

Graduation Report
Cognitive Perception for Dyslexic Readers



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Introduction

This document is the report of my graduation project that includes all my work in the span of five months (February - June). This thesis was born out of a deep interest in how people with dyslexia interact with text and digital reading tools. My goal was to identify and investigate the gaps between existing technological solutions and the nuanced challenges faced by this diverse group. Following this, I propose a new tool the ReQuest application, which has been created to support dyslexic readers by offering tailored reading assistance based on individual cognitive profiles and reading challenges. This journey reflects a balance between empathy-driven inquiry and methodical exploration, grounded in real user experience.

This graduation project is a collaborative effort between myself and Koninklijke Bibliotheek/The National Library of the Netherlands (KB) in The Hague. The KB's Online Bibliotheek (digital library) houses a collection of about 45,000 e-books and is committed to making this collection available to its extensive user base (KB Nationale Bibliotheek, n.d.). This resonates strongly with my objectives in this thesis as well. Additionally, research shows that many people struggle to navigate library materials and that a universal design does not meet the diverse needs of those with dyslexia (Kous & Polančič, 2019).

Large problem scope: This report provides a detailed exploration of the findings and progress of my research on 'Cognitive Perception for Dyslexic Readers.' Positioned at the intersection of cognitive sciences and inclusive design (Figure 1), this study

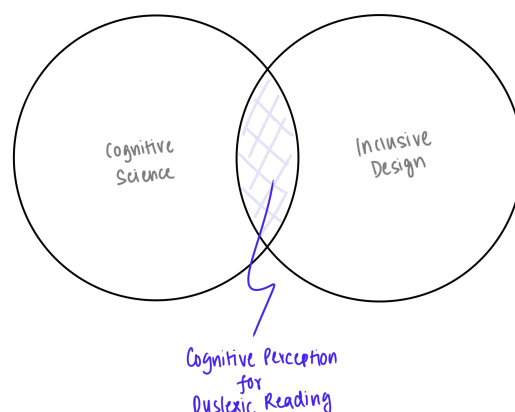


Figure 1: Intersection of cognitive science and inclusive design leading to the area that this topic lies in

seeks to develop impactful solutions for dyslexic readers. Dyslexia affects approximately 780 million people worldwide (around 10%), making it one of the most common learning disabilities (Brighter Strides ABA, 2024, para. 2).

Specific problem scope: Reading difficulties for dyslexic individuals stem from the huge gap between the scientific research done in detecting various subtypes of dyslexia (for example: (Borsting et al., 1996) and (Tzouveli et al. 2008)) and the assistive technology (Zakopoulou et al., 2017) that dyslexic readers use in their everyday life. On the one hand, there are four commonly known subtypes of dyslexic reading; Surface dyslexia, Phonological Dyslexia, Dysphonemesia and Deep Dyslexia (Borsting et al., 1996). On the other, many digital tools which have been created for dyslexic readers, fail to adequately support the cognitive processing needs of a dyslexic reader as they are viewed as a homogenised group with one problem (Borsting et al., 1996), which is not the case. This report mainly investigates how this gap can be bridged by developing design interventions with a dyslexic-centric perspective. Specifically, it examines how digital tools can enhance cognitive perception (the process through which the brain interprets the presented stimuli and it includes how individuals process the written language) thereby improving the experience of the reader. This resulted in the concept of a digital reading tool, the ReQuest app, which was developed to bridge this gap.

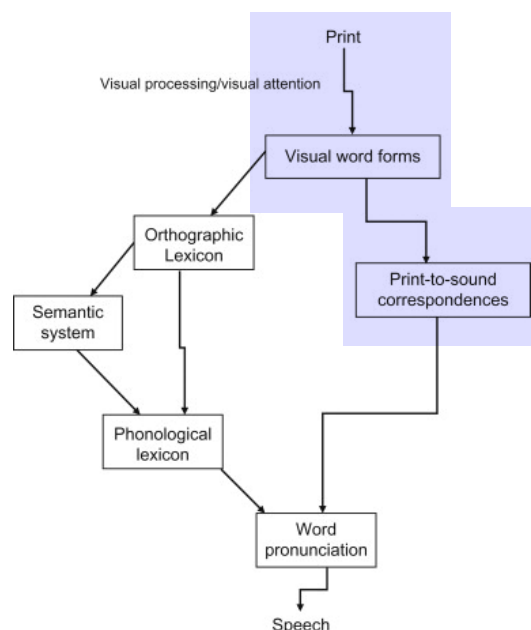


Figure 2: Figure from (Coslett & Turkeltaub, 2016), page 792, showcasing reading and speaking cognitive perception in people. The highlighted section indicates the part that affected for reading in dyslexics.

Novel approach: The significance of this research lies in its potential to develop accessible solutions for dyslexic readers, a population that has been overlooked in assistive technology development. This is discussed in Chapter - 1 in more detail. By examining the interaction between assistive technologies and dyslexic reading processes, this study advances the field of inclusive design within cognitive science and digital reading, offering insights that contribute to more effective and tailored interventions.

The report is split into 8 sections and structured as follows: Chapter - 1: dives into the research findings, including subtypes of dyslexia and existing assistive technology. Chapter - 2: defines the design goal and problem statement. It discusses the insights from interviews conducted with experts and dyslexic readers and delves into the development of personas. Chapter - 3: details the creation and results of a cognitive test designed to investigate dyslexic reading patterns. Chapter - 4: outlines the ideas generated and evaluates them. Chapter - 5: delves into the development of the concept concerning technical functionality and the experience design of the proposed solution. Chapter - 6: showcases the testing process and user insights. Chapter - 7: is a round of iteration that focuses on the feedback provided by dyslexic readers. Chapter - 8: discusses and reflects on the contributions, limitations and personal development through the course of this thesis. The report then concludes with an overview and future scope. Finally, the Appendix and References provide supplementary materials for this report.

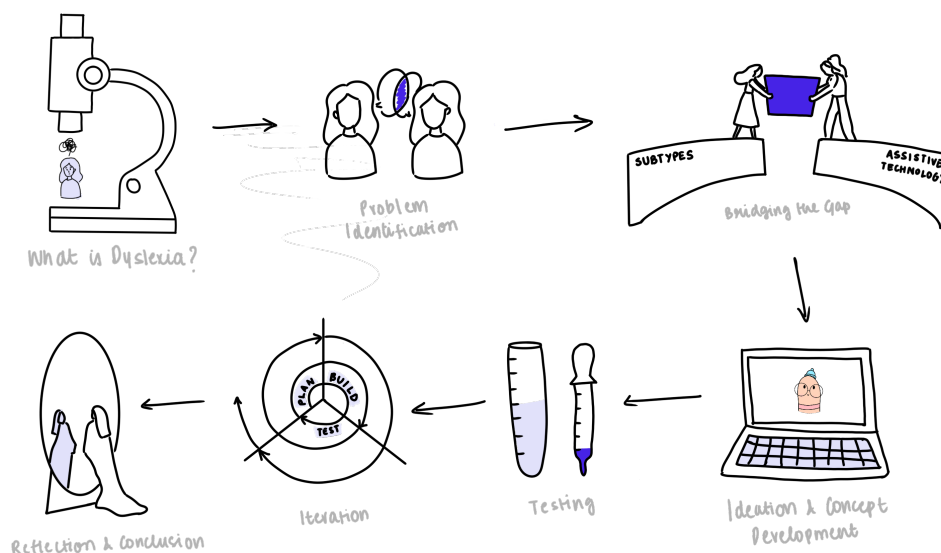


Figure 3: Visual representation of the contents of this report which highlights my process

Before diving into the rest of this report I would like to establish my overarching and main goals with this project in a few points:

Overarching aim 1: Employ dyslexic-centric practices that focus on the user group and their needs exclusively. Here dyslexic-centric means keeping the dyslexic reader user group as the point of focus and building a solution around their needs.

Overarching aim 2: The KB and I share the vision of increased digital accessibility for the general public using the Online Bibliotheek. In this thesis, the dyslexic user group is being considered, which may uncover broader accessibility challenges.

Design goal: Design a [digital assistive tool](#) that [improves the reading experience of dyslexic readers](#) so that they can [comprehend e-books in an immersive/engaging manner](#).

CHAPTER - 1
What is Dyslexia?
A Literature Review

Chapter - 1: What is Dyslexia?

In this Chapter, I explore the literature on dyslexic subtypes and assistive technology. (Hudson et al., 2007) defines dyslexia as 'dys' meaning difficult and 'lexia' meaning reading or words; this literally means difficulty with words. However, the current research on dyslexia suggests that dyslexia is a dynamic condition for every individual (Augur, 1992 as cited in Rutledge, 2002). It is best described as a specific difficulty in learning. While one might face a challenge with reading, another might find it difficult to write (dysgraphia) and a third individual might have difficulty in performing mathematical calculations (dyscalculia) (ibid). In this research, I am going to focus on the reading aspect of dyslexia. This directly relates to my design goal, as stated in the introduction, of creating an immersive and engaging experience around dyslexic reading which in turn might help in enhanced cognitive perception. It is important to understand the unique needs of dyslexic people, especially for a public forum such as a library like the KB, because (i) the number of dyslexic primary and secondary school pupils has increased decelerations in recent years with secondary schools dyslexic rate at 14% in The Netherlands (Inspectie van het Onderwijs, 2019, p. 2) and (ii) according to dyslexia expert Beve Hornsby, about one in ten people have the condition of dyslexia to some degree (Hornsby, 1984 as cited in Rutledge, 2002). The Dutch in particular have around a 1 in 20 dyslexia rate, which amounts to about 900,000 people (PSM Innovations, 2022).

Research Findings through Literature Review

Following a month of focused literature-based research, four key factors have emerged as particularly significant in understanding dyslexic reading. These four aspects build the foundation of this thesis and help understand the experience of reading with dyslexia at a grass root level:

- 1. Subtypes of dyslexia:** As mentioned above, there are different types of dyslexia, but within the reading type there are subtype types that point to specific deficits and deepen one's insight into dyslexic reading. It is further explained in this Chapter.
- 2. Assistive technology:** Dyslexic readers tend to use various

forms of assistive technology to make their reading experience better in terms of both comprehension and enjoyment. In this and the following Chapter, a rich analysis has been done to uncover these technologies and understand their usage in context.

3. Pseudo-word testing: Research points out that pseudo-word testing; i.e. reading and speaking tests with non-words, is a great way to detect dyslexic subtypes. This has been discussed in Chapter - 3 in more detail.

4. Eye-tracking: Lastly, eye-tracking has also proved to be an effective way of testing for dyslexia. In this thesis, I use it to identify subtypes and have it support the pseudo-word testing, by looking at gaze patterns. Chapter - 5 explores this process in detail.

In this Chapter I will discuss the first two points in depth. The third and fourth points can be found in Chapter - 5.

Subtypes of Dyslexia

Dyslexia in reading occurs largely due to an abnormal magnocellular pathway processing (Borsting et al., 1996). This essentially means that the part of the brain responsible for processing (cognition) visual information quickly (perception) does not function effectively which leads to inaccuracies in recognising text while reading. (Boder, 1971 as cited in Borsting et al., 1996) also identified three subtypes of dyslexia; namely, (i) Dyslexia: difficulty in recognising whole words as visual patterns and associating them with their corresponding auditory forms (for example: 'laf' instead of 'laugh'), (ii) Dysphonics: struggling to apply letter-sound relationships when reading unfamiliar words and may also substitute words with similar meanings while reading (for example: 'anaple' instead of 'abandon') and (iii) Dysphonics: a condition that combines deficits in both visual word recognition and phonetic decoding skills. The first two subtypes are commonly known as, Surface Dyslexia and Deep Dyslexia. There is another subtype of dyslexia that is key to understanding the scope of this research and it is called Phonological Dyslexia. Phonological Dyslexia is characterised by significant difficulty in reading non-words and unfamiliar words while overall word-reading ability remains relatively strong (for example: 'topple' instead of 'table') (Tree & Kay, 2006).

These different subtypes are essential to understand so that the potential design intervention can create a meaningful impact. Currently, dyslexic individuals are treated as a homogenous group with one problem, this is far from reality. While there are some common types and subtypes of dyslexia, it affects every individual quite differently. In reading, dyslexia may lead to semantic substitutions (for example; 'home' and 'house'), mismatch of visual and auditory gestalts (for example; 'laf' for 'laugh'), confusing a letter for another (for example; reading 'd' as 'p'), dancing letters, etc. (Borsting et al., 1996). This shows the diversity of deficits in dyslexia which ultimately calls for diversity in solutions.

As a result of neurodiversity, there are various subtypes of dyslexia that stem from particular deficits, but for the scope of this research, I am considering the four subtypes that have been discussed above.

Existing Assistive Technology

Assistive technology (AT) encompasses a wide range of services and devices that support individuals with disabilities in performing daily tasks, facilitating communication, education, employment, etc. Ultimately, AT aims to promote greater independence and improve overall quality of life (Dell, Newton & Petroff, 2016 as cited in Dawson et al., 2019). There are many assistive technologies in the reading space that cater to a multitude of user groups like low vision and blind individuals, dyslexic readers, people with cognitive disabilities, elderly people and so on. Each of these user groups also has its own specific needs from such technologies, for example, low vision and blind individuals primarily make use of text-to-speech software to navigate through daily life and read books. The main aim of these ATs would be to provide a system or product that helps individuals with learning. This could be in the form of a software program, hardware wearables etc. (What Is AT? - Assistive Technology Industry Association, n.d.).

iLearnRW is a great example when it comes to the technology that has put dyslexic users at the forefront. It is a game-based software that integrates learning activities while focusing on the language areas most challenging for children with dyslexia and

provides an engaging and motivating experience (Zakopoulou et al., 2017). Another example is the AGENT-DYSL approach which combines speech recognition and image recognition to provide personalised support to the user (Tzouveli et al., 2008).

Some tools are not directly designed with the dyslexic reader in mind but prove as an extendable solution that can cater to dyslexics as well. For example, the Thorium Reader (Figures 4 & 5) and VoiceOver on Apple are widely used by many neurodivergent groups. A couple of well-known issues with these technologies are that they are complicated to use and they can be used only for specific types of texts. In Chapter - 2 I go on to interview a few dyslexic AT users, one of them; Interviewee A, pointed out that due to these issues, they prefer using only one type of device, an iPad, as this is the best way for them to use VoiceOver.

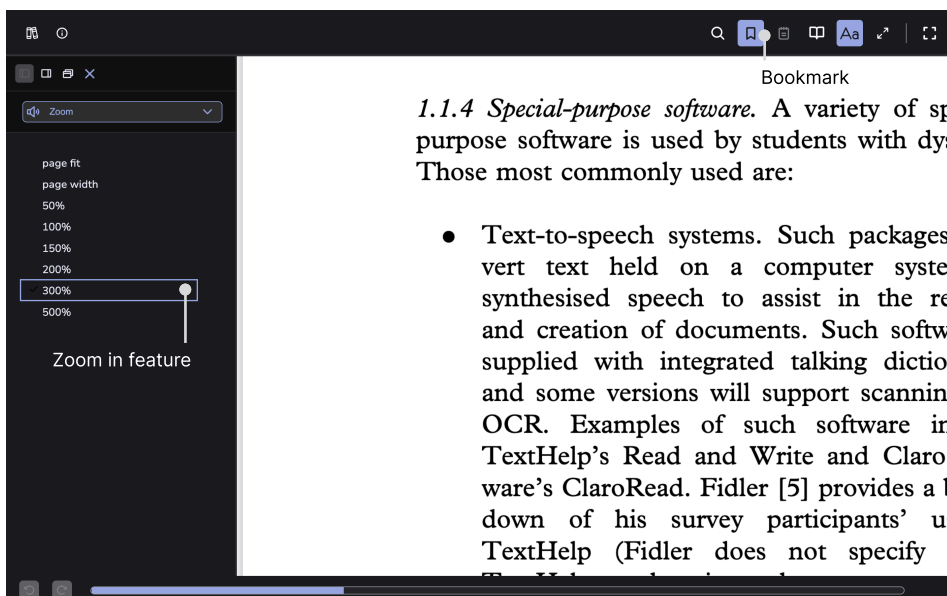


Figure 4: Thorium reader engaged with the zoom feature and bookmark feature

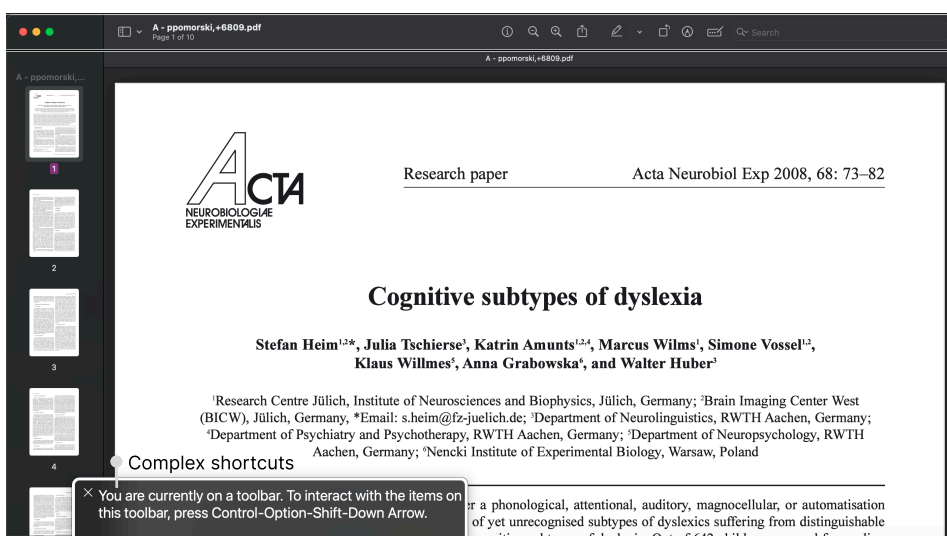


Figure 5: VoiceOver being used on a PDF file

The unique quality of an assistive technology is that it has the power to enable the user in tasks like reading and writing which improves their experience positively. However, what the dyslexic assistive technology space lacks is a connection with the subtypes of dyslexia. This is due to the homogenisation of the dyslexic reader group and employing a 'one-size-fits-all' approach. To bridge the gap between the subtypes of dyslexia and assistive technology, it is essential to first identify the specific reading challenges of each subtype. This can be seen in a criteria list formulated on pages 53 & 54, Figure 22 of Chapter - 4. By understanding these distinct difficulties, technology can be better tailored to meet the diverse cognitive needs of dyslexic readers. When assistive tools fail to address these variations, users often struggle with ineffective support, leading to frustration and disengagement; this was a key finding from the pre-test moderated questionnaire that I conducted during testing can be found under 'Benefits' point 2. As a result, rather than facilitating reading, these tools can become an additional source of frustration, discouraging users from engaging with them effectively. To map these positives and negatives, a tech repository has been made to collect the features that are relevant to dyslexic readers from different assistive technologies that are commonly used and to understand which parts they struggle with the most (Figure 6).

Most technologies designed to support dyslexic readers are built by adding features to existing tools that were originally made for other user groups. My aim, as mentioned in the introduction, is to take a 'dyslexic-centric approach' so that dyslexic readers are not the afterthought in the development of technology that they use on a daily basis. To elaborate on the various assistive technologies that have been developed, I have created a table below that identifies the purpose of the tool, its relation to dyslexic readers and my personal insights on it. These tools have individual components that are essential to dyslexic readers. I have gathered inspiration from these tools to help analyse the needs of my user group and dive into their condition in depth.

The technologies in the following table (Figure 6) have been numbered from 1 - 10 and will be referred to later.

Assistive Technology Repository				
Name of assistive technology	What does it do?	Primary element for dyslexia	My insights on it	Links
<p>1</p> <p>Accessibility on Apple Devices</p>	<p>It helps customise your apple devices in ways that work best for you with features for vision, hearing, mobility, speech, and cognitive accessibility—whether you need them temporarily or on an ongoing basis.</p>	<p>VoiceOver, Safari Reader, Predictive Text, Guided Access, Zoom etc.</p>	<p>Although the amount of tools are large, they are all independent and don't work in all contexts; for example the Safari reader which helps increase font size and change fonts is applicable only for the safari browser. The predictive text feature is only for keyboards that are on a touch screen and do not apply to laptops. VoiceOver is fairly difficult to employ, it takes some time and knowledge of the different terminologies to have it exactly right so it takes sometime with experimentation to enable it properly.</p>	<ul style="list-style-type: none"> https://support.apple.com/en-sa/guide/iphone/iph3e2e4367/ios#:~:text=Or%20make%20text%20bigger%2C%20zoom,you%20can't%20see%20them. https://dystech.com.au/learning-difficulties/10-accessibility-features-for-dyslexics-on-apple-devices/
<p>2</p> <p>Thorium Reader</p>	<p>It seems to be a bit more inclusive in terms of technology that it can adapt with - Thorium Reader is the EPUB reader of choice for Windows 10 and 11, MacOS and Linux. This EDRLab application is in constant development and aims at becoming a reference for accessing EPUB 3 publications in reflow or fixed-layout format, audiobooks and visual narratives, PDF documents and DAISY 2.02 and 3 accessible ebooks, LCP protected or not.</p>	<p>Screen readers like JAWS, NVDA, Narrator and Voiceover. Other accessibility features include support for high-contrast, customisable font (including dyslexia font), colour themes, text size and Text To Speech (TTS) read aloud.</p> <p>Radium component - open source to build reading software but with your own UI</p>	<p>Thorium has a good overall functionality. There seems to be a lack of flexibility as to which documents can and cannot be used in it, this makes users want a more extendable tool.</p>	<p>https://thorium.edrlab.org/en/</p>
<p>3</p> <p>Read&Write</p>	<p>Read&Write offers a range of powerful support tools to help you gain confidence with reading, writing, studying and research, including:</p> <ul style="list-style-type: none"> • Text-to-speech • Text and picture dictionaries • Word prediction • Collect highlights from text in documents • Summarise text on web pages to remove ads and other copy that can be distracting 	<p>This tool has not been designed for dyslexic reading in particular and caters more to boosting reading and writing confidence.</p>	<p>The application seems to have more a few key aspects of dyslexic assistive technology, but reviews by users suggests that there are also many issues that "it gets in the way".</p>	<p>https://chromewebstore.google.com/detail/readwrite-for-google-chrome/inoeonmfajpbkmdafoankkfajkcpghd</p>
<p>4</p> <p>NaturalReader</p>	<p>NaturalReader converts any text, PDF, image, webpage and physical book into natural-sounding audio featuring the newest and highest AI voice technology. There are also features such as voice cloning to other languages which can be quite impactful for an international audience.</p>	<p>While it is not designed only for dyslexic individuals, they are still in the fore-front of this tool; "NaturalReader is designed to make reading more accessible for individuals with dyslexia, ADHD and other reading-based learning differences."</p>	<p>This technology is quite revolutionary and deeply appreciated by dyslexic and normal readers as they are looking for a more human like experience in this technologically advanced world.</p>	<p>https://www.naturalreaders.com</p>
<p>5</p> <p>Lexia Learning</p>	<p>Lexia provides science of reading-based solutions that support every student and educator. With a comprehensive suite of professional learning, curriculum, and embedded assessment solutions, we help schools connect educator knowledge with practical classroom instruction to accelerate literacy gains.</p>	<p>While this tool is not focussed on providing solutions to the dyslexic user group, they have a system of personalised learning that is essential to provide user-centric experiences and help dyslexic readers as well.</p>	<p>I think that the aspect of personalisation is key to a good user experience for the dyslexic user group in particular.</p>	<p>https://www.lexialearning.com/products/</p>
<p>6</p> <p>Nessy</p>	<p>At Nessy we are best known as advocates for children with dyslexia around the globe. But the Nessy programs are not only for dyslexia. Nessy is widely used for whole class, phonics, math, typing and early reading instruction. Nessy collaborates with some of the world's leading academics, and follows the Science of Reading, to ensure our programs are based upon proven research. Our goal is to provide effective learning to all children, at an affordable cost.</p>	<p>Nessy is focussed on dyslexic children in five aspects; understanding the condition, how can Nessy help?, testing and screening, related difficulties and free learning resources.</p>	<p>What I liked most about Nessy is that although they are not a digital platform, they have studied the dyslexic user group to support them with relevant learning materials. They have done this by splitting the users into different age groups and providing different methods of learning like phonetic sound cards and e-books.</p>	<p>https://www.nessy.com/en-us</p>

TTS (main tech here is OCR which is Optical Character Recognition and it basically converts different types of documents (such as scanned paper documents, PDFs, or images captured by a camera) into editable and searchable text which can then be read aloud)

Multi-sensory tools

<p>Highlighting</p>	<p>Immersive Reader (by Microsoft)</p> <p>7</p>	<p>It can be activated in the Microsoft word document from the header. Support reading and writing by using Immersive Reader to customise how word documents appear while you read and edit. Immersive Reader provides options for a comfortable and easy to process experience by allowing you to listen to the text read aloud or adjust how text appears by modifying spacing, colour and more.</p>	<p>It is more of an accessibility addition that has been made and does not solely focus on dyslexic individuals.</p>	<p>This tool is mostly used to read text aloud, but it does have other features like line spacing, breaking syllables etc. which are quite essential for dyslexic reading.</p>	<p>https://support.microsoft.com/en-us/office/use-immersive-reader-in-word-a857949f-c91e-4c97-977c-a4efcaf9b3c1</p>
<p>Fonts and typography</p>	<p>OpenDyslexic</p> <p>8</p>	<p>OpenDyslexic is a typeface designed against some common symptoms of dyslexia.</p>	<p>Letters have heavy weighted bottoms to indicate direction. You are able to quickly figure out which part of the letter is down which aids in recognising the correct letter, and sometimes helps to keep your brain from rotating them around. 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.</p>	<p>This is a font that has been created with a focus on dyslexic readers therefore it caters to them quite effectively. But through my interviews in Chapter - 2, I discover that this font is not preferred by all dyslexic individuals, they rather look for simple fonts like Arial.</p>	<p>https://opendyslexic.org</p>
	<p>Lexend</p> <p>9</p>	<p>In 1999, as an educational therapist, Dr. Bonnie Shaver-Troup, working with clients, began observing that reading issues masked the individual's true capability and intelligence. In 2000, Bonnie theorized that reading performance would improve through use of:</p> <ol style="list-style-type: none"> 1. A sans-serif font to reduce cognitive noise 2. Expanded scaling to improve potential for character recognition 3. Hyper-expansion of character spacing, which creates a greater lag time and reduces potential crowding and masking effects <p>These changes led to the development of seven specially-designed fonts, which create an immediate improvement in reading performance.</p>	<p>This is another font that can be seen as malleable with it's context.</p>	<p>It is not designed solely for dyslexia but it may be able to make an impact here as well.</p>	<p>https://www.lexend.com</p>
<p>Artificial Intelligence</p>	<p>ChatGPT</p> <p>10</p>	<p>ChatGPT is a form of generative AI a tool that lets users enter prompts to receive humanlike images, text or videos that are created by AI.</p>	<p>This tool is mainly used for its personalised and conversational nature.</p>	<p>It is not designed solely for dyslexia but more dyslexic readers are use it to write and make summaries of difficult text.</p>	<p>https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://chatgpt.com/&ved=2ahUKewFhOfa0dKNAxXj0wIHHZ3ZB64QFn0ECawQAQ&usq=AOvVaw29vbCnS_7PDD4xupasoOfg</p>

Figure 6: Various assistive technologies and their functions

As defined on page 12, AT can be defined as a system or product that helps individuals with learning. This can be done through software and hardware integrations. In this analysis, I explore how ATs can be offered to the user in different software formats for an improved reading experience. These technologies can be categorised into three main sectors (Dawson et al., 2018):

1. An operating system of a computer or mobile phone which supports readers when they are reading with that particular device. For example, Accessibility or VoiceOver only work on Apple devices as it is integrated into a specific operating system. Dyslexic users can benefit from this to an extent but they are not the primary user group.
2. Applications like the Thorium reader can be created as a generic e-reading application that caters to the cause of accessibility. Again, this is not specific for dyslexic readers but for a wider audience but dyslexic individuals can benefit from them. Applications like iLearnRW are created solely with the dyslexic reader in mind. The AGENT-DYSL approach is another way of catering to the personalisation that the dyslexic reader requires with a scientific outlook. I will take aspects from this is this sector for this thesis.
3. Extensions for web browsers similar to the Lean Library application (widely used in TU Delft) so that the user can carry the tool with them across platforms. I will also use this type of web plugin design in the end result. Therefore, it will be a combination of points 2 and 3.

Connecting Subtypes and Assistive Technology

In the following Chapters of this report, I discuss the link that I created between subtype detection and the relevant assistive technology (Figure 7). These connections matter because when assistive technologies fail, dyslexic readers can feel discouraged and disengaged, sometimes giving up on reading entirely. Therefore, it is essential that they have an experience that immerses them in the act of reading. My approach consists of the following elements:

1. In Chapter - 2, the dyslexic readers are interviewed and they share the technologies that they use while reading. They also elaborated on their specific reading difficulties, which I connected to the corresponding subtype. This was my first way of bridging the gap.

2. In Chapter - 3, a cognitive test was created in the form of a survey to analyse if pseudo-word testing is an effective way of detecting subtypes.
3. As elaborated in Chapter - 5, eye-tracking also proved to be an optimal method of subtype detection.
4. The refined concept in Chapter - 4 (Figure 22) showcases a table that connects the subtype to its deficits and further to the fitting assistive technology.

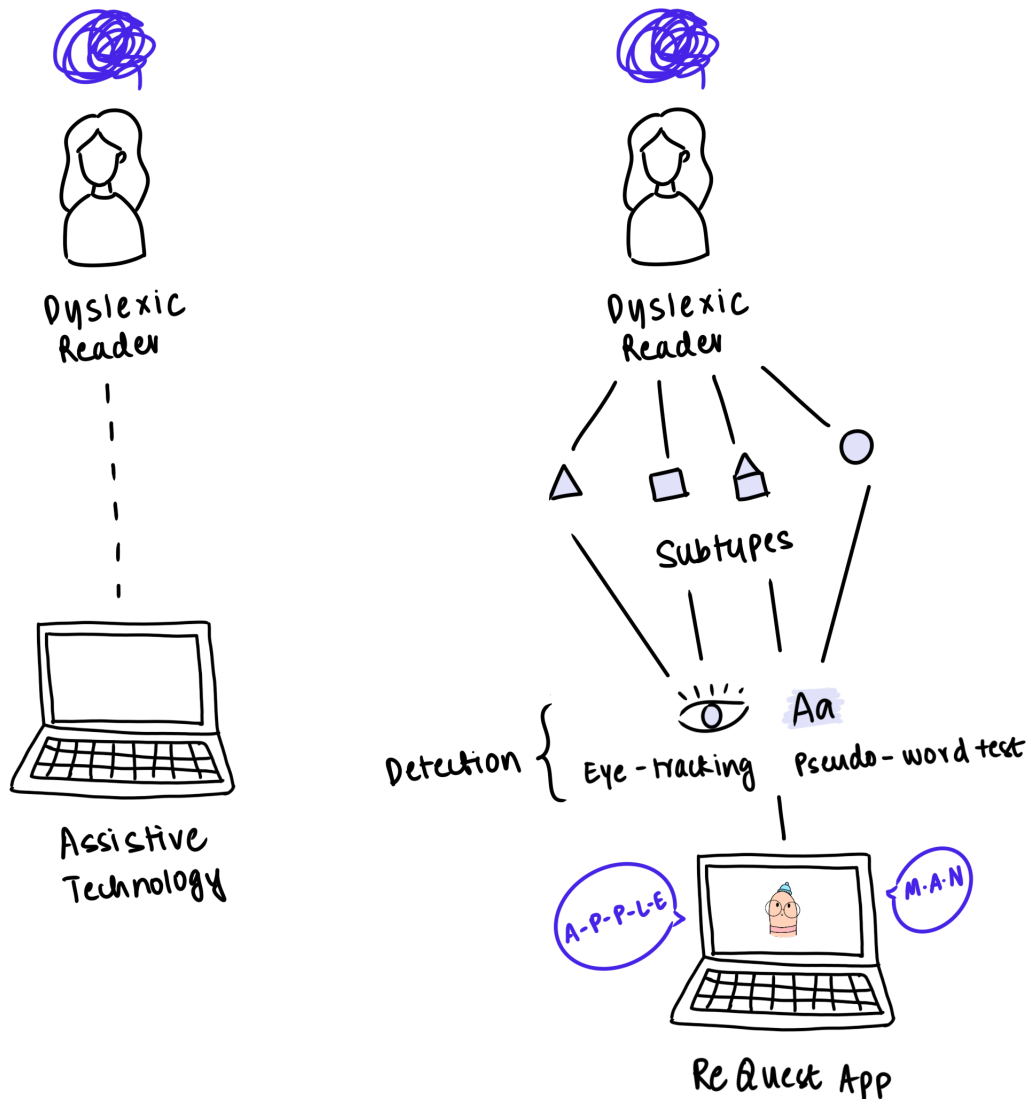


Figure 7: Current method of connecting dyslexic readers to assistive technology (L) vs. my process of connecting dyslexic readers to their subtypes and then corresponding assistive technologies for better results (R)

CHAPTER - 2

Problem Identification

Uncovering the Gaps to Define the Way Forward

Chapter - 2: Problem Identification

Understanding the core challenges faced by dyslexic readers is important for developing effective solutions. Therefore, this Chapter explores the next stage of research, which focuses on the difficulties encountered by dyslexic readers through real-life experiences. By interviewing the user group and experts in the field I was able to gain insight into their perspective and experiences. Then, I go on to examine six 'stories of dyslexia'. Through articles and blogs, first-hand insights were gained into the struggles and coping strategies of dyslexic readers. These narratives helped shape personas, which serve as a representative user group, allowing me to empathise with their diverse demographics, goals and frustrations. Further, research questions to be answered through the course of this thesis, problem statement and design goal were formulated.

Research Questions

To align with the central aim of this thesis, enhancing the experience for dyslexic readers through inclusive design, I formulated research questions to guide my inquiry. These questions reflect the core challenges explored in the thesis: the disconnect between dyslexia subtypes and current assistive technologies, the varied needs of dyslexic readers, and the role of digital platforms like the Online Bibliotheek in providing effective reading support. To narrow down my scope for this thesis I have three research questions. These questions are of three types:

1. Relational questions, which examine the relationship between different variables in the study.
2. Remedy questions, which are about finding a solution to a specified problem based on previous research.
3. Design questions, which is an effective policy or an effective type of question with a particular goal in mind.

(Guide on how to write your research, Methodology Shop. (n.d.). Universiteit Twente)

Based on these three types of questions, my 2 research questions and 1 sub-question are:

1. How can the gap between dyslexic subtypes and existing

assistive technology be bridged so that dyslexic readers can have a smooth e-book reading experience? (1)

- Further, how can subtypes be used to recommend specific and better-fitting assistive technology to dyslexic readers? (2)

2. What features can the Online Bibliotheek incorporate to make the e-books on the platform more dyslexic reader friendly? (3)

These questions were framed to anticipate the outcome of this thesis. They were answered through the course of the design process and the collated results can be found in Chapter - 8.

Problem Statement

From the findings so far, it was evident that there was a lack of connection between subtypes and assistive technology. Due to this, the needs of dyslexic readers are often not fully addressed, leading to a frustrating reading experience. To frame a problem statement around this issue, the 5Ws framework was used to understand each aspect of the scope of this project.

1. What is the problem?

The gap between the dyslexia subtypes detection and assistive technology.

1. Who is affected by the problem?

Dyslexic readers.

1. Where does the problem occur?

In most digital texts including the Online Bibliotheek.

1. When does the problem occur?

The problem mainly occurs while reading.

1. Why does the problem occur? **Why** is it important?

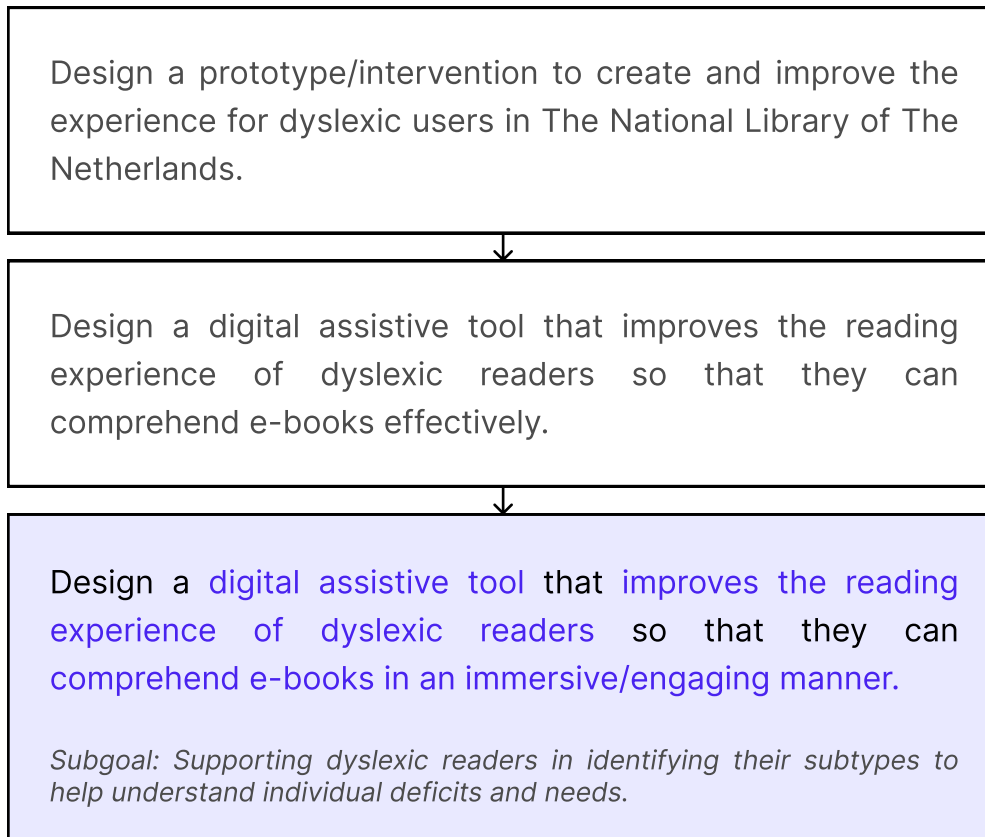
It occurs due to the lack of focus on dyslexic readers when designing assistive technology. It is important to help them read more efficiently and effectively.

Therefore the final problem statement is:

There is a **lack of research and focus on the needs of the dyslexic reader community**, particularly on the integration of **dyslexia subtype detection** for assistive technologies that support digital text reading, such as **e-books from the Online Bibliotheek** of KB.

Design Goal

The following design goal was framed to discuss the potential solution, the effect that it creates, the intended user group and the interaction vision. This was a way to reframe the problem statement into an actionable aim. This design goal evolved over time in the following way:



Insights from Interviews

Through the literature review on subtypes of dyslexia and the existing assistive technology, I was able to identify the gap that exists between dyslexic subtype detection and assistive technology. To address this gap, I conducted an interview study that investigates the activities of dyslexic readers. By interviewing dyslexic readers and experts in the field I gained deeper insights into the user group, uncovered pain points, identified trends, enhanced empathy and explored context-specific information. With this form of primary research, I aim to understand what kind of assistive technology dyslexic users incorporate in their daily lives, how they expect it to function and how aware they are of their subtype.

Interview Setup

1. Sample: I conducted five interviews in total; three dyslexic

readers and 2 experts in dyslexic readers were interviewed.

2. Procedure:

The interview was conducted in a semi-structured setup, wherein a few questions were written down as a guide, but the follow-ups were built on the responses given by the interviewees and were more conversational in nature.

All the questions were guided by the literature research conducted before the interviews. The questions were mainly framed to have the interviewee reflect on their current experience and point out the parts that they struggle with.

- With my previous knowledge from Chapter - 1, I was aware about the different ATs and their key features. Therefore, when a user spoke of specific technologies, I asked them to give me a demo and dive deep into their own journeys with reading. This helped identify any gaps that they face and proved as a way to recollect their experience with AT.
- My probing techniques were to clarify, ask for a demo of the assistive technology if needed as well as echo and summarise the responses of the interviewees to ensure that I comprehended their experiences appropriately. All of these techniques were employed to
- Additionally, with the given knowledge of subtypes of dyslexia from before, I asked them where they think they might lie in the spectrum to bring in their hypothesis as well. I did this by introducing the four subtypes and listing a few reading deficits that correspond to it.

3. Results: The results of the interviews are put into clusters based on the key themes that I observed. This was a way for me to extract the commonalities between all the interviews.

Dyslexic Readers - Analysis

Through the secondary research I found a lot of academic information to the question 'What is dyslexia?', but, to understand the mindset of a real person's experience it was crucial to speak with the user group directly. I interviewed three dyslexic readers and analysed the findings in two ways; first, by diving deep into each of their responses to showcase that every person with dyslexia is like a fingerprint, they have their unique struggles and experiences; second, I discuss the results through a thematic analysis to highlight the common discrepancies that dyslexic readers face with assistive technology. For the sake of anonymity

I will be replacing pronouns like 'he/she' with 'they'. Below are my insights from each interviewee:

1. Interviewee A

Interviewee A uses Apple's Accessibility setting (point 1 in Figure 6) on their iPad to read documents (Figure 8), as a laptop does not allow them to select text freely with their fingers. But it was still "quite a hustle" to use this technology. They expressed the need for a simple and smart solution that is compatible in multiple contexts. They usually use the Voice Over (text-to-speech) software with highlighting of words to follow along as the main issue they have with reading is presumption. They end up assuming what a sentence might mean before reading each individual word, which can lead to misinterpretation of the text. Additional features that they find important are alternate meanings, pausing and playing from any part of the text, increasing the speed of speech, detecting the structure of the document and having an overview of the text rather than isolating words and blurring out the rest of the text.

The voice and accent of the software should be according to the language in the text as this also plays a huge role in their experience. They recalled that the robotic voice of text-to-speech ruined the essence of an audiobook previously. The Open Dyslexic font claims to make reading more accessible for dyslexic readers but Interviewee A finds it ineffective, which says that dyslexia does not have a one-size-fits-all solution. Every person's dyslexia varies depending on many variable factors and cannot use the same solutions.

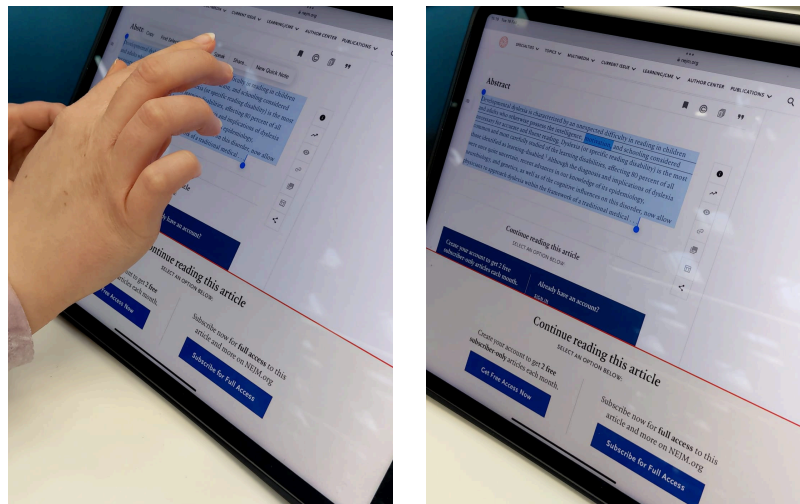


Figure 8: Interviewee A showing a demo of the Apple Accessibility VoiceOver feature on their iPad. (Left) Selecting the text and clicking on the 'speak' pop-up. (Right) The voice playing with corresponding words being highlighted

2. Interviewee B

When asked to reflect on their experience with reading, interviewee B said that they mainly face issues with spelling; for example 'd' and 'p' look similar. They use e-book readers to help with text and mostly use the highlighting features and make notes to better comprehend the content. They moved to The Netherlands at a young age so language also might have played a role in the development of dyslexia. They said that words like 'people' are mostly read as 'pee-op-luh' which is a more phonetic way to remember it.

Interviewee B also pointed out that they "have beef with audio because it is not fast enough" and goes on to say that assistive technology should adapt to the user's needs but be simple enough to use. They also see a lot of value in personalisation and something that they can use in multiple contexts like PDFs, presentations, webpages etc.

1. Interviewee C

Interviewee C said that they have an impoverishment of phonological awareness due to which letters dance around when they try to read. They also sometimes tend to forget the names of movies for example, which shows a lapse in memory. Their dyslexia is more intense when compared to the other interviewees since she makes adjustments in her daily life due to dyslexia. They do not drive because of a slower response time (quick judgment calls between left and right take a longer time for example) and since the roads have an abundance of stimuli it overwhelms them. They mentioned that they mostly use AI to write and read and I hypothesise that this is due to the personalised experience that AI can offer to its users. They also said that there is usually a lot of shame associated with being dyslexic and this creates frustration and struggle as a child. They definitely feel that investigating subtypes is important; "You feel more seen with a subgroup". They also felt it is important to view dyslexia as neurodiversity rather than an impairment.

Similar to interviewee B, interviewee C also brought up language and said that it plays a huge role. English is a second language to them and they also mentioned that some dyslexic friends of her's found Dutch easier than English and vice-versa.

Experts on Dyslexic Reading - Analysis

1. Interviewee D

Interviewee D is a dyslexic writer who has done research into dyslexic reading and published books on it as well. They do not use any assistive technology on their own but they face issues with writing (dysgraphia) rather than reading. They prefer real books to e-books but feel that the read-aloud function and enlarging letters are useful to many. "What I like the most is highlighting words as it is reading aloud; it helps children to build vocabulary and make word patterns better, and then they tend to switch off read aloud". They also emphasised that since everyone has their own challenges, personalisation is essential.

They also recommended making a simple solution with minimal features so that users are not confused. They also brought my attention to the fact that practising one's problem area every day can be quite useful in building skills. For example, interviewee D writes a little every day to keep in touch with it. "It took me half a year to get back to writing when I did not practice regularly on my world trip".

1. Interviewee E

This interviewee is the creator of many interventions for dyslexic readers. They view dyslexic reading from the lens of neuroscience which is very similar to the approach that I am taking for this project. We mainly spoke about the role of specific technologies in dyslexic reading as they have the expertise in developing similar technology. They brought my attention towards agile methods (user-centred design) as they are more groundbreaking and a real impact can be made to help dyslexic readers. We discussed the impact that metadata creation within texts can have in improving the quality of the text-to-speech software output. "For example, text-to-speech is able to adapt the accent if language is known in the metadata and has been flagged. In the sentence 'Have you ever gone to Paris?' the word 'Paris' can be tagged as French which can lead to automatic detection while reading aloud".

They also pointed to the value of changing the format of text to better suit dyslexic reading. Breaking down a sentence, simplifying it, and presenting it to the user is quite effective in

their research and work in the field. “If you want to help dyslexic people read rather than big fonts try more spacing, long sentences are another issue then they forget the beginning of the sentences. If you split the sentence effectively it already helps them form three different images.” One difficulty with this formatting is that it is currently done with a manual method to make each sentence shorter and we needed a way to do it automatically. This will take a long time for entire collections in larger contexts like the KB.

Results and Discussion

To investigate the results of the interviews, the reflective thematic analysis method was utilised (Braun et al., 2019; Brulé, 2021). Under this technique, the semantic and constructionist approaches were combined to report what people say and how they perceive their situation respectively. The following results were obtained based on the key themes (Figure 9) that were identified in the interviews:

1. Assistive Technology

- (i) Text-to-speech is highly frustrating to use because it has primarily been designed for low-vision or blind individuals. Therefore, the extra assistance is not appreciated (Hu and Downie, 2024).
- (ii) The speed of the text is too slow for them since they are reading along, so having a personalised speed is essential.
- (iii) The accent and language settings do not get automatically set based on the context.
- (iv) When paused most readers start reading from the top again, it also does not scan out irrelevant information.

1. Fonts and letters

- (i) Dyslexic-friendly fonts are not everyone’s cup of tea. (2/3 interviewees do not find them useful)
- (ii) Enlarging letters is something that helps a few people.
- (iii) Highlighting is an important feature to have.

1. Personalisation: As mentioned before, everyone’s dyslexia is very different, therefore, it is essential to have a tool that can adapt to their personal needs.

2. Adaptability: Users are seeking smart assistive technology that can understand their needs in specific contexts. This can potentially be done by picking up specific context cues as discussed with interviewee D (for example: attaching

metadata tags to specific words in a different language).

5. Presence: The potential intervention needs to be usable in multiple digital contexts.

6. Simplification: Almost all the interviewees mentioned that they are looking for a solution that is simple and does not overwhelm them.

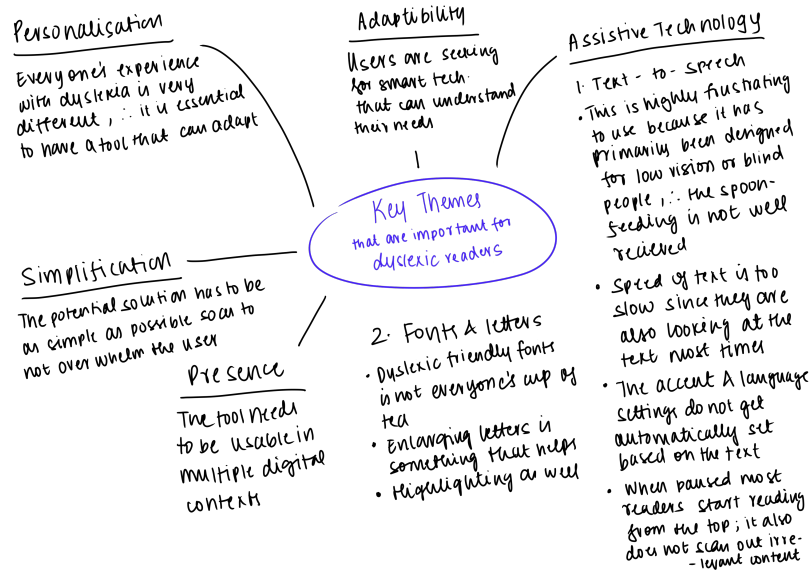


Figure 9: Mind map of insights derived from thematic analysis from interviews

Stories of dyslexia

Through the secondary and primary research, there was clarity on what the dyslexic user needs from a design intervention. But, there were still a few missing links that I wanted to address before framing the research questions. I located six inspiring and emotionally powerful stories that helped re-align the purpose of this research. I extracted some insightful points from each story and put them in a key themes framework similar to the interview analysis.

1. My Story...or at least the bit that relates to Dyslexia by Alice Frendo (Frendo, (n.d.)).

Her mother used to come up with innovative techniques to teach her words for example, the shape of the word 'bed' looks like a bed. Although this method is not great for spelling-sound correspondences and people with phonological impairments it did help her read more easily. She would often remember people as "long name starting with A" which shows signs of surface dyslexia or dyslexia as seen in the primary research. She also exhibited dyscalculia (difficulty in performing mathematical calculations) as she says "I simply didn't know my times tables, I

couldn't do basic arithmetic in my head." The main issue was that even though she had supportive parents, the teaching staff around her could not recognise that dyslexia was a specific learning condition. She started to devise her own methods to bypass her dyslexia such as taping lectures and revisiting them on her own time, photocopying and highlighting articles, making mnemonics to remember citations etc. She strongly feels that the education system is not letting a dyslexic student reach their full potential simply due to the lack of awareness of literacy difficulties. Currently, she is a teacher who provides assistance to dyslexic children as she empathises with them and approaches them from a cognitive and psychological level.

2. Giving Voice to a Young Person's Dyslexia Journey by Sue Glader (Glader, 2022).

This story is about a very ambitious girl, Jennifer Smith. At 12 years old she wrote a book about her experience with dyslexia. Till the age of 9 she could not read at all, in fact she even said, "I would remember how to read an easy word like "the" on some days, and on other days I would forget". It was quite confusing and frustrating for her because she could not understand why she was unable to do what came so easily to her friends. She took special tutoring sessions called the Orton-Gillingham tutoring (a combination of visual, auditory and kinaesthetic teaching approaches used with great success on those with dyslexia). She found that she could read whole sentences but not recognise individual words; "I wasn't just reading the word "be," "at," or "it," but I could actually read whole sentences." From this statement, I hypothesis that she might have phonological dyslexia as she has trouble in deciphering each word individually. She also emphasises "Find out that you are more than just being able to read a book." She did a lot of outdoor activities like horseback riding, scuba diving etc. which boosted her self-confidence. She discovered that she was quite good at extracurriculars and even went on to earn a black belt in tae kwon do. Another important aspect that she brings up is the IEP - this is an Individual Education Plan/Program which is designed to guarantee that a child with a recognised disability attending an elementary or secondary school receives tailored instruction and necessary support services. The IEP is created collaboratively by a team of professionals from different educational fields, along with the child, their family, and/or designated advocates (What Is

an Individualised Education Plan? | AccessComputing, n.d.).

3. My Dyslexia Story - Sophie Jones (Jones, 2023).

Sophie was diagnosed as dyslexic at the age of 34 by an educational psychologist. She did not even think that was possible because she was working as a director of a FTSE100 company and had done her MBA. She brings up 3 main points in her article: (i) Think differently! She has been yelled at for her spelling mistakes at work and always had verbal disabilities therefore, people would make her do different tasks. This is something that she thought she could do on her own as well, performing in places where she was best. (ii) Prove them wrong.

As a 9-year-old her speaking abilities were lower than that of a 3-year-old. She quickly realised that there are two ways to proceed, accept it or try to prove people wrong and she chose the latter as being “an outsider” did not align with her vision of who she was. Finally, (iii) Taking action. She continued speech therapy and public speaking for a long time and made her own space in the world. “People that thought I was stupid, started to question their judgment of me. Turning things around on them.” A very important point that she highlights towards the end is that “It (dyslexia) gives you strengths in other areas of intelligences. Intelligence is not just the ability to read and write. Most dyslexics like me, think in 3D and achieve higher intelligence for visual awareness. Intelligence comes in different formats.”

1. Personal Story: The World Needs Dyslexia - Told by Lucien York (York, 2024).

Lucien York is a writer who was diagnosed with one of the highest levels of dyslexia. He says, “When I was about five or six years old, going to school in Nevis, it became more apparent that I struggled with reading, spelling, identifying words by sight, and focusing.” This indicates that he could have a combination of dyslexia (surface dyslexia) and dysphonics (deep dyslexia) which is dysphonics, which also explains why it is higher in intensity. He also had embarrassing events early on in his life which aggravated his claustrophobia and anxiety. It would even go to the extent of him blacking out when he was in a high-pressure situation. He feels that the testing procedure could have been explained better to make him feel safer at a young age. He was quickly drawn towards horseback riding and had the

opportunity to pursue it. It was pure joy when he was told that he was really good at it since he also heard words like lazy, dumb or stupid. Once he gained more self-confidence, he was willing to work on reading and provided him the affirmation that he required. He learnt how to read from the Bible and he found that when the words were sung, he could recite and remember them much better. He also enjoyed the old style of English in the Bible which made him want to try reading more and more till he finally could! "I see the world in a different way than people without dyslexia. It fuelled my determination to excel – and has made me powerful."

5. Dyslexia Stories: Claire Landry (Landry, 2021).

Claire had her dyslexia diagnosed and got her IEP (Individualised Education Plan) in primary school. Up until this happened she faced a lot of trouble doing basic reading in even contexts like playing Scrabble. She felt quite isolated because she was given "easier" reading material to catch up and was asked to practice during the summer and not be lazy. Her mother came up with an innovative method of crafting the letters by hand with clay or writing the letters in the sand on the beach. Although this did not help her much, it could be seen as a new way of interacting with text. In grade eight she had a resource teacher who gave her one-on-one attention and was like a personal coach. She was able to read much better with the personal attention that she was given and knew where she had to go when she wanted help. She also recalled that in primary school students would get stickers when they would do well in class and she never got any. Lastly, she was very good in sports baseball, volleyball and basketball which goes along with her academics. "I like to use a baseball analogy to describe my dyslexia; You are going to strike out, everyone does, but when you do you will pick yourself up and adjust for the next pitch." In her blog, she also gave a list of technology that helped her read with dyslexia.

1. Struggling with Dyslexia – Mark's Story (Mind Bath, 2023).

Mark speaks about his journey with dyslexia in the form of this blog. Much like the previous stories, he had a bad experience with reading at school. "If I was called out to read, uncontrollable fear/anxiety would rush through my body like a pressure pot ready to explode. I would much rather stand in front of a loaded gun than feel the embarrassment of openly struggling to my

peers.” He had two types of writing, one that he copied and one that he wrote on his own which was filled with nonsensical words. He had an issue with forming words phonetically which leads me to believe that his subtype might be phonological dyslexia. One incident in school set him back years and his confidence took a major hit. “The supply teacher noted to the whole class, “If you’re stuck on any words, please ask me and I’ll write them on the blackboard.” Of course, I got stuck on the word ‘man’. Too embarrassed to ask a classmate, I approached the supply teacher and asked if they could write “man’ on this piece of paper. At the top of her voice, she shouted, “Are you a complete moron?! You want me to write man?! Well here you go!”. She stood by the blackboard and began to write the word, slowly shouting “M!!!!!! A!!!!!! N!!!!!! Man! Now sit down, you idiot!” This incident made him conscious and he did not ask for any help after that. What helped him was finding keywords and memorising the letter combination like a phone number. He started working as a support worker where he took quick notes for his manager and then he was able to slowly move on to writing essays! He also took refuge in hands-on activities like sports. “I joined an athletics club when I was about 8 years old and found I had quite a talent for running. By the time I was 15, I was competing at a national level, training with the same coach that John Regis and Daley Thompson were trained by.” But he let go of his passion for running when his imagination went wild and he went for media training which involved not just speaking, but reading as well. He thought that he would get exposed in front of the whole world and so he moved on to other things. “ I’ve been a chef, locksmith, painter and decorator, croupier, bar work and even tried my hand at DJing. All very practical hands-on jobs that didn’t require too much reading or writing.”

Key themes that stand out from the stories:

Similar to the interviews a reflexive thematic analysis approach (Figure 10) was used to analyse the stories (Braun et al., 2019; Brulé, 2021).

1. Outdoor and hands-on activities are very well received by dyslexic individuals. They really excel at sports, painting and cooking for example as they do not require much reading and lessens the pressure on many of them to perform well.
2. The education system is usually failing them at key moments when they require specialised attention or when they need

guidance for their specific condition.

1. The internal struggle of a young dyslexic child who has yet to discover their condition is quite evident in these stories. They are overwhelmed and often pushed to try reading the traditional way as opposed to trying other methods. When they eventually do overcome or learn to read with their dyslexia it is because of a few things like learning through song, forming mnemonics, positive reinforcement, practical learning etc. Once they create strategies to read, they cope with their dyslexia on their own terms and feel more confident in reading.
2. Maybe some kind of positive reinforcement or encouraging mechanisms make a huge difference in the way dyslexic readers engage with reading as children, especially if 'normal' children receive stickers for example, and they do not.
3. Due to the nature of the subject, the stories were emotionally driven and commanded the attention of its reader. This was a great method to use in the 'empathise' phase as it really helped me understand the dyslexic reader user group better as I do not belong to it myself.
4. Lastly, the detection of dyslexia subtypes was not discussed in any of these stories. Although one story did mention a phonological deficit, none of them went into subtypes as a topic. From the context, they were also not informed about the different subtypes by their IEP or any other diagnosis. They only knew the exact issue they were facing based on which I made some hypotheses on what their subtype might be.

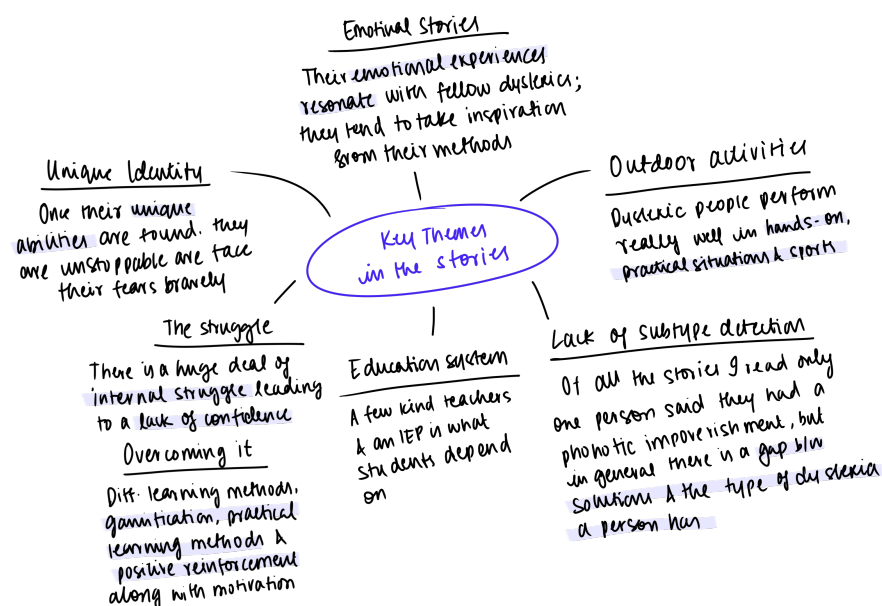


Figure 10: Mind map of insights derived from thematic analysis of stories

Personas

As a culmination of the primary and secondary research discussed in the report so far, these personas were created to better understand the demographics, needs and goals of a potential dyslexic reader who will use my design. The pain points and frustrations focus more on their relationship and experiences with reading and their goals highlight their expectations from assistive technology. Each subtype that I am going to focus on (Surface dyslexia, Deep dyslexia, Dysphonetic dyslexia and Phonological dyslexia) has one persona that isolates the specific problem that needs to be addressed. The KB also provided me with a set of personas that helped me create these final versions. The KB is doing extensive research on various accessible groups and identified four important subtypes as well. These subtypes coincidentally matched with my research as well. While I was considering only 3 subtypes at the beginning of this research, the Phonological Dyslexia group was added as there were a few similar deficits with Surface Dyslexia. Although I only had the scientific terms for the subtypes, these personas helped me find their colloquial names as well. The final personas we built from here to take my designs further (Figures 11 and 12 - following page). Meet Sharon, Mike, Devi and Daan!

1. Every time Sharon opens an academic paper, the walls of text feel like an unsolvable maze. She tries different tools, but none seem to fit, so she adapts, even when it costs her accuracy and time. All she wants is to read with ease and confidence, where understanding doesn't come at the cost of exhaustion.
2. Mike wants to fall back in love with stories, but the letters always play tricks—flipping, swapping, slowing him down. He listens to audiobooks but misses the feeling of being truly inside a story, word by word. With guidance and a visual rhythm, he hopes to rebuild his pace and reclaim the joy of reading.
3. Devi lights up in the kitchen, but written recipes feel like locked doors. Her mind needs soothing visuals and audio cues, not overwhelming text blocks. She dreams of skimming through instructions with fluid ease just enough to let her creativity flow freely.
4. For Daan, words often blur into associations that pull him off course - 'daughter' becomes 'sister', 'apple' becomes 'pear'.

"I end up replacing spellings of words based on sounds; for example, 'laugh' becomes 'laf'"



Sharon

Demographics

Age: 24 years

Occupation: Design master's student at TU Delft who has a passion for medical research

Pain points: Not being able to read the overwhelming amount of text on academic papers which leads to a feeling of distress and does not help with finishing tasks punctually - Dyseidetic or Surface Dyslexic.

Frustrations

- With assistive technology she struggles to find the right fit for her needs and tends to adjust with the way it functions.
- She finds it difficult to read a few words and so she ends up replacing with a familiar looking word which leads to learning incorrect information.

Goals

- She wants to comprehend the academic materials better with the help of any easy to use digital tool.
- She wants to be able to change the fonts and increase the sizes of letter in her text so that she can recognise words more easily.

"I sometimes replace words that look unfamiliar to me; like 'daughter' becomes 'sister'"



Daan

Demographics

Age: 30 years

Occupation: Director

Pain points: Mixing up words when it is unfamiliar with some other form of association; for example 'daugther' with 'sister' or 'apple' with 'pear' - Dysphonetics or Deep Dyslexia.

Frustrations

- Reading is a very exhausting activity for him since he has to use a lot of energy to comprehend the text deeply.
- Since reading is such a puzzling activity he am unable to maintain a certain pace and ends up taking too long.

Goals

- He wants to get quick over views of his scripts, for example when a story is pitched to him, or when a certain scene is to be shot the next day.
- He wants to have summaries of his text with audio so that he can ensure that he is comprehending the story correctly.

Figure 11: Persona of a Surface Dyslexic (L) and a Deep Dyslexic (R)

"I love watching videos over reading to learn new skills!"



Devi

Demographics

Age: 23 years

Occupation: Influencer

Pain points: Devi just recently discovered after her Bachelor's in food technology that she has a passion for cooking and wants to start an Instagram and Youtube space for it. She often needs to read recipe books and origin of ingredients but finds it difficult as she is unable to read huge chunks of text so she likes videos of recipes better - Dysphonic Dyslexia.

Frustrations

- She is unable to make both visual and auditory distinction between words.
- She usually finds it very difficult to read as her condition is at a higher intensity.
- She does not like the fact that learning to read is only done in one way when she reads better by singing or watching video which have a soothing audio in the background.

Goals

- She mainly wants a way to scan through the recipes without having to read every word.
- She wants to be able to read with some highlighting so that she can follow along.
- She wants to be able to change the font size.

"Did you mean 'topple' or 'table'? They both look the same to me"



Mike

Demographics

Age: 25 years

Occupation: Artist

Pain points: His dyslexic journey has been mainly about how he keeps mixing up 'b', 'd' and 'p'. He wants to start reading novels again but due to his condition sticks to audiobooks - Phonological Dyslexia.

Frustrations

- He ends up having to decipher each word individually so it takes a long time to read even a short passage.
- Sometimes he feels that audiobooks are not as immersive as reading a novel, even if it is digital, since the feeling and tone generated is more personal when he reads.

Goals

- He wants to start with a guided audiobook so that he is not completely lost and can develop his own pace of learning.
- He primarily wants his text to be highlighted as the audio plays so that he can follow along.

Figure 12: Persona of a Dysphonic Dyslexic (L) and a Phonological Dyslexic (R)

CHAPTER - 3
Bridging the Gap
A Cognitive Survey Study

Chapter - 3: Bridging the Gap

After framing the aim of this research and taking steps to empathise with the user group, the next step is to start bridging the gap between subtypes and assistive technologies. To do so, a cognitive test was created. This Chapter aims to analyse the effectiveness of the pseudo-word cognitive test. The goal of this test is to deduce what subtype of dyslexia one might have based on their ability to read a set of 12 pseudo-words (words that do not have any meaning but follow the semantics of a language). The survey was created as a pilot test and explored the reliability of such a test to detect subtypes, which is in turn used to recommend assistive technologies.

Cognitive Test - The Creation

To prepare this cognitive test I used Microsoft Forms as it has a 'read aloud' feature which can assist dyslexic users in reading the questions effectively. The test was structured in a total of 6 sections. Section 1: consent to participate, Section 2: demographic data collection which included; gender, age, occupation and highest educational degree (which might help me draw parallels with subtypes), Sections 3 and 4: subtype detection tests, Section 5: reflection on their reading experiences with respect to difficulty and language of the text and Section 6: potential results of the test.

From my previous understanding of what subtypes are in dyslexic research, I created a few pseudo-words with two main distinct semantic styles. In (Siegel & Ryan, 1989) a similar study with pseudo-words was created in order to analyse the manner in which a reading deficit plays a role in defining the characteristics of the disability. They further elaborate that, single-word and non-word reading is the purest measure of reading since the word cannot be comprehended by context cues. In the research words such as 'tash, chid, plen, etbom, and spong', in the format of a GFW Sound-Symbol Test which is a test that is designed to assess a child's auditory language comprehension by identifying their developmental level and diagnosing specific areas where they experience difficulties in understanding language (Brown, 1987).

First, two sets of words that follow phonetic rules and are a combination of consonants and vowels but are spelt irregularly, for example, 'mip' or 'driffical'. Second, two sets of words that are irregularly spelt but phonetically sound the same, for example, 'yaught' (instead of yacht). The reason for choosing these two semantic styles is to identify the difficult areas of reading from the primary and secondary research. Participants were asked to read both sets of words out loud and rank them from easiest to toughest (Figures 14 & 15). They were then asked to reflect on which set of words they found more difficult the first type (ex: mip) or the second type (ex: yaught).

Hypotheses

- **Subtype detection:** While this is not an official diagnosis by any means, based on research I hypothesise that difficulties with the first set of words can mean that one belongs to the first subtype (dyseidesia). Difficulties with the second set of words can mean that one belongs to the second subtype (dysphonetics) and problems with both sets of words can mean that one belongs to the third subtype (dysphoneidesia).
- **Language:** Almost all my participants have English as a second language and so they were asked about the differences in experience when reading in their first language vs. when reading in English. This test explores the preliminary effects of non-native English speakers or English as a second language on dyslexic reading in English.

Goals

- From this test, I hope to identify how these three subtypes can affect the experience of dyslexic reading.
- The current test might be able to determine which subtype is more common among young adults.
- This test aims to gather information on which parts of the text are especially difficult to read, for each specific subtype.

Cognitive Test - The Results

This cognitive test was sent in the form of an online survey and was completed by 21 people. To anonymise participants they will be referred to as P1, P2...P21. Through this survey, I aimed to

understand which differentiating factors can be used to predict dyslexic subtypes. The results of the test are as follows:

1. Demographic data: 65% of the test takers were female and 35% were male. The respondents fell within an age range of 22-56 years and 70% of them were students, there were also 3 engineers. There was a mix of Bachelor and Master students with 40% being Bachelor students.

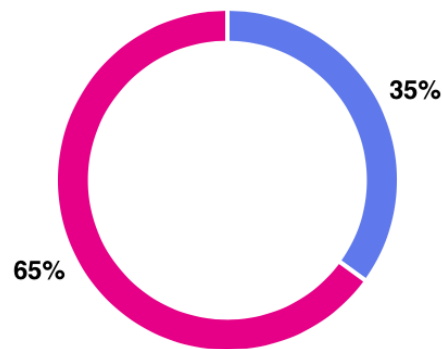


Figure 13: Pie chart of the gender distribution of participants who took the cognitive test

2. Subtype awareness: 81% of the respondents did not know which subtype they fall under and 14% answered that maybe they know. Only 1 person knew which subtype they fell under. 50% replied that they might have dyslexia or surface dyslexia. This leads me to believe that there is a lack of awareness in the understanding of what subtype an individual might have.

1. The subtype test 1: In the first set of the first subtype test, the word 'mip' was ranked first with 42.9% finding it difficult to read. It was followed by 'drim' and 'driffical'. 23.8% could read all the words equally well and 9.5% could not read any of the words. In the second set of words 'rif' was ranked first at 45% followed by 'I could read all of these words', 'gliven' and 'blint'. 5% of the respondents could not read all of the words. When asked to elaborate on what exact challenges they faced in reading these words, the main problem seemed to be "P8: I also have more problems with longer words." This also leads to assuming words or letters by the brain when they are long. This is a contrasting opinion because the test suggests that the shorter words are ranked higher than the longer words.

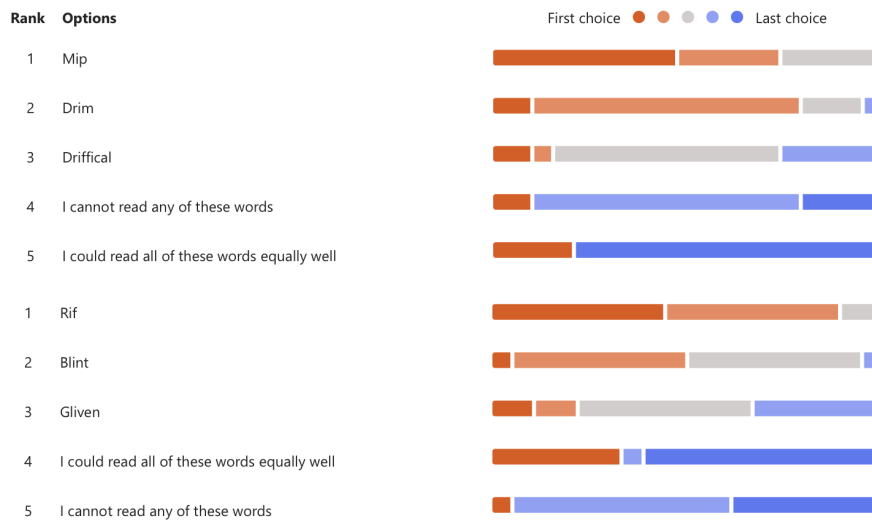


Figure 14: Pseudo-words that were presented in the first set

4. The subtype test 2: In the first set of the second subtype test, the words ‘yaught’ was ranked at first with 42.9% finding it difficult to read. It was followed by ‘wridge’ and ‘chighm’ rated equally at 19%. 9.5% could read all the words equally well as well as could not read any of the words. In the second set of words, ‘fawght’, ‘I could read all of these words’ and ‘I cannot read these words’ were ranked 20%. 30% rated ‘phaulk’ at the first spot. Lastly, 10% rated ‘thyslte’ in the first place, but interestingly, 55% rated it in second place. When asked to elaborate on what exact challenges they faced in reading these words, the main problem was the number of consonants and combinations “P6: Difficult combinations: ght, thys, chi and ghm”. One participant, P13, also mentioned that the letters seemed to be squeezed together and that difficulty in reading if the letter sounds the same in their head (p and h for example).

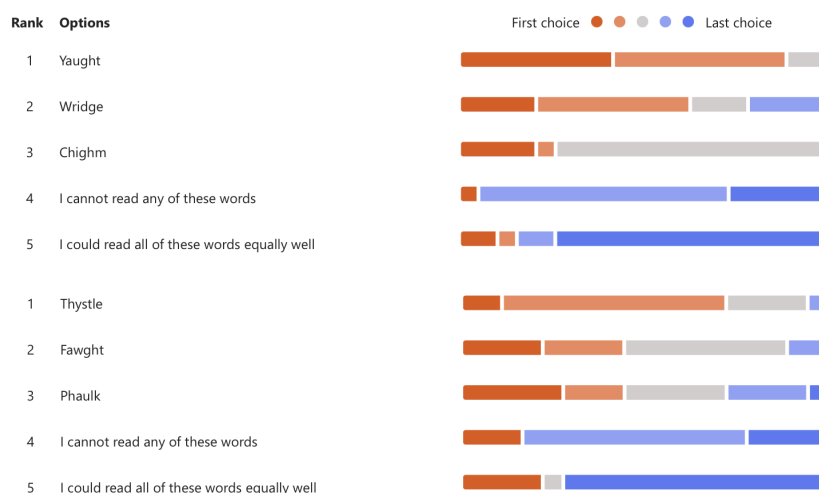


Figure 15: Pseudo-words that were presented in the second set

5. Comparing the results: When comparing the results of the 2 tests, 5% reported that they found the first set of words tough to read, 57% reported the second task was tougher and 10% reported that both sets were equally tough.

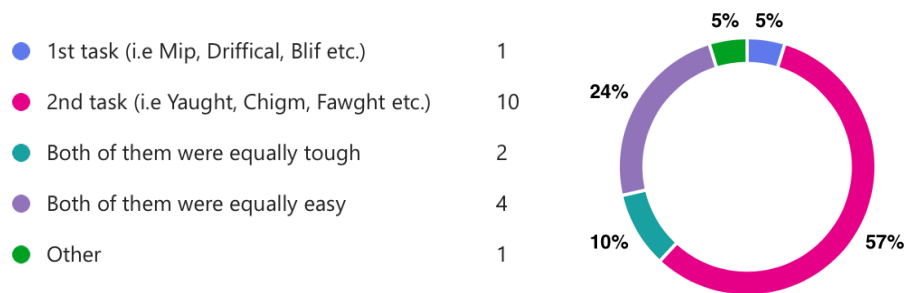


Figure 16: Analysis of which set of words were tougher for the participants

6. Language: When asked about their experience with English as a second language, a few people mentioned that it is easier to read in their first language when compared to a second language. But they do mention that: “P8: Reading is easier if I understand the words better, this is obviously the case in my first language.” They also replied; “P14: I have the feeling that when I read in English, the words I read and the meaning these have are less connected. This sometimes results in me reading phrases, without actually knowing what I read. So I need to concentrate more.” While some people find English difficult because they feel it is more phonetic, others say that both English and Dutch can feel equally tough to read since it is more about understanding the meaning of the word.

Discussion and Key Insights

- **Awareness:** There is limited awareness among dyslexic readers regarding the specific subtype of dyslexia they experience as only one participant knew their subtype. This lack of awareness may be one of the reasons that tailored support in assistive technologies which align with individual cognitive profiles are missing. The finding highlights the gap in detecting subtypes and the underlying way in which custom tools can be recommended to dyslexic readers.
- **Subtype detection:** By analysing the results (from points 3, 4 and 5), it appears that the majority of this group might belong to the second subtype (dysphonetics or deep dyslexia). While this is not a definitive diagnosis, the trends in this survey suggest a leaning toward this subtype. This offers a preliminary understanding that will inform the cognitive test in

Chapter - 5.

- **Pseudo-words:** The test also indicates that the shortest words (like 'mip') were ranked the toughest whereas participants say that they usually make mistakes in the longest words (from points 3 and 4). This did not match my expectations and was a new finding, since in the interviews most participants articulated that they find longer words to be tougher to read. This is something that survey takers mentioned as an additional comment as well, but the results of the ranking indicate that shorter words can also be difficult to comprehend. With the combination of letters being random, the participants could not make assumptions through context cues and were able to pinpoint their exact difficulties as illustrated in points 3 and 4.
- **Language:** It is quite evident that dyslexic readers require a strong understanding of what a word means in order to make sense of it while reading. They do make a few assumptions based on the context. Contrary to belief, English is quite a dense language and is not very phonetic when compared to other languages globally (Caravolas, 2005).

Iteration and Next Steps

While the current cognitive pseudo-word test has provided me with viable insights, in this section I plan some next steps to detect the subtype in a more dependable manner and refine the following version of the test.

The future iteration of the test can include:

1. A way to AB test which type of formats, fonts, typography etc are better suited to read, this will not only give me a quicker understanding of what they can read but it also represents a real scenario where they are expected to read rapidly.
2. The current test only included three subtypes. Including another subtype in the next version of the test (i.e. phonological dyslexia) is beneficial as it would allow for a more comprehensive classification.
3. The next version can be tested by a more diverse set of occupations as the current one primarily focuses on students.
4. The set of words can be alternated and randomised to potentially track their gaze and find insights into their eye movements.

CHAPTER - 4

Ideation

Translating Insights into Innovative Concepts

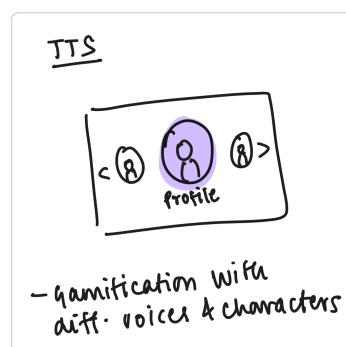
Chapter - 4: Ideation

To reiterate, my design goal is to “Design a digital assistive tool that improves the reading experience of dyslexic readers so that they can comprehend e-books in an immersive/engaging manner.” In this Chapter, I discuss ideation with the primary and secondary research elements (such as subtype detection through pseudo-word testing) in mind. The purpose of this phase is to generate relevant ideas that help bridge the gap between subtype detection and assistive technologies. The process of ideation started with a Crazy 8’s session which is a way of brainstorming individually. It is a rapid sketching activity that pushes individuals to generate eight distinct ideas within eight minutes. This method helped me generate basic ideas before selecting three ideas for a more focussed ideation. Then, through the process of evaluation, the strengths and weaknesses of each idea were mapped before refining them into concepts.

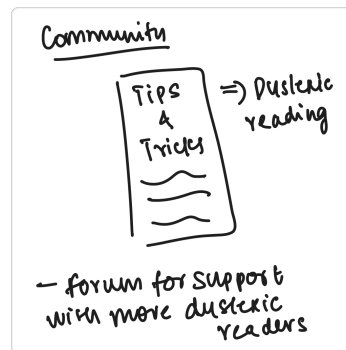
Crazy 8’s

The Crazy 8’s activity was done to spark some creativity and start converting rough thoughts into initial ideas. Generating brief, diverse and innovative ideas is a crucial step in the design process, and this method is an effective technique that fosters rapid creativity. The aim is to move beyond initial ideas and explore a diverse range of potential solutions to the challenge. The uniqueness of this method is that it can be used as an individual means of ideation (Core Method, n.d.). Below is a short description and sketches of the 8 ideas that were developed:

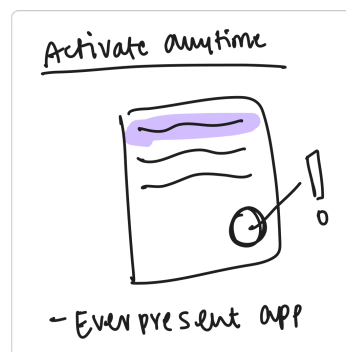
Idea 1: Gamification of text-to-speech software and modified voices to create a fun reading experience that removes the pressure from the activity of reading and could increase attention.



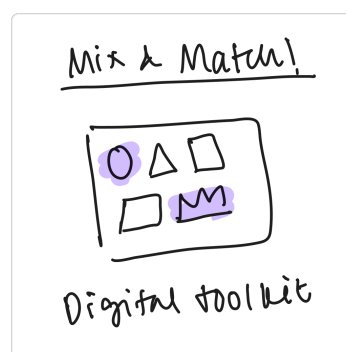
Idea 2: On speaking with dyslexic readers I found that they relate most to the experiences of fellow dyslexic individuals. The coping mechanisms and guidance they devise for each other are the most accurate. On these lines, a community of dyslexic readers exchanging tips and tricks to support each other could be created.



Idea 3: An ever-present application that can be activated at any point to engage a voice-over. The text also gets highlighted as the contents are read aloud.

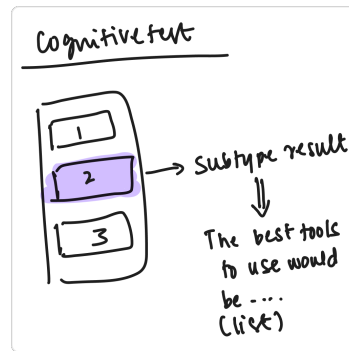


Idea 4: A digital tool kit that houses various technologies that dyslexic readers usually use. These technologies can be mixed and matched to give a customised tool kit to the user. As the different subtypes require different needs, the user has the autonomy to select what they require. For example, the tool kit might contain text-to-speech software, highlighting, thesaurus etc.

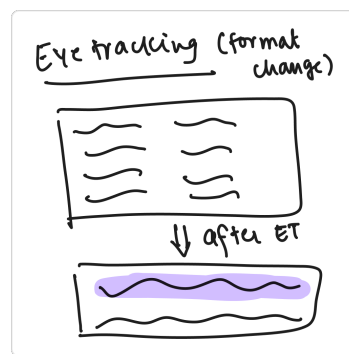


Idea 5: As an extension of the cognitive test discussed in Chapter

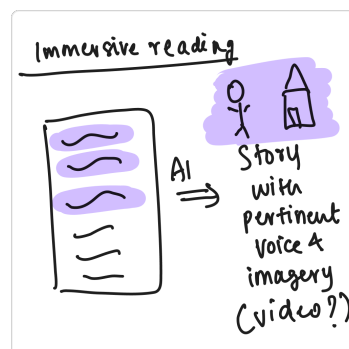
- 3, this idea is to make the cognitive tests more concrete and recommend the best tools for their particular subtype of dyslexia.



Idea 6: From the secondary research I found that the eye movements of dyslexic readers vary from normal readers (Borsting et al., 1996). Keeping this in mind, a potential idea is to map the patterns generated from each subtype and make changes in the format of the text based on the inputs from the eye tracker.

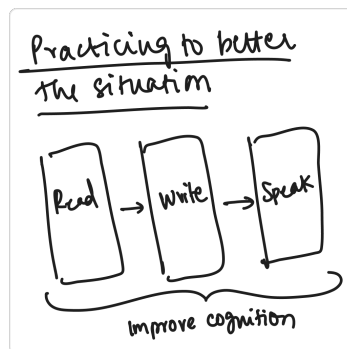


Idea 7: From my primary research I understand that dyslexic readers often use AI to read text aloud in a more human-like voice or even write emails. AI could also be used to give them a more interactive way of reading. Entering the e-book or text into an AI-powered solution to give an immersive solution by presenting it with the pertinent voice and imagery.



Idea 8: When I spoke to Interviewee D, they mentioned that one of the ways to cope with dyslexia is to practice the problem area every day. This has been rooted in evidence through academic researchers and medical practitioners as well. The idea here is to

curate an experience that walks the user through reading, writing and speaking assignments to help them practice. They can personalise the experience by focusing on areas that they need more help with (for example: reading).



Focused Ideation

From the Crazy 8's activity, it was evident that there are many points of intervention in the domain of dyslexic reading. Through the method of Morphological Analysis (Nayebi and Ruhe, 2015), a few of the ideas were combined to create more focused ideas that could potentially lead to valid concepts. Once these ideas were created they were evaluated with a Harris Profile.

The Digital Toolkit

This concept explores a toolkit that is customised based on the users' needs and their subtype. A cognitive test will be conducted in the beginning with the reader to deduce the dyslexic subtype and then offer a set of assistive technologies that are pertinent to their problem area in reading. The toolkit will house all the major tools that dyslexic readers usually use but only recommend the relevant ones to them based on their subtype. They can opt in and out of all the tools as per their preference, but the customised suggestion is made to efficiently simplify their experience. This is a combination of ideas 4 and 5 from the Crazy 8's.

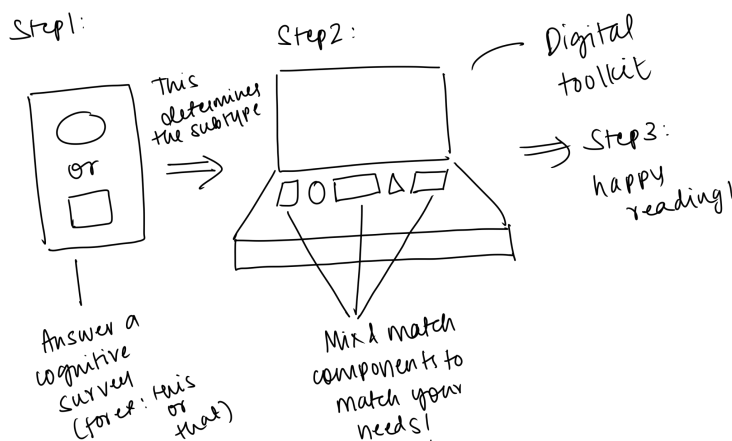


Figure 17: Sketch of the digital toolkit concept

Smart Assistant

As indicated before by interviewees and academic research, many kinds of assistive technologies are used in the process of dyslexic reading. This idea employs the results of the subtype test to detect the needs of the user in a smart manner (for example: visualising information or reading it aloud). When the user chooses any e-book, they can engage with an AI-powered assistant that starts with a cognitive test and further selects their reading goals. This entity will be ever-present and can be activated with the touch of a button. This is a combination of ideas 3, 5 and 7 from the Crazy 8's.

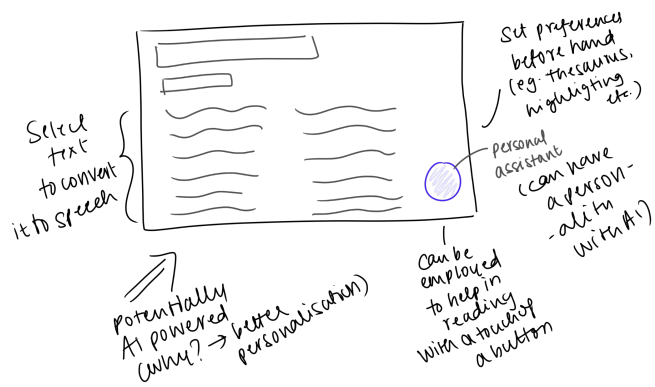


Figure 18: Sketch of the smart assistant concept

Reading Actively

The main idea behind this concept is to change the reader's state of mind by engaging them in an activity that they are good at either before, after or in between their reading session. It could also be a combination of all. Dyslexic people usually enjoy hands-on activities, so I hypothesise that they will feel better when they alternate reading with a more hands-on activity and make it experiential in nature. That could ultimately translate into a good reading experience. The concept can be customised based on a cognitive test conducted initially to discern the dyslexic subtype. This idea is inspired by idea 5 from the Crazy 8's and the stories of dyslexia (page 32, key theme point 1).

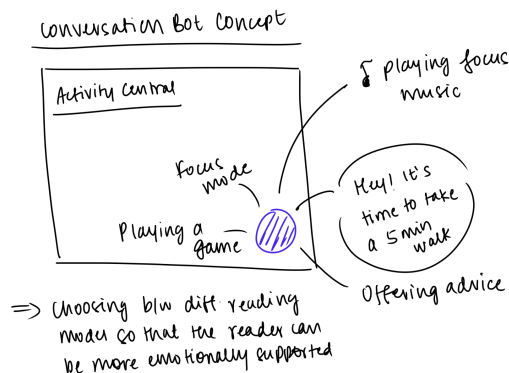


Figure 19: Sketch of the reading actively concept

Evaluation of Ideas

An evaluation was done on the focused ideas with a Harris Profile (Figure 20). This scoring helped me determine where each concept is lacking. Evaluating also reveals any assumptions that have been made in the course of the research which can affect the relevance of the final design. Additionally, catching any issues early on prevents time-intensive redesigns later. In the next section, a refined concept will be produced based on these criteria to create maximum impact. The criteria have been drawn from the key themes (stories and interviews) in this report. The word criteria inspired a connection between the evaluation and key themes.

The Harris Profile template I followed is from (Erasmus University Rotterdam, n.d.) and it is depicted as follows:

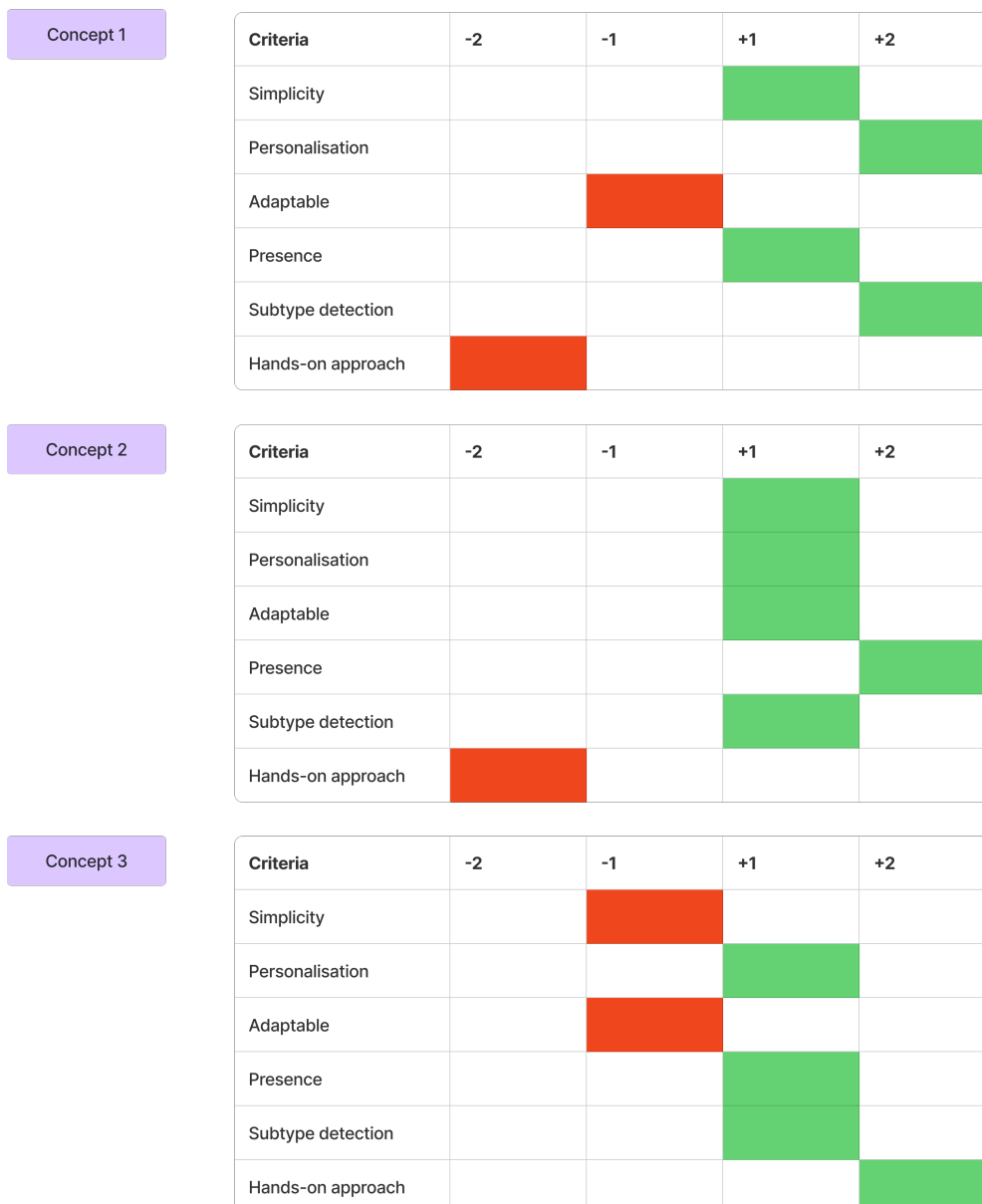


Figure 20: Harris Profile to evaluate the concepts

Refined Concept

Based on the Harris Profile it is clear that each idea has its own merits. Therefore, to create a comprehensive and rounded concept the method of Morphological Analysis (Nayebi and Ruhe, 2015) was once again used to combine the enriched parts of each idea. Although key decisions were driven by insights from the Harris Profile, the refinements were extracted from the qualitative criteria (for example: personalisation) to form a refined concept. In Figure 63, Chapter - 8, the criteria were weighed against the final designs to show how they were fulfilled. This concept has three main parts:

1. The cognitive test: This part mainly focuses on detecting the user's subtype (Figure 21). As illustrated in Chapter - 3, there is a gap between specific assistive technology for a particular subtype. This test will analyse the user's subtype through a series of cognitive tests that are yet to be decided. The test will potentially include, (i) an AB test to determine which format, fonts, text size and spacing the user prefers, (ii) an eye-tracking test to map the gaze of the user which can result in a custom text format, (iii) pseudo-word testing which is an extension of the work done in Chapter - 3 and (iv) setting personal preferences that the user has from previous experiences. The pseudo-word testing, eye-tracking and personal preferences were carried over to the final concept as these had scientific backing and prior testing setups.

Cognitive Test

~ What are some potential question types that can be asked?

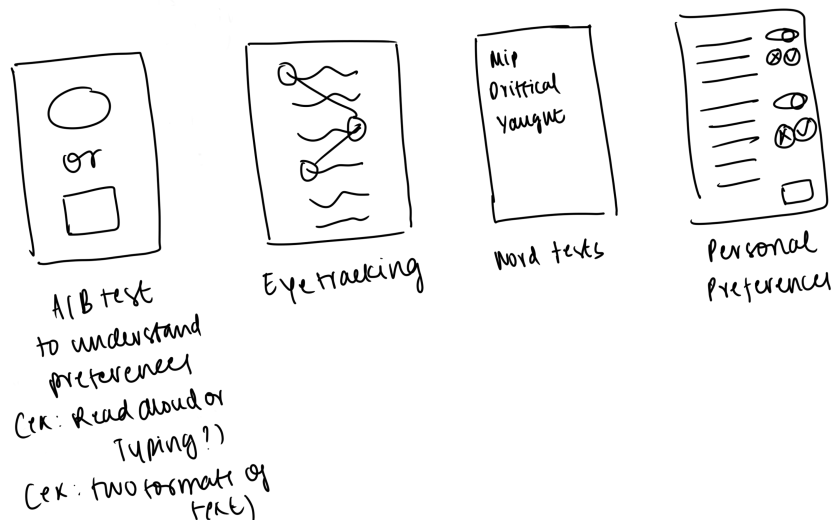




Figure 21: Sketch of the cognitive test part of the concept

Each dyslexic reader has their own set of strengths, weaknesses and tell-tale signs that they belong to a certain subtype. Due to this, they have specific ATs that are relevant to them. These have been derived from interviews, the stories and making direct connections, for example; deficits with unfamiliar words can be fixed with a thesaurus since it provides alternate meanings. Figure 22 (following pages) showcases the criteria for the four subtypes (Surface dyslexia, Deep dyslexia, Dysphoneidesia and Phonological Dyslexia) which will shape the cognitive test and help detect the user's subtype.

Subtype	What makes a person fall under a certain subtype?	Assistive tech that helps
<p>Dyseidnesia/Surface Dyslexia</p>	<p>Definition</p> <ul style="list-style-type: none"> Inability to read words with “irregular” or exceptional print-to-sound correspondences. <p>Potential problem area:</p> <ul style="list-style-type: none"> Phonetically irregular words (e.g., laugh, does, foreign) may not be decoded correctly (e.g., log for laugh). This occurs more often when words aren’t phonetic, such as “subtle” or “yacht” because they end up making a phonetic substitution there. Spelling errors often include phonetic equivalents (e.g., laf for laugh or duz for does). Misapplication of memorised phonetic rules may also lead to poor spelling, such as spelling “quite” as “kwright”. People with Surface Dyslexia may confuse letters that are visually similar (b and d, p and q) or words that can be reversed (par and rap), and skip letters or words when reading. <p>Strength:</p> <ul style="list-style-type: none"> In contrast, these patients perform well with words containing regular correspondences (e.g., state, hand, abdominal) as well as non-words (e.g., blape). <p>Attached problems:</p> <ul style="list-style-type: none"> Struggle to memorise sight words, and often have reduced reading ability in terms of speed, accuracy, and comprehension. 	<ol style="list-style-type: none"> Thesaurus - due to the visual confusion in letter identification Highlighting (single word or sentences) - to put focus on certain Formatting and sectioning of text into smaller chunks - to help with accuracy and comprehension (ex: increasing line height) Font and font size selection - to reduce visual error <p>Example of tools from Chapter - 1:</p> 
<p>Dysphonetics/Deep Dyslexia</p>	<p>Definition</p> <ul style="list-style-type: none"> Initially described as an intriguing but complex acquired dyslexia, the hallmark of which is the production of semantic errors in which a word related in meaning is substituted for the target word. <p>Potential problem area:</p> <ul style="list-style-type: none"> Difficulty using grapheme-phoneme relationships when encountering unfamiliar words and may also make semantic substitutions during reading (e.g., home for house). Thus, shown the word castle, a deep dyslexic may respond “knight”; presented with bird, the patient may respond “canary.” Additionally, their spelling errors are not adequate phonetic equivalents (e.g., anaple for abandon). Deep dyslexics also typically produce frequent “visual” errors (e.g., skate read as “scale”) and morphological errors in which a prefix or suffix is added, deleted, or substituted (e.g., scolded read as “scolds”; governor read as “government”). Reading of non-words, for example, is typically profoundly impaired. Nonword letter strings such as flig or churt frequently elicit “lexicalization” errors (e.g., flig read as “flag”). Deep dyslexics manifest particular difficulty in the reading of functors (a class of words that includes pronouns, prepositions, conjunctions, and interrogatives including that, which, they, because, under, etc.). The striking part of speech effect may be illustrated by the patient reported by Saffran and Marin (1977) who correctly read the word chrysanthemum but was unable to read the word the. Many errors to functors involve the substitution of a different functor (that read as “which”). Summary: First, the strikingly impaired performance in reading non-words and other tasks assessing phonologic function suggest that the ability to translate between print and sound is severely disrupted. Second, the presence of semantic errors and the effects of image-ability (a variable thought to influence processing at the level of semantics) is taken as evidence that these subjects also suffer from a semantic impairment. Finally, the production of visual errors suggests that these patients suffer from impairment in the visual word form system or in the processes mediating access of the stimulus to the visual word form system. A third potential account is that deep dyslexia derives from a post-semantic impairment <p>Strength:</p> <ul style="list-style-type: none"> Thus, words such as table, chair, ceiling, and buttercup, the referent of which is concrete or imageable, are read more successfully than words such as fate, destiny, wish, and universal, which denote abstract concepts. 	<ol style="list-style-type: none"> TTS - for better word recognition since reading of non-words is impaired and it will be a similar result for new words Font and font size selection - to reduce visual error <p>Example of tools from Chapter - 1:</p> 

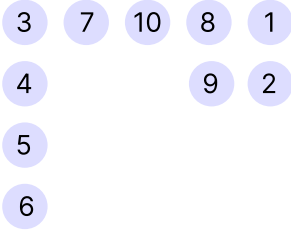
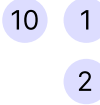
<p>Dysphonia Dyslexia</p>	<p>Definition</p> <ul style="list-style-type: none"> It is a combination of the two types of deficits in eidetic and phonetic coding skills. (Surface dyslexia + Deep dyslexia). <p>Potential problem area:</p> <ul style="list-style-type: none"> Probably some combination of the above. Dysphonic dyslexia represents the most severe type of dyslexia. 	<p>Combination of 1 and 2</p> <p>Example of tools from Chapter - 1:</p> 
<p>Phonological Dyslexia</p>	<p>Definition</p> <ul style="list-style-type: none"> Phonologic dyslexia is attributable to a selective deficit in the procedure translating between print and sound. This type of dyslexia is the most commonly thought of when someone mentions the word dyslexia. <p>Potential problem area:</p> <ul style="list-style-type: none"> People with Phonological Dyslexia have difficulty breaking words into their individual phonemes, or sounds. This makes sounding out words, blending sounds into complete words, and creating words using sounds, difficult. Good performance with real words suggests that the processes involved in normal "lexical" reading—that is, visual analysis, the visual word form system, semantics, and the phonological output lexicon - are at least relatively preserved. The impairment in nonword reading suggests that the print-to-sound translation procedure is disrupted. Some patients are relatively impaired in the reading of functors (or "little words"). Many errors in response to real words bear a visual similarity to the target word (e.g., topple read as "table"); errors with non-words typically involve the incorrect application of print to sound correspondences (e.g., stime read as "stim" [to rhyme with "him"]) or the substitution of a visually similar real word (e.g., flig read as "flag"). Standard classroom activities that can be difficult include substituting letters ("If we know that B-A-T says 'bat', what would happen if we replace the 'b' with a 'c'?"), decoding new or unknown words. Unusual, non-phonetic words, are not commonly spelled correctly. Syllables may be omitted, or extraneous letters included, when attempting spelling of unmemorised words. <p>Strength:</p> <ul style="list-style-type: none"> Patients with this disorder correctly read 85 - 95% of real words. Some patients with this disorder read all different types of words with equal facility. Therefore, they are likely to correctly pronounce orthographically irregular words such as colonel as words with standard print-to-sound correspondences such as administer. 	<p>Specialised dictionary - replacing with phonetic equivalent words</p> <p>TTS</p> <p>Example of tools from Chapter - 1:</p> 

Figure 22: Subtype detection criteria and relevant ATs. (Borsting et al., 1996), (Tree & Kay, 2006), (Coslett & Turkeltaub, 2016) and (NeuroHealth Arlington Heights, 2021)

2. The digital toolkit: Once the user has completed the subtype detection, the application (which houses multiple assistive technologies based on the most relevant ones to dyslexic readers) will curate a customised toolkit for them with the most relevant technology for their subtype (based on Figure 22). The user can then view their personal toolkit and also add any other technology that they deem fit which ensures their autonomy. The reason for using this method of building a toolkit is because it is quite a natural step from the pseudo-word testing in Chapter - 3 and step 1 in this section. As a user is provided with their subtype, it is also connected to the corresponding AT from Figure 22 as it contains specific ATs for particular deficits.

Digital Toolkit
 ~ Enabling tools that are most relevant for a certain subtype based on certain criteria that have been set beforehand
 (or parts of them)

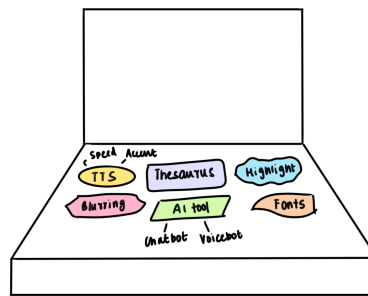


Figure 23: Sketch of the digital toolkit part of the concept

3. The usage: An ever-present button will appear on the right-hand corner of the screen when the application is active. As users mentioned the need for an ever-present tool in the interviews it is fitting for the toolkit to contract into a button that can adapt and be used in multiple contexts. Users can hover over it to view their top tools. They can also click on it to engage with the settings part of the application.

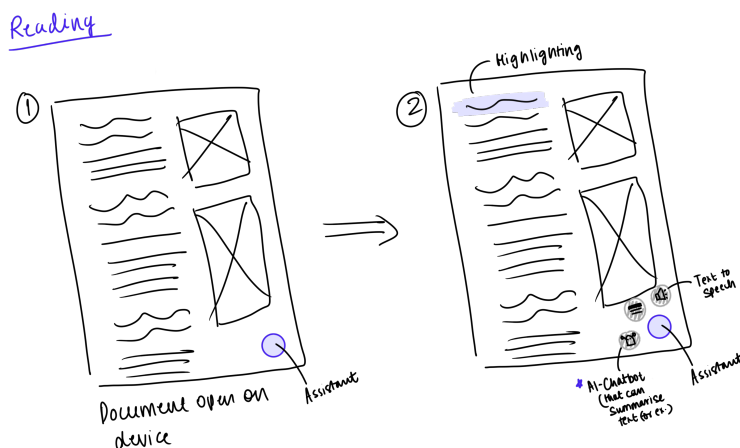


Figure 24: Sketch of the reading part of the concept

This design has been created with a dyslexic-centric approach. It not only simplifies the engagement with assistive technology it also personalises the experience to their specific needs. This is done in order to move away from a generalisation of dyslexia as a condition and focus more on providing the relevant technology to dyslexic readers. This concept looks into the main criteria derived from primary and secondary research; simplicity, personalisation, adaptability, presence, subtype detection and hands-on approach.

Below is the predicted **user journey** with the application:

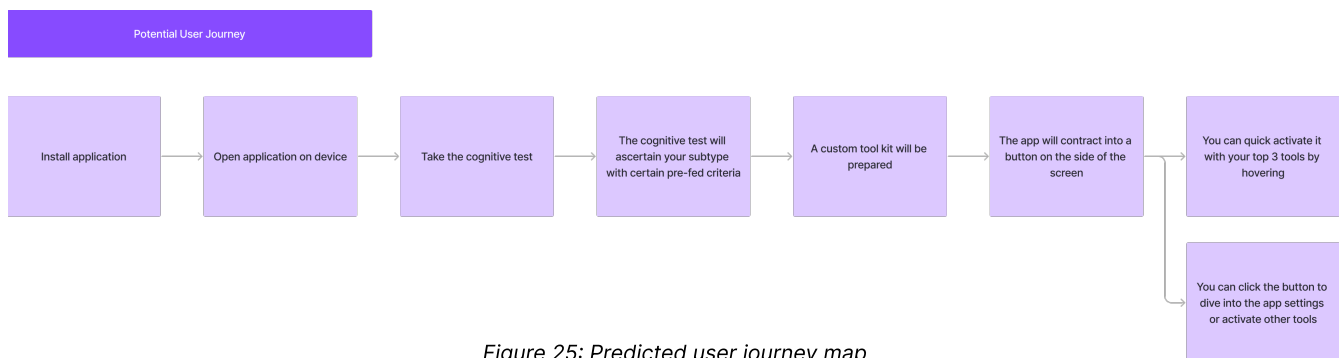


Figure 25: Predicted user journey map

CHAPTER - 5
Concept Development
Framing the Solution

Chapter - 5: Concept Development

In this Chapter, I focus on developing the refined concept further by enhancing elements of the concept from Chapter - 4. There are three technical building blocks; the cognitive test, preparing the toolkit and usage in context. This Chapter concentrates on understanding the operational aspects of the final application. Other processes like the interaction vision, mood boarding and designing the user interface (or UI) addressed the experience of the user. This led to the development of a well-rounded concept that took shape in the form of a digital Figma and Wix prototype.

Technical Functionality

The technical functionality of this concept has three components; a cognitive; test which is key in determining the user's subtype, preparing the toolkit; that matches a subtype and finally the usage of the product in context; i.e. an e-book or similar reading material.

Cognitive Test

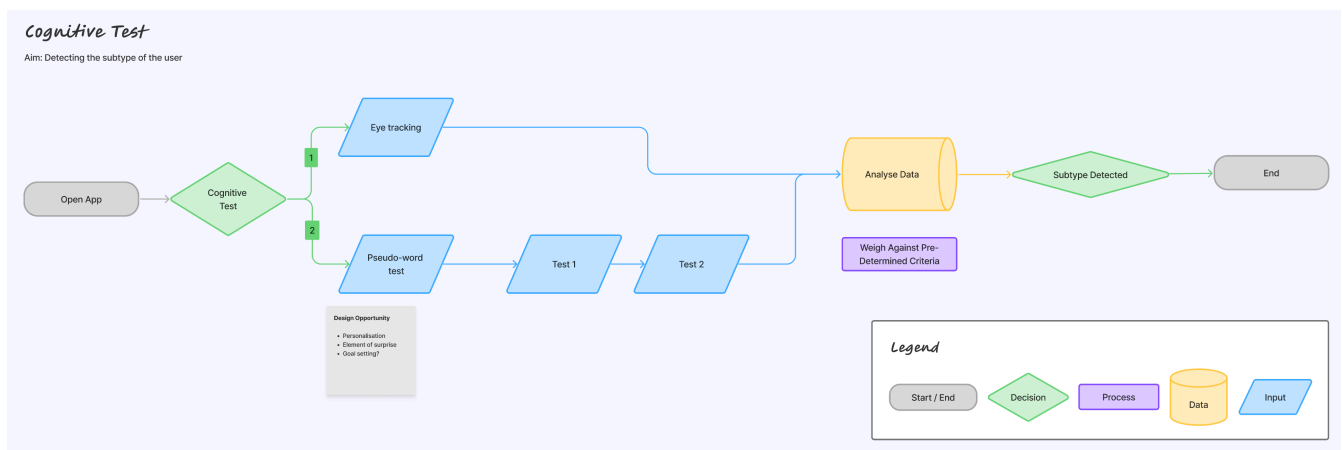


Figure 26: A flow chart of the cognitive testing process

This cognitive test was created with insights from the previous cognitive testing in Chapter - 3. This one time test is taken by users before they can create their toolkit. It is split into two parts, which were created to determine the user's dyslexic subtype.

1. Pseudo-word testing: In this section, there are 2 main types of testing (Figure 26).

a. Isolated word test - In the first test, four sets of three isolated words will be presented to the user which they were

asked to read aloud. While the first two sets are phonetic equivalents to existing words (for example: 'laugh' and 'laf'), the second two sets are non-phonetic in nature (ex: 'tash'). This was done in order to differentiate between the four subtypes. By definition (Appendix 5 and Chapter - 4), Surface and Phonological dyslexia have similar criteria with one difference the substitution; it is phonetic for surface and visual for phonological whereas, Deep dyslexics make non-phonetic substitutions to unfamiliar words.

As mentioned in Chapter - 3 (page 38), (Siegel & Ryan, 1989) conducted a similar study with pseudo-words to analyse the manner in which a reading deficit plays a role in defining the characteristics of the disability. They further elaborate that, single-word and non-word reading is the purest measure of reading since the word cannot be comprehended by context cues. From this research, words such as "tash, chid, plen, etbom, and spong" were also extracted and used for my cognitive test.

b. Context test - In this form of testing, the participant was asked to read through a short story and identify the eight hidden pseudo-words in a one-page text. (Takala & Kuusela, 2009) define literacy in two components; comprehension and fluent word recognition. They specifically state that deficits in word recognition can indicate dyslexia. Further, three theories (cerebellar deficit theory, magnocellular theory which contain visual, auditive theories and phonological theories were discussed and they speak about specific impairments in reading that relate to the subtypes as noted in this report in Chapter - 1 (page 11). This particular test can be used to study phonological coding and requires that the words are of two types similar to the isolated word test; resembling the phonotactics of the current language and non-words that are where the spellings not the used in the current language as well.

From (Takala & Kuusela, 2009) it is also evident that phonological issues in dyslexia can be identified by inserting pseudo-words into text. Four pages from The Jungle Tales of Tarzan was used with an addition of 65 pseudo-words to diagnose phonological processing. In this research, the authors have highlighted that the 'Tarzan Test' was used to measure speed and accuracy in reading. For my own study, I want to consider the aspect of

accuracy in identifying pseudo-words among normal text. While scanning through the entire story, the subtype can be deduced based on the type of words (phonetic/non-phonetic) they locate.

2. Eye-tracking: In this test, pictures of objects will be provided with 2/3 word options to select. There was only one right answer and the other two words were distractors. This test was created to identify which type of word the participant fixates on the most. To identify the fixation I will employ the Gaze Recorder software that produces interactive heat maps. Five main aspects were considered; rhyme awareness (for example: scandal, candle and sandal), phonetic similarity (for example: yot, yaught and yacht), visual similarity (for example: apple, adble and aqql), non-phonetic similarity (for example: colonel, kernel and journal) and semantic substitutions (for example: knight and castle). These aspects were selected to identify difficulty in reading and relate it to each subtype of dyslexia.

SUBTYPE	DIFFICULTIES
Surface Dyslexia	<ul style="list-style-type: none"> Phonetic irregularities decoding (leads to phonetic substitution)
Deep Dyslexia	<ul style="list-style-type: none"> Spelling errors are not phonetic equivalents
Dysphonemia	<ul style="list-style-type: none"> Combination of surface & deep
Phonological Dyslexia	<ul style="list-style-type: none"> Substitution of visually similar words Unusual, non-phonetic words

Figure 27: Subtypes linked to the most major impairments

This test was inspired by (Desroches, Joanisse and Robertson, 2006). In this paper, a similar eye-tracking study was conducted where participants were presented with four object images and were asked to look at the target item. Rhyme and distractors were added to eventually to track the participant's (control + dyslexics) eye movements. The dyslexic group displayed prolonged fixation times in the cohort and cohort + rhyme conditions relative to baseline, with no significant effect noted in the rhyme condition.

It was found that dyslexics scored lower than controls on word

reading ability, nonword reading and phoneme deletion. This shows a correlation between the first test and the eye-tracking test. They also found that dyslexics were faster than that of the control group and the accuracy results were similar. In this test by removing the factor of sound, the input trigger for the test, I want to check if I can find any variance within different subtypes. They concluded that eye-tracking holds strong potential for uncovering aspects of phonological difficulties and abilities that traditional assessment methods may overlook.

In another study, (Nguyen et al., 2024), an in-depth examination of the application of eye-tracking technology was created to support individuals with dyslexia. The paper reported that the personalised support that different dyslexic subtypes requires is achievable by eye-tracking. Although very few studies used this method, it was found that examining dyslexia subtypes via eye movement analysis and developing targeted interventions can substantially advance support approaches for affected individuals.

Through the pseudo-word and eye-tracking tests, I aim to identify the user's subtype which will then give the system some information on what tools will best suit the user's day to day needs. The tests (discussed in Chapter - 6) are designed to evaluate whether my assumption of linking subtypes to specific assistive tools hold true.

Preparing the Toolkit

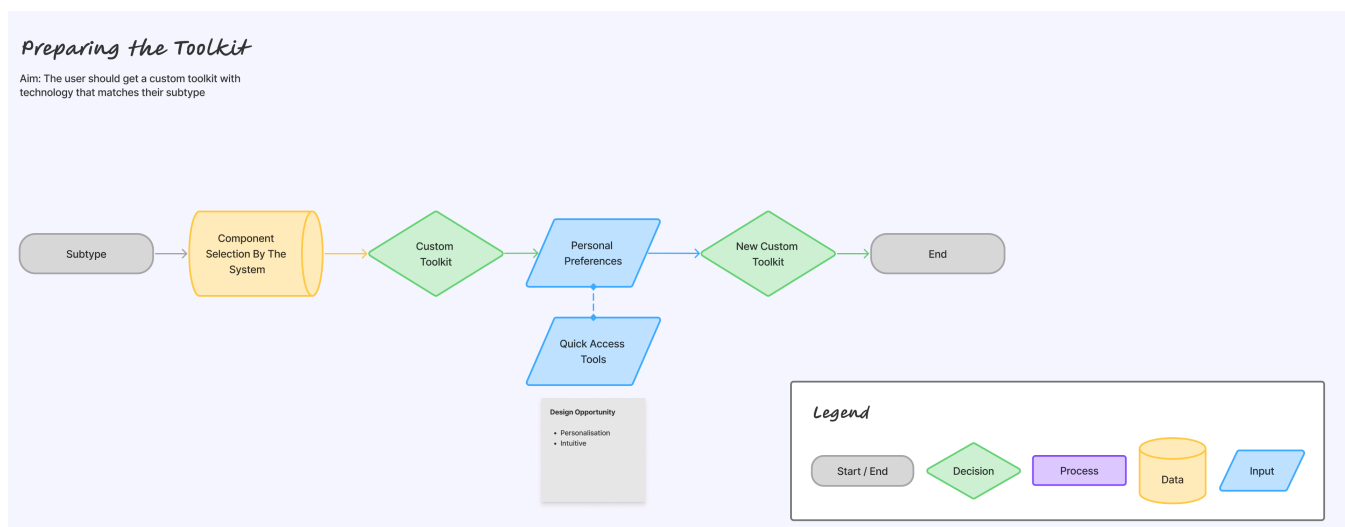


Figure 28: A flow chart of the toolkit preparation

In this part of the prototype, the user has been informed of which subtype they might have and are presented with a toolkit that could match their needs from research on their deficits (Appendix 5, criteria database of subtype selection). For example, Surface dyslexics tend to have visual confusion in letter identification therefore they will be suggested to use a thesaurus within their toolkit.

While the toolkits have been curated from scientific evidence, it is still important to give the user autonomy. Therefore, they will also be able to add and engage with tools of their choice, even if it does not match the original toolkit. The most important idea behind this toolkit is that it will house all the tools that the user requires under one umbrella and be easily accessible to them through this application.

The toolkit will contract into a logo and users can easily pick from the tools that they use the most frequently. These are called 'quick access tools' as seen in Figure 28.

Using the Toolkit

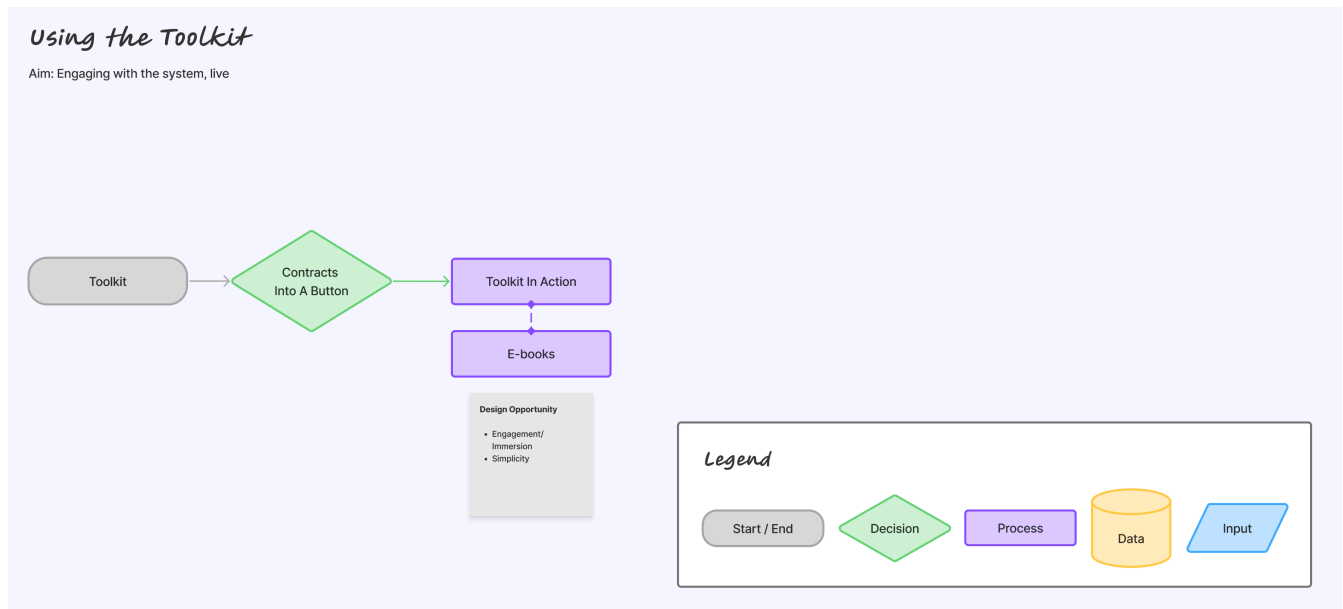


Figure 29: A flow chart of the usage of the toolkit

This part details the employment of the toolkit in context. When the toolkit has been curated and given to the user, they can then open an e-book from the Online Bibliothek of KB. Then the application will be on the right-hand corner of the screen and will help the user navigate through their reading experience. The

prototype offers a 'reading demo' at the end that guides the user and showcases all its features step-by-step. This way the user has a way to become familiar with the application before using it in context, thereby decreasing their cognitive load.

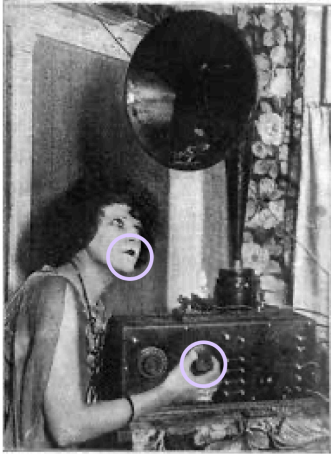
The Experience

To create this experience I used a total of three tools which have been mentioned in the previous section (Technical Functionality) as well. Prototyping tools Figma and Wix were used to make the interfaces that users interact with and GazeRecorder was used to generate heat-maps on the eye tracking part of the Wix prototype. Figma and Wix were chosen as they are able to give the user an experience of using a real application with ease. They are intuitive tools and can also help guide the user along the task.

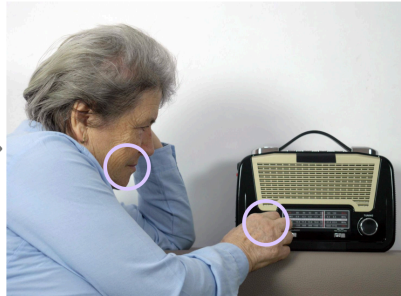
Interaction Vision

Interaction Vision is a method used to generate the interaction qualities from a metaphor. The primary goal of this approach is to develop a detailed representation of the moods, emotions, or experiences that interactions with the future product should evoke in the user (Pasman et al., 2011). In using this method, I drew parallels between using my application and tuning an off-key radio. This metaphor affords the qualities 'assistive', 'engaging' and 'simple'. The Interaction Vision is shown in Figure 30 (Figure on the following page).

What visual captures your interaction vision?



Frustration with off-key radio



Trying to find the right frequency



Found the right frequency and is content with the outcome

Write down your one sentence interaction vision:

The interaction(s) with my concept should be like **tuning an off-key radio.**

Characters of interaction

What 3-5 descriptive adjectives (qualities) describe your vision?

Assistive, Engaging and Simple

Affordances

What is the quality?

Assistive

What does the quality afford?

1. The instruction manual that comes along with the radio.
2. Picking up on audio cues.
3. Asking someone else to help

Engaging

1. Immersed in the music.
2. Immersed in the process of locating the right frequency.
3. Explorative in nature as you can discover the frequency eventually.

Simple

1. Sounds gradually change from a static buzz to music, leading the user to have an indication that they have completed the tuning process.
2. Once the radio is set-up (after first time use) the tuning process only consists of: rotating a knob to set a frequency is the only point of contact with the radio's interface.

Figure 30: Interaction Vision

The ReQuest Application

In this section, I will introduce how the technical functionality and the experience shape up to become an application. The name of the application, ReQuest, has been coined from the combination of two words; Reading and Quest. The essence of the application is that it acts as a buddy for every reading adventure that the reader takes on. ReQuest aims to provide the right assistance to dyslexic readers by identifying their subtype, giving them a custom toolkit and making the experience of reading enjoyable. The application has four main components; onboarding, quests, toolkit creation and product demo. The quests are of four types; pseudo-word testing with single words, pseudo-word testing with a story, eye-tracking testing and self-reporting. The cognitive tests from Figure 26 were made into quests that gamified the overall experience by encouraging users and increasing engagement.

Onboarding

ReQuest opens up with a welcome screen inviting users into the system with excitement. They are then shown the three simple steps in which the app works. Further, the app's mascot, Loopi the bookworm, is introduced at this stage. Loopi is a personal assistant that guides the user through the application and their reading endeavours. Incorporating a mascot like Loopi enhances the user's experience by adding a friendly and consistent point of interaction that fosters engagement. Lastly, an insight is provided into the upcoming quests and the user is triggered to start the quests.

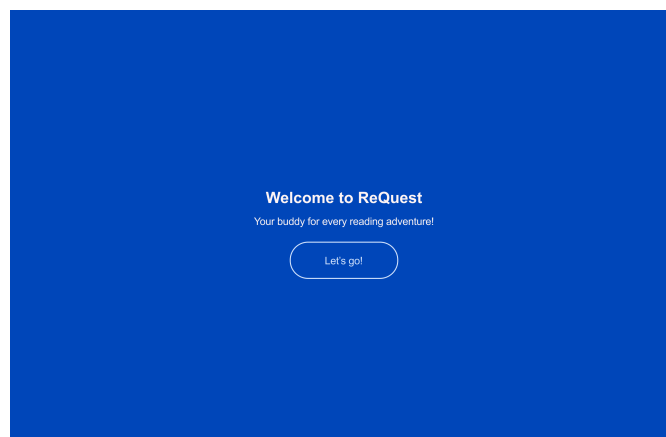


Figure 31: Onboarding screen

Quest 1

The first Quest is a pseudo-word test where participants were asked to read aloud four sets of three non-words each. The first two sets were phonetic equivalents (for example: 'Rane' for 'Rain') and the second set were non-phonetic in nature (for example: 'Tash'). This Quest was designed to identify the Surface and Phonological dyslexics with each set respectively. Surface dyslexics are usually able to read all the words with ease, especially the first set since they tend to make phonetic substitutions while reading. Phonological dyslexics might make substitutions while reading the second set of words.

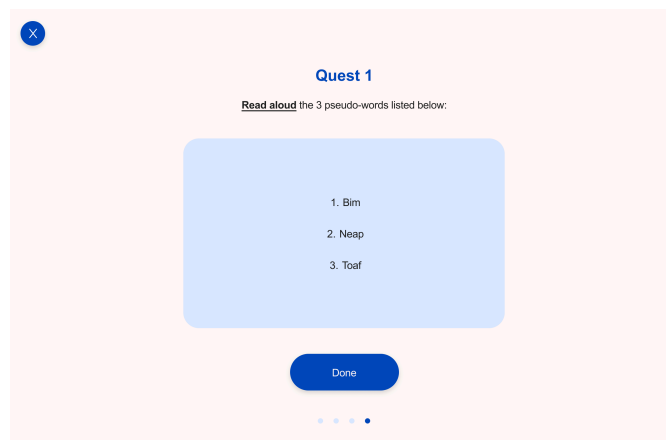


Figure 32: Quest 1

Quest 2

The second Quest was an interesting short story with eight pseudo-words hidden in it. Similar to Quest 1 there were four phonetic non-words and four non-phonetic ones. This method of testing was to include the context of reading as mentioned on page 59 of this Chapter.

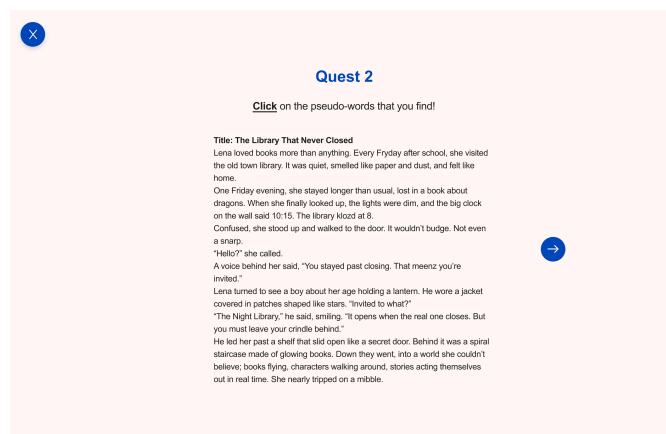


Figure 33: Quest 2

Quest 3

This Quest was an experiential version of the eye-tracking test. The users were presented with an image and two/three words of which only one is right. GazeRecorder was running in the background to generate a heat map that I could analyse at the end of the Quest. The fixation between words helped me further with subtype detection (for example: confusion between 'Laf' and 'Laugh' indicates phonological dyslexia since the words are phonetic substitutions) (Appendix 5).

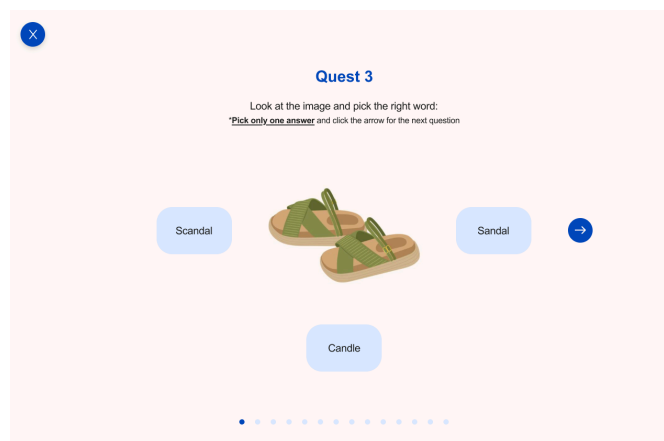


Figure 34: Quest 3

Quest 4

In the final Quest the user was asked a final question as a form of self reflection. When they picked a choice they were presented with a subtype. If a subtype could not be determined due to an unknown combination, they would receive the results later. This information was used to create a custom toolkit.

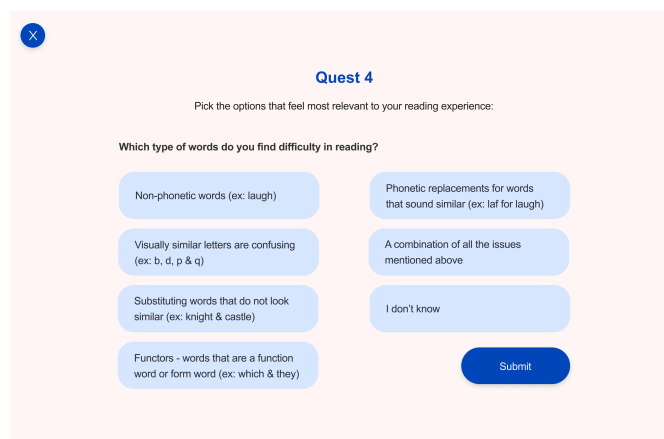


Figure 35: Quest 4

Toolkit Creation

The custom toolkit was created with the subtype detection criteria and pertinent technology in mind. These toolkits are can be personalised by the user as per their needs and context of use.

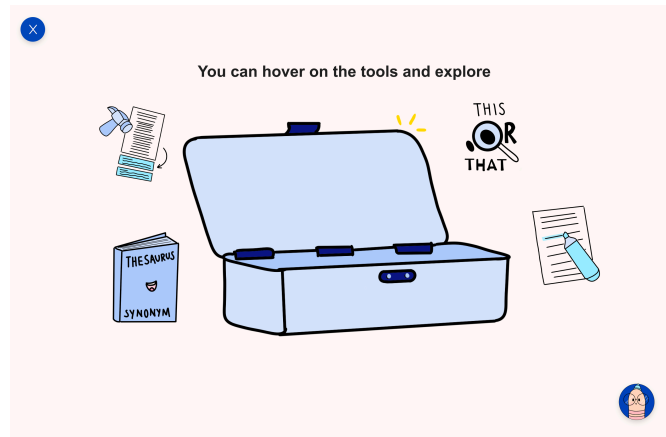


Figure 36: Custom toolkit

Product Demo

The product demo is a guided tour of the application for the user, where Loopi walks them through every function of ReQuest and showcases its abilities. The demo includes; chatting with an AI-powered Loopi where any questions can be asked, fun facts about Loopi are shown, the process of adding tools to the kit and personalisation is covered and the purpose of each tool from the kit are walked through. By following this guided demo, the user is able to quickly grasp the idea of how ReQuest works and how they can utilise it for their needs.

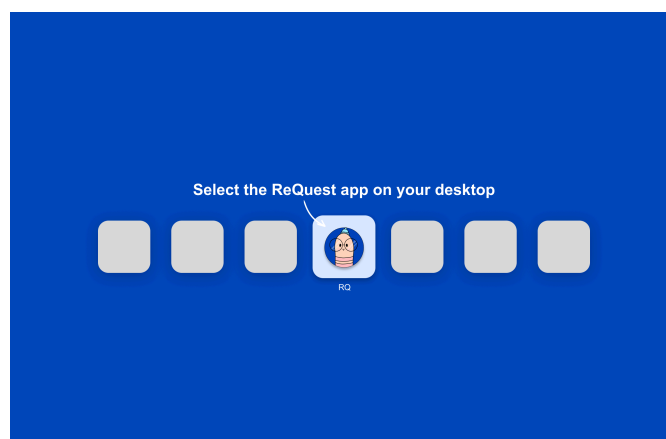


Figure 37: Product Demo

Intended User Journey

In Figure 38, as shown below, the experience that I ideally intended to provide has been represented through a user journey map. But, the actual user journey (Figure 52) indicated different results.

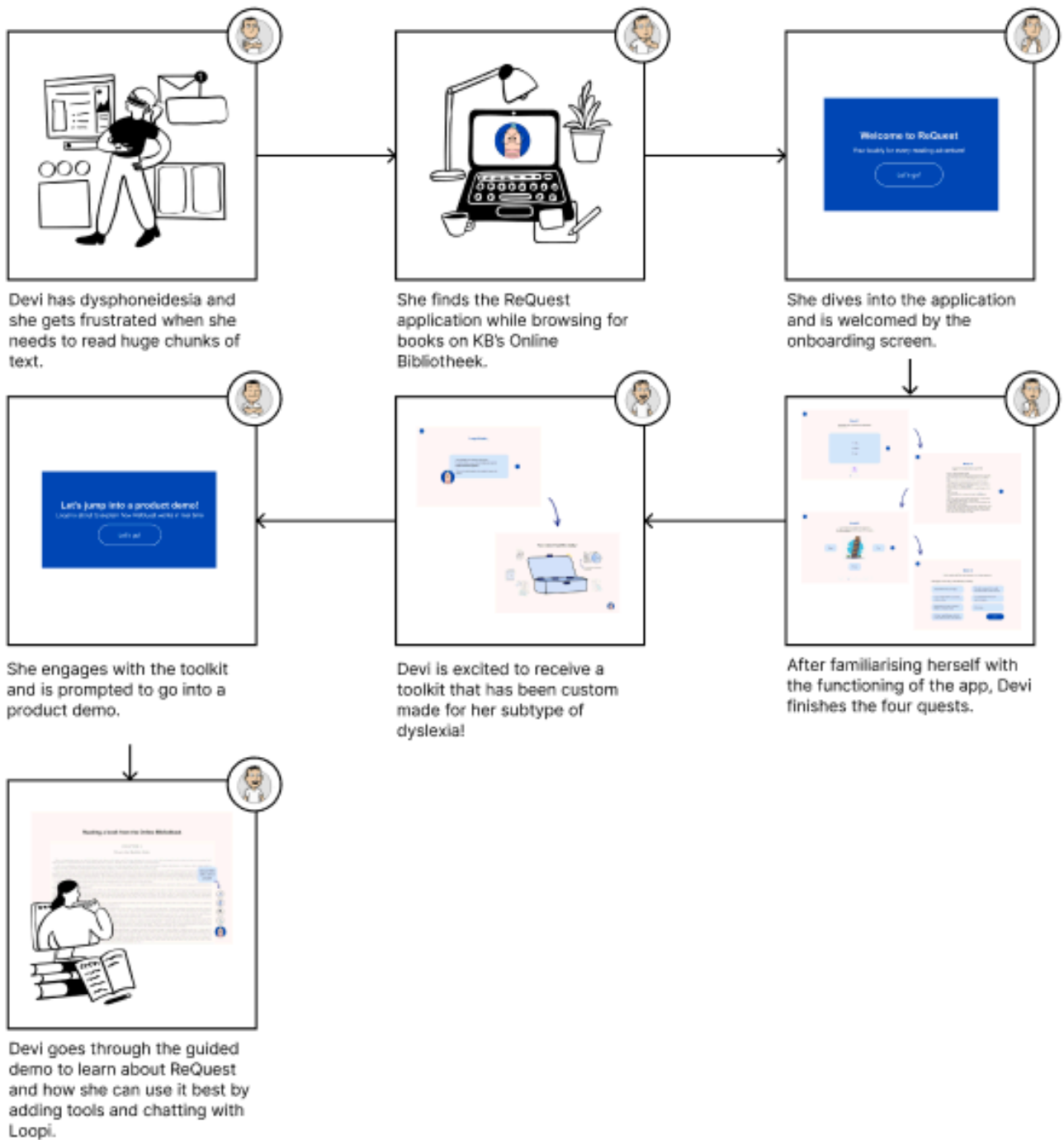


Figure 38: Intended user journey map

Designing the User Interface (UI)

After the qualities of the experience were clearly defined, it was translated into visual interfaces. These interfaces were created with the following specifications:

1. Design system: The design system (building blocks that keep the look and feel of products and experiences consistent) includes a colour palette, font family, buttons and icons. In Figure 39 it can be seen that the colour palette consists of a primary, secondary, accent and background colour. The selected font family is Arial as it has a simplified form with clear ascenders and descenders as well as an open and rounded shape (Bergman, 2024).

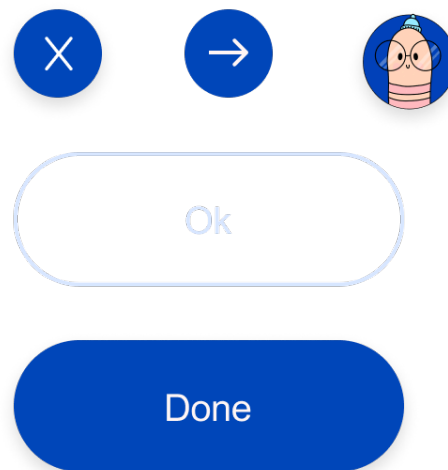


Figure 39: Sample components

2. Accessibility guidelines: From the W3C Editor's Draft (Seeman and Cooper, 2025) of accessibility standards the following measures were incorporated into the prototype:

- Using left-justified text with a ragged edge on the right
- Line spacing of 1.5
- Using bullet points rather than a large piece of text
- Using short sentences with simple language
- Easy navigation
- Using graphics and imagery to convey information
- Dark-coloured text on a light, non-white background to avoid glare and maintain contrast (Figure 40)
- Using bold text instead of all block letters
- Using larger bold text in lower case for headings

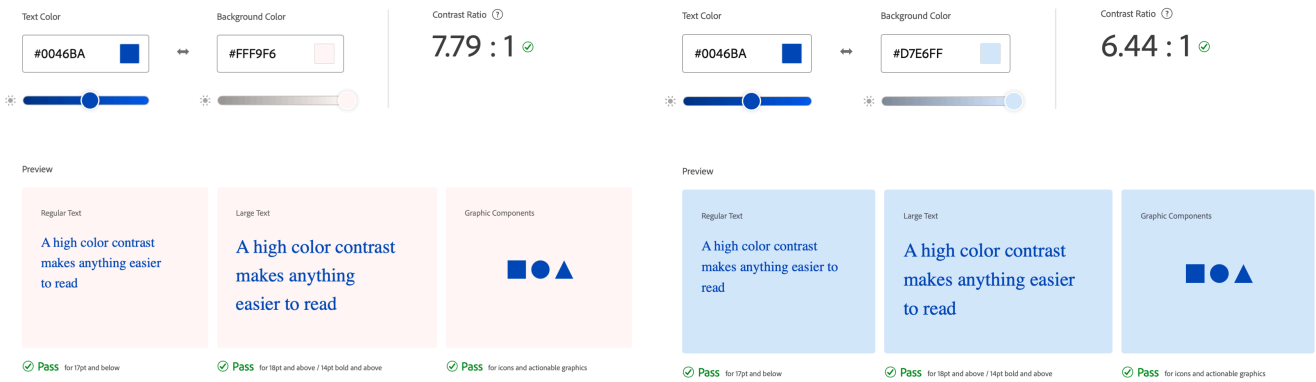


Figure 40: Passed colour contrast check

3. Prototyping: A prototype was made to simulate the experience that a user would have in a real context using Figma and Wix. Two types of prototypes were made:

- a. A low-fidelity prototype was created to form an overview of the journey that the user will experience. This was a basic interface which was black and white that helped me as a designer to walk through each step before refining the prototype. [Click here for Low-fi prototype.](#)

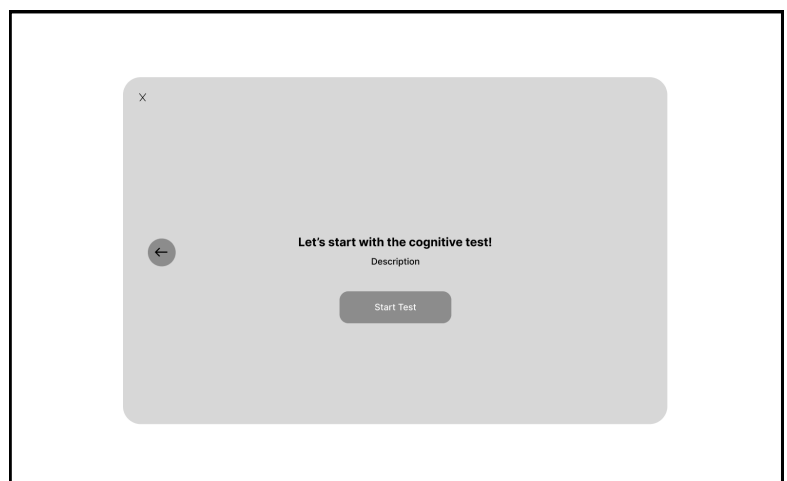
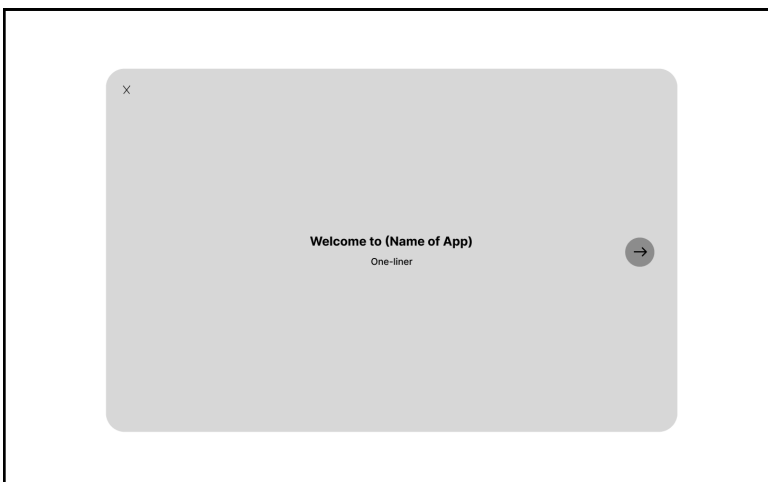


Figure 41: Samples of low-fidelity screens

b. Later, a high-fidelity prototype was created from the blueprints of the low-fidelity prototype. Here, the design system and accessibility guidelines were implemented in order to manifest a smooth experience for the user. Design choices like illustrating a mascot and gamifying the experience through 'quests' instead of 'tests' were also made at this point. [Click here for Hi-fi prototype.](#)



Figure 42: Samples of high-fidelity screens

CHAPTER - 6

Testing

Validating the Vision Through the User's Eyes

Chapter - 6: Testing

This Chapter dives into the methodology in which the testing was conducted. Starting with a pilot test to ensure that the experience runs smoothly, recruiting relevant participants, setting up a testing environment and insights from the participants. After the high-fidelity prototype was developed, I aimed to understand if it created the experience I intended for my users. As stated in the design goal, I wanted to analyse if ReQuest can engage the user in the reading experience and provide them with the right subtype and tools for their needs. This Chapter discusses my methods of testing and reflection with the user group to gain deeper insights into their experiences, needs, and expectations.

Pilot Testing

This method of testing was used to identify any inconsistencies in the experiential workings of the application. Two pilot tests were conducted with non-dyslexic individuals so as to avoid any content bias. In this way, the insights they provided were purely based on the user experience and did not get disoriented by the content of the text on the screens (Figure 43). Through this test, I identified the following:

1. In the first pseudo-word Quest the words that were meant to be read aloud were shaped like buttons and users were confused. The instructions on the top were not visible enough leading them to wonder what the task is. To solve this, the buttons were changed into one body of text and the instructions on top were bolded and underlined.
2. The definition of what a pseudo-word is confused users and they did not understand it's meaning therefore, it was simplified by using more colloquial language.
3. Conducting these sessions first also allowed me to practice the flow of events and make a to-do list of all the essential parts so as to keep all the tests equal from my end. For example keeping the eye tracker ready, making sure the screen-recorder is on, getting the consent form signed etc.

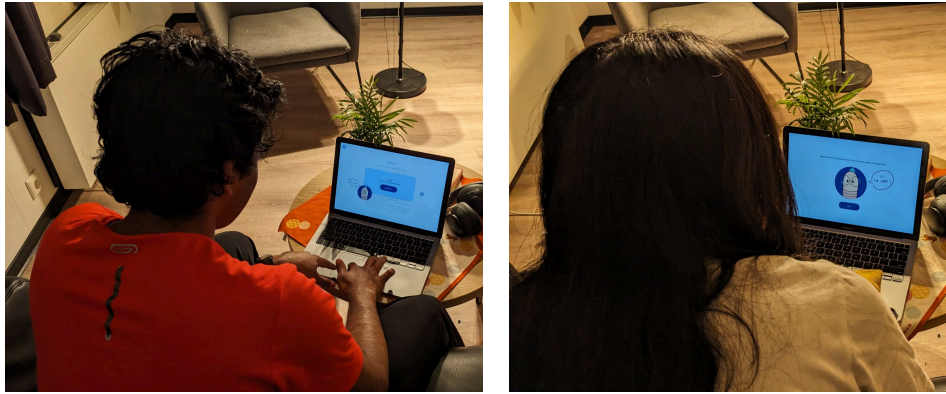


Figure 43: Pilot testing in progress

Recruiting Participants

I recruited a total of 7 dyslexic readers as my participants with a few criteria in mind:

1. They were within the age group of 18 - 26 years of age.
2. There was a mix of female and male testers.
3. Some participants did not have an official doctor's diagnosis but all of them identified with having dyslexia and problems with reading.
4. The 7 of them were completing their education and were required to read frequently as part of their courses or had reading as an integral part of their job.

Test Set-up

The testing procedure was designed and implemented as described below:

- 1. Introduction and informed consent (5 mins):** This part of the session is to introduce the participant to the structure of the test set-up. They were also given a consent form informing them of all the data I would be collecting, their rights and my plans with the results of the study.
- 2. Pre-test moderated questionnaire (10 mins):** The testing started with a moderated questionnaire where I used an interview format to ask 6 questions about their current experiences with reading and assistive technology (Appendix 6).

The aim of this interview was to identify specific issues that these participants had while reading with technological support. This was also done to compare whether these problems were addressed by the ReQuest app. PrEmo (Laurans & Desmet, 2017) was used as a probing tool to help participants articulate their emotions better.

- 3. Engaging with the prototype (30 mins):** This section consists of the four quests as mentioned in Chapter 5 (pages 66 & 67). Participants were given time to complete the quests and interact with the toolkit that was made for their custom needs. Quests 1, 2 and 3 were randomised to reduce any experimental manipulation, increasing fair comparison of the obtained data (Field, 2013). Additionally, it is a way of conducting a control experiment and reduces fatigue effects (Salkind, 2010).
- 4. Post-test moderated questionnaire (10 mins):** Based on their interviews, testers were asked 4 key questions (Appendix 7). These questions aimed to understand if the presented subtype was appropriate, weigh the contents of the toolkit against their needs, their experience with ReQuest, the context of use and collect any feedback they might have for me. Similar to the pre-test moderated questionnaire, PrEmo (Laurans & Desmet, 2017) was used as a probing tool to help participants articulate their emotions better.

This whole process of testing along with answering questions and giving feedback lasted for about 1 hour per participant.



Figure 44: 1st and 2nd row: Participants engaging with the ReQuest app while testing

Data Collection

Data was collected in three methods for the following purposes:

1. Screen recording to analyse the usage of the prototype.
2. Voice recording for the pseudo-word tasks and to capture any other verbal thoughts that the participant might express.
3. Eye-tracking to generate a heat map that helps with analysing which words testers fixate on the most.

Ethical Practices

To ensure that all the collected data will be stored and utilised ethically, an application was submitted to the Human Research Ethics Committee (HREC). I shared a Data Management Plan, Informed Consent Form and HREC Checklist.

All identifiable information (such as name, gender etc.) will be anonymised.

Participant Insights and Analysis

There were a total of 7 participants taking part in the testing sessions. For the sake of anonymity they will be referred to as P1, P2, P3, P4, P5, P6 and P7 respectively.

While testing and collecting feedback, participants provided a lot of insights on what was successful and opportunities for refinement. In Figures 45 and 48, the benefits and opportunities are discussed through a thematic analysis as mentioned in (Clarke & Braun, 2016). This form of analysis offers a structured and accessible approach to identify patterns and develop themes from qualitative data. Additionally, it allows flexibility in terms of sample size, data collection, research questions, approach etc.

Benefits

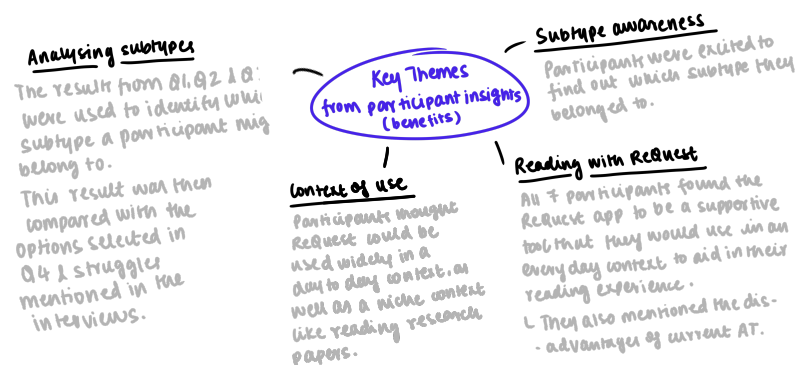


Figure 45: Thematic analysis of benefits

Figure 45 showcases a combination of the benefits that I observed and valuable insights from users:

- 1. Subtype awareness:** As established previously in Chapter - 3, the dyslexic reader group is unaware of the different subtypes that exist within dyslexia for specific deficits. The situation was similar during this test session as well. Users were curious to find out which subtype they belonged to and understand their deficits better. For example, P6 had received a toolkit for Dysphonia based on their test results, and they said; “Yeah, I think I might have this one while reading. I have this kind of problem (difficulty in reading non-phonetic words like ‘subtle’). Also, like the meaning, like it's really difficult to understand what it would mean.”
- 2. The experience of reading with ReQuest:** When asked about their experiences with reading in general and how they would describe the process, all 7 participants used phrases like “inability to focus”, “does not come as natural to me as it does for others”, “missing links between the beginning and ending of a sentence”, “frustrating”, “tiring and takes up too much energy” or “discomfort with unfamiliar words”.

Once they used the ReQuest app and explored the effect that it creates, participants found the tool to be impactful. P1 said; “Right now I create my own toolkit, like I print out my text and I use a marker and stuff to make it easy for myself. So if that would be incorporated in one tool, then I would really use that!”. 7/7 participants did not find one tool that is able to cater to all of their requirements. As a result, they either give up reading or create their own mechanisms as a coping strategy. 4/7 users mentioned that they use ChatGPT because of its ability to personalise their experience, a quality that they see with the custom toolkit as well.

The two-part experience of performing a cognitive test and engaging with a product demo was well-received. For example, P4 said; “I liked the experience and the user interface was nice.” “I liked the personalisation of it. It made it feel more like a game, less like an interview.” Almost all the participants enjoyed having the reading buddy, Loopi, as it provided encouragement and put the user at ease. While the application was being used, testers often smiled and said “The worm is so cute” when Loopi appeared. They found this aspect of the prototype to be scalable

to a younger age group as well. In terms of the contents of the toolkit, users found it to perform effectively. P7 - "I thought it was pretty nice that you can customise what you want to use, that's definitely a plus." Additionally, the product demo explaining the usage of the toolkit in simple and clear instructions helped users understand its usage fully. "I think because it's like the demo you get like, it's your first time meeting the program. So in this case, it's not too guided" - P4. Therefore, the aspect of gamification, attention to a dyslexic-centric approach and personalisation give ReQuest an edge over the other assistive technologies in the market.

3. Context of use: When asked if they envision using ReQuest on a day-to-day basis or in a niche setting, 6/7 of the participants said they would use it in all contexts but would especially appreciate having it for more high-stake situations like reading academic papers for an exam. P2 - "It is open-ended enough to use day-to-day, it's like really only supporting and waiting where you just don't really notice it". P5 - "I think it could be applied to all situations. With the text-to-speech tool it was very helpful." A more niche context was also discussed by P1 - "I would really use it for like academic papers or like non-fiction books, you know because they're often too difficult."

4. Analysing subtypes from collected data: To best explain this section I will share a detailed analysis of P5 as a case study:

- In Quest 1 they read the pseudo-word "Chid" as "Child" which indicated substitution of unfamiliar words with familiar ones. This could mean that they might have deep dyslexia.
- In Quest 2, they missed the word "Snarp". This could be because it was a non-phonetic word which hints at surface dyslexia.
- In Quest 3, P5 was confused between words like "Shuttle" and "Shuffle" as well as "Tower" and "Towel" which could indicate surface dyslexia (Figure 46).
- From their response in Quest 4 (Figure 47), they picked one option from surface (visual similarity) and one option from deep (phonology), they also selected and de-selected deep's substitution option 3-4 times and ended up de-selecting it in the end. This resulted in a dysphonetic toolkit. This is consistent with their results from all the quests and verbal definition of their reading issues.
- From the pre-test moderated questionnaire, P5 mentioned that they found reading to be a frustrating and tiring activity

since they had a severe form of dyslexia. They use audio tools extensively and avoid reading altogether.

Lastly, during the post-test moderated questionnaire they felt that the problems that they face are similar to the subtype presented (dysphoneidnesia); "It does fit, yeah." They spoke about how their problems are relating to the subtype as mentioned from the pre-test moderated questionnaire as well.

The predictions made in the analysis from the quests are coherent with the 'Technical Functionality' section of Chapter - 5. None of the participants felt that the subtype presented to them was completely incorrect. They also wanted to learn more about the subtype and try to do their own analysis to dive deeper into the intricate meaning of the subtype.

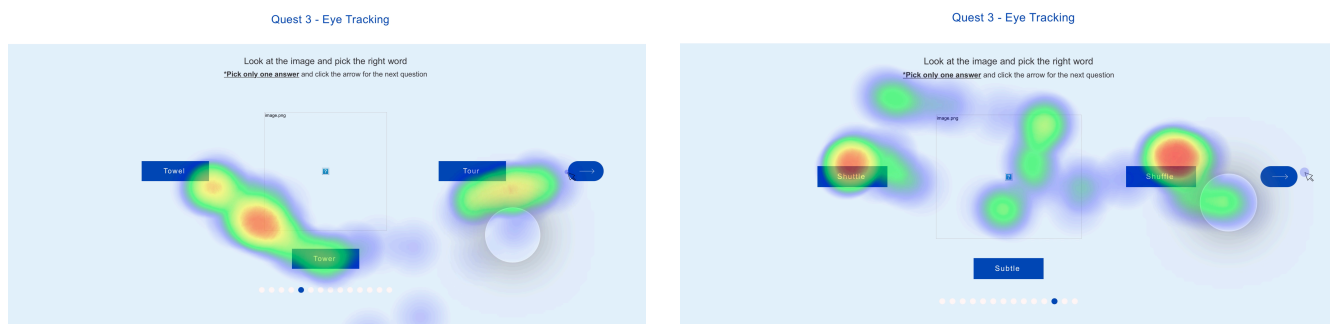


Figure 46: Heat map showing fixations from Quest 3 (eye-tracking test)

The screenshot shows a question titled "Quest 4" with the instruction "Pick the options that feel most relevant to your reading experience:". Below the instruction is the question "Which type of words do you find difficulty in reading?". There are seven options in rounded rectangular buttons: "Non-phonetic words (ex: laugh)", "Phonetic replacements for words that sound similar (ex: taf for laugh)", "Visually similar letters are confusing (ex: b, d, p & q)", "A combination of all the issues mentioned above", "Substituting words that do not look similar (ex: knight & castle)", "I don't know", and "Funciors - words that are a function word or form word (ex: which & they)". A "Submit" button is located at the bottom right. A mouse cursor is visible over the "I don't know" option.

Figure 47: Options selected by P5 in Quest 4

Opportunities

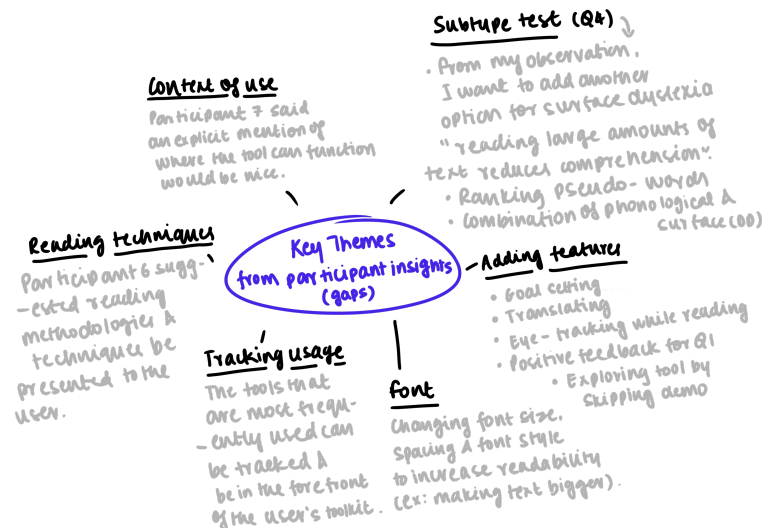


Figure 48: Thematic analysis of opportunities

Figure 48 showcases a combination of the opportunities that I observed and valuable insights from users to iterate on:

1. Font size flexibility: Participants liked having the Arial and Open Dyslexic fonts as part of the toolkit. In the prototype, the second onboarding screen had a few points that conveyed the functioning of the app (Figure 49). Many participants said that the spacing and font size can be increased to provide better readability.

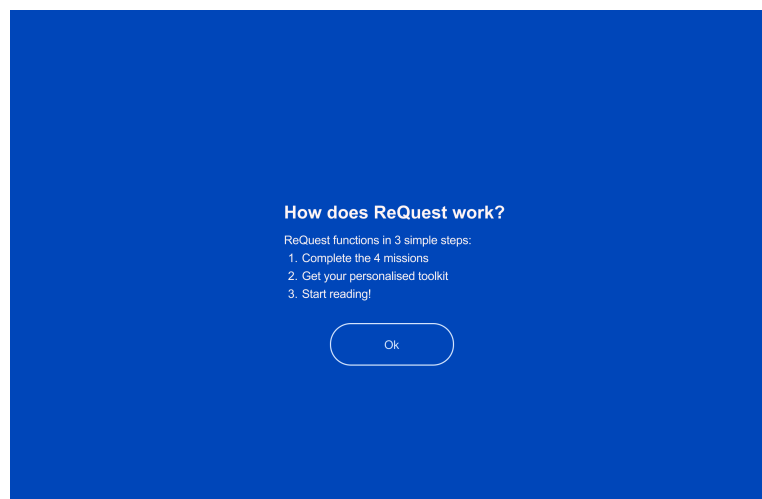


Figure 49: Onboarding screen with functions of ReQuest explained

2. Tracking usage: Participants suggested having a way to track the usage of tools from the toolkit. This way the system can automatically suggest tools pertaining to their growing needs. It is also a way of keeping track with their subtype in a more extensive manner.

3. Reading techniques: After assembling the toolkit, there could

be some reading techniques as well to help the user further. P6 said, “Maybe methods or ways that can help you read.”

4. Context of use: P7 recommended having the context of use explicitly mentioned since user’s might get confused about where ReQuest can be used. The idea is to have a floating button across various contexts like PDFs, the internet and e-books. But for starters the app will be attached to the e-book collection that the KB houses.

5. Subtype detection options:

- From my observations and interviews, there is another way to detect if users are surface dyslexic. It is by adding the option “unable to connect the beginning and ending of a sentence”. 3/7 participants mentioned that they face this problem. For example, P1 said. “I can often just read something completely different from what is actually there, because my brain works faster than what I'm actually reading. So I just fill in what I think it says and then it doesn't say that.” Adding this option in Quest 4 can be another way to recognise surface dyslexics.
- There should be a way to convey to users if they have a double deficit that does not have a scientific name yet; for example, P7 picked one option from surface dyslexia and one from phonological dyslexia, therefore they should be able to get information on both these deficits (Figure 50).
- From my earlier test Chapter - 3 (Bridging the Gap), the method of ranking and self reporting difficulties with pseudo-words was highly effective in understanding subtypes. This can once again be included in Quest 1 after the words have been read aloud.

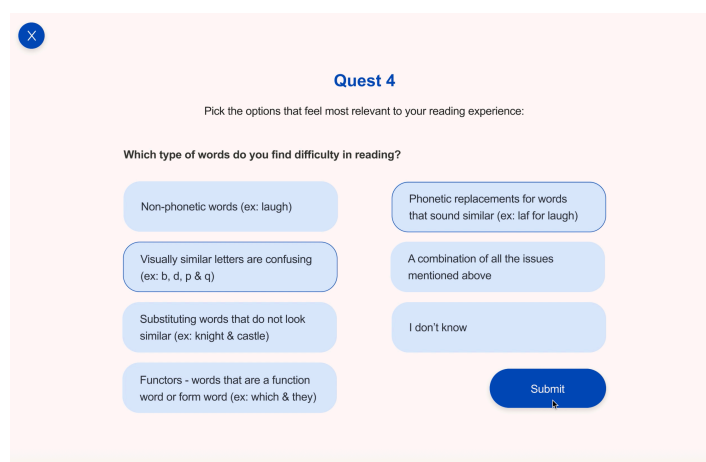


Figure 50: P7 picking one option from surface dyslexia and one from phonological dyslexia

6. Adding features:

- All the participants were confused whether they were saying the pseudo-words correctly and turned to me for validation with phrases like “I guess?” and “Is that ok?” (from P1 and P2 respectively). Having a way to ensure that they have recorded the audio correctly and that it matches the pronunciation is vital. For this I will be adding an animation of a tick mark and cross mark, as well as an option to re-record if they choose to.
- Setting goals can also be a way to customise the toolkit further and give users a toolkit that matches their needs closely.
- A participant suggested that the eye-tracking mechanism can be used to further track the method in which the user reads and give them an analysis that could either recommend more tools or help users reflect.
- Some participants wanted to explore the tool more freely while others found it to be the right amount of guidance (Figure 51). To cater to both audiences, I will retain the demo and add a ‘skip tour’ option that allows the user follow their own journey. A participant also suggested having the demo as an option even after initial use as user’s might want to come back for a demo later on.



Figure 51: Guided demo

CHAPTER - 7

Iteration

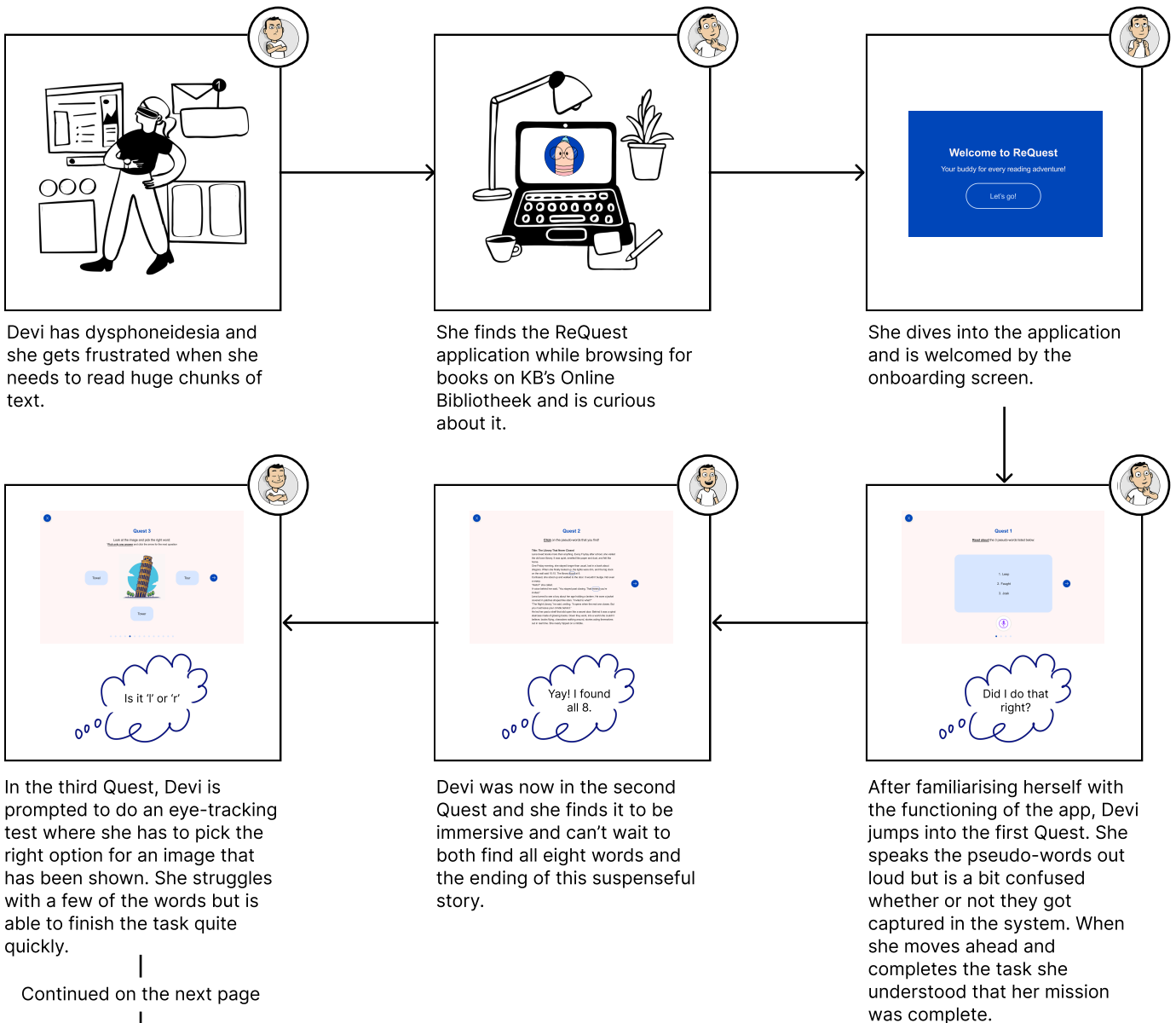
Progression Through Feedback Loops

Chapter - 7: Iteration

In this Chapter, I go over the changes that I made to the ReQuest app based on the test participant's insights from Chapter - 6. This is a method of including the user in the process and empathising with their needs. To map and identify these changes visually, I compare the way in which the user's journey was intended by me and how the user interacted with ReQuest.

Intended Journey vs. Actual Journey

The intended user journey was created before the user's tested my prototype as shown in Figure 38. The actual user journey (Figure 52) slightly differed in a few places which has been highlighted with a purple background. These differences were either brought to light by the user or came from an observation.



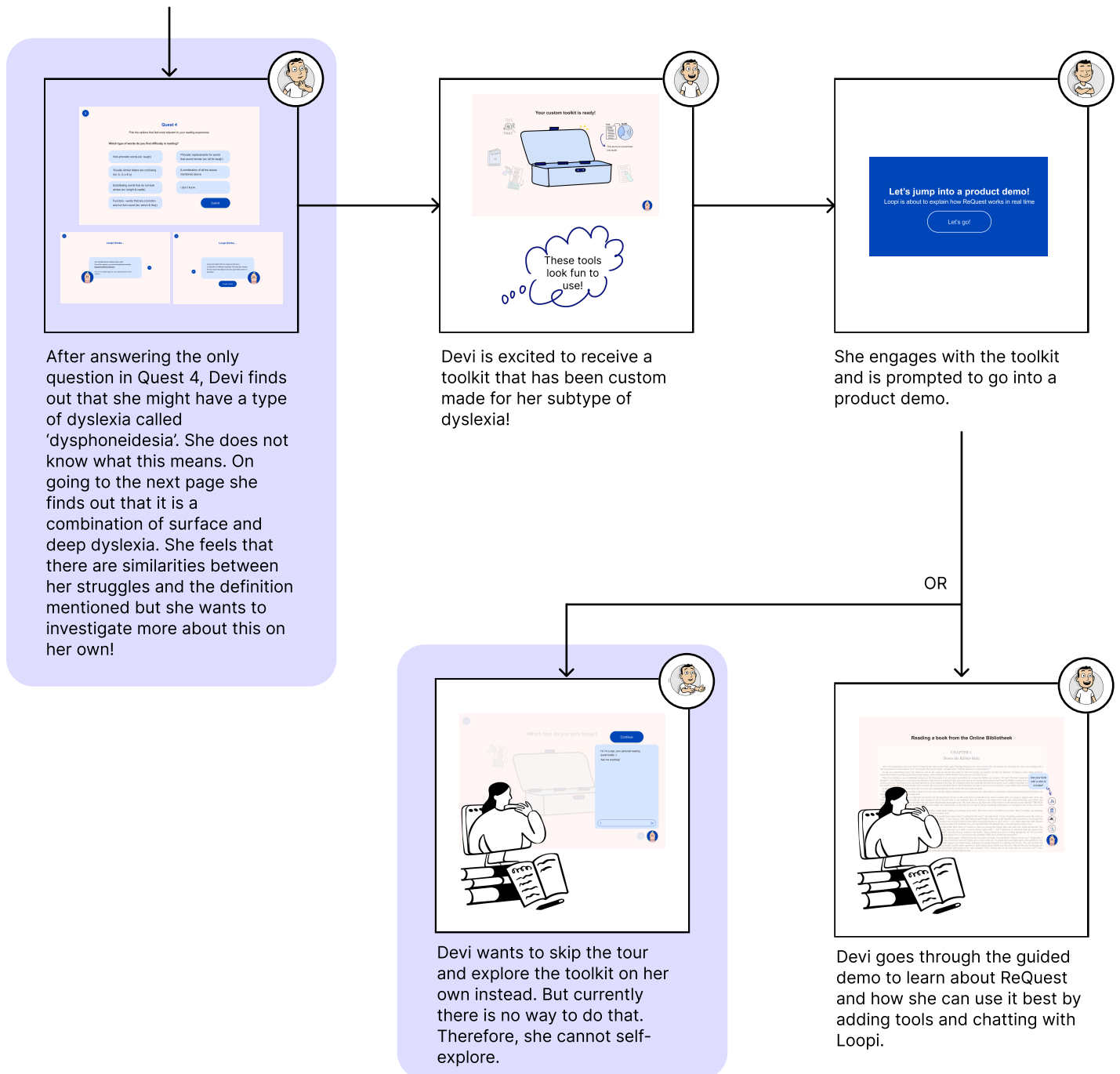


Figure 52: Actual user and emotional journey mapping

Apart from the opportunities identified in Chapter - 6, the observed opportunity for refinement through the user journey maps is at two points, the sudden change to the subtype prediction and the user wanting the option to freely explore the tool if they choose to do so in the end (purple highlighted portions of Figure 52). Since the quests are curated in a way that the users are required to follow a sequential path, there is no difference in progression.

Proposed Changes

In the following points (Figure 53) I will discuss the actionable changes that are going to be implemented based on Chapter - 6 both in terms of UI and UX.

Proposed Changes

Gaps Identified	Actionable Change
1. Font size and spacing	Splitting the information into a small three step story board which showcases how the user will do the three steps in the context, as seen previously in Figure 40. The user previously struggled with consuming this information and found it to be dense. By making the screen more visual the user can still grasp the information by looking at the images.
2. Tracking usage	Users wanted a way for the system to track their tool usage and keep those tools on high priority. The ReQuest app currently displays the toolkit and also allows for the user to pick from the quick access tools as seen previously in Chapter - 5, Figure 26. But this was not made clear to the user when they add/remove tools. Therefore, I will be adding icons that indicates the most used tools as well.
3. Reading techniques	After providing a toolkit to the user, in the product demo a new screen will be added to highlight features like translation and zooming into text so that people can employ these methods of reading better.
4. Context of use	To make it clear where the tool can be used, the product demo will include a description stating "open any e-book and start reading" to make it clear that the tool is intended to be used with this file type. The plan is to expand to a wider range and be able to use the tool in any context like pdf, web browsers, presentations etc.

<p>5. Subtype detection options</p>	<ul style="list-style-type: none"> • Another option will be added to quest 4, “unable to connecting the beginning and ending of a sentence”. This is another way to detect surface dyslexia as discussed previously. • There is no scientific name for a combination of phonological and surface dyslexia, but I can inform users that they might have a double deficit by giving them information on both these subtypes. • If more than one subtype of deficit is chosen, there can also be information collected by ranking pseudo-words and the deficits themselves to personalise the experience further. To do this, I will add screens after quest 1 and quest 4 to further analyse the subtypes.
<p>6. Feature additions</p>	<ul style="list-style-type: none"> • Validation with an animation of a tick mark or re-record option if the sound has not been picked up. There will be no way to change the recorded audio as that is a way to analyse the subtype. • Setting goals can also be a way to customise the toolkit further and give users a toolkit that matches their needs closely. This can be done by making a page with a few options that I suggest; for example: ‘reading for pleasure’, ‘academic reading’ etc. • Using eye tracking to track a user’s gaze and recommend a good set of tools from time to time. This feature can be combined with the second point on this table to give the user some form of analytical data. • Some participants wanted to explore the tool more freely while others found it to be the right amount of guidance. To cater to both audiences, I will retain the demo and add a ‘skip tour’ option that allows the user follow their own journey.
<p>7. Subtype prediction</p>	<p>From my observations, the subtype is presented to the user right after clicking submit on quest 4, therefore it is a bit sudden. I will add a buffer screen where I add a loading screen which will read; ‘calculating subtype’, then they will be directed to a page ‘ready to see your subtype?’ which will open up the subtype screen.</p>
<p>8. Doesn’t quite fit me</p>	<p>What if the user does not resonate with the given subtype? Before they create a toolkit they should be able to go back and pick a different subtype.</p>

Figure 53: Opportunities identified and the pertaining actionable changes

A few of the proposed changes were higher in priority (marked in purple in Figure 53). Therefore, these actionable changes are depicted in the UI through the following Figures:

1. Spacing of text: Splitting the information into a small three-step story board which showcases how the user will do the three steps in the context.

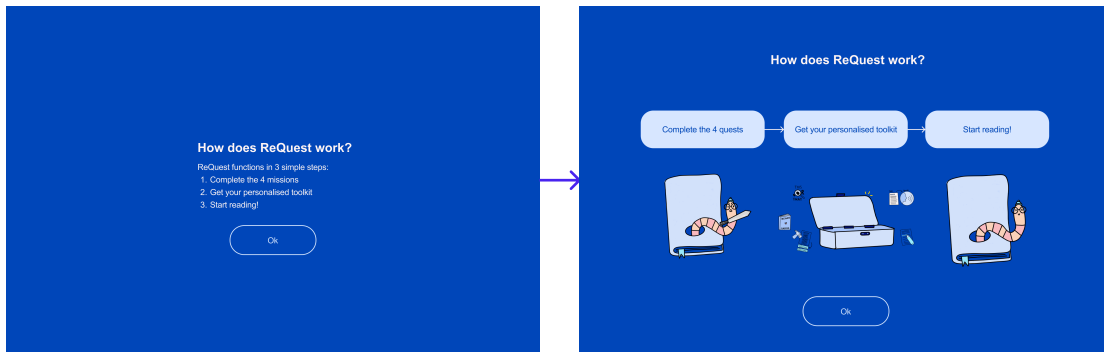


Figure 54: Before (L) and after (R) of the 1st actionable change

2. Tracking usage: Users wanted a way for the system to track their tool usage and keep those tools on high priority.

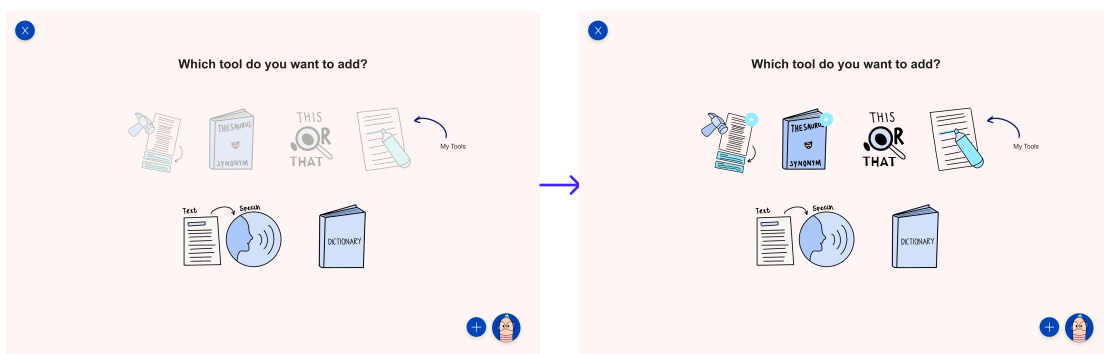


Figure 55: Before (L) and after (R) of the 2nd actionable change

3. Subtype detection options: Another option will be added to Quest 4, “unable to connect the beginning and ending of a sentence”.

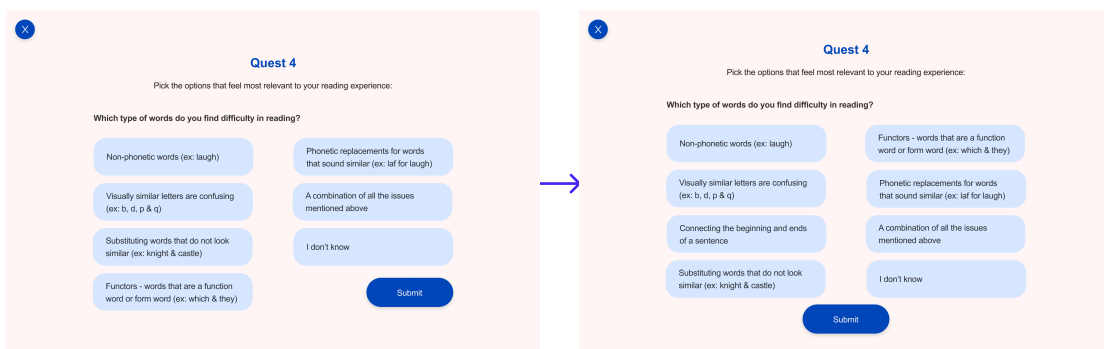


Figure 56: Before (L) and after (R) of the 3rd actionable change

4. Subtype detection options: There is no scientific name for a combination of phonological and surface dyslexia, but I can inform users that they might have a double deficit by giving them information on both these subtypes.

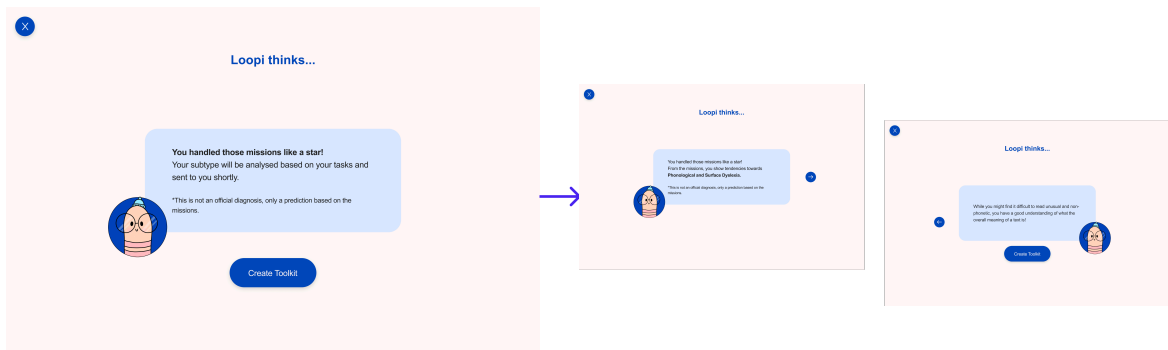


Figure 57: Before (L) and after (R) of the 4th actionable change

5. Feature additions: Validation with an animation of a tick mark or re-record option if the sound has not been picked up.

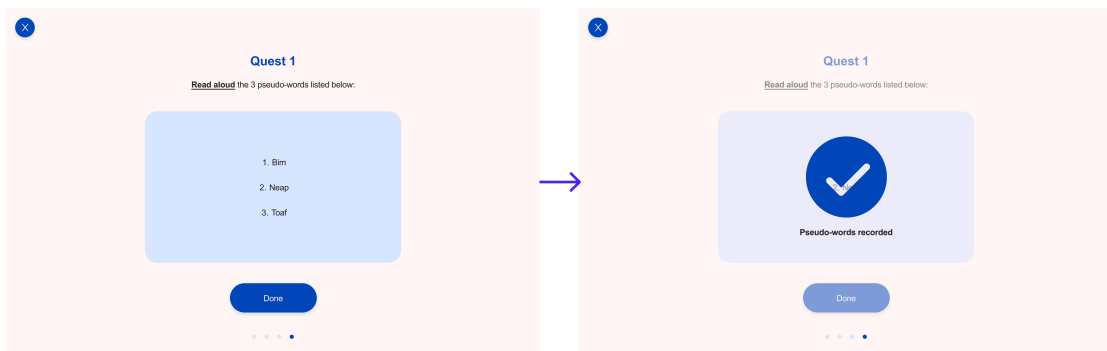


Figure 58: Before (L) and after (R) of the 5th actionable change

6. Feature additions: Setting goals can also be a way to customise the toolkit further.

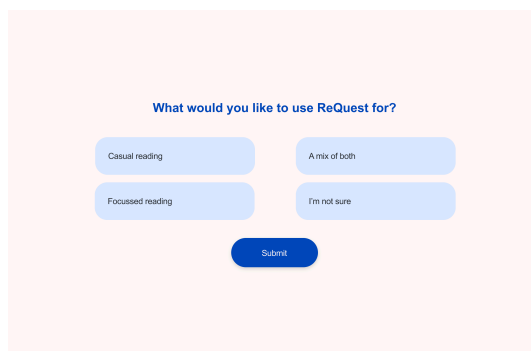


Figure 59: 6th actionable change

7. Feature additions: Retaining the ReQuest demo at the end and adding a 'skip demo' option that allows the user follow their own journey.

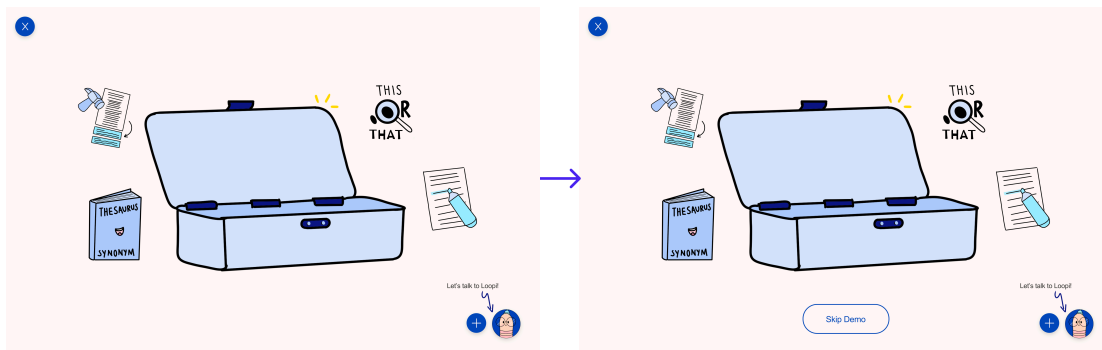


Figure 60: Before (L) and after (R) of the 7th actionable change

8. Subtype prediction: The subtype is presented to the user right after clicking submit on Quest 4, therefore it is a bit sudden. A buffer screen will be added to ease the transition.

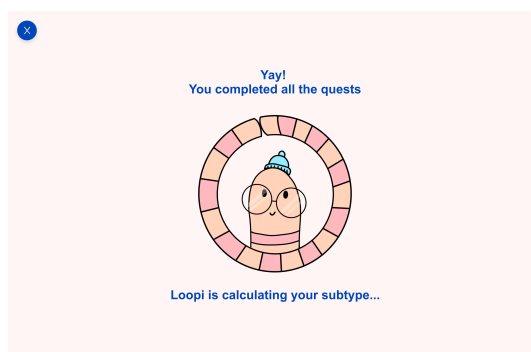


Figure 61: The 8th actionable change

9. Doesn't quite fit me: Before the user creates a toolkit they should be able to go back and pick a different subtype.

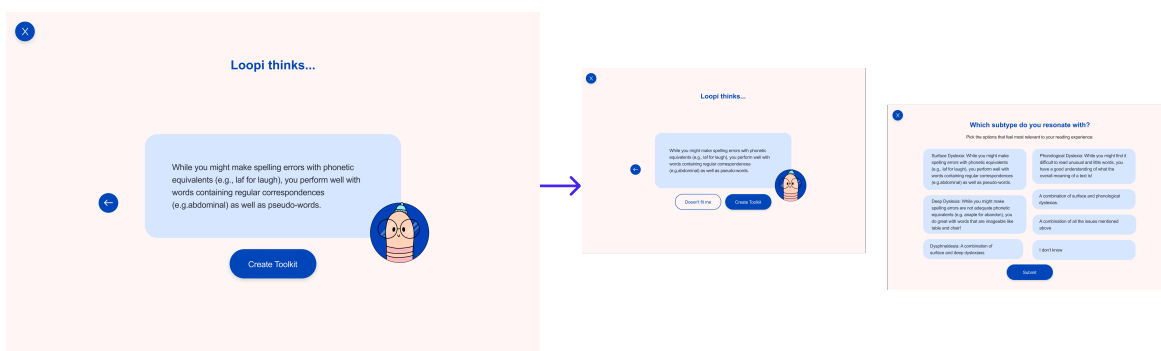


Figure 62: Before (L) and after (R) of the 3rd actionable change

CHAPTER - 8

Reflection and Discussion

Deriving Meaning from Results and Practice

Chapter - 8: Reflection and Discussion

In this final chapter, the key findings, insights and implications derived from the research and design process are brought together. By critically examining the outcomes in relation to the initial objectives, it reflects on the strengths and limitations of the contributions. It also explores the broader relevance of the findings, the lessons learned, the connection to existing literature and opportunities in the real context.

Reflection

I will be using three key parts to reflect on my thesis; the process, the results obtained and my personal developments and takeaways.

Contributions

Through the following questions, I will discuss the knowledge contributions obtained from the thesis:

1. What is subtype testing and why is it relevant for dyslexic readers?

As seen in this thesis, two types of subtype testing were used; pseudo-word testing and eye-tracking. Through literature study, I identified the need to incorporate these tests, as dyslexic readers benefit from personalised solutions, and subtypes serve as a key factor in tailoring those interventions effectively. Subtypes indicate specific deficits that a dyslexic person may exhibit and detecting it helped in shaping the contents of the toolkit in ReQuest.

2. How does the initial proposal (kick-off brief) match the literature discussed?

The initial proposal talks about making creating enhanced user experiences for dyslexic users. Alongside that, it the end result must also promote user empowerment, customise the use of technology and facilitate social impact. The focus lies on the accessibility of the digital content in the library for the dyslexic users as they currently face difficulty in reading them. Additionally, the initial design goal was to “Design a prototype/ intervention to create and improve the experience for dyslexic users in The National Library of The Netherlands.”

The literature in this thesis is discussed in four main parts as seen in Chapter - 1 (under research findings through literature review); subtypes of dyslexia, assistive technologies, pseudo-word testing and eye-tracking. These four elements relate to the initial proposal with user empowerment, customised technology and improved user experience for dyslexic readers.

3. How does this project tie into KB's Online Bibliotheek?

As mentioned in Chapter - 1, KB's vision is to make reading accessible for various inclusive groups. The KB has created a few profiles/personas for this purpose and it includes individuals with ADHD, dyslexia, colour blindness etc. This ties in perfectly with my aim for this project with dyslexic readers. Since the KB and I view these groups as separate pools of users that cannot all have a generic solution, this collaboration led to a focus on the dyslexic group and their needs with digital reading.

The ReQuest application will be housed in the KB's Online Bibliotheek which contains around 45,000 e-books. Once the user completes the cognitive quests, the app will contract into a button on the right-hand corner of the screen and function as a plug-in would. The plug-in will contain embedded tools like a thesaurus, dictionary, text-to-speech etc. The reason for integrating the app as a plug-in is to avoid any deep system integration or changing of the current e-book software. This way the operating systems remain untouched. Once it is validated, it can be easily implemented with other stakeholders like the EDRLab who work towards the same goal of accessible reading. Additionally, when more projects around other neurodiverse conditions are built, they can use a similar plug-in format and scale the existing solution, this also relates to the 'playground' vision that these stakeholders have with respect to e-reading. This integration will also require a few rounds of testing with the user group to ascertain how the task of reading functions with the plug-in

Results

Through my research, I find that the main results of this thesis are:

1. Cognitive testing in terms of pseudo-word tests and eye-tracking are effective ways to detect a dyslexic reader's subtype. This is supported by (Siegel & Ryan, 1989), (Takala &

Kuusela, 2009) and (Desroches, Joannis & Robertson, 2006) as well as through my testing in Chapter - 6.

2. The ReQuest application provides a curated reading experience to dyslexic readers with the detection of their subtype and a custom toolkit. This way they are able to engage with the e-books at the Online Bibliotheek in an immersive manner. This ultimately leads to a smooth reading experience that encourages the user to read more.
3. In this point, I will answer the research questions and compare the results of my research against the problem statement and design goal:

- **Research questions:**

1. How can the gap between dyslexic subtypes and existing assistive technology be bridged so that dyslexic readers can have a smooth e-book reading experience?

The gap was bridged by proposing the ReQuest application that provides personalised support to dyslexic readers. This application was built on scientific research which uses the readers' dyslexic subtype to create a custom toolkit that is relevant to their unique needs.

- Subquestion: Further, how can subtypes be used to recommend specific and better-fitting assistive technology to dyslexic readers?

Subtypes can be predicted through pseudo-word testing and eye-tracking which point to specific deficits that the reader faces. These deficits are then connected to specific assistive technology and finally translated into a custom toolkit. The connection between deficits and AT was made in Chapter - 4, Figure 22.

2. What features can the Online Bibliotheek incorporate to make the e-books on the platform more dyslexic reader friendly?

The features from the ReQuest application like the cognitive test and the resultant custom toolkit will be the most relevant for a large-scale organisation like the KB. The plug-in can occupy a dynamic position within the platform and engage with users. Even non-dyslexic users can make use of features like goal setting and the toolkit for a personalised reading experience.

- **Problem statement:** There is a lack of research and focus on the needs of the dyslexic reader community, particularly on the integration of dyslexia subtype detection for assistive technologies that support digital text reading, such as e-

books from the Online Bibliotheek of KB. This problem statement was addressed by placing focus on the lack of connection between scientific research in subtype detection and assistive technologies for dyslexia as seen in Chapters 1 and 4. I deeply explored these two aspects and brought them together (Chapter - 3) in the form of the ReQuest app (Chapter - 5). This can now be developed and integrated into KB's Online Bibliotheek.

- **Design goal:** Design a digital assistive tool that improves the reading experience of dyslexic readers so that they can comprehend e-books in an immersive/engaging manner.

The design goal was successfully achieved, as the ReQuest app received a positive review while being tested for reading experience by dyslexic readers. The offered features such as the toolkit and gamification element increased user engagement and kept them immersed.

Process

This project is a culmination of cognitive science and inclusive design, therefore it has two main components:

1. The cognitive science aspect provided a basis for understanding the gap between dyslexic reading and existing assistive technology. Cognitive science tests also uncovered the user's tendencies towards a particular subtype were also uncovered. Inspired by the approaches in (Siegel & Ryan, 1989), (Takala & Kuusela, 2009) and (Desroches, Joanisse & Robertson, 2006), I designed a cognitive test that draws on the strengths of both methods (pseudo-word testing and eye-tracking) and tailored it to my context. As seen in Chapters 5 and 6, I adapted and conducted these tests with 7 users from the target group, which uncovered its potential to detect dyslexic subtypes. Building upon these testing methodologies, the ReQuest app uses a combination of pseudo-word testing and eye-tracking to detect subtypes. Additionally, the method of self-reporting was added to reduce errors in subtype predictions. The combination of these three quests resulted in positive comments from all seven users. They drew connections between their own challenges and the elements of their toolkit which led to a smooth experience. This is an important revelation for the field of Human-Computer Interactions (HCI).

2. Design methods were used to create an engaging reading

experience for the user, primarily the five stages of design thinking; empathise, define, ideate, prototype and test. Through this design process, I was able to execute a dyslexic-centric interface that involved the user every step of the way. For the empathise phase, I interviewed dyslexic readers and experts as well as read the stories of dyslexia. For the define phase, I used a cognitive test with dyslexic readers to ascertain if subtype differentiation is possible. For the ideate and prototype phases, I used methods like user journey mapping, interaction vision and a Harris Profile to evaluate my developments against the needs of the user. Lastly, the testing was done with dyslexic readers to collect feedback and iterate on it. These steps were taken to better accommodate dyslexic-centric research since I am not dyslexic myself. I made sure to collect feedback before and after using my prototype and before I started the design process in an effort to have dyslexic needs represented. Lastly, I made sure that the language used and questions posed were not offensive on any level since there was mention of the specific deficits and subtypes quite frequently. Users were continuously asked to take their time and informed that it was not a 'test' to relax them. While the broader design method was based on the five stages of design thinking (Dam, 2025), co-creation practices from (Sanders & Stappers, 2016), ideation techniques like the Crazy8's (Core Method, n.d.) and evaluation methods like the Harris Profile helped create a cohesive design process. This way of combining methods is significant because it demonstrates the application of a core principle of design: the creation of iterative and adaptable processes.

Together, both of the above findings contribute meaningfully to the field of Human-Computer Interaction and Inclusive Design. As mentioned in the introduction, the novel approach of this project lies in the dyslexic subtype detection that has been used as the foundation for interactive product design. This appears to be a relatively unexplored approach and has the potential to open up new directions for research, especially in the design of assistive technologies for accessible user groups. For example, the cognitive tests back the elements of the toolkit while providing an accessible and simple interface for dyslexic readers.

Personal Development

This section reflects on my personal growth and development

throughout the course of this project. At the beginning of this project, I articulated three main points of motivation for this project. By highlighting key moments, I will discuss how these ambitions captured the development of my perspective, as a designer and researcher:

Writing a paper to gain experience in academic writing and publishing materials: In the next few months after the completion of my graduation, I will be writing a research paper to showcase my findings in an academic context. Through this report, I have already collected the key information that will frame the basis of the paper.

Working in close contact with an inclusive group, like the dyslexic, to increase my understanding of the user group: As mentioned in the process section, every stage of the design process included dyslexic users which taught me to plan my interactions with them in advance so as to be cognisant of their feelings and dyslexia. The whole process taught me to be empathetic through the accessibility guidelines and advice from my mentors.

3. Learning and investigating in the world of cognitive sciences through experiments: In this project, I have had a couple of chances to create cognitive tests. First the survey in Chapter - 3 and second the tests within the ReQuest application in the cognitive test section (under technical functionality) of Chapter - 5. Through these tests I gained two main things; I was able to learn the method of creating a cohesive experience around testing and I developed an understanding towards data collection and analysis.

Apart from the points mentioned above, I also had several other learning moments along the way:

- 1. Working with KB:** This provided me with meaningful exposure to the inner workings of a large scale organisation, while also offering relevant hands-on experience within an industrial setting.
- 2. Overall project management:** I effectively acquired knowledge on creating and accomplishing goals within a given timeline while managing expectations and making relevant decisions. This allowed me to deliver a cohesive project in the end. For example; when I began to plan my testing process, I realised that it is quite time intensive, therefore, I allowed some buffer periods as backup and to synthesise the

collected data such as voice recordings, transcripts and screen recordings of the user journey. I also learnt to create an overall structure rather than plan everything to the 't'. This way I was able to add and remove methods that were relevant to my process.

Discussion

One of the key contributions of this thesis lies in how dyslexic subtypes are detected through a series of gamified cognitive quests, that are housed within the ReQuest application. This leads the user towards a personalised toolkit of assistive technologies that are specifically aligned with their deficits. In doing so, the gap between assistive technologies and subtype detection is bridged through the lens of inclusive design and cognitive science. Positioned within the broader context of KB's goal to make their digital collections more accessible, this thesis offers a valuable opportunity to explore how assistive technologies could be integrated into existing e-book platforms while keeping the dyslexic user at the centre of the process. This prompted me to use a 'dyslexic-centric' approach throughout the project; a term I coined to reframe and deepen the practice of empathetic design. Employing this approach allowed me to better understand the intricate challenges dyslexic readers face when engaging with digital reading. This was done mainly through qualitative research methods like interviewing dyslexic readers and experts, reading stories, cognitive tests surveys and experience testing.

Backed by existing literature on subtypes and assistive technology, this project extends into the creation of a targeted intervention for dyslexic readers. In (Borsting et al., 1996), the authors cite (Boder, 1971) where three basic dyslexic subtypes were identified; dyseidesia, dysphonesia, and dysphoneidesia. By comparing the definitions of these subtypes to definitions of surface dyslexia (NeuroHealth Arlington Heights, 2021) and deep dyslexia (Coslett & Turkeltaub, 2016) it was revealed that there is a significant convergence of meaning between the two sources. Therefore, I re-framed to research to use the later terms since they are more accessible or commonly known to dyslexic readers.

To connect subtypes with the corresponding deficits literature mentioned above was consulted to extract specific difficulties in reading from the definitions and articulation of each subtype. A table was created (Column 2, Figure 22) to map the deficit against the four subtypes.

From publications that have a detailed analysis of ATs, for example, (Dawson et al., 2018), (Zakopoulou et al., 2017) and (Tzouveli et al., 2008), it can be seen that dyslexic readers are considered a homogeneous user group without any distinction. There are recommendations for different tools in (Dawson et al., 2018) specific to reading and writing/spelling but this is still a high-level variation. From my approach, I conclude that the current literature lacks an approach to address individual challenges rather than task-based support. My work addresses this gap by creating another level of personalisation that is missing from academic research on assistive technology currently. This element of personalisation caters to dyslexic readers in a specific and effective way that benefits their reading experience by engaging them.

Figure 22, Column 3 shows that each deficit has been tabulated against a specific set of ATs. This information was leveraged from the citations above and Chapter - 1 and helped identify the right kind of support for each deficit.

What sets my approach apart is the integration of these points on subtypes and AT together. The gap is being bridged by first detecting subtypes and connecting them to the relevant deficit.

Then it is possible to align the deficit to the corresponding AT.

The insights gathered were translated into a functional high-fidelity prototype that supports personalised reading journeys through gamification, thereby keeping users engaged and immersed in the experience of the application. By taking a dyslexic-centric approach, this project focuses on both the cognitive science and inclusive design angles. This shift in perspective, supported by the user's insights, not only informed the final solution but also highlighted the importance of adaptability, presence, personalisation and simplicity (as seen in Chapter - 2, Figure 9). Reflecting on the process, the

collaboration with KB and continuous engagement with users helped shape the outcome of this project - The ReQuest Application, a solution that contributes to ongoing discussions in both design research and accessibility practices. Through the course of this thesis another major finding was that there is a lack of subtype awareness among dyslexic readers. From testing I found that users are curious about subtypes and want to find unique ways to tackle their reading deficits.

The limitations and future scope are discussed on page 101 and page 105.

Evaluation Checklist

In the checklist on the following page I compare the points of the thematic analysis from Chapter - 2, Figures 9 & 10 to its counterpart in the ReQuest app. This is a way to evaluate how the criteria from the empathise phase have been executed in the solution. They also match the qualities in the Interaction Vision (assistive, engaging and simple) as seen in Figure 30.

Requirements and Criteria	Design Feature in the ReQuest Application
<p><u>Subtype Awareness</u> Currently, users are not aware about their deficits being classified into different subtypes. When introduced to the concept they are quite excited to know more about their subtype and why they belong there.</p>	<p>The cognitive tests (pseudo-word testing and eye-tracking) on the app informs the user of their subtype.</p>
<p><u>Personalisation and Unique Identity</u> Since every dyslexic reader's subtype is different, they have different needs when it comes to AT.</p>	<p>The ReQuest app creates a personalised toolkit based on the user's subtype which caters to the user's specific deficits.</p>
<p><u>Presence</u> The users asked for a solution that can be carried across multiple contexts when they read digitally.</p>	<p>While the ReQuest app does not directly address this technical functionality yet, the goal is to have an ever-present application that can be used on any platform. Currently, the ReQuest app is a plug-in that can be attached individually to a particular context.</p>
<p><u>Adaptability</u> Users are seeking smarter technology that can understand their needs better.</p>	<p>The ReQuest application houses various ATs like text-to-speech and thesaurus for example, that are able to cater to the needs of a dyslexic person (as seen in Chapter - 6). There is also an AI-powered personal assistant, Loopi, that is present to answer any questions that the user might have.</p>
<p><u>Simplification</u> The potential solution has to be simple to use and not overwhelm the user with redundant features.</p>	<p>To make the app easy to use, information has been broken down into small sections, accessibility guidelines are implemented and there is a guided demo to help the user understand how the app functions. The user is walked through each step with easy to read instructions. Lastly, the app contracts into a button in the right-hand corner of the screen and can be accessed whenever the user wishes.</p>

Figure 63: Checklist to compare thematic analyses from problem identification to the solutions in ReQuest app

Limitations

While this research provides valuable insights into dyslexic reading, it also has certain limitations that present opportunities for further exploration:

1. Cognitive Test

(i) While the current cognitive tests from Chapter - 5 can be a preliminary test to identify which subtype of dyslexia one might have, it is not an official diagnosis. More criteria, for example, the influence of language adding the IEP (Individualised Education Plan) and AB testing with different formats can be integrated into the process to get more clarity on what subtype one might have.

(ii) The ranking of words gives me an insight into what is easier and tougher to read, but, it does not give me a sense of what the degree of increase from easy to tough is. For example, is 'mip' much tougher to read than 'driffical' or just slightly tough or vice-versa?

(iii) There is a lack of quantitative data in from the eye-tracking test. Although the error rates were calculated, it was negligible because the testers associated images with sounds and were therefore able to pick the right answers mostly. Simulating the context like with the second pseudo-word test (reading a story to identify hidden pseudo-words) was more effective since the text was densely packed similar to a real book.

2. Sample size

(i) There are real insights in this report from dyslexic readers and experts, but they are still a small sample size compared to the number of dyslexic readers globally. This could lead to a limited result which can be extended into other subtypes that have not been accounted for.

(ii) Every person has a different type of dyslexia even if they fall into the same subtype. Since this is a variable component, this research only focuses on the four subtypes discussed in this report. I used qualitative methods which do not require a minimum sample size, but for some quantitative insights on error rates for example, it could be a beneficial measure for this topic.

3. Technical Feasibility

(i) Developing a plug-in that can function across various contexts can only be implemented in stages. For this thesis, the primary aim is to be able to implement it in the KB's Online Bibliotheek amongst e-books, but in the future ReQuest's goal is to be

available on webpages and gradually in specific applications like presentation or emailing platforms.

4. The Role of AI

(i) It is quite apparent from Chapter - 6 that tools like ChatGPT are quite popular among dyslexic readers as they offer a personalised experience. While it is able to engage the user effectively, it lacks a sense of empathy, at present, to cater to all the needs of a dyslexic individual. It is used more for writing than reading because it helps users reduce spelling errors. But when they do use it for reading they do so by asking for summaries of long texts. P5 also mentioned that they used to prepare for tests only with ChatGPT and used to score significantly lower than their peers. Therefore, they now try to use other non-AI ATs.

(ii) There is definitely a chance of integration and a quality of smartness that users seek in their ATs. As seen in Chapter - 2 Figure 9, the interviewees mentioned the need for simple technology that adapts to different contexts of reading. At the rate at which AI is developing and making strides, it is definitely not a faraway reality when all inclusive user groups and normal readers are using some format of AI to read and write. I speculate that this does not eradicate the need for designers, but rather strengthens their position as a researcher and co-creator in the process.

(iii) When I experimented with ChatGPT in the beginning of my research, I had gained a few insights on how it can be leveraged in different ways.

My experience with ChatGPT was quite interesting in three main areas:

The Dyslexia Helper Bot - When I asked for a story in a chat where I had already asked for assistance with a sentence, it gave me a story of a dyslexic girl and made sure to mention that it would be short. It highlighted only one word where it assumed I might have difficulty.

When I tried in a fresh chat it gave me a story about a dragon and highlighted multiple words based on (see picture). When I further asked why only these three types it responded by saying that these three are mainly required for comprehension of the story.

When I asked ChatGPT directly by not telling it that I am dyslexic, it first asked me what kind of story I would like to hear with a few genre examples. When I selected one, it started reciting the story then, stopped at a key moment and asked me if I wanted to continue. It repeated this three more times until I asked it what

the bolded words meant. It then said that the bold words are there for emphasis and drawing attention to certain important feelings and events.

In all cases it asked be whether I wanted to readjust the bolding so either underlines or a different colour. But the regular ChatGPT was much more conversational and receptive of my needs rather than telling me what it thinks is the best for me.

Conclusion

Conclusion

Overview of Report

This report set out to explore the cognitive perception in dyslexic reading. As mentioned in the introduction, cognitive perception is the process in which the brain makes sense of the information provided, including text. Dyslexic individuals mainly face issues with reading, and the focus of this thesis is to enhance cognitive perception by revisiting the role and usage of assistive technology. This report highlights the significant gap between dyslexic subtypes and assistive technology. The insights gained from the primary research such as; interviews and cognitive test surveys as well as secondary research such as; stories of dyslexia and academic literature emphasise the need to bridge this gap. Potential ideas have been discussed in order to improve the reading experience for dyslexic individuals. The refined concept showcases the ReQuest app which requires the user to complete a cognitive test that will detect their subtype and recommend a toolkit with the most relevant components. Further, it is an ever-present assistant that will be stagnant on the right-hand bottom corner of the screen and can be activated by the user at any time.

Future Scope

This study lays the groundwork for future interventions and investigations in the field of cognitive science and inclusive design. The following points highlight the potential evolutions and suggestions that are promising paths for future inquiry:

1. The current work is a high-fidelity prototype that is meant to test the dyslexic readers experience with ReQuest. As seen in Chapter - 6 it demonstrates the potential to be translated into a practical tool. The ReQuest app can be advanced from a validated concept to a fully developed and scalable digital platform in the KB's Online Bibliothek.
2. The look and feel of the platform can be tested with a dynamic UI. While this has not been tested in the current setting an example was created (Figure 64) to showcase a more clean approach to the UI, which can be AB tested with the user group. It would be interesting to understand whether this increases or decreases cognitive load in users.

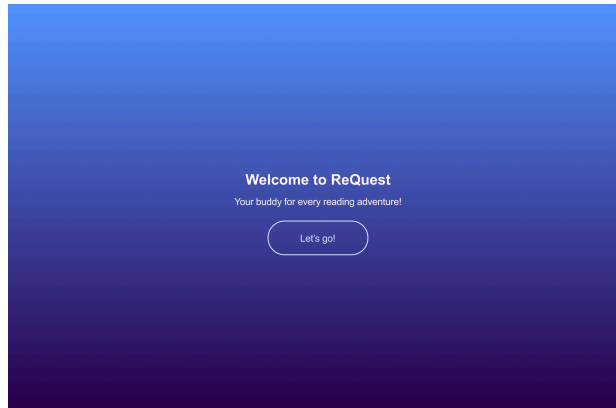


Figure 64: Dynamic UI

3. Testing of ReQuest in the context of the Online Bibliothek. After the development of the application, it is essentially to run a test with real e-books as well to measure its impact and make effective iterations.
4. Future work could involve the advancement of concept that builds on the current findings to better support dyslexic readers. The analysis of the cognitive tests reveals that it is a concrete way of getting results and identifying subtypes. More testing can be done with these tests to identify patterns that might distinguish each subtype further. This way the error rate of the presented subtype can be quite low.
5. By involving more experts and doctors into the making of this platform, it holds the potential to be developed into a diagnostic tool. This requires more research into subtypes themselves and specific criteria that differentiate them, ensuring accurate identification and personalised support for each user profile.
6. This research takes a step forward in understanding 'Cognitive Perception in Dyslexic Readers', and also opens up opportunities to enhance assistive technologies. Efforts can be made to make current ATs more inclusive and raise awareness about dyslexic user needs.
7. Expanding the project to fit other subtypes that were not considered in this thesis. Other types of dyslexia can also be considered in the long run for example dyslexia with writing since these are sometimes complementary with reading.
8. Currently my prototype has been tested for the age group of 18 - 26 years. Insights from my testers and user study suggest that the ReQuest app might be implementable to a younger age group as well and Loopi can be a great way to engage children and young adults (10 - 16 years of age).

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Christina, I am especially grateful for the empathetic approach and clarity you brought to the most complex ideas (especially with the definitions of the subtypes :)). Your deep knowledge in cognitive science helped me explore solid academic grounds and gain a better understanding of the investigative side of this topic.

Ted, your practical perspective and thorough grasp of the KB context were key in grounding this project in reality. Additionally, your hands-on nature facilitated an environment of curiosity which helped me stay true to the project's goals while experimenting and approaching the project from different lenses. Thank you so much!

Working under your supervision has been both a privilege and a deeply enriching learning experience. Thank you for your time, trust, and mentorship!

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I am equally grateful to my parents, whose constant belief in me and unconditional support formed the foundation of this entire endeavour. Their encouragement gave me the strength to persevere through challenges and pursue this project with dedication and passion. Thank you so much Amma and Appa!

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Appendix



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	<input type="text"/>	IDE master(s)	<input type="text"/>
Initials	<input type="text"/>	2 nd non-IDE master	<input type="text"/>
Given name	<input type="text"/>	Individual programme <i>(date of approval)</i>	<input type="text"/>
Student number	<input type="text"/>	Medisign	<input type="text"/>
		HPM	<input type="text"/>

SUPERVISORY TEAM

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

Chair	<input type="text"/>	dept./section	<input type="text"/>	<p>! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.</p> <p>! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.</p> <p>! 2nd mentor only applies when a client is involved.</p>
mentor	<input type="text"/>	dept./section	<input type="text"/>	
2 nd mentor	<input type="text"/>			
client:	<input type="text"/>			
city:	<input type="text"/>	country:	<input type="text"/>	
optional comments	<input type="text"/>			

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

Sign for approval (Chair)

Name	<input type="text"/>	Date	<input type="text"/>	Signature	<input type="text"/>
------	----------------------	------	----------------------	-----------	----------------------

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

<input type="checkbox"/>	YES	all 1 st year master courses passed
<input type="checkbox"/>	NO	missing 1 st year courses

Comments: _____

Sign for approval (SSC E&SA)

Name _____ Date _____ 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	<input type="checkbox"/>	Supervisory Team approved
NO	<input type="checkbox"/>	Supervisory Team not approved

Comments: _____

Based on study progress, students is ...

<input type="checkbox"/>	ALLOWED to start the graduation project
<input type="checkbox"/>	NOT allowed to start the graduation project

Comments: _____

Sign for approval (BoEx)

Name _____ Date _____ Signature _____

Personal Project Brief – IDE Master Graduation Project

Name student

Student number

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Cognitive Perception for Dyslexic Readers

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)

Context: This project is set within the context of The National Library of The Netherlands - KB. The KB has been a source of inspiration and development for centuries. Their core values are to open, unify, innovate and to be reliable to the general public by ensuring that their digital and physical content is accessible to users with diverse needs (for example: visual impairment and dyslexia)

Domain: This project is set at the intersection of cognitive sciences and inclusive design. At the cusp of these two fields lies the exploration of how dyslexic users perceive and process information. Through the fusion of these domains I aim to improve accessibility, enhance user experience and create social equity through my innovation. I see huge potential in creating a design intervention which caters to a specific user group (dyslexic users in this case) that can be extended to many others in the future. As mentioned in (Shovman and Ahissar, 2006), the main difficulty for dyslexic people in visual perception is due to impoverished phonological processes. On executing their experiment it was found that dyslexics need to acquire accurate visual information to compensate for their phonological deficits.

Stakeholders: Dyslexic users are the primary stakeholder group for this project. I want to run a study and present how technology can be assistive leveraged to enable dyslexic users while accessing digital materials from the library. The KB will be the secondary stakeholder as I will be working with their current e-book systems.

Opportunities: As mentioned previously, the main goal of this project is to create enhanced user experiences for dyslexic users. Alongside that, it promotes user empowerment, customises the use of technology and facilitates social impact. I want to focus on the accessibility of the digital content in the library (such as e-books, magazines etc.) for the dyslexic users as they currently face difficulty in reading them.

Limitations: Currently I envision having access only to users with specific types of dyslexia which can lead to

introduction (continued): space for images



image / figure 1

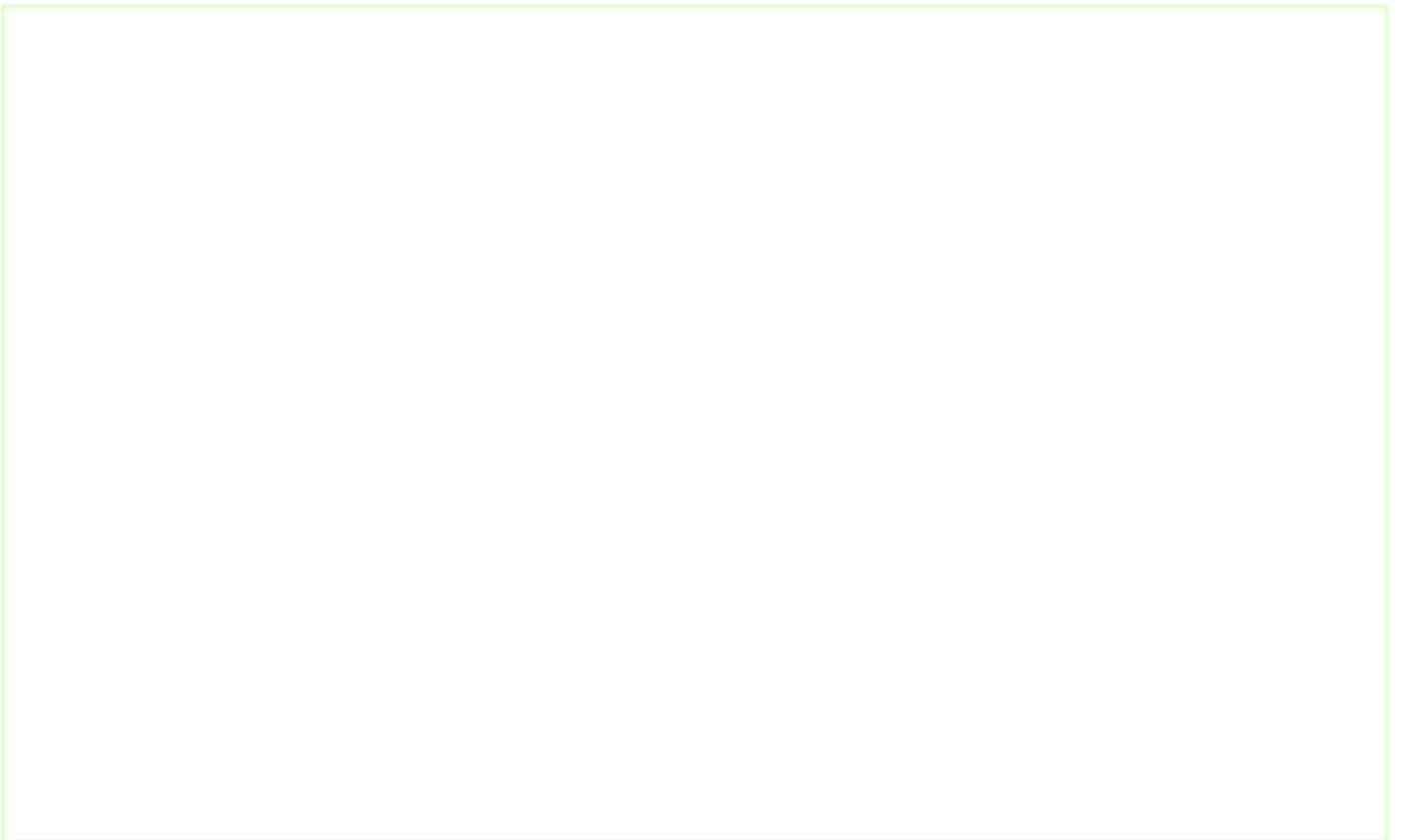


image / figure 2

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)

Dyslexia expert Beve Hornsby notes that about one in ten individuals has some degree of dyslexia (Hornsby, 1984, as cited in Rutledge, 2002). Despite its prevalence, resources for supporting reading and comprehension in dyslexic individuals are lacking. Many struggle to navigate library materials, and research shows that a universal design does not meet the diverse needs of those with dyslexia (Kous & Polančič, 2019).

Reading involves two processes: decoding and comprehension (Gough and Tunmer, 1986). In dyslexia, a phonologic deficit impacts the ability to segment and link sounds to letters, leading to challenges in decoding and identifying words (Shaywitz and Shaywitz, 2005). Dyslexia can also involve broader issues like short-term memory problems, difficulty distinguishing direction, weak organizational skills, and poor coordination (Rutledge, 2002). This suggests that cognitive perception is crucial for dyslexic users in the library, and I plan to explore this further by interviewing some users at the KB. My design process aims to enhance accessibility to library reading materials for dyslexic users using adaptive technologies and empathetic practices.

Opportunities exist for designing immersive experiences that enhance library interactions for users, particularly those with dyslexia. The AGENT-DYSL approach (Tzouveli et al., 2018) shows promise in utilizing adaptive technologies. Previous research highlights tools like iLearnRW (Zakopoulou et al., 2017) and assistive technologies (Dawson et al., 2018) that have improved metacognitive control and phonological awareness among

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:

Design a prototype/intervention to create and improve the experience for dyslexic users in The National Library of The Netherlands.

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)

I want to carry out my graduation project with interaction design techniques as the basis. To conduct research I will primarily use literature review and interviews. Then I will analyse and evaluate these findings to create a concrete design goal. Further, this design goal will be used to generate ideas and create prototypes which will be tested with the user groups and then improved upon based on the given feedback. I foresee iterating upon some of these steps to increase the quality of my work. My broader process will be similar to that of the design thinking method (Simon, 1969); i.e. empathise, define, ideate, prototype and test.

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	<input type="text"/>
Mid-term evaluation	<input type="text"/>
Green light meeting	<input type="text"/>
Graduation ceremony	<input type="text"/>

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	<input type="checkbox"/>
For how many project weeks	<input type="text"/>
Number of project days per week	<input type="text"/>

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)

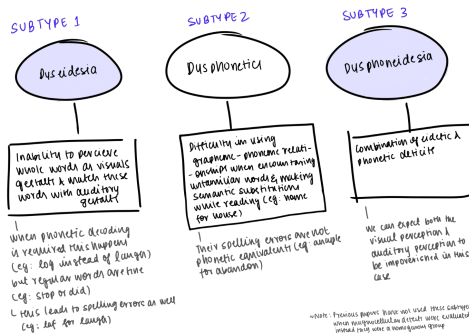
As a designer, I am drawn to real-world problems that challenge me to think creatively. I strongly believe that working at the intersection of inclusive design and cognitive science allows me to contribute to meaningful change while advancing my expertise in designing for diverse user needs. I have worked with designing inclusively for a couple of years now and I would like to take this project as an opportunity to deepen my experience in the field. Additionally, I am very intrigued by the world of cognitive sciences and the reasons behind human behaviour in response to various stimuli, making this the ideal project to investigate and conduct research effectively. I am especially excited to collaborate with the KB as a stakeholder because the right to access knowledge should be extended to everyone, irrespective of the disabilities they face. I am confident that creating a tool that can be implemented in The National Library of The Netherlands has the power to transform experiences around reading and enable dyslexic readers positively.

I see this project as an opportunity to align my passion for design and achieve my ambitions of:

- Writing a paper to gain experience in academic writing and publishing materials.
- Working in close contact with an inclusive group, like the dyslexic, to increase my understanding of the user group.
- Learning and investigating in the world of cognitive sciences through experiments as to why humans behave a certain when a certain stimuli is presented to them.

Appendix

1. Dyslexic subtypes and their definitions:



Surface dyslexia, first described by Marshall and Newcombe (1973), is a disorder characterized by inability to read words with "irregular" or exceptional print-to-sound correspondences. Languages differ with respect to the consistency with which letters are mapped to sounds; in some languages (e.g., Italian), letter-to-sound correspondences are predictable, whereas in other languages (e.g., English) rules govern the mapping between print and sound, but there are also numerous exceptions. Patients with surface dyslexia fail to read words such as *colonel*, *yacht*, *blonde*, *there*, and *though* for which the mapping between print and sound is not governed by rules. In contrast, these patients perform well with words containing regular correspondences (e.g., *stake*, *hard*, *abdominal*) as well as nonwords (e.g., *blond*). A significant effect of word frequency is typically encountered such that regularization errors are far more common with low-frequency words. The great majority of patients with surface dyslexia also demonstrate semantic impairment on tasks that do not involve reading.

word reading deficits (Brambati et al., 2009). Similarly, another recent study identified an area of left anterior middle temporal cortex that was active in control subjects during an exception versus pseudoword reading comparison, and it was also atrophied in a patient with surface dyslexia related to semantic dementia (Wilson et al., 2012). Another study examined the neu-

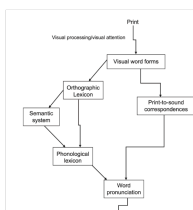


FIGURE 63.1 A simplified information-processing model of the procedures involved in reading provided for illustrative purposes.

<https://pdf.scienceirectassets.com/313126/3-s2.0-C20110073519/3-s2.0-B9780124077942000638/>

Surface dyslexia
Nanditha Sathyanarayanan

Deep dyslexia
Nanditha Sathyanarayanan

Combination
Nanditha Sathyanarayanan

Several alternative explanations have been proposed for deep dyslexia. Some investigators have argued that deep dyslexia is on a continuum with phonological dyslexia (Crisp, Howard, & Lambon Ralph, 2011; Patterson & Lambon Ralph, 1999). With this account, the two disorders share as the primary disorder an impairment in phonological processing, but the deficit is more severe in deep dyslexics. Friedman (1996) noted that as subjects with deep dyslexia recovered, they often stopped making semantic errors, thereby meeting criteria for phonological dyslexia (see also Closser & Friedman, 1990). On the basis of 12 subjects with acquired dyslexia, Crisp and Lambon Ralph (2008) argued that deep and phonological dyslexia were distinguished by the severity of their semantic and phonologic impairments.

Phonological dyslexia: Phonological dyslexia is a disorder in which reading of real words may be nearly intact or only mildly impaired. Patients with this disorder, for example, correctly read 85-95% of real words. Some patients read all different types of words with equal facility, whereas other patients are relatively impaired in the reading of function words (or "little words"). Unlike patients with surface dyslexia described later, the regularity of print-to-sound correspondences is not relevant to their performance; thus, phonological dyslexics are as likely to correctly pronounce orthographically irregular words such as "colonel" as words with standard print-to-sound correspondences such as "administer". Most errors in response to real words bear a visual similarity to the target word (e.g., "topple" read as "table").
Nanditha Sathyanarayanan

Surface Dyslexia

An individual who can sound out new words with ease but fails to recognize familiar words by sight may have surface dyslexia. In this case, experts believe that the brain fails to recognize what a word looks like in order to process the word quickly. This type of dyslexia affects words that need to be memorized because they don't sound how they are spelled, making it more difficult to sound them out. Other names for surface dyslexia include visual or dysideitic dyslexia. It's not uncommon for an individual with dyslexia to also have both phonological and surface dyslexia. Symptoms of surface dyslexia can include:

- Difficulty with whole word recognition
- Slow to read
- Avoidant of reading activities
- Difficulty with spelling
- Difficulty reading words that don't sound the way they're spelled
- Difficulty reading new words by sight

Phonological Dyslexia

This type of dyslexia is the most commonly thought of when someone mentions the word dyslexia. It deals with difficulties in matching sounds to symbols and breaking down the sounds of language. Individuals with phonological dyslexia struggle to decode or sound out words. It's believed that phonological dyslexia is the most common type of dyslexia. Symptoms of phonological dyslexia may include:

- Difficulty learning sounds made by letters/letter combinations
- Difficulty sounding out unfamiliar words
- Difficulty spelling
- Spelling the same word different ways on the same page
- Slow reading
- Avoiding reading activities
- Difficulty recognizing familiar words in new contexts

2. Cognitive test link: <https://forms.office.com/e/u8KSbWciGm>

3. Tech repository of assistive technology that are currently being used by dyslexic readers [Image on next page].

Tech Repository				
Name of assistive technology	What does it do?	Primary element for dyslexia	My insights on it	Links
Accessibility on Apple Devices	It helps customise your apple devices in ways that work best for you with features for vision, hearing, mobility, speech, and cognitive accessibility—whether you need them temporarily or on an ongoing basis.	VoiceOver, Safari Reader, Predictive Text, Guided Access, Zoom etc.	Although the amount of tools are large, they are all independent and don't work in all contexts; for example the Safari reader which helps increase font size and change fonts is applicable only for the safari browser. The predictive text feature is only for keyboards that are on a touch screen and do not apply to laptops. VoiceOver is fairly difficult to employ, it takes some time and knowledge of the different terminologies to have it exactly right so it takes sometime with experimentation to enable it properly.	<ul style="list-style-type: none"> https://support.apple.com/en-sa/guide/iphone/iph3e2e4367/ios#:~:text=Or%20make%20text%20bigger%2C%20zoom,you%20can't%20see%20them. https://dystech.com.au/learning-difficulties/10-accessibility-features-for-dyslexics-on-apple-devices/
Thorium Reader	It seems to be a bit more inclusive in terms of technology that it can adapt with - Thorium Reader is the EPUB reader of choice for Windows 10 and 11, MacOS and Linux. This EDRLab application is in constant development and aims at becoming a reference for accessing EPUB 3 publications in reflow or fixed-layout format, audiobooks and visual narratives, PDF documents and DAISY 2.02 and 3 accessible ebooks, LCP protected or not.	Screen readers like JAWS, NVDA, Narrator and Voiceover. Other accessibility features include support for high-contrast, customisable font including dyslexia font), colour themes, text size and Text To Speech (TTS) read aloud. Radium component - open source to build reading software but with your own UI		
Read&Write				https://chromewebstore.google.com/detail/readwrite-for-google-chromeonmfajpbkmdafoankkfajkcpghd
NaturalReader				https://www.naturalreaders.com
Grammarly				https://app.grammarly.com/ddocs/2690380617
Ginger				https://www.gingersoftware.com
Lexia Learning				https://www.lexialearning.com/products/
Nessy				https://www.nessy.com/en-us
Immersive Reader (by Microsoft)	It can be activated in the word document from the header			https://support.microsoft.com/en-us/office/use-immersive-reader-in-word-a857949f-c91e-4c97-977c-a4efcaf9b3c1
OpenDyslexic				
Lexend				

TTS (main tech here is OCR which is Optical Character Recognition an dll basically converts different types of documents (such as scanned paper documents, PDFs, or images created by a camera) into editable and searchable text which can then be read aloud)

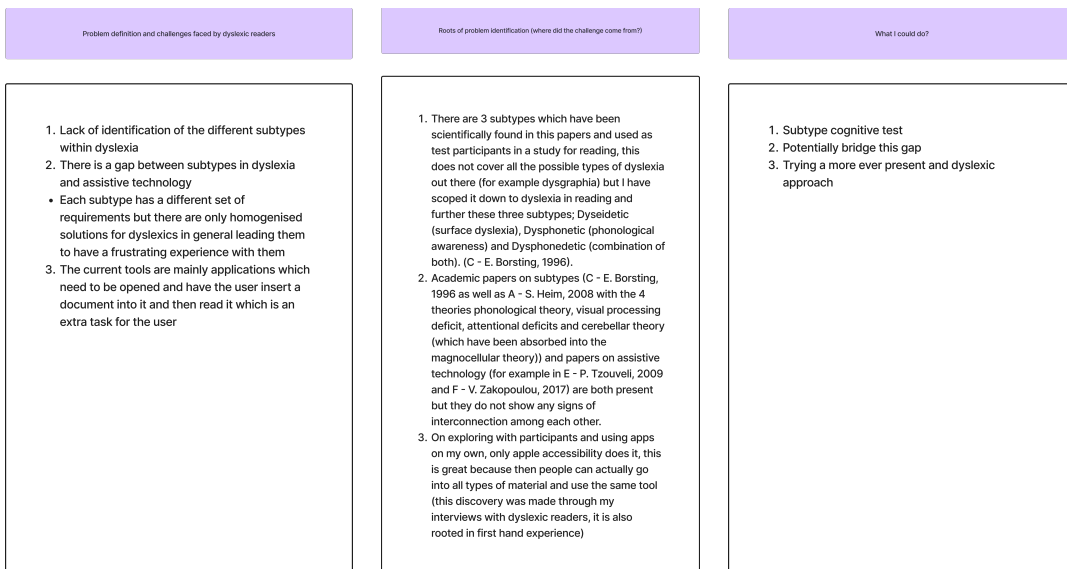
Word prediction

Multi-sensory tools

Highlighting

Fonts and typography

4. Linking the problem to the root academic evidence and my potential role in solving it:



5. Eye-tracking and subtype with pseudo-word co-relation:

Phonological

Rhyme awareness

e

Phonetic similarity



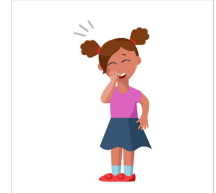
Scandal Candle Sandal



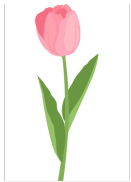
Candy Sandy Candle



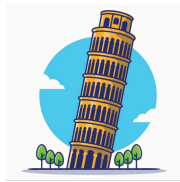
Sandal Candle Candy



Laugh Laf Lahf



Flower Flour Floor



Towel Tower Tour



Sour Scour Shower



Yaught Yacht Yot

Surface

Surface

Deep

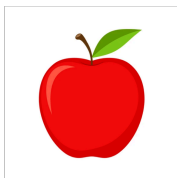
b

Visual similarity

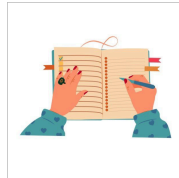
a - can non-phonetic words be decoded?

Non-phonetic similarity

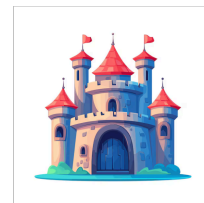
c - Semantic substitutions



Apple Adble Aqle



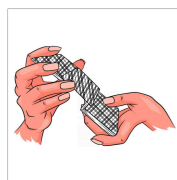
Colonel Kernel Journal



Castle or Knight



Flap Flog Flag

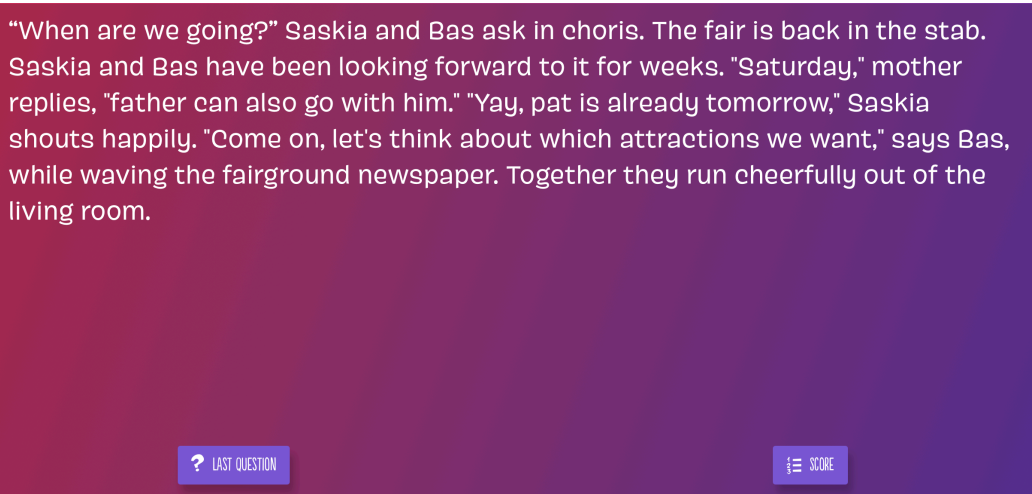


Shuttle Subtle Shuffle



Skate or Scale

6. Find the pre-test moderated questionnaire here: <https://forms.office.com/e/wvXZ9KX8kh>
7. Find the post-test moderated questionnaire here: <https://forms.office.com/e/Ggj5HnQad3>
8. To understand dyslexia further, I also used a simulation that re-creates a reading experience for dyslexics for normal readers. This was a method for me to immerse myself and empathise with my user group and understand their deficits more closely. Source



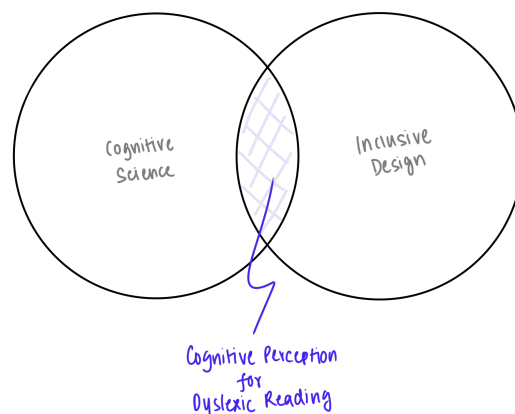
9. Eye tracking softwares that I explored before choosing Gaze Recorder for my testing:
 - (i) Mupixa
 - (ii) Focus Map
 - (iii) Real Eye
 - (iv) Use Berry
 - (v) Eye Quant
 - (vi) Tobii

These softwares did not fit well with my format of testing and therefore were not used. Some of them also used AI to predict eye movements which was not coherent with my form of testing where I needed to map the user’s gaze with precision.

Summary

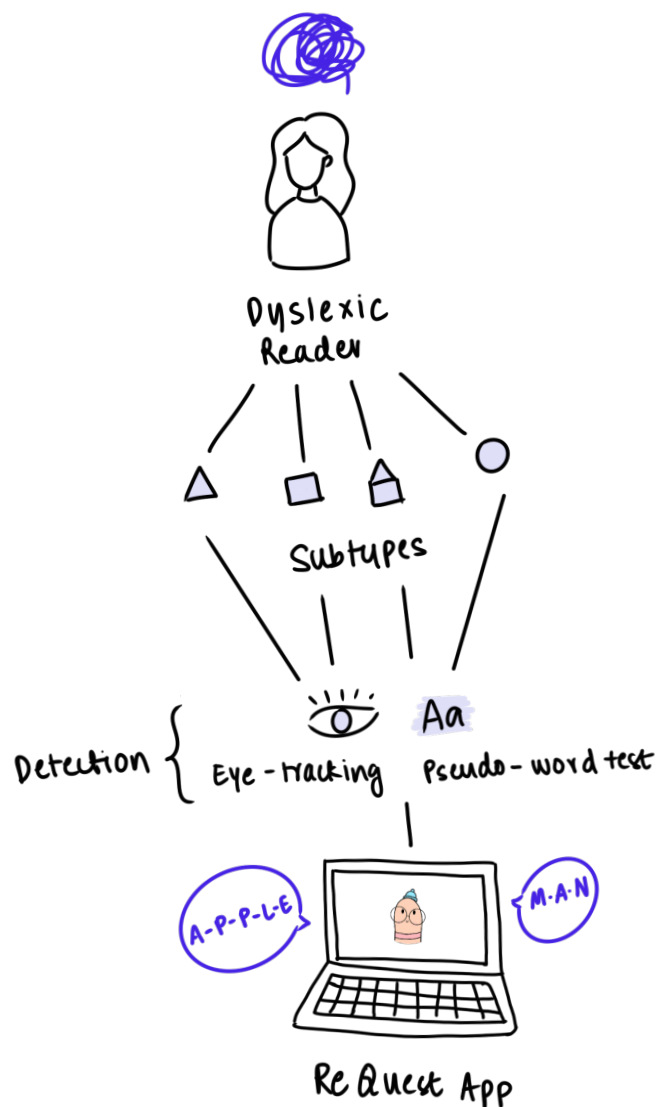
Summary

This thesis investigates the topic of 'Cognitive Perception for Dyslexic Readers,' with a focus on the dyslexic subtype detection and the use of assistive technology. Through a review of existing literature, it became evident that there are separate insights into the challenges faced by individuals with dyslexia, as well as the assistive technologies that are available to support them. However, a significant gap exists between these two areas, as current technologies are often designed for a homogenised group of dyslexic individuals without considering the specific subtypes. This oversight can result in a frustrating reading experience and may lead to disengagement with texts.



The goal of this project is to design a digital assistive tool that improves the reading experience of dyslexic readers so that they can comprehend e-books in an immersive/engaging manner. The project was developed in close collaboration with the Koninklijk Bibliotheek (The National Library of the Netherlands) and emerged from a shared vision of creating accessible digital reading experiences with their extensive e-book collection. As a result, an assistive tool, the ReQuest application was created. The name of the application, ReQuest, has been coined from the combination of two words; Reading and Quest. The core idea of the application is that it acts as a buddy for every reading adventure that the reader takes on. ReQuest aims to provide the right assistance to dyslexic readers by identifying their subtype, giving them a custom toolkit and making the experience of reading engaging and immersive. When a reader opens the application they are onboarded in a few simple steps. They will then be guided into 4 quests that will detect their

subtype. The first two quests focus on pseudo-word testing in isolation and context. The third quest employs eye-tracking to analyse gaze patterns. Research points out that pseudo-word testing; i.e. reading and speaking tests with non-words, and eye-tracking are effective ways of testing for dyslexic subtypes. Lastly, the fourth quest is to self-report reading deficits. Through these quests, the user will be presented with a relevant subtype and will then be prompted to open a toolkit that has been created for their personal needs.



Readers will then be led into a product demo that showcases how their toolkit can be used while reading with the Online Bibliothek (online library) at KB. The application will then contract into a button on the right-hand corner of the screen and function as a plug-in would. It will contain embedded tools like a thesaurus, dictionary, text-to-speech etc. based on the contents of the custom toolkit. The user will also have the autonomy to add and remove tools as per their preference.

