have been added to the technical expansion of the platform, which will not only enrich the reading experience of the general audience, but also bring the pleasure of reading for the visually impaired and blind groups. In such an inclusive design, the eye-tracking and smart AI technology play a role that cannot be ignored.

In summary, the Three Horizons model outlines a comprehensive growth trajectory for the platform, focusing on inclusive accessibility, intelligent assistance, and extensive cooperation. Each horizon builds upon the previous one, ensuring continuous improvement and expansion of the platform's capabilities and reach.

8.2 Experience Design: System to Flow

In the previous section on the Strategic Roadmap, a comprehensive understanding of the entire design system was established. We explored the anticipated achievements outlined in the Future Vision and detailed the business plan through the 3 Horizons. These sections provided a vertical overview of the future growth and development steps along the timeline.

In this section on Experience Design, the specific design framework will be focused on. This includes how different stakeholders and functional departments interact with each other, and how users engage with the service system to gain benefits. Additionally, this section will conclude with a user flow diagram to visualize the utilization process, setting the stage for the prototype design.

8.2.1 System Map

To provide a clearer explanation of the design system, two types of system maps were created: a Service System Map and a System Structure Map. Great effort was put into finding a harmonious form and layout to show the internal connections between these two maps of the external service system and the internal system structure. If you take a careful look at the coming two diagrams, you'll notice that the gray pattern is the same for both, corresponding to five parts of the system structure: Strategic Design Management, Interaction Design, Intelligent Support, Product Operation, and the Digital Library. These five parts function as departments within the business organization (if the system run as a business organization), each with its own vision aligning with the 3 Horizons introduced before. This creates a 3D business planning structure, encompassing both a horizontal organizational structure and a vertical development over time.

Specifically, the Digital Library manages public relationships with publishers and libraries, and is responsible for information and data security. Interaction Design includes the design of customized interactive interfaces, human-machine interaction (HMI) with eye-tracking, and the

implementation of AI features. Intelligent Support handles hardware and software enhancement, AI and machine learning development, and the overall system structure. The Product Operation department researches and updates the personal reading platform and co-reading platform, to make the system more inclusive and playable.

The layout of these five parts forms a loop shape on the diagram, representing the pathway of service in the first map. From the user's perspective, the journey moves through the Digital Library, Customized Interactive Interface, Eye-Tracking Monitor, AI Reading Assistance, Personal Reading Profile, and Co-Reading Platform. This user journey in the set of maps serves as a visual guide, effectively telling the story of the system service.

Service System Map

Digital Library is a comprehensive stakeholder system envisioned in Horizon 3. Building a reading platform requires substantial resources. We collaborate with libraries, publishers, authors, and NGOs to enrich the digital library database with books and articles. This extensive database provides users with a wide range of reading materials, from classic literature to the latest research articles. Additionally, the eye-tracking system gathers valuable reading data from both dyslexic and non-dyslexic individuals. With the users' consent, we seek partnerships with research institutions to enhance our design's reliability through theoretical and technical support. These collaborations ensure that the platform remains at the forefront of technological advancements and user-centric design.

Customized Interactive Interface, which aligns with the vision of Inclusive Accessibility, is the primary and most fundamental function of the entire system. This functionality is common in various assistive reading software, as mentioned in the research section. It provides intuitive accessibility, allowing users to customize the interface to their preferences. Users can adjust the font, text size, text color, background color, and highlight colors. Additionally, features such as highlighting and memo functionality can be toggled on or off.

Eye-Tracking Monitor, which embodies the vision of Seamless Interaction, is the core highlight and informational pivot of this system. This group of functions branches into two main areas: the real-time digital reading ruler and the reading pattern. Research shows that individuals with reading difficulties often lose focus and struggle to locate their reading position. Eye-tracking technology, combined with digital reading rulers, offers a solution. The real-time tracking display provides immediate feedback, while the eye-tracking pattern serves as data input for valuable analysis. This data includes reading speed, frequency of word focus, reading order, and direction, all visualized as colorful blocks of varying colors, sizes, and directions. Prolonged stares result in bright yellow highlights. In the background, AI processes this data to generate a personalized reading record and report.

AI Reading Assistance, aligning with the vision of Intelligent Assistance, is the most powerful tool behind the interactive interface. Introduced in Horizon 2 as a near-future step, it aims to achieve several goals. First, before reading each text, the AI generates a pre-summary. In the reading interface, a button allows users to hide or show this AI-generated memo. Second, as the reading pattern is generated, the AI updates the summary according to the reader's progress, resulting in a personalized conclusion. Third, over time, the AI analyzes the reader's habits and generates a personal reading report. This feature ensures that users receive continuous support and tailored assistance based on their reading behavior.

Personal Reading Profile extends the AI-generated function by combining reading records and personal preferences. It serves as a reference for personal reading and can be shared as a social page, allowing others to access the user's reading data if permission is granted. This profile includes detailed reading statistics, favorite genres, and personalized recommendations, enhancing the user's engagement with the platform.

Co-Reading Platform envisions a social reading platform open to all readers. It creates an online community centered on reading, enabling users to share dynamic reading progress, notes, comments, and reports. Real-time reading patterns act as visual bridges between users, fostering discussions and common interests. This feature supports the vision of Emotional Engagement by encouraging users to connect with others, share insights, and form reading groups based on common interests.

System Structure Map

The System Structure Map not only delineates the organizational structure but also highlights the dynamic interactions between various business elements. At the core of this system is the **Strategic Design Management** department, which oversees system operations and business activity planning. This central department plays a pivotal role in coordinating and managing the entire system, ensuring that all business activities align with the overarching strategic goals.

The **Interaction Design** department is one of the most prominent elements. It collaborates with the Intelligent Support and Product Operation departments. Among these business actions, intuitive visual, interface and interaction design helps with user growth and retention, while real-time data on the user side helps with research for the design department. The technical support is the downstream of design. The department handles human-machine interaction by translating user needs into delightful digital experience. The integration of AI plays a significant role here, leveraging large language models to respond to ever-changing user needs.

The **Intelligent Support** department acts as the technical backbone of the system. It supports and enables the functionalities of other departments through software development and hardware integration. The design of a robust and scalable system architecture is another critical function, capable of handling extensive user bases. Furthermore, the development of AI language models ensures data security and enhances the platform's intelligence.

The **Product Operation** department is closest to the end-users, managing features like personal profiles and co-reading. Its responsibilities include data collection and analysis, gathering user data to drive research and design improvements, and community management to enhance engagement and retention.

The **Digital Library** department operates somewhat independently. Its key roles involve maintaining partnerships with external organizations like libraries and publishers to enrich the content available on the platform and organizing and maintaining a vast array of reading materials. Ensuring information privacy is another critical function, managing all user and repository information securely.

● Digital Library

The Digital Library collaborates with libraries, publishers and authors to offer diverse reading materials. With data that users have consented to use, design reliability, user-centric and advanced technology is enhanced under the guide of research institutions.

- Library access¹
- Text Import²
- Privacy authorization³



● Customized Interactive Interface

The Customized Interactive Interface is a fundamental function of the system, embodying the vision of Inclusive Accessibility. It allows users to adjust the interface to their preferences.

- Pre-test⁴
- Format Setting⁵
- Functions Hide and Show⁶
- Celebration Anime⁷



● Eye-Tracking Monitor

The eye-tracking function highlights the vision of seamless interaction. It visualizes real-time reading data and serves as input for AI analysis and feedback. After that, AI processes reading data to generate a personalized reading record and report.

- Digital Reading Ruler⁸
- Reading Pattern⁹



● Co-Reading Platform

Co-Reading Platform envisions a social reading possibility open to all readers. It provides an online community centered on reading, supporting the vision of emotional engagement by encouraging users to connect with others.

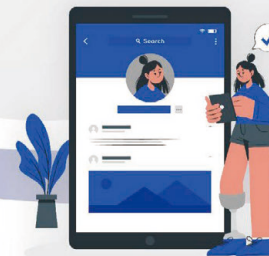
- Co-reading²⁰



● Personal Reading Profile

Personal Reading Profile serves as a reference for personal reading and can be shared as a social page, including reading statistics, favorite genres, and personalized recommendations.

- Personal Reading Profile¹⁸
- Reading reports¹⁹



● AI Reading Assistance

AI plays a crucial role of instant information processing in the system. Machine learning helps understand the immediate needs of users, while the language model provide thoughtful advice.

- Machine Learning Quick Questions¹⁰
- Live Reminder¹¹
- Text Summaries¹²
- Explanations¹³
- Translation¹⁴
- Replacement and Sentence Break¹⁵
- AI Q&A¹⁶
- Excerpts¹⁷

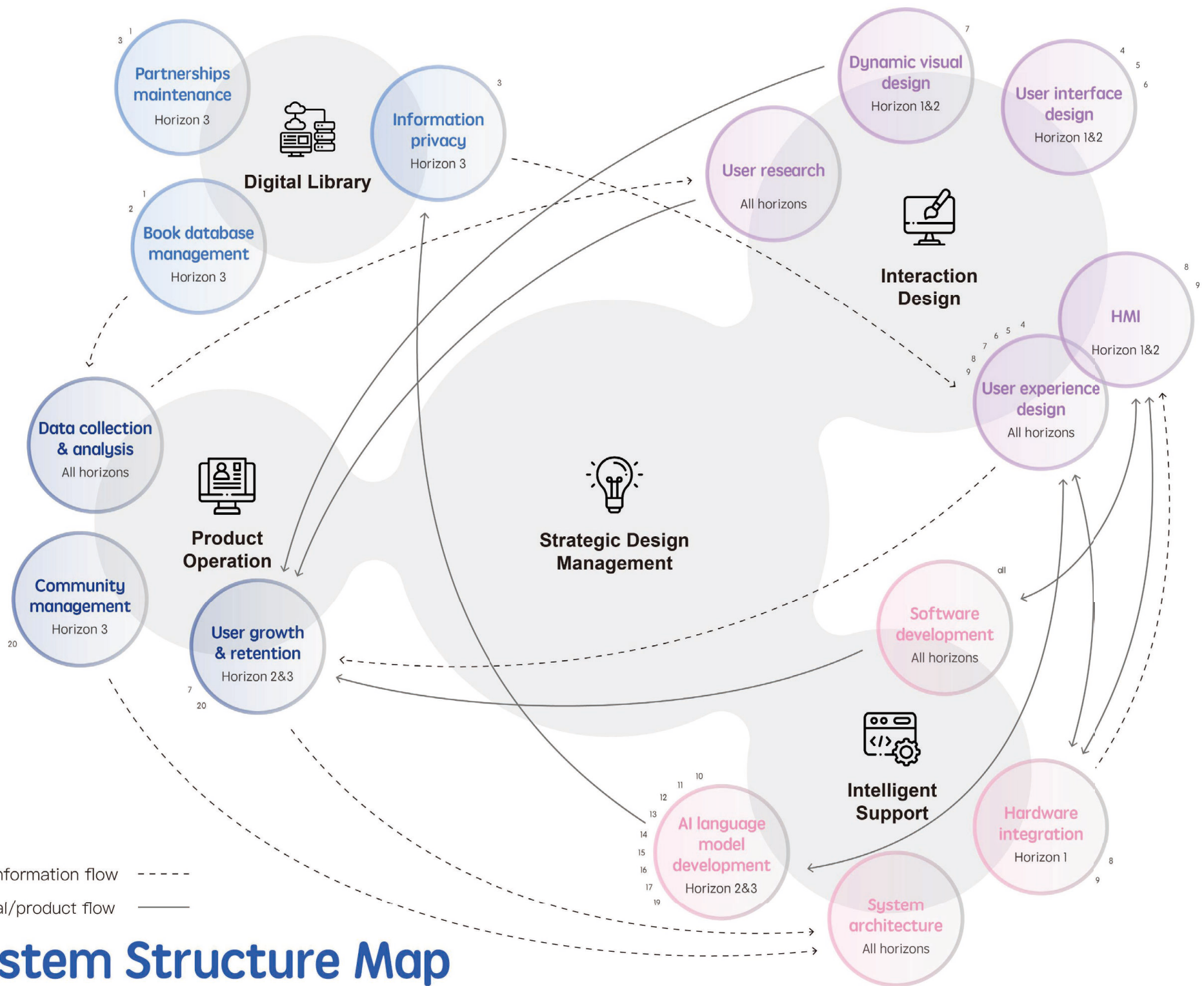


This map shows the key components that enhance the functionality of intelligent reading assistance. The user journey serves as the visual guide, with different functional groups contributing at various stages.

Service System Map

System Structure Map

Data/information flow - - - - -
Material/product flow —————



8.2.2 From User's Perspective: Scenarios

After finalizing the system map, we now have a relatively clear view of various functional blocks: a customizable interface, an eye-tracking feature for highlights and data input, a smart AI assistance, the collection and analysis of reading data into a personal profile, a co-reading platform, and a rich digital reading resource. The features are fixed, but users' intentions and paths can differ significantly from the system planning. Therefore, in this section, we will shift our perspective to think from the users' angle using the tool of Scenario, and reorganize a bit the current functional blocks. This section also acts as a bridge leading to the user-centered workflow design.

Let's think from user's perspective and consider the functional blocks of the system as pieces of a puzzle:

Now you click into the homepage of the platform. If you are new here, a small test for pre-setting is recommended. The test includes the dyslexic test, format preference, and a demo reading. This procedure could help the AI to build your portrait for a better personalized experience.

To achieve the goal of an enhanced reading experience, firstly, a rich digital library of books is irreplaceable. After selecting a text, or simply input some content, you formally enter the reading page.

The interface format might still not be comfortable enough for you, so you adjust it to your preferred style. With these adjustments done, you're ready to read.

The eye-tracker assists significantly by locating your reading path and providing helpful hints. If you have questions or doubts about the content, you can use the function bar to request translations or explanations, or even directly ask the AI chatbot. The reading process is recorded in the background. The AI analyzes and generates a personal summary of the text and a final reading report.

After your reading session, a reward animation will appear, and the report will be recorded in your personal profile. If you are connected with friends

on this platform, they can check your reading progress, reports, and recommendations.

You can also join a co-reading session to read the same article together online and share your thoughts in real-time.

Continuing with the persona in 4.2.1, we can create the coming concrete scenarios for the usage of the system. According to specific requirements of reading, the different functions might be used in different scenarios.

Scenario 1: Federico - University Student

Needs: Efficient reading of academic papers, taking notes, in-depth analysis, and collaborative discussions.

Experience: Federico logs in the platform, uploads an academic paper, adjusts the interface for comfortable reading, uses the eye-tracker for focused reading sessions, and interacts with the AI for quick summaries and explanations. He also uses the AI summary function to cross-reference articles and provide comprehensive insights, and join a co-reading group to discuss findings with peer students.

Scenario 2: Emma - Casual Reader

Needs: Enjoyable and engaging reading experience, discovering new content.

Experience: Emma likes to explore the digital library to find escape literature. She would personalize the reading interface according to different types of contents, using the eye-tracker for an immersive experience and interacting with the AI for excerpts. She joined an online reading club via the platform to share thoughts and discover new reads.

By thinking through these scenarios, we can better understand the diverse needs of users and design a system that is flexible, intuitive, and supportive, ensuring a superior reading experience for all.

After a thinking process of perspective transformation, a user flow is naturally generated as follows.

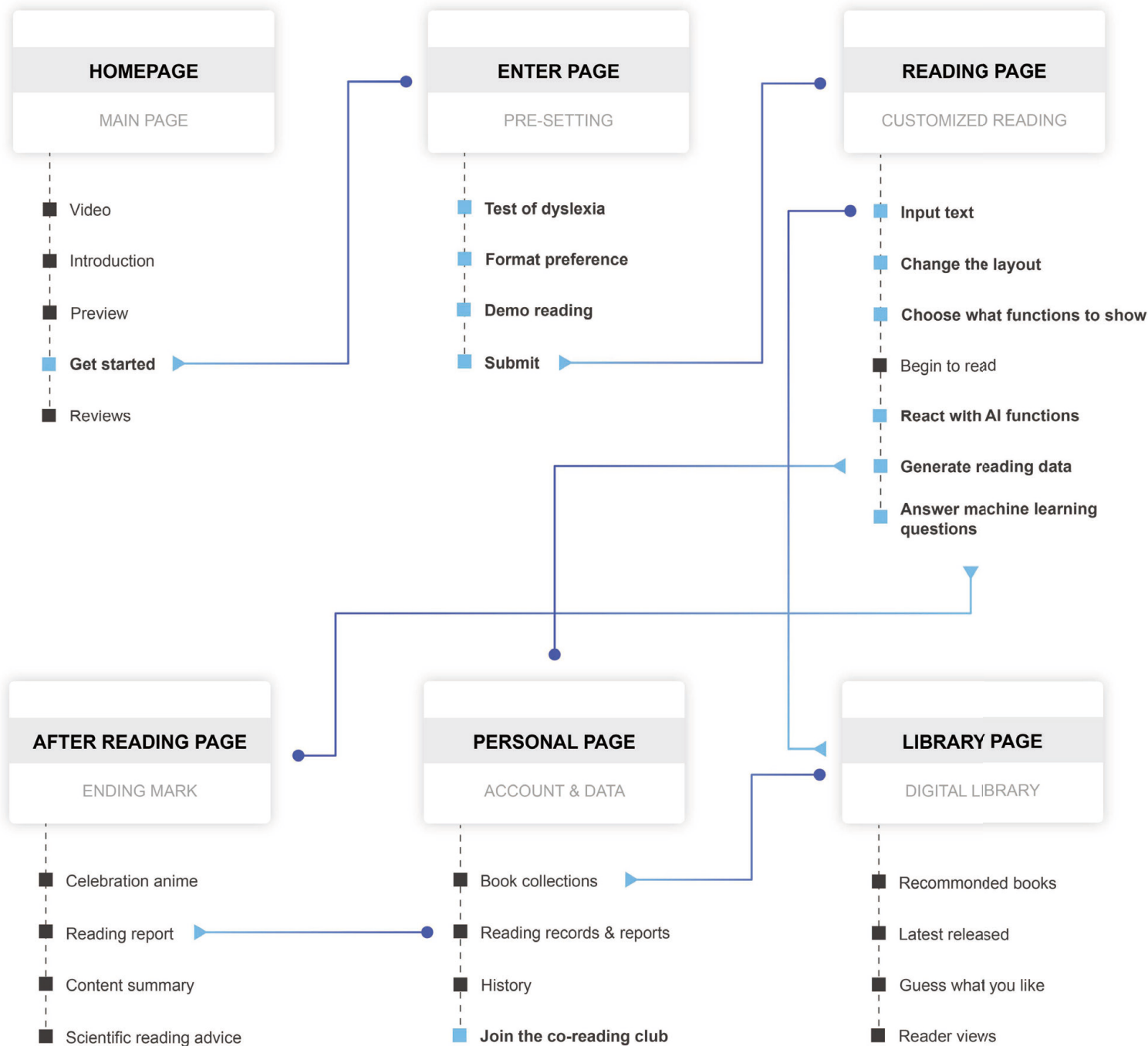


Figure 23: User flow of the entire platform

8.2.3 Workflow of Reading Page

We now have a clear understanding of all the functional blocks and how they benefit the readers. The user flow above reveals the interaction process of the entire platform. However, the most important section is **the reading page — the main webpage conducts the function of eye-tracking and AI assistance reading**. The next step in the design process is to develop a clear and feasible workflow for the reading page to elucidate the system's mechanism. In this section, the background workflow behind the reading page will be introduced. Incorporating suggestions from experts and technology professionals, this workflow aims to practically demonstrate the feasibility of webpage interaction and prepare for the next functional prototype.

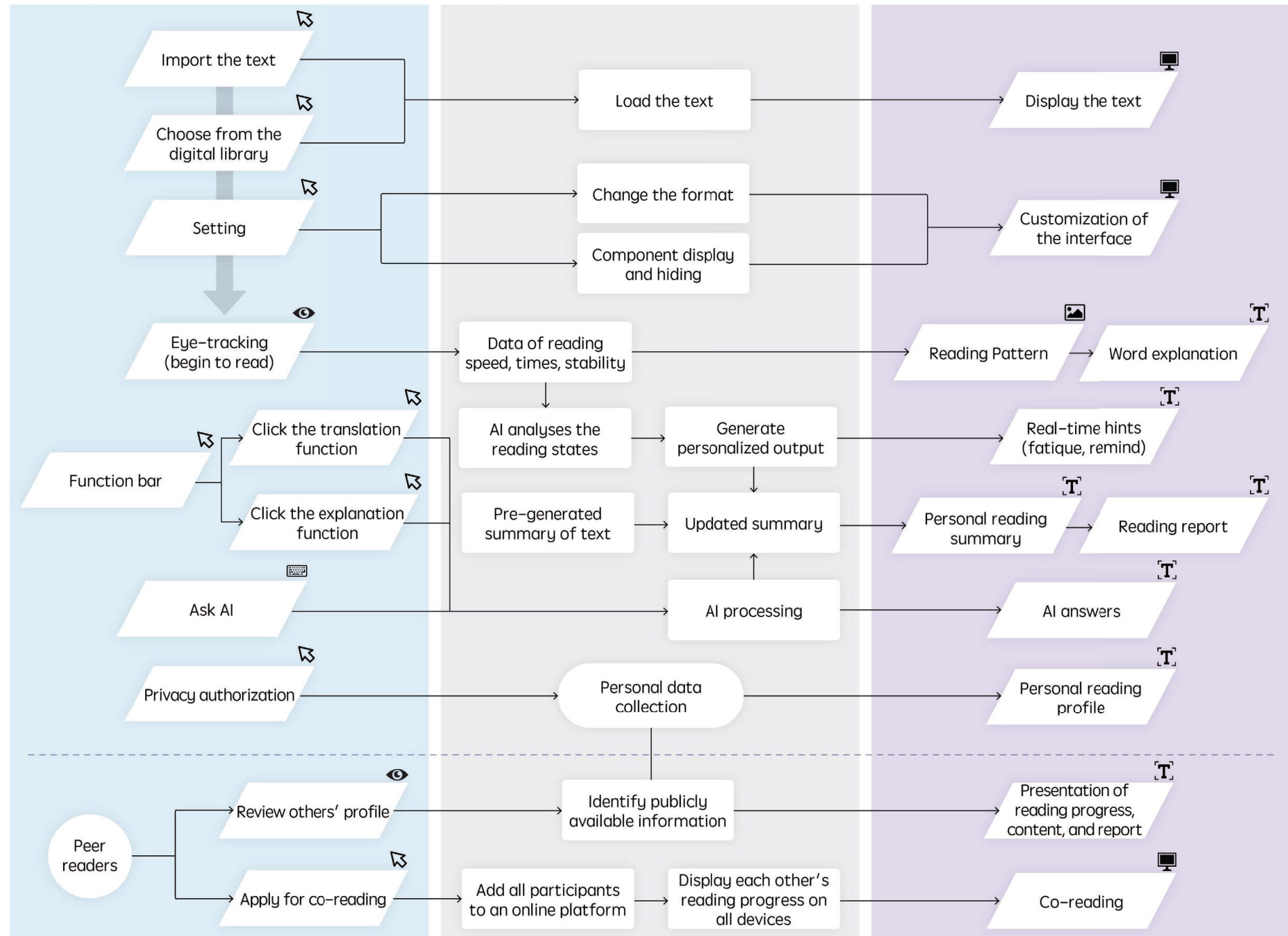
The reading page is central to the entire platform. It is the primary interface for conducting the reading function and serves as a crossroads connecting all auxiliary functions. This means that the six aspects of the system are all integrated through the reading page. The coming diagram illustrates the information workflow, effectively integrating user inputs, data processing, and interface outputs. This comprehensive interactive platform is designed to enhance the reading experience by incorporating advanced features including customizable interfaces, eye-tracking technology, smart AI, and a co-reading platform. The system not only adapts to individual user preferences but also facilitates a collaborative reading environment, ensuring a more engaging and efficient reading process.

The workflow integrates user inputs, data processing, and interface outputs to create a personalized, interactive, and supportive reading environment. Each feature is meticulously designed to enhance user engagement, understanding, and satisfaction, making the reading process more efficient and enjoyable. The comprehensive system ensures that users have access to a wide range of tools and resources, facilitating a superior reading experience that is both individualized and collaborative.

User input

Data process

Interface output



User Input Phase: In the initial phase, users interact with the system by importing text or selecting from a rich digital library. The ability to upload personal documents or choose from an extensive library ensures that users have easy access to a variety of reading materials, thus meeting diverse reading needs. Customization plays an indispensable role in the user input phase. Users can adjust the interface settings to their preference, including font size, background color, and layout. This level of personalization is essential for reducing eye strain and enhancing comfort, particularly during extended reading sessions. By allowing users to tailor the reading environment to their needs, the system significantly improves readability and overall user satisfaction. The eye-tracking feature is another pivotal component, beginning to monitor the user's eye movements as soon as they start reading. This technology provides real-time feedback and data, which are instrumental in dynamically adjusting the reading interface and offering contextual hints. The eye-tracker helps in locating the reading path and can provide subtle reminders to maintain reading efficiency, thereby enhancing the overall user experience.

Function Bar and AI Interaction: The function bar offers additional support by providing translation and explanation functions. Users can click on these options to get immediate translations of difficult words or explanations of complex concepts. This feature is particularly beneficial for non-native speakers and individuals dealing with technical or complex texts. It ensures that interruptions in the reading flow are minimized, thereby facilitating better comprehension and retention. The AI chatbot further enriches the user experience by answering questions and providing additional information. This interactive element allows users to delve deeper into the content without needing to leave the reading interface. The AI's ability to provide real-time assistance ensures that users can maintain their focus on the text, enhancing the overall reading efficiency.

Data Processing Phase: In the data processing phase, the system handles several critical tasks to enhance the reading experience. Once the text is loaded, the system processes it to allow for format adjustments and the selective display of components. This ensures that the text is presented in the most user-friendly manner, tailored to individual preferences. The AI plays a significant role in analyzing reading data. It monitors reading speed,

frequency, and stability, providing valuable insights into the user's reading patterns. This data is crucial for generating personalized outputs, including real-time fatigue hints and attention reminders. The AI's continuous analysis helps in identifying areas where the user may need additional support, thereby making the reading process more efficient and enjoyable. Pre-generated and updated summaries of the text are another key feature. The AI initially generates a summary and updates it based on the user's progress and interactions. This dynamic summary helps users quickly grasp the main ideas and revisit key points, enhancing understanding and retention. By providing a concise overview of the text, the system ensures that users can easily track their reading progress and comprehend complex information.

Interface Output Phase: The final phase focuses on delivering personalized and interactive outputs to the user. The text is displayed according to the customized settings, providing a comfortable and tailored reading environment. This customization reduces strain and encourages longer, more focused reading sessions. The system generates visual patterns of reading behavior using eye-tracking data, offering word explanations and real-time hints. These features provide continuous support and feedback, ensuring a seamless and productive reading experience. Users receive personalized reading summaries and reports, which are displayed in their personal profiles. These reports offer insights into reading habits, identify areas for improvement, and help set future reading goals. AI answers to user queries are integrated into the interface, facilitating deeper understanding and engagement with the text. This feature ensures that users have access to immediate assistance, making the reading process more interactive and engaging. The co-reading platform fosters a community of readers by enabling shared reading experiences. Users can join book clubs, participate in co-reading sessions, and engage in live discussions. Features such as synchronized highlighting, shared annotations, and group discussions facilitate collaborative learning and enhance the overall reading experience. By promoting social interaction, the co-reading platform enriches the reading process and fosters a supportive community of readers.

8.3 Prototype

8.3.1 Website Wireframes

The user flow and workflow offer complementary perspectives on the platform's potential form. At this stage, I have developed a relatively comprehensive vision of what the webpage would look like.

The user flow provides a general overview, outlining the rough pathway of platform usage. From this, a network structure of the pages emerges, consisting of four main webpages: the homepage, the reading page, the personal profile page, and the digital library page. Additionally, there are auxiliary pages that appear during the initial utilization or act as bridges connecting different functionalities, such as the entry page and the after reading page. Within each main page, various functionalities are abstracted. Although these abstractions are not highly specific, it is easy to envision the interactive functions of the home page or the personal profile page.

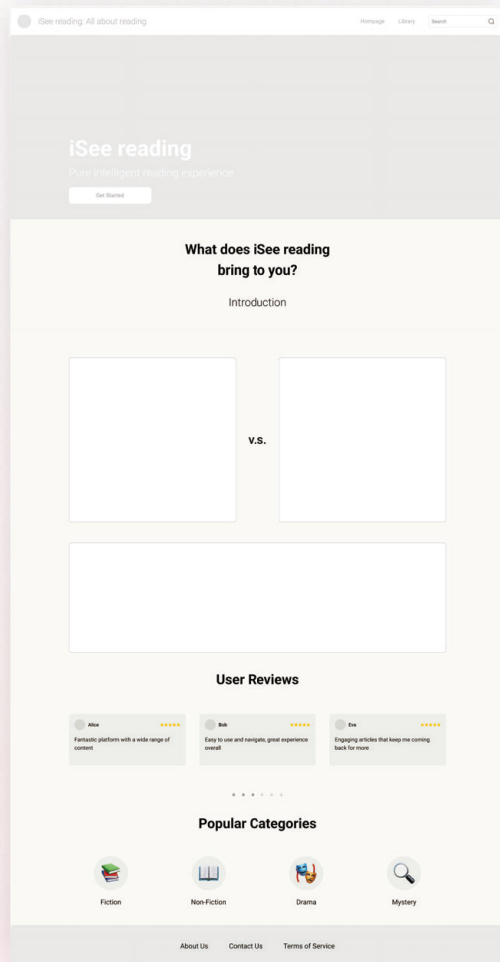
Among all the pages, the reading page is the most functionally complex. As discussed above, it “serves as a crossroads connecting all auxiliary functions.” From the workflow, a match between input/output and interface interactions can be gradually formulated. Consequently, the reading page guarantees several features before the formal design of the wireframe: text input, digital content selection, interface customization, eye-tracking reading visualization, real-time hints, translation, explanation, AI chatbot, reading report, and co-reading.

This structured approach ensures that the design is both comprehensive and user-centric, aligning with the platform's goal of enhancing the reading experience through both advanced technology and thoughtful design.

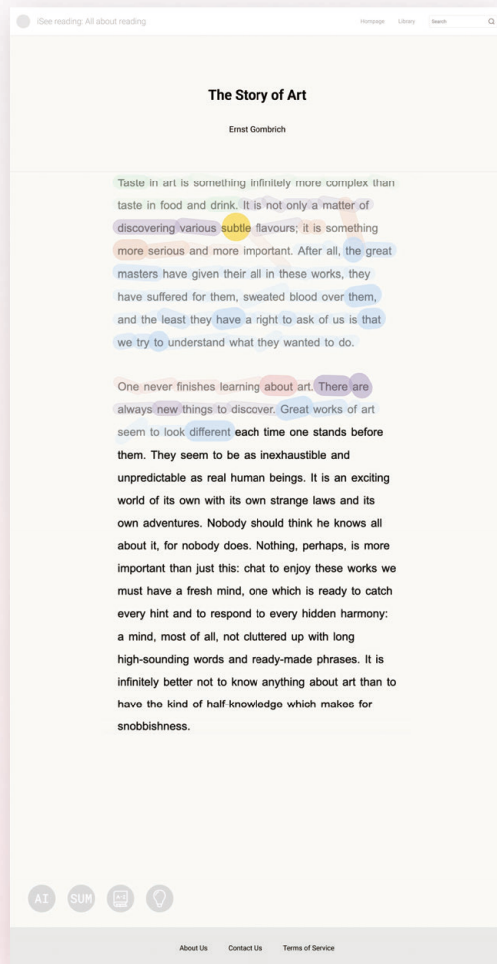
I can't wait to see what the website wireframe design will look like!

The website is named iSee Reading. The name combines the elements "I," "See," and "Reading," which means that users can achieve an excellent digital reading experience with assistance triggered by eye movement. Following the guidelines from the literature research (section 3.2), the webpages use fonts larger than size 12 and deliberately increased line spacing, word spacing, and character spacing. Pure black text is avoided in favor of cream yellow and gray to reduce contrast and improve readability for individuals with dyslexia. The titles and default text are set in sans-serif fonts, Roboto and Arial, respectively. Additionally, in the reading interface, users can further customize text font, size, and other parameters to suit their preferences.

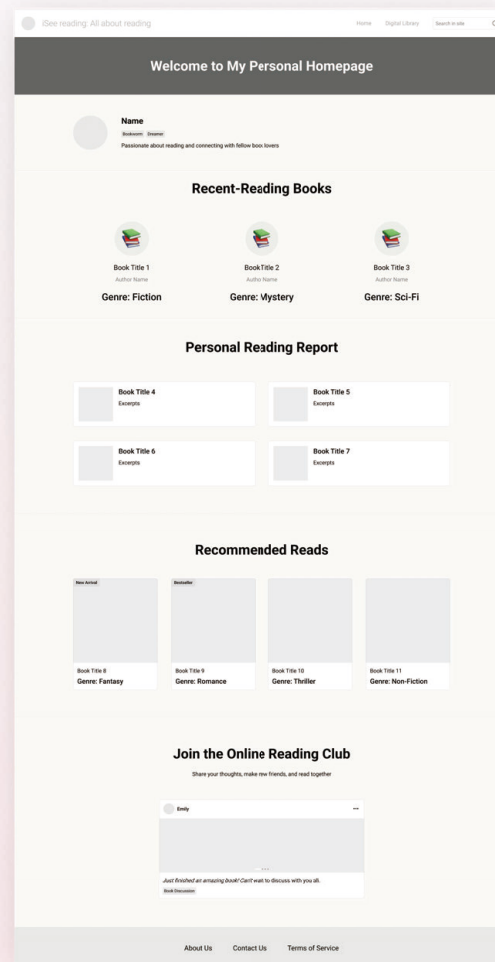
Given that finalized interactive prototype design is not the primary focus for this stage, we will concentrate on developing functions based on editable Figma wireframe design. A higher-fidelity model can be refined and improved in future design phases.



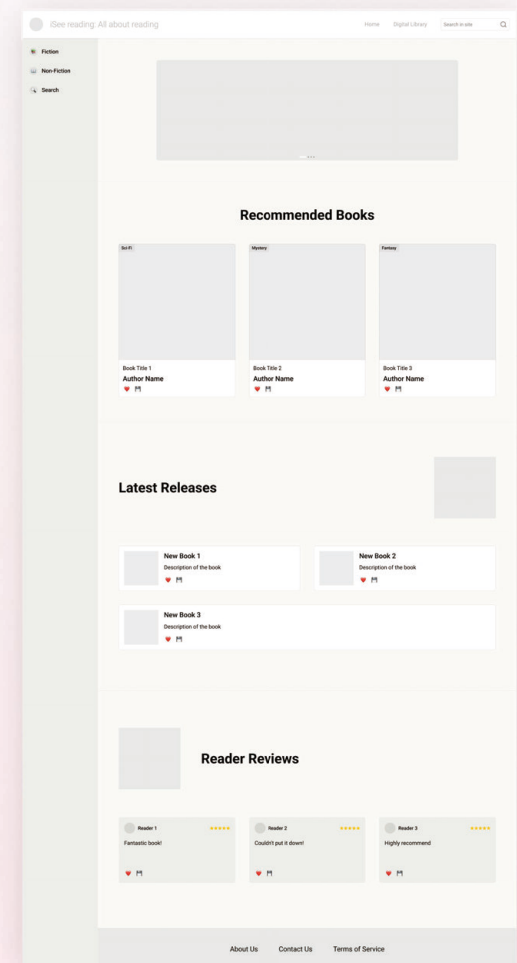
Homepage



Reading page



Personal profile page



Digital library page

Figure 25: Frameworks

8.3.2 Interaction Design Brief

Pre-test¹: When using the platform for the first time, users can participate in this test. It includes dyslexia assessment, layout preferences, and reading the text demo. The purpose is to understand the user's reading ability, habits, and preferences in advance to automatically set some interface parameters before they start reading. Additionally, this process helps machine learning.

Figure 26: Pre-test

1. How long do you usually read at a time?

- ☐ 10 minutes around ☐ 20 minutes around ☐ More than 30 minutes

2. When you are staring at a sentence for a long time, you tend to?

- ☐ Feel tired ☐ Feel confused ☐ Feel interested

3. Which of these fonts makes you feel less tired?

- ☐ Arial ☐ Comic Sans ☐ Verdana

¹ The questions in this interface are only for indication, which should be flexibly adjusted according to further relevant research.

Content Import: Before reading, users need to select the reading content. The platform offers two possibilities of sources: the digital library in collaboration with external organizations, providing extensive reading materials; and the option for users to import online web pages or local documents, which the system will recognize and present.

Format Setting: This includes customization of layout and font adjustments. If the user has participated in the pre-test, the interface will show relatively personalized presets. Users can further adjust background color, text color, line spacing, word spacing, font size, and type based on their mood.

Functions Hide and Show: After setting the format, the system will ask if the user needs real-time features like reading pattern, live reminders, or gaze-triggered functions. Users can decide at this point or turn these features on or off during reading. A series of single buttons for enabling and disabling these functions is located at the bottom left of the interface.

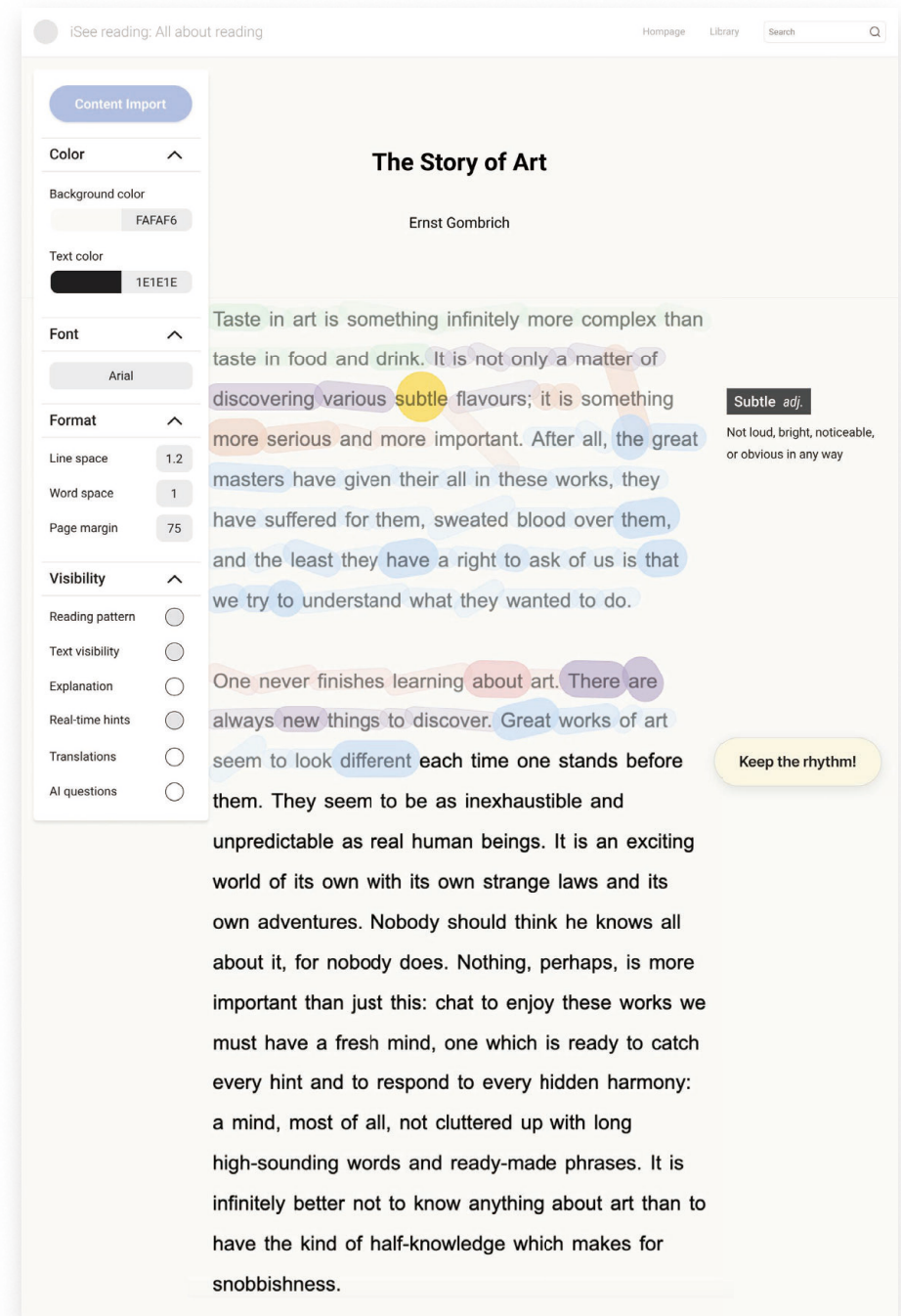
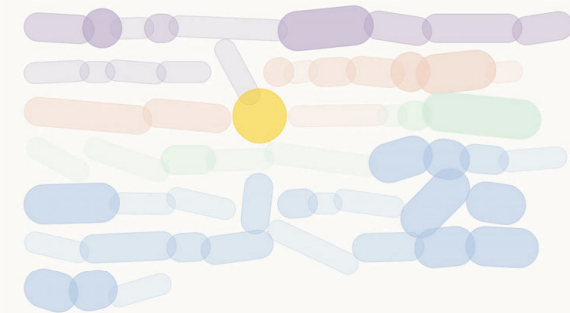


Figure 27: Adjustment sidebar

Digital Reading Ruler: This is the most direct result of eye-tracking. The text color of content passed by the user's gaze gradually fades within 2 seconds, indicating reading position and progress in real-time.

Reading Pattern: Eye-tracking turns to real-time reading data recorded in the background, valuable for analyzing reading status. According to information from 3.3.2 Eye Gaze & Reading, speed, frequency, and fluency are critical parameters. For reading speed, long fixations (longer than 0.7 sec.) are associated with difficult words, medium-length fixations (0.4 - 0.7 sec.) with less difficulty, and short fixations (less than 0.4 sec.) with easy words. So in this system, gaze durations over 0.7 seconds are set as slow, 0.4-0.7 seconds as medium, and less than 0.4 seconds as fast, corresponding to wide, moderate, and narrow word blocks. For reading frequency, each additional view deepens the block color by 20%. Reading fluency is represented by the average direction of gaze over the word block. These parameters visualize the reading pattern.

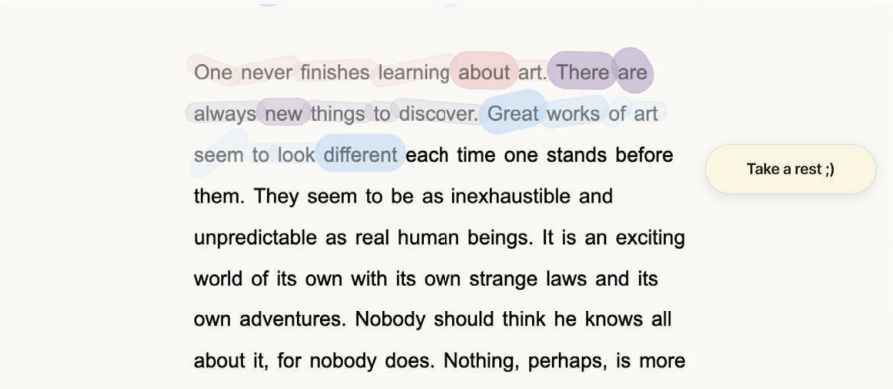
Taste in art is something infinitely more complex than taste in food and drink. It is not only a matter of discovering various subtle flavours; it is something more serious and more important. After all, the great masters have given their all in these works, they have suffered for them, sweated blood over them, and the least they have a right to ask of us is that we try to understand what they wanted to do.



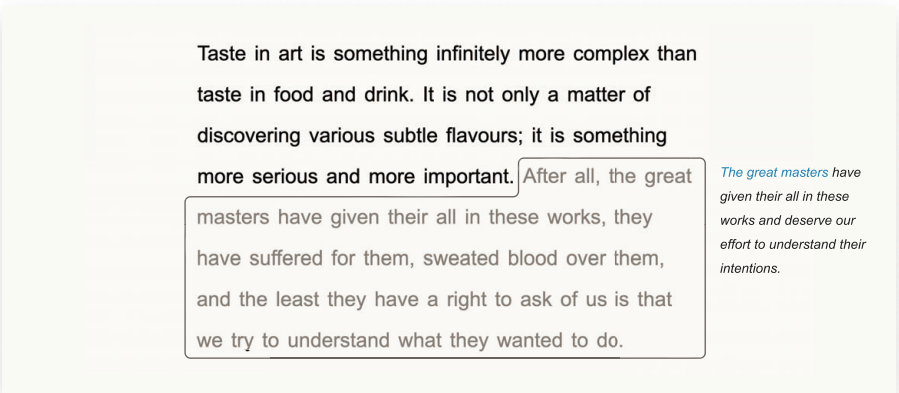
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Set of figure 28: Reading ruler, reading pattern, and the combined version

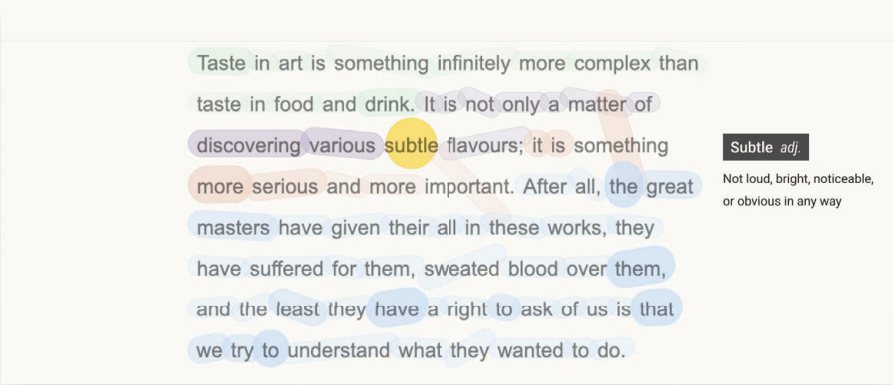
Live Reminder: One of the functions that can be turned on or off with a button at the bottom left. When enabled, the system offers real-time scientific reminders about the user's reading state, such as speed or rest suggestions.



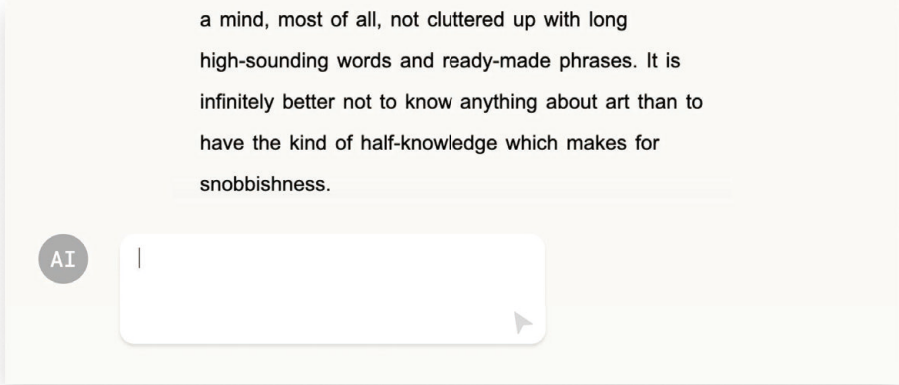
Replacement and Sentence Break: This turnable function automatically breaks down complex sentences and replaces rare words with simpler synonyms.



Explanation and Translation: This function can also be turned on or off from the bottom left. When enabled, the system provides real-time explanations and translations for sentences or words that receive long fixations or repeated attention.



Replacement and Sentence Break: This turnable function automatically breaks down complex sentences and replaces rare words with simpler synonyms.



Set of figure 29: AI & machine learning interaction features

Machine Learning Quick Questions: Slow, repeated or unstable reading might indicate interest, difficulty, or fatigue. When such a situation is detected, a multiple-choice question may appear, letting users give quick feedback with a single click. This helps the system learn the user's personalized states and patterns.

important than just this: that to enjoy these works we must have a fresh mind, one which is ready to catch every hint and to respond to every hidden harmony: a mind, most of all, not cluttered up with long high-sounding words and ready-made phrases. It is infinitely better not to know anything about art than to have the kind of half-knowledge which makes for snobbishness.

×

Do you feel?

Figure 30: When the reading data shows multiple repetitions, abnormal speed, or significant fluctuations, the intelligent system will prompt the user with questions. Upon receiving answers, the machine learning component records and learns from the user's habits.

Content Summaries: Another function can be turned on or off from the bottom left. When enabled, paragraph summaries will appear in the text sidebars.

Excerpts: Based on eye-tracking data, the system identifies key sentences and records them as excerpts in the background. Users can view these excerpts also in the text sidebars, or after completing a whole section of reading. These excerpts are also saved as a part of reading reports.

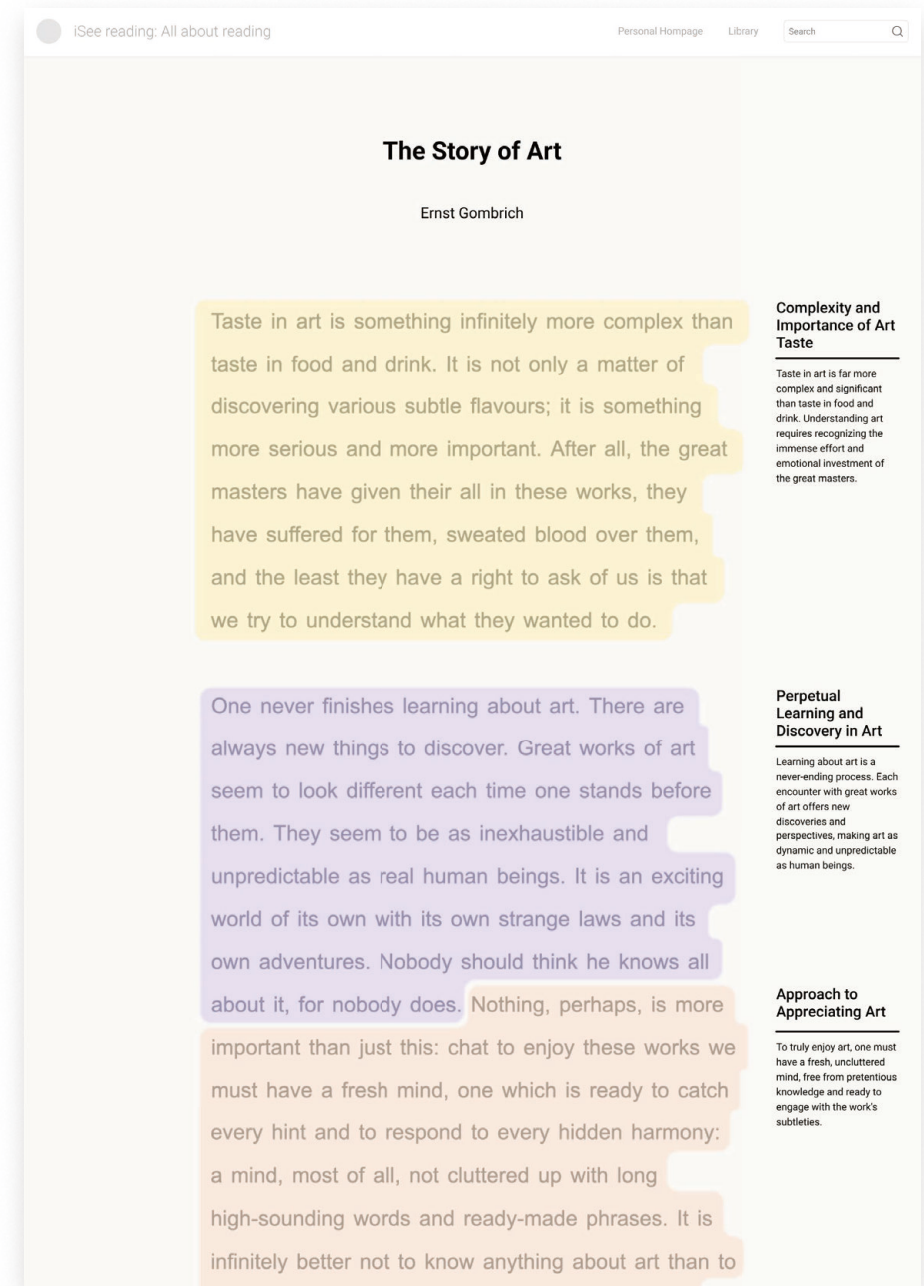


Figure 31: The sidebar shows an example of Content Summaries

Celebration Anime: After completing a reading section, a celebratory animation plays, with word blocks dropping to the bottom of the interface. These blocks are collected as a visual representation of reading completion for emotional encouragement.

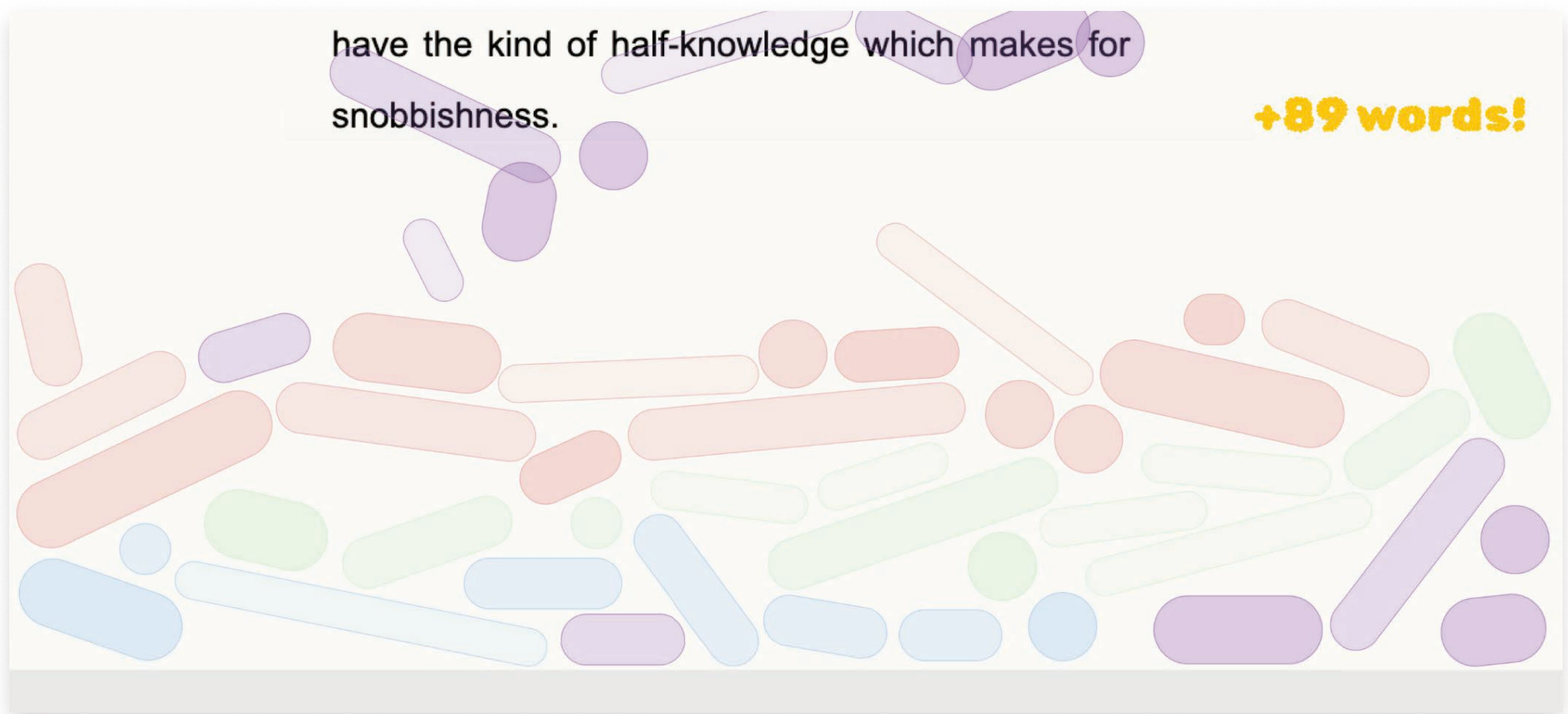


Figure 32: Animation: After completing a section of reading, all blocks of reading patterns are dropped, collected and counted

Reading Report: Upon completing a section of text reading, the AI generates a personalized reading report based on real-time reading data, including a summary of the content and personalized reading suggestions.

Personal Reading Profile: This is the user's personal page on the platform where they can view reading history, progress, reports, and other information.

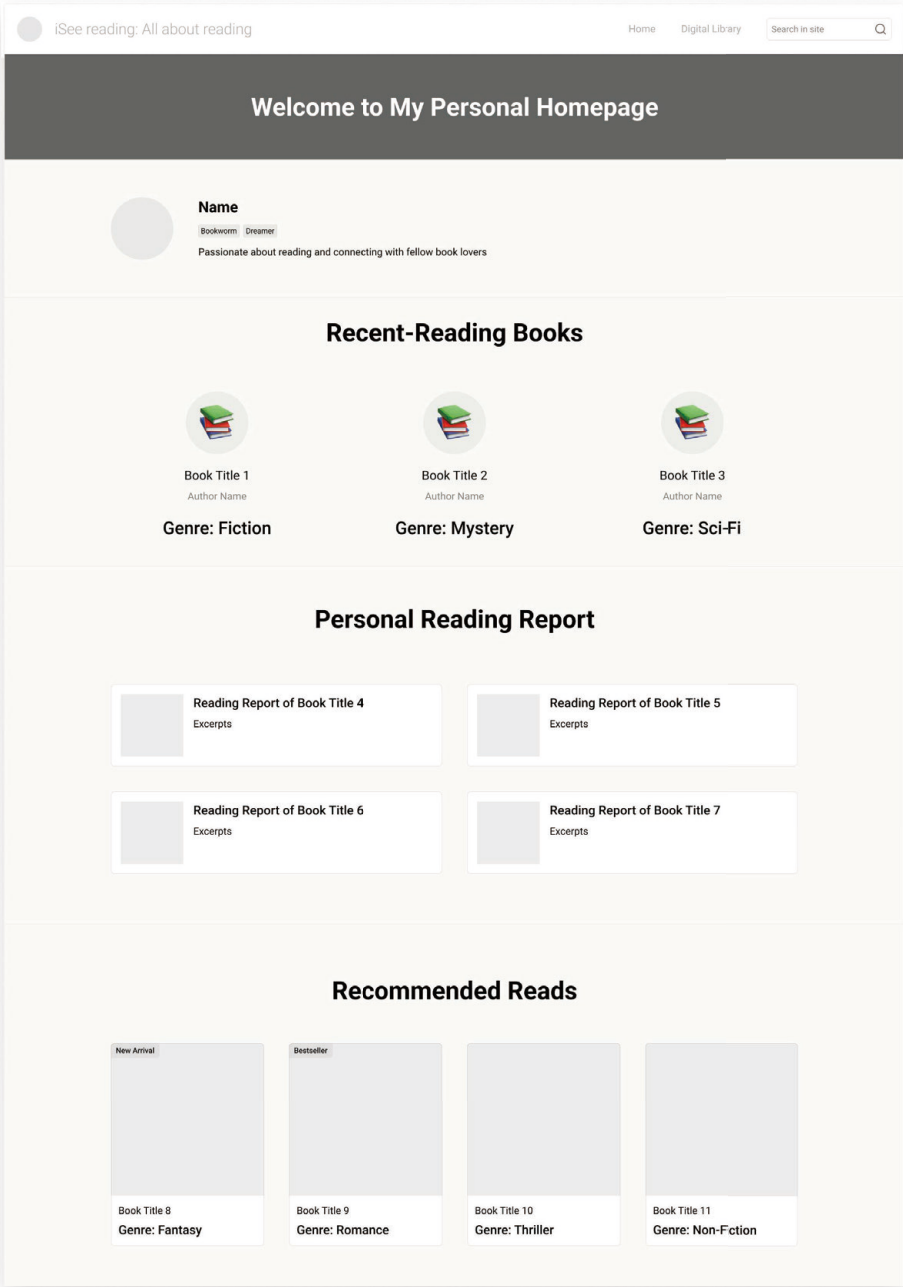


Figure 33: Reading Report can be found on the Personal Profile

9 Discussion

9.1 Findings and Innovations

Throughout the research process, the design direction for developing an interactive reading assistance system using eye-tracking technology to enhance reading efficiency and experience for individuals with dyslexia gradually took shape. The original goals includes:

1. Real-time reading support: Utilize eye-tracking technology to monitor eye movement in real-time and provide prompts or highlights.
2. Enhanced comprehension: Implement AI features to lower the barrier of content reading, making it more enjoyable and easier to understand.
3. Simplified and personalized interaction: Design an intuitive interface to ensure a smooth and user-friendly reading process.

To achieve these goals, a comprehensive and iterative process was conducted. Insights gathered from interviews and tests became boosters for refining the design closer to the ideal form. Several notable innovations emerged from this process.

The most significant innovation is the integration of eye-tracking with data input for reading state analysis. Although there were already design research that used eye-trackers as data input to help with digital reading (e.g. GARY mentioned in 3.3.3), the eye gaze was more similar to the function of the mouse, which only revealed the real-time reading position on the digital interface. In this project, the real-time data collected by eye-trackers was transformed into not only real-time reading position, but also input for intelligent analysis of personal reading states, leveraging recent advancements in AI technology. This innovative approach received positive feedback in iterative tests, with participants in the fourth focus group discussion remarking it as the project's standout feature, awarding it a

perfect score of 10 out of 10.

This project also represents a pioneering attempt to use eye-tracking as a touchpoint in reading experience design. Literature research confirms that tools like the Reading Ruler, which highlights the current reading position, effectively aid concentration for dyslexic individuals. While several digital reading assistance systems offer the feature of the real-time reading position indication, they are often triggered by the mouse cursor. GARY is able to work as a digital Reading Ruler controlled by eye gaze, but lacks comprehensive design for ease of usage. In this project, the eye gaze movement can seamlessly trigger the real-time Reading Ruler, with the interactive interface iterated through several rounds of user feedback. This approach leverages the natural action of eye movement in reading, creating an intuitive and seamless interaction without additional effort.

Another significant innovation is the strategic system formulation, encompassing interaction design, roadmap design, technical planning, and public relationship organization. Initially, the project focused on interaction design, to build a user-friendly reading assistance platform. However, as it progressed, systemic, technical, and organizational questions arose, calling for targeted iteration and in-depth design. Although the AI technology and business structure aspects could not be practically demonstrated, a reasonable plan for the future development and the system structure was created based on professional advice.

Revisiting the original design goals: “develop a system that optimizes the interactive reading experience for individuals with dyslexia by leveraging eye-tracking technology and AI content generation,” we find that the project

has effectively addressed these objectives. The three aspects of seamless reading, comprehension enhancement, and customized interaction have all been improved. Especially, the technical ability of eye-tracking, enhanced by AI technology and design innovation, has created more possibilities for potential reading assistance features (as is introduced in 7.3.2 Interaction Design), exceeding initial expectations.

Comparing this project with other designs reveals its unique contributions. Existing popular digital reading assistance platforms, such as Reader Mode (refer to 3.3.1), offer features like format adjustment tools, the Reading Ruler, and AI chatbots. However, these elements operate independently and provide limited assistance in dynamic situations. Solutions like EyeMetricsLive (refer to 3.3.2) and GARY incorporate eye-tracking but lack engaging interaction design and user engagement. This project integrates AI to analyze reading data, offering real-time feedback, personalized assistance, and a user-friendly experience. While it builds on previous designs, it aims to provide a more comprehensive and cohesive solution.

However, due to time and technical constraints, further user tests to validate effectiveness and additional technical tests have not yet been conducted. To fully convey the concept, the design elements related to these aspects are primarily presented as strategic concepts. This approach leaves room for further exploration in the future. The limitations of this project and potential future directions will be discussed in the following sections.

9.2 Limitations

Despite its innovations, the project faces several limitations. These can be categorized into two general aspects: workload limitations and technical limitations. This categorization is only for convenience and does not imply that the two categories are independent of each other.

The first limitation is the lack of verification and validation due to the workload, reflected in the insufficient number of samples. This shortage exists during the whole research and design process. This is not only because of time limitations, but also because it is not easy to find dyslexics with active feedback in everyday environments. In the iterative test section, only 10 participants joined the tests, and half of them reported dyslexic symptoms. On average, only about four participants take part in each test. As the sample size is small, information deviation and contradiction is inevitably common. When compiling the data, I was often confused by the dramatic differences in the views of different participants. For example, in 6.1 the first round of the functional test, participants had very different opinions about the animate effects in reading — Participant 1 and 2 expressed strong negative attitudes, while Participant 3 found it interesting and attractive. In order to balance this contradiction, I chose to conservatively delete the dynamic effects from the main reading process, and save them as an optional motivation at the end of each reading session. If there is more time to delve into, more detailed AB tests are required for verification.

Time and workload constraints also led to limited fault tolerance. As the research progressed, discussions arose about designing for universal populations, causing me to reconsider the definition of the target user. For a

long time, I questioned whether to consider the needs of general non-dyslexic users at the same level as those of dyslexic users. This debate is one reason there was an equal number of participants with and without dyslexia in the testing phase (the other reason being the difficulty of finding suitable participants). This struggle caused some aspects of the research process to deviate from the original focus on dyslexic individuals, leading to ambiguity in user needs in the relevant results. Additionally, there are subdivided groups within people with dyslexia, but this aspect was not adequately considered.

As for technical limitations, at the beginning of this project, the design was mainly to enhance the reading experience using eye-tracking technology. However, as the design research deepened, AI began to play a more significant role. **This sudden increase in technical difficulty prevented me from completing a full functional prototype as planned.** Following suggestions from a professional participant specializing in computer science and AI, it became apparent that a proprietary large language model would be necessary to ensure the desired features and data security. To address this, I transformed the design scope to include strategic design. Consequently, the functional model can only implement the interaction design part and cannot complete all the underlying architecture with coding. Additionally, the prompts required by the AI have not been thoroughly studied. Understanding which prompts can effectively build an interaction system is a topic left for future exploration.

Reflecting on the limitations encountered in this project provides critical insights into how future research and design efforts can be organized.

First, the user definition should be more decisive and clear. Individuals with dyslexia are a group with distinct characteristics and needs. As the primary group of target users initially identified, it should be adhered to throughout the design process. Conversely, if the target users are generalized to individuals without dyslexia, the views and needs become too broad, leading to a lack of effective restrictions and judgment criteria during the design process.

Second, user research should be more carefully considered. One of the current limitations was the small and mixed sample size, which diluted the focus on the primary target audience — individuals with dyslexia. Future projects should prioritize recruiting a larger and more targeted participant pool exclusively comprising dyslexic individuals to ensure that the feedback is directly relevant.

Third, the latest technology trends and prototype technologies should be emphasized in the earlier research phase. Given the ambitious scope of combining multiple innovations (interaction design, AI integration, and systemic planning), interface prototypes that correspond to functionality need to be carefully crafted and rigorously tested. This approach helps maintain a balance between innovation and practicality, ensuring that each phase builds reasonably and effectively.

9.3 Future Prospects

Looking ahead, several areas offer promising opportunities for further development and refinement of the reading assistance platform:

Technological Advancements: The primary technological focus should be on the development and refinement of AI prompts. This involves researching the most effective types of prompts that can enhance user interaction and reading comprehension. Following this, the feasibility of creating a proprietary large language model should be considered. This model would need to ensure data security and provide personalized reading assistance, enhancing the platform's overall functionality.

Interaction Design Iterations: To continually improve the user experience, AB test should be employed as a fundamental part of the interaction design iteration process. By testing different interaction methods and designs, the platform can gather valuable user feedback to guide future iterations. This iterative approach will help identify the most effective and user-friendly designs, ensuring that the platform evolves in response to actual user needs and preferences.

Multimodal Enhancements: Incorporating multimodal features based on expert interview suggestions is another key area for future development. Initially, the introduction of Text-to-Speech (TTS) technology will provide significant benefits, making the platform more accessible to users with varying reading abilities. Following this, exploring the use of Extended Reality (XR) technologies can add an element of interactivity and playfulness to the platform. These enhancements can significantly enrich the user experience, making reading more engaging and enjoyable.

User Segmentation: A more focused approach to user segmentation will also be crucial. While the primary target group remains individuals with dyslexia, it is important to consider other specific groups who could benefit from the platform, such as individuals with ADHD or other visual impairments. By tailoring the platform to address the unique needs of these subgroups, the system can become more inclusive and effective.

Commercial Strategies: From a commercial perspective, the platform can initially be introduced as a small-scale web and app-based version. This approach allows for testing and refinement in a real-world environment before scaling up. Early adopters can provide valuable feedback, which can be used to improve the platform before a wider release. This phased approach to market entry can help manage risks and ensure that the platform meets user needs effectively.

In conclusion, the future prospects for the reading assistance platform are vast and varied. By focusing on technological advancements, iterative interaction design, multimodal enhancements, targeted user segmentation, and strategic commercial rollout, the platform can continue to evolve and provide significant benefits to its users.

9.4 Reflections

Reading experience enhancement with eye-tracking technology: Is this a true proposition?

At the very beginning of this project, my interest in dyslexia and cognition led me to explore the design topic of digital reading enhancement. Eye-tracking, with its seamless and intuitive interaction capabilities, caught my attention then. Through extensive research and literature review, its potential to aid reading was somewhat confirmed. This stimulated the design process, focusing on eye-tracking and AI as core innovations. As time went by, several interface and function prototypes have been developed, and partially validated through testing. However, these tests were conducted on a small scale, and the product's feasibility has not been verified in the real market. Here, I would like to express some of my underlying concerns.

First, despite being affordable, few people are likely to consider purchasing an eye-tracker. This makes it difficult to envision it as a lightweight, portable personal tool in everyday scenarios. Then what if it's arranged as public devices? According to the interview with library experts, we knew that public libraries might prefer more engaging and participatory devices like VR, which positions eye-tracking assistance in a somewhat awkward niche.

Second, from discussions with technology professionals and the practical user tests, it is clear that eye movements are unconscious and constant, unlike hand movements which are more easily controlled by the brain. This results in unavoidable errors and accidental activations when using eye movement triggered interfaces. Although more in-depth user research and interaction testing might mitigate some issues, the usability of "eye gaze"

as an interaction touchpoint remains a doubt.

On a positive note, we are happy to see that nowadays some smart device manufacturers are attempting to integrate eye-tracking functions into the front cameras of common smartphones and tablets. This will have the potential to become one of the reading assistive technologies available on mobile smart devices in the future. Tech enthusiasts are also creating entertaining eye-tracking interaction designs through creative coding. Whether aimed at serious cognitive enhancement and reading assistance, or simply providing a richer, more enjoyable reading experience, designing around eye-tracking for reading is undeniably meaningful. That's why, despite the controversies, I still feel proud of my design research.

10 Conclusion

This project aimed to develop an interactive reading assistance system to enhance the reading experience for individuals with dyslexia. Through comprehensive research and an iterative design process, incorporating insights from functional tests, expert interviews, and a technical focus group, we found that integrating eye-tracking data with AI content generation within customized interfaces can significantly enhance user's reading experiences. If the system is organized as planned, it can effectively reduce the conflict between users' desire for fluent reading and the fatigue and frustration caused by dyslexia. This design is also with a universal significance to benefit general users. According to our future horizons, an ideal inclusive, intuitive, and intelligent digital reading platform can greatly improve users' reading comprehension and motivation.

However, our study has several limitations. First, the sample size was limited, which may affect the generalizability of our findings. Additionally, due to technical constraints, functional prototypes were limited to interactive interfaces. These limitations leave areas for further optimization, particularly in enhancing ease of use and managing technological complexity.

Despite the constraints, the design outcomes achieved within the half-year graduation design cycle represent a promising attempt at comprehensive system design. This project integrates strategy design and interaction design, requiring in-depth study of eye-tracking principles and HTML processing abilities. Designing from a technological perspective has commercial applications and facilitates the deep integration of user needs with technology. This approach contributes to the creation of a more inclusive and accessible future reading environment.

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IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Yu	IDE master(s)	IPD ☐	Dfi ☐	SPD ☒
Initials	X.	2 nd non-IDE master			
Given name	Xihan	Individual programme (date of approval)			
Student number	5810515	Medisign	☐		
		HPM	☐		

SUPERVISORY TEAM

Fill in the required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Jeff Love	dept./section	SDE/HCAI	! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why. ! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter. ! 2nd mentor only applies when a client is involved.
mentor	Christina Schneegass	dept./section	HCD/HICD	
2 nd mentor				
client:				
city:	Delft	country:	the Netherlands	
optional comments				

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Digitally signed by
Jeff Love
Date: 2024.03.28
15:27:19 +01'00'

Name J.S. Love

Date 23 Feb 2024

Signature _____

CHECK ON STUDY PROGRESS

To be filled in by **SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total _____ EC

Of which, taking conditional requirements into account, can be part of the exam programme _____ EC

★	YES	all 1 st year master courses passed
	NO	missing 1 st year courses

Comments:

Sign for approval (SSC E&SA)

Robin den
Braber

Digitaal ondertekend
door Robin den Braber
Datum: 2024.04.11
09:26:36 +02'00'

Name Robin den Braber

Date 11-04-2024

Signature _____

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team
comply with regulations?

YES	★	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Chair: Christina Schneegass, Mentor: Jeff Love

Based on study progress, students is ...

★	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique
von Morgen

Digitally signed by
Monique von Morgen
Date: 2024.04.23
11:43:05 +02'00'

Name Monique von Morgen

Date 23/4/2024

Signature _____

Personal Project Brief – IDE Master Graduation Project

Name student Xihan Yu

Student number 5810515

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Universal Digital Reading - Reading Experience Enhancement for People with Dyslexia

Project title

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

In our progressively digital world, where information is efficiently conveyed through text, a distinctive group encounters unique challenges. Individuals with dyslexia, who grapple with impediments in text reading, face difficulties in maintaining the necessary focus to comprehend written content. This project aims to use digital media as a tool to enhance reading accessibility for people with dyslexia.

Contrary to common perception, 5-17% of the global population experiences dyslexia. Research also indicates that dyslexia can manifest as symptoms of internalized issues like depression, anxiety, and ADHD. This evidence underscores the widespread prevalence of dyslexia. However, dyslexia is often overlooked, contributing to a scarcity of mature solutions.

Based on the research on the existing reading assistance tools for people with dyslexia in the market, and the observation of online dyslexia communities, I found that some solutions are used: 1) Low-tech physical tools (from Niklaus et al.) to capture the reader's attention and maintain focus, e.g. color overlays and underline overlays; 2) Web browsers, certain typefaces and layouts to change the visual presentation; 3) text to speech generation, similar to a karaoke style; 4) Tactile learning, most used in early childhood education.

However, most of the existing means concentrate on visual assistance or audio-visual combinations, and remain rooted in single interactions and traditional interfaces. This project endeavors to explore a multi-sensory, cognitively enhanced reading method based on user behavior research and testing, and is open to incorporating new technologies such as AI, AR/VR, and eye tracking.

introduction (continued): space for images

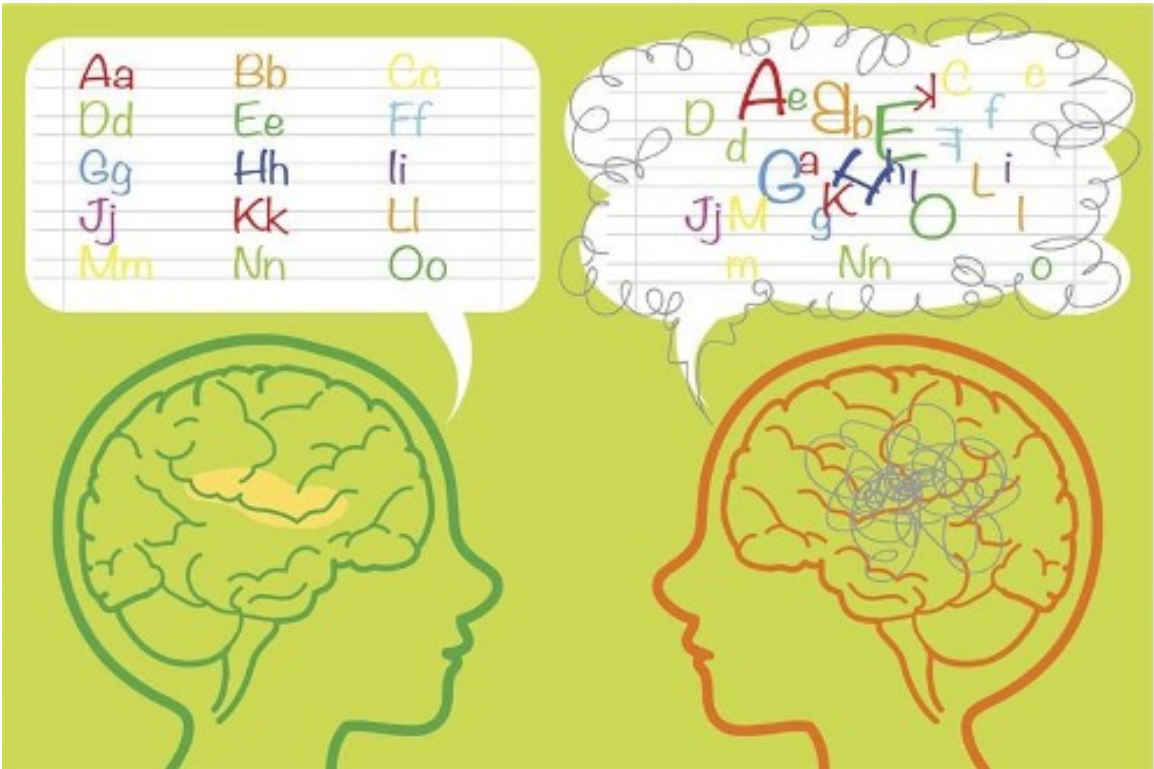


image / figure 1: Individuals with dyslexia have vary degrees of difficulty in reading

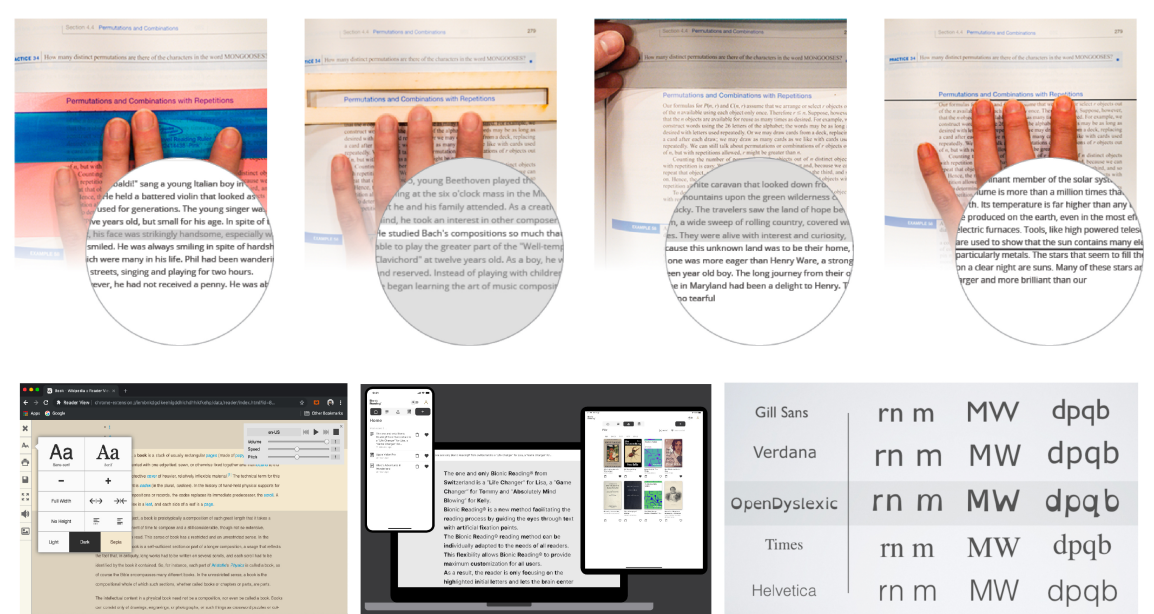


image / figure 2: Physical and digital tools currently available for individuals with dyslexia

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.

(max 200 words)

Commonly used assistance methods and strategies for individuals with dyslexia have predominantly focused on singular visual enhancement, such as using easily identifiable colours, weight, fonts, etc. Besides, some studies mention an approach that combines visual and audio elements, resembling a “karaoke” style. However, it remains in an initial stage due to the high demand for manual customization and correction. In other words, assisted reading technology for dyslexia is mostly still grappling with single visual sensory and stuck to traditional interfaces. Meanwhile it's currently more about “communication” than “interaction”. With the recent technologic advancements in artificial intelligence, virtual reality, and eye tracking, there is an opportunity to break away from current limitation. I aim to leverage these emerging tools to create a multi-sensory digital reading experience for individuals with dyslexia.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for.

Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)

As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Create a prototype to enhance the multi-sensory digital reading experience for individuals with dyslexia in modern libraries.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

Extensive research is necessary to achieve this goal. Dyslexia is a widespread but often overlooked problem. Individuals with dyslexia have significant individual variability and are cross-affected by other related conditions. To comprehensively understand and evaluate intervention methods, I will engage with a specific number of individuals with dyslexia. The process involves solicitation, targeted subject screening, followed by interview, iterative test, and both qualitative and quantitative analyses.

Based on the Design methodology of Vision in Product Design (Hekkert & Van Dijk, 2011), I'll explore diverse design directions and craft initial prototypes. A second round of contact with subjects includes inviting them to tests and gathering feedback. The conclusive phase will involve careful organization of the entire research process, resulting in a reference-worthy report, and the final prototype will be submitted.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting, mid-term evaluation meeting, green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting 21 February, 2024

Mid-term evaluation 25 April, 2024

Green light meeting 25 June, 2024

Graduation ceremony 8 August, 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	☐
For how many project weeks	25
Number of project days per week	5

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.

(200 words max)

I have a background of industrial design in my undergraduate studies. However, since becoming an SPD student, my thought process has often started with the role of a facilitator, used to approach problems from a business and social perspective. As the graduation project is the final and most significant project in my master 's journey, I aim for a comprehensive design perspective, encompassing broad systemic design while also allowing for in-depth understanding and analysis of real user needs (much like a 'T-shaped' mindset). I think this project is a good platform for me to approach my goal. I hope to construct a relatively complete design blueprint, and try my best to include user research, interaction design, and system services.

Additionally, my mentor, Christina Schneegass, is an experienced scholar in cognitive design. I am eager to enhance my research capabilities under her professional guidance. Therefore, conducting qualitative or quantitative analyses will be a crucial part of the early stages of the project. I hope an experience like this will help me build a more rigorous and practical design thinking methodology. It will also help me further think whether I'd like to step into the academic field in my future life.

Schedule:

	19 Feb - 3 Mar		4 Mar - 31 Mar				1 Apr - 28 Apr				29 Apr - 2 Jun					3 Jun - 30 Jun				1 Jul - 28 Jul				29 Jul - 11 Aug	
Calendar week	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	5.1	5.2	5.3	5.4	5.5	5.6
Project week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Key moments	Kick-off						Break				Mid-term					Final				Green light				Graduation	
Kick-off	21 Feb																								
Literature research																									
Brief interview																									
Technological study																									
Generate demos																									
Demo test & reflection																									
Stage summary + definition																									
Transition: demo to prototype																									
Report - Research part																									
Mid-term evaluation																									
Prototype																									
Iterative test																									
System design (optional)																									
Report - Design part																									
Final evaluation																									
Green light																									
Visualization & finalization																									
Presentation																									
graduation																									