Master

Explore
haptic
exper

Siji

r Thesis

e a new reading rience

e Li

Explore a new haptic reading experience

Delft University of Technology
Faculty of Industrial Design Engineering
MSc. Design for Interaction

Master Thesis
October 2022

Supervisory Team
Chair - Dr. Huisman, G.
Mentor - Dr. Love, J.S.

Author
Sijie Li

Executive Summary

Today, thanks to digitization, publications are no longer fixed, but dynamic and fluid. The convenience of carrying, the diversity of interaction and the convenience of resource acquisition provided by e-reading make e-reading more and more popular. However, there is still a lot of room for exploration in this field based on the more reading experience brought to readers by electronic screens, and it is also the direction that more laboratories and companies want to develop. There are many interactions and feedback that cannot be achieved in physical reading, such as how to make readers immerse themselves in the scene and truly feel the objects in the book; the reader establishes an emotional connection with the objects described in the book through touch and generates emotional resonance; or through touch senses attract readers' attention, enhance their reading concentration, etc. And these can be achieved through e-reading.

Furthermore, in the process of reading, because the reading medium is mostly limited by paper books, most people memorize the contents of a book by vision, except for some auxiliary tools, such as bookmarks or dog-earing pages. But with the development of e-reading, readers can have more forms of interaction with e-books, not limited to visuals; at the same time, e-books can also provide more feedback modes. So, will this multi-sensory reading mode provide new opportunities for people's long-term memory of reading content?

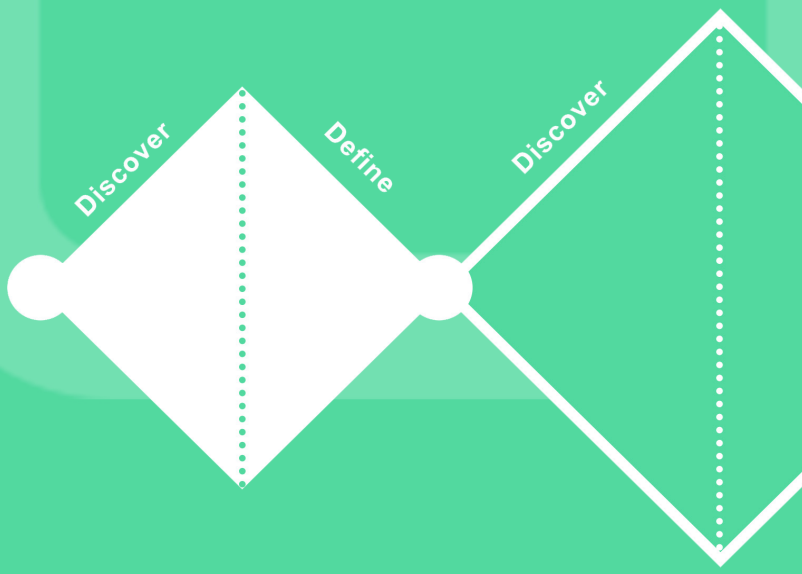
This graduate project explores how to improve the readers' e-reading experience and the long-term memory of the content through haptic technology. I gained more relevant information through literature reviews on topics such as haptic exploration and reading comparisons of print and e-books, as well as research with target users. The target group was identified as 20-30 year olds who are familiar with and own electronic reading devices. In order to achieve the design goal, an interaction vision with three qualities of immersed, focused and playful is proposed.

Based on the insights gleaned from the research phase, I designed 5 initial prototypes and tested them with 11 participants. After this, test results are collected and analyzed for a second iteration, resulting in an integrated prototype. Then, the test was conducted again with 3 participants, and the test results were collected and analyzed, resulting in a third prototype. Finally, I tested the third prototype again with 6 testers and finally got the final design. A total of three test evaluations and prototype iterations are used to continuously refine the design prototype to improve its usability and functionality.

The final design of this project is a mobile-based e-reading application. It can transmit the emotional changes of characters in the story through vibration, thus bringing users a more immersive, focused and playful reading experience.

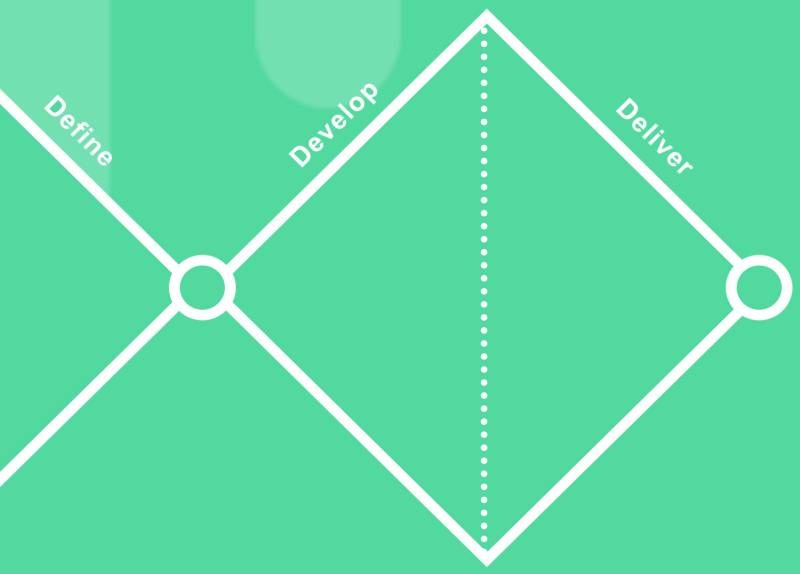
Table of contents

This chapter starts by introducing the two k
beginning of this project. Through background r
ourselves with the current development of reac
process, what are the benefits of these applic
be explored and worth developing. So I propos
determined the methods I followed in the whole



CHAPTER 1
INTRODUCTION

key words "haptic" and "reading" around the research, the development of we will familiarize ding, what applications of haptic in the reading ations to reading and what are the benefits to sed my original design goals at this stage, and project.



1.1 Project background

The major trend

1.1.1 The rapid development of e-reading

Today, thanks to digitization, publications are no longer fixed, but dynamic and fluid. The convenience of carrying, the diversity of interaction and the convenience of resource acquisition provided by e-reading make e-reading more and more popular.

In the case of China , The 19th National National Reading Survey in 2022 shows that the contact rate of digital reading methods (online online reading, mobile reading, e-reader reading, iPad reading, etc.) is 79.6%, an increase of 0.2 percentage points from 79.4% in 2020 . (The 19th National Reading Survey in 2022, 2022)

Moreover, not only the number of people reading e-books is rising, but more and more young people are "captured" by e-books and become the main population of e-readers.Take the use of Amazon's Kindle e-reader as an example. The younger the reader, the higher the acceptance of reading with the Kindle. The report shows that the proportion of post-00s who choose to use Kindle to read is as high as 71%, which is in sharp contrast with the proportion of post-50s who are only 25%. (Amazon, n.d.)

Because of the covid-19 epidemic, many university professors have even abandoned print textbooks and switched to digital text or multimedia teaching.(Whitford, 2021)

At the same time, because of the interactivity of e-reading, it can realize many interactions that cannot be done in printed books, bringing more design opportunities.

However, there is still a lot of room for exploration in this field based on the more reading experience brought to readers by electronic screens, and it is also the direction that more laboratories and companies want to develop. For example, Immer's reading application can provide users with a multi-scenario reading experience and fit the current user's fragmented reading habits, etc. *(see figure 1.1.1)*; and Koninklijke Bibliotheek is also trying to explore the use of AR, VR, 360-degree video and other technologies to display texts instead of printed books on libraries or shelves, attracting public attention through more immersive technologies.(Hermans, 2021)

Based on these two points, I limited the reading medium of this project to e-books, and mainly explored the haptic interaction in the process of e-reading.

Figure 1.1.1 Immer app interface and its function introduction

The project focus

1.1.2 The application of haptic in the reading process

First of all, the goal of the project itself is to explore the applications of haptic in the reading process, and what benefits these applications will bring to reading. Multi-sensory experience is also a research focus among the new interactive modes that can be achieved by e-reading.

There are many interactions and feedback that cannot be achieved in printed book, such as how to make readers immerse themselves in the scene and truly feel the objects in the book; the reader establishes an emotional connection with the objects described in the book through haptic and generates emotional resonance; or through haptic senses attract readers' attention, enhance their reading concentration, etc. And these can be achieved through e-reading. That's why in this project, I want to explore how to use haptic technology to bring readers a newer and better reading experience based on e-reading.

For readers, the benefits of reading include not only a good sense of experience during the reading process, but also the memory of the reading content.

So, I also hope that this project not only explores how to improve readers' reading experience, but also how to increase readers' long-term memory of reading content through embodied design and Human-Computer Interaction in combination with my own reading experience.

Nowadays, many haptic technologies have been applied in e-reading, such as simulating the vibrations brought by real situations or actions through several dimensions (amplitude, frequency, etc.), just like building a sound library. (Israr et al., 2014) Then, by simulating the situations in the book, readers can better understand and remember the scenes in the book. But it is worth verifying whether this enhanced effect really helps readers memorize reading content.

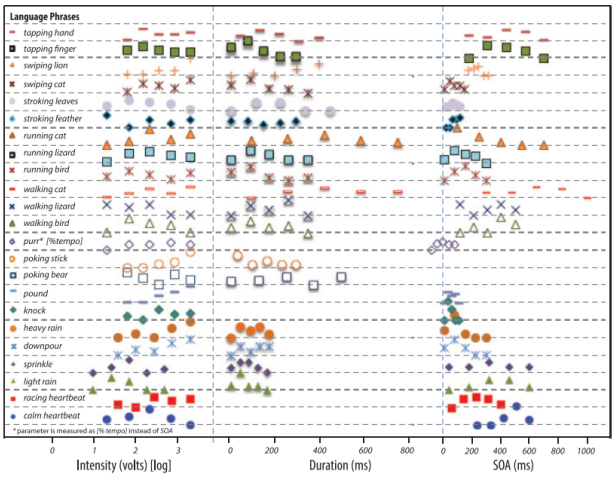


Figure 1.1.2 Established the "feel effect" library (Israr et al., 2014)

1.1.3 Haptic helps improve long-term memory during reading

In the process of reading, because the reading medium is mostly limited by paper books, most people memorize the contents of a book by vision, except for some auxiliary tools, such as bookmarks or dog-earing pages. But with the development of e-reading, readers can have more forms of interaction with e-books, not limited to visuals; at the same time, e-books can also provide more feedback modes. So, will this multi-sensory reading mode provide new opportunities for people's long-term memory of reading content?

It is well known that memory is divided into short-term sensory design, working memory and long-term memory. At present, there are a lot of articles to study the enhancement of multi-sensory for people's working memory, and in these studies, visual and auditory has been proved to increase working memory, and the results of visual and haptic enhancement of working memory are uncertain. (Rath, 2013)

And compared to the various limitations of working memory, long-term memory seems to provide unlimited storage space for information (Forsberg et al., 2020), so rather than exploring the enhancement of working memory by haptic, I would like to explore whether long-term memory, which may have greater benefits, can be improved with the help of haptic interaction.

Therefore, the purpose of this project is to provide people who love reading with **a better reading experience,** and at the same time **improve the long-term memory of reading content** through multi-sensory haptic and vision.

1.2 Design goal

Improve readers' e-reading experience and long-term memory of content through haptic technology.

1.2.1 Project scope

First, a new reading experience based on haptic technologies is designed for readers:
a. It is convenient for users to quickly understand the content of the text.
b. It allows users to quickly establish a connection between the sense of haptic and the text.
c. This connection can also help the user's long-term memory of the text.

1.2.2 Research questions

1. Under the background of the rapid development of electronic reading, what are the new reading needs and new reading habits of readers?

2. What haptic technologies are currently available, and what are their applications in the reading process?

3. How to apply some interesting and interactive haptic technologies on electronic screens to help people who love to read, provide them with new reading feedback, and improve their reading experience?

   - Explore the difference between the reading experience of printed books and e-books.
   - Explore a new haptic experience to bring users a reading experience that they have not experienced before.

4. Can readers improve long-term memory of contents in e-books through haptic feedback or haptic technology?

1.3 Project approach

This project followed the double diamond model with four phases (Design Council, 2019). The whole process is divided into three parts: research (background research and methodological research) and design.

The first part of the project is background research, because the initial design goal is very broad (just how to make the sense of touch play a role in the reading process), so at this stage I understand the current development of reading media through desk research. (thus identifying the reading medium as e-books), the development process of haptics in the field of reading and research vacancies to determine my specific design goals.

The second part of the project is the methodological research. I learned through literature research and user research to determine my future design direction at the end of this section.

The third part of the project is design. After the completion of the second part, I have specific research results and know which reading behaviors can achieve my design goals. So at this stage I need to brainstorm and concretize and refine the concept in 3 iterations, and finally produce the final concept and complete the design goal.

Discover

The Discover phase aims to dive into the problem and existing haptic technologies. By understanding the existing tactile technology as an entry point to contact embodied design, multi-sensory design and human-Computer interaction, it provides more literature basis for the subsequent concept divergence, and understands what new experience haptic can bring to the reading experience. Then, through research, we understand the problems existing in readers' reading experience, the pros and cons of reading printed books and e-books, and their tips for improving long-term memory of reading content. Finally, the chapter presents the research process and the results of the data analysis, which provide the necessary arguments for the definition phase.

Define

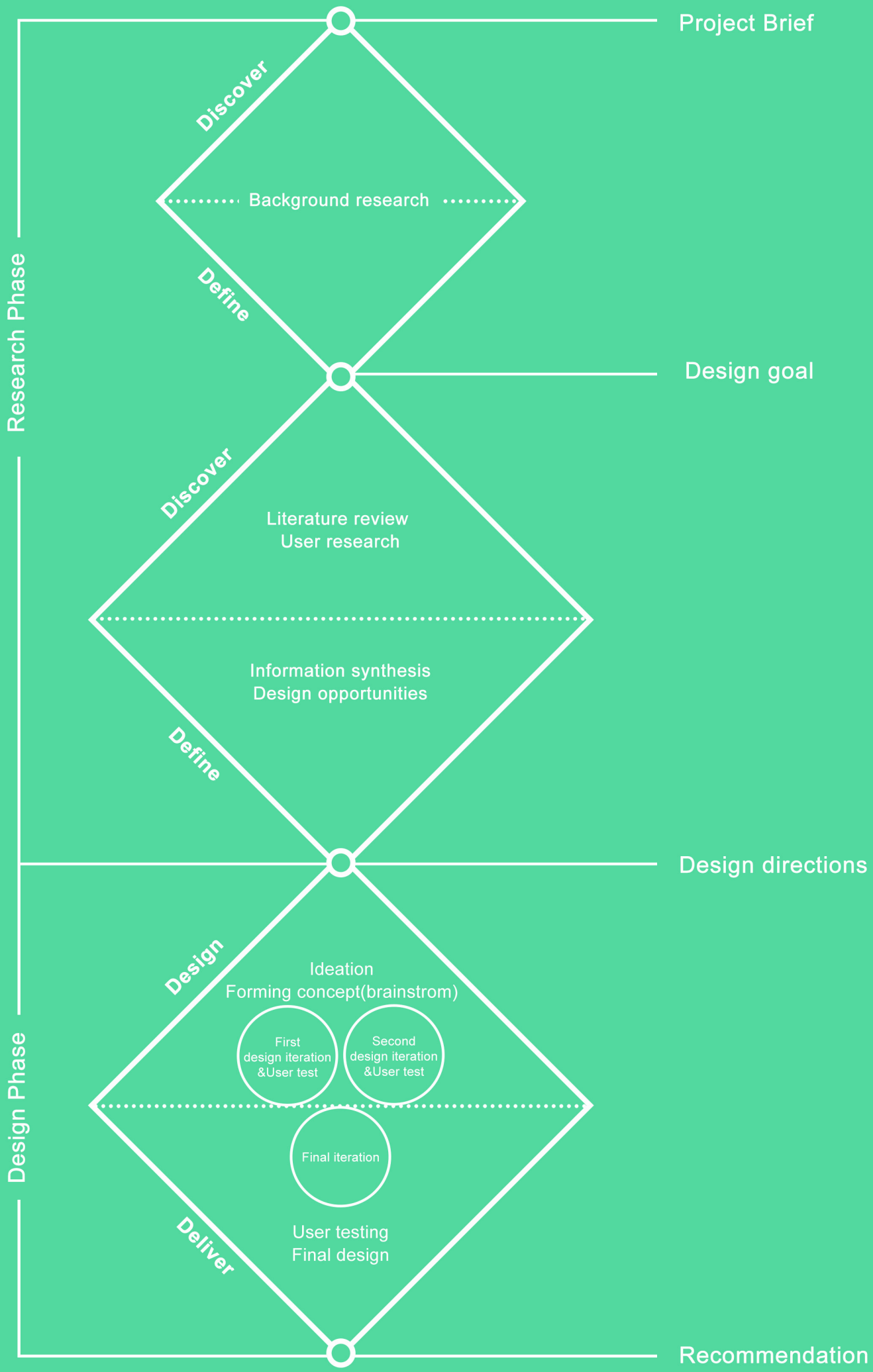
In the define stage, synthesizing the research results of the previous stage, by means of literature research and user research, we can understand which tactile technologies currently exist, the cases of tactile technologies used in reading, the advantages and disadvantages of printed books and e-books in reading, and Which behaviors (tactile contact) can improve readers' long-term memory of the content, narrow the scope of reading materials, and the scope of target users.

Develop

At this stage all kinds of ideas and ideas will be generated. First, brainstorm to get the first few ideas. On this basis, five initial concepts were generated, simple prototypes were made, and quick tests and evaluations were conducted with target users and design students, and test results were obtained through questionnaires (quantities research) and interviews (qualities research), and Perform visual data analysis to choose directions for further development. Then continue to iterate on a complete concept based on the original concept, and prototype again and test the prototype with users. Finally, the final concept is designed on the basis of this concept.

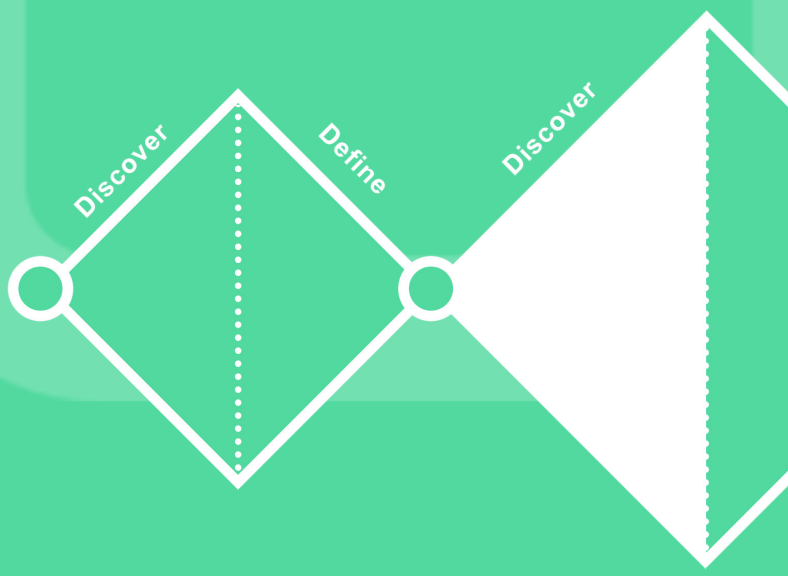
Deliver

Delivery is the final phase of a project to deliver the final design and evaluation results. An interesting, logical, usable, and actionable interactive prototype is created for user experience to provide feedback for evaluation purposes. The final concept is evaluated, and the final evaluation is made from the two dimensions of quantities results and qualities results, and finally some current problems and future feasibility suggestions are put forward.


Project Brief
Discover
Background research
Define
Design goal
Research Phase
Discover
Literature review
User research
Information synthesis
Design opportunities
Define
Design directions
Design
Ideation
Forming concept(brainstrom)
First design iteration &User test
Second design iteration &User test
Final iteration
Deliver
User testing
Final design
Design Phase
Recommendation

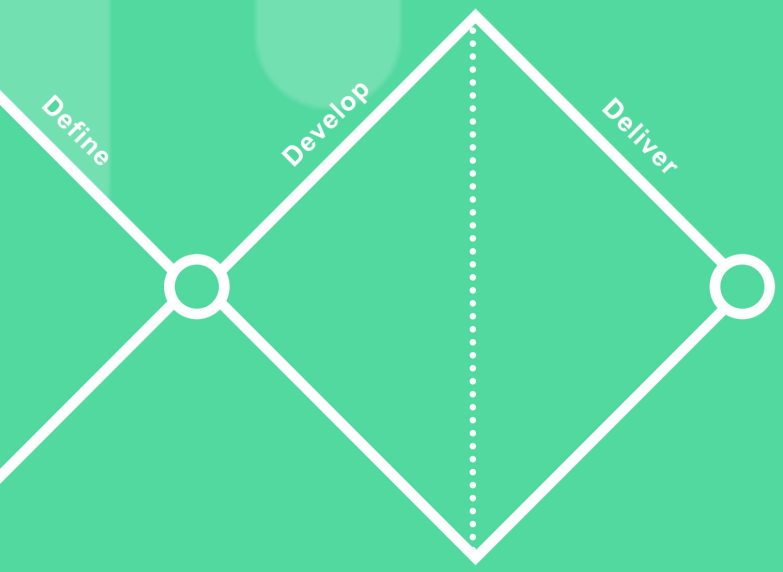
L

This chapter presents findings from literature
with the use of various haptic technologies in
difference of reading experience and technic
versus e-books reading process. The chapter c
of the key insights from the review, leaves ope
strong arguments for the subsequent define pha



CHAPTER 2
LITERATURE REVIEW

e review, from which we can become familiar
the e-reading process (see Chapter 1.1.2), the
ques for improving long-term memory in print
concludes with a discussion of the implications
n questions for subsequent user research and
ase.



2.1 Haptic exploration

In this sup chapter, to understand how haptic enhances the reading process, we will have a basic understanding of haptic——the functions of haptic, its relationship to other senses, the application of haptic design in reading, and the sensory channels of haptic. Finally, it explains the necessity of the multisensory experience during haptic enhancement, and why we chose the vibrotactile sensation as the haptic channels in this project.

2.1.1 The functions of haptic

The skin is the largest organ in the human body, and it contains receptors that sense touch. Touch can provide the brain with the most information, and it is also the most complex and widely distributed. Most of these information are diversified and complicated, so the scope of touch functions is quite wide (Yang et al., 2022):

1.Express emotions and promote communication.
The haptic action itself, a strong handshake, a gentle hug, or a parent's reassurance, can all express emotion directly. (Yang et al., 2022). And the emotions experienced by the feelers will change with different haptic behaviors. In the report of Amélie D.L.Jean, it was found that babies will have different distress levels because of the different quality of maternal touch. (Jean & Stack, 2007) The quality of maternal touch is encoded as haptic strength, frequency, active or passive touch, haptic actions, sound and expression, etc., so touch may bring calm and soothing may also cause irritation. (Jean, A.D.L., Stack, D.M., 2007)

2.Improve cognitive ability.
Human cognitive abilities include perception, memory, attention, thinking and imagination. Testers were reported to receive touch stimulation at a 15 Hz rhythm for 16 minutes, after which it was found that participants achieved significantly higher scores on the attention test. This also demonstrates the feasibility of enhancing short-term attention based on touch. In the future, if users are allowed to perform long-term touch training, it may improve other cognitive abilities, such as memory (Zhang, 2016). At the same time, touch can also be used as a supplement to vision, and actively assist vision to recognize objects. The touch compensation can promote visual perception, and the perception of size, shape, etc. through touch can improve the sensitivity of visual perception. When visiting a museum, we only use vision to perceive information, compared with the combination of visual and touch perception. We found that the touch exploration of museum exhibits does affect visitors' recall of the objects and the themes they represent, and the extent to which visitors are autonomy felt during the visit and satisfaction after the visit (Novak et al., 2020) (see Figure 2.1.2 & 2.1.3).

Of course, there are other possible functions of haptic, such as improving protection and defense, stimulating growth, improving fine motor skills, and so on. However, these functions may not be related to the reading process at present, so they will not be explained (Yang et al., 2022).

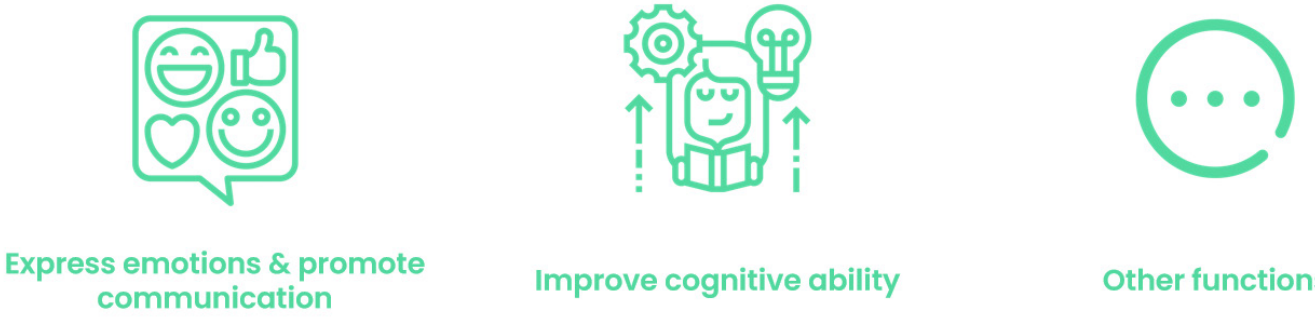


Figure 2.1.1 The functions of haptic

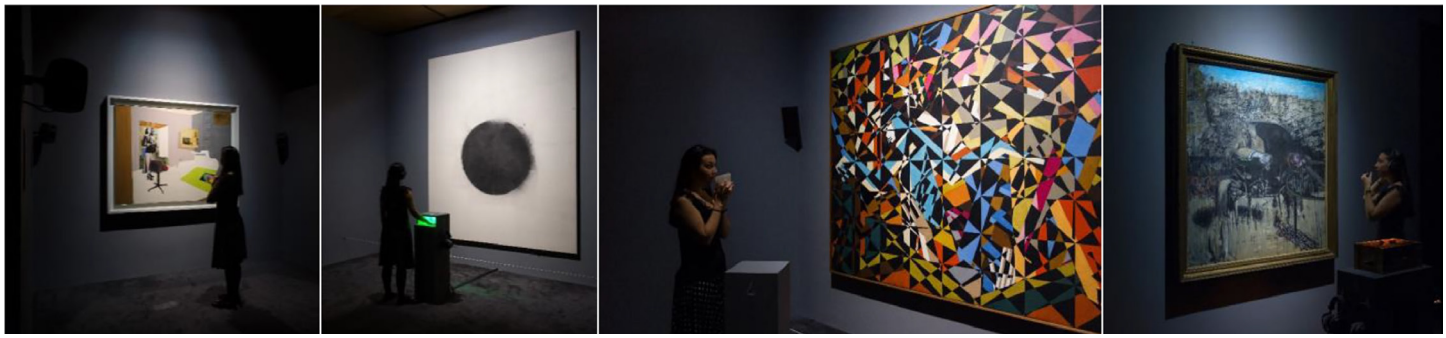


Figure 2.1.2 Tate Sensorium exhibition at Tate Britain in 2015 (Vi et al., 2017)

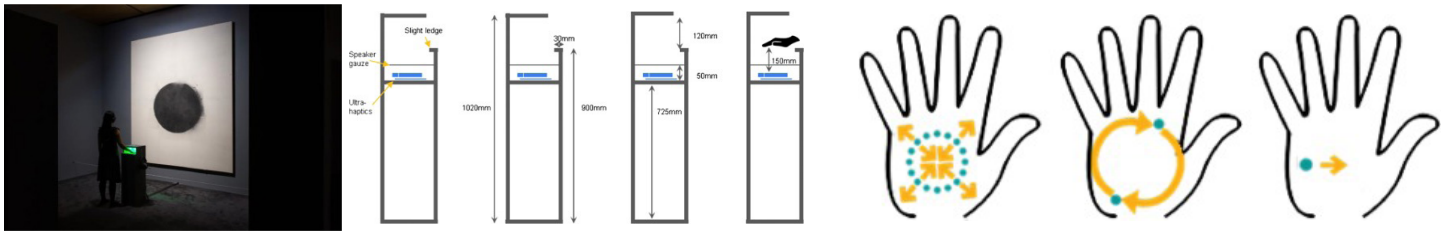


Figure 2.1.3 Multisensory experience design in the museum context, integrating sound and mid-air haptic (Vi et al., 2017)

2.1.2 The meaning of multisensory

As mentioned in chapter 2.1.1, the two most important functions of touch are (1)to express emotions and facilitate communication, (2) to improve cognition. To make these functions better, we need multisensory integration.

Multisensory integration, is the study of how information from the different sensory modalities (such as sight, sound, touch, smell, self-motion, and taste) may be integrated by the nervous system. (Stein et al ., 2009) and then combining these diverse sources of information enables animals to have meaningful sensory experiences. At the same time, different sensory modalities will also affect and change each other.

Perception is inherently multisensory, and touch perception is no exception. (Spence, 2021)

And perhaps due to the variety of haptic functional physiology, the dominant view of touch in the recent cognitive science literature often sees touch as inherently multisensory, rather than as a single unified modality like sight and hearing (Linden, 2015).

For recognizing or learning objects, when multimodal senses are generated, such as visual and touch experiences at the same time, if they are in contact with the same object, the response will be enhanced. (Rath, 2013) For example, in letter recognition, visual-haptic exploration of letters can improve children's decoding ability. (Bara et al., 2004)

At the same time, **for the long-term storage** of old things or information, there is also evidence that multisensory or multimodality can maximize the long-term retention of touch information (Lacey et al., 2019).

For emotional touch, sensory-discriminative and affective touch is influenced by other senses. The perception of emotional touch does not only happen in unimodal or unisensory, people's perception of emotional touch is also largely influenced by vision, hearing , and the effect of smell.(Spence, 2021)

Therefore, it can be concluded that **a single touch sense** is relatively **weak** in terms of object recognition, information storage, or emotional expression. However, combining other senses to form **a multisensory experience** in turn **enhances** the haptic experience.

2.1.3 Application examples of haptic in reading

After investigating a variety of haptic technologies and their application in the reading process, it was found that they can be mainly divided into the following four categories according to the way of enhancing reading. They each used the two functions of haptic mentioned in chapter 2.1.1.

1. Help people immerse themselves in stories, stimulate emotions, and create context.

Here using the expression of tactile emotion and improving the function of cognitive, will originally turn the narrative silence that can only be perceived by the eyes (Sanchez et al., 2016) into an embodied experience. Through the haptic transmission characters or plot emotions, enhance their perception of the story, improve the reader's reading immersion and concentration, and then affect their memory of content.

FeelSleeve (Yannier et al., 2015)

Figure 2.1.4 FeelSleeve use context and interface

FeelSleeve is a interface designed to cater to children's love for tablets and various computer games, and for less acceptance of traditional reading methods, using haptic enhancement technology to make children's story reading experience more interesting and memorable.

Children strengthen their understanding of the story by placing their hands in the glove and feeling the vibrations created in the transducers and audio output of the glove.

The hardware is composed of two haptic exciters s driven by electronic driver, who can amplify the stereo audio output of the tablet, while using different vibration to form different feel effects s and appear together with the corresponding text content. The feel effects s currently only target simple events in the story, such as rain, pounding, and heartbeats.

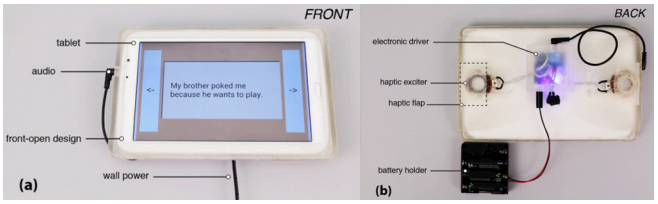


Figure 2.1.5 FeelSleeve hardware

The test results also proved that the multi-sensory reading process did make children more immersed in the story and had a more accurate memory of the plot.

Sensory fiction (Heibeck et al., 2014)

Figure 2.1.6 Sensory fiction use context

Sensory fiction is a connected book and wearable device that conveys plot, mood and emotion through multisensory augmentation.

The prototype chose a story with a strong emotional change. The book cover has programmable LEDs connected to it that continuously change color based on the plot of the book. The corresponding music will also be played along with the plot.

Among other things, certain passages trigger various haptic changes in the wearable: including a vibrating device that affects heart rate, an airbag that changes pressure, and a heating device located at the collarbone.

This project creates a more diverse reading experience through the multi-sensory channels of visual, auditory, and touch, and also fully confirms the feasibility of the emotion transmission through haptic.

Figure 2.1.7 Sensory fiction wearable

2. Understanding or learning about new things in books, or identifying old things, can deepen people's understanding and memory of content.

The cognitive-enhancing function of haptic is used here. This category usually occurs in the learning process, multi-sensory acquisition of information about things which can deepen understanding and cognition of things through haptic.

A multi-fingered haptic interface (Webb et al., 2022)

Figure 2.1.8 Two points of contact of the thumb and index fnger on the same hand

A multi-fingered haptic interface combined with 3D virtual models creates a prototype for children to explore cell membrane structure and function. Among them, it simulates the mechanism of the cell membrane through a three-dimensional virtual model. Children can wear VR glasses to see the structure of the cell membrane, as well as the surrounding colored particles, and interact through the two contact points of the fingers.

When the haptic feedback is turned on, the child's fingers can feel different forces acting on the object they are grasping, such as in the case of different concentration gradients. Use haptic feedback to compensate for elements that cannot be seen visually.

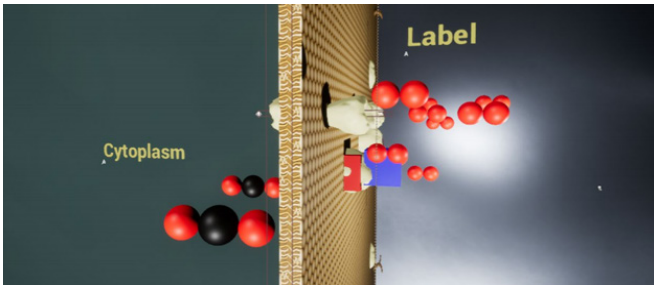


Figure 2.1.9 The perspective of wearing VR glasses

The test results are not very good. Children still pay attention to the visual effects first. When there is no special reminder, it is difficult for children to notice the information contained in the haptic feedback effect.

However, it is still worth exploring to deepen people's understanding and memory through appropriate haptic effects paired with consistent visual information. And when this method is used in reading, I believe it is possible to help readers understand some complex knowledge and deepen their memory.

3. Store and remember information by transforming the text in the book through some haptic behavior or methods.

The cognitive-enhancing function of haptic is used here. Readers are encouraged to use their imagination, or other perceptual abilities, to understand and memorize pure literal information. There is an old Chinese saying, "The palest ink is better than the best memory.", which shows that the process of writing is beneficial to the storage of memory. Hptic behavior is not just writing.

Friction panel (Cingel et al., 2015)

Figure 2.1.10 The child's use of the tablet

Fiction panel uses the surface haptic technology to move the reader's fingers around the screen, while changing the friction coefficient of the screen, so that the reader can feel different textures.

Fiction panel is composed of a piece of Tablet, a glass sheet with piezoelectric actuators, a microcontroller circuit, and and a lithium polymer battery. The surface changes the friction coefficient of the surface by changing the out-of-plane oscillating motion with high frequency and low amplitude.

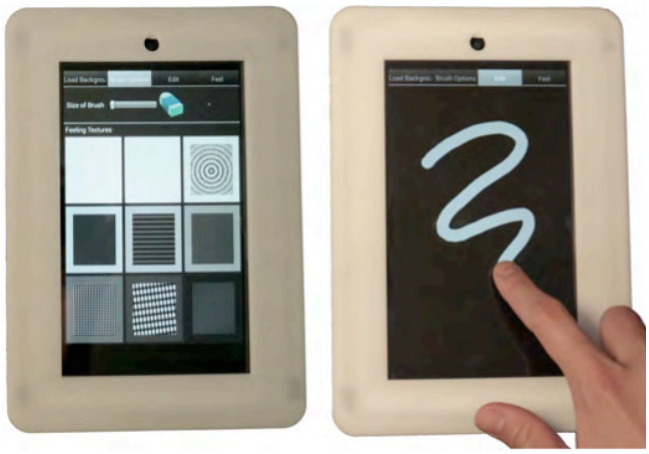


Figure 2.1.11 Fiction panel interface

Children read the stories, then they mostly choose the most prominent objects on each page, and use the "pen" and "eraser" to freely draw and edit to create the textures they think best suit their feelings.

Test results showed that younger children were not yet able to connect textual descriptions to tactile textures, but older children added textures that matched real life and thought it was meaningful, and parents could even More complex haptic feedback not only reflects the texture of the object, but even adds its own feelings, understanding and imagination. Increase immersion in reading stories and understanding of things by adding haptic feedback.

4.Feedback on user instructions, or prompts to guide user behavior.

The cognitive-enhancing, emtion-expressing and communication-promoting function of haptic is used here. Provide more possibilities for people to interact with reading materials or between people through haptic feedback.

EV-Pen (Wang et al., 2016)

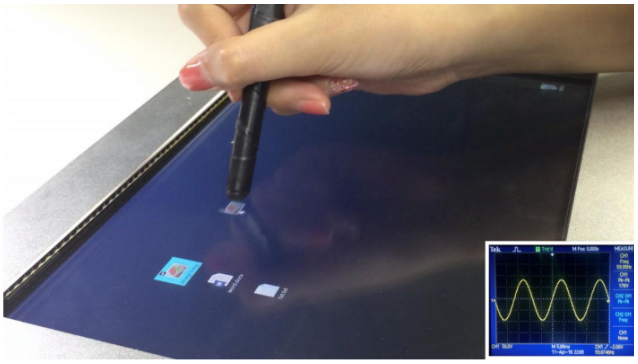


Figure 2.1.12 GUI Elements with haptic feedback

The EV-Pen (an Electrovibration Pen) provides haptic feedback to the user through electrical vibrations, simulating a real writing experience, different texture haptic feedback, and different haptic feedback when the user interacts with the gui element.

It produces different haptic feedback by controlling the electrostatic friction between the pen tip and the touch surface. The voltage inside the screen changes with different interactions, changing the electrostatic friction.

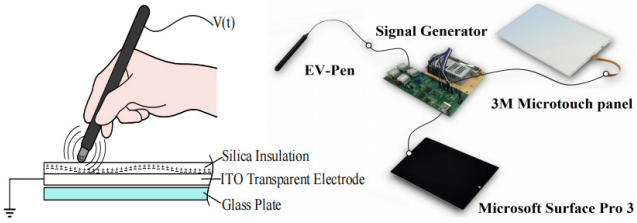


Figure 2.1.13 The schematic diagram and components of the EV-Pen

The principle of giving users different tactile feedback through different dynamic tactile channels may have many possibilities in the reading process. For example, when the reader takes notes or highlights, it will be the same as in the real printed book; when the reader performs some interactive operations, the system will give tactile feedback to indicate that it has received instructions; or when the reader flips the book, you can pass Different haptic feedback prompts them to read progress and more.

2.1.4 Haptic sensory channel

Touch involves a wide variety of sensations throughout the body. These sensations can be roughly divided into several "sensory channels", each of which is sensed by a different subset of biological receptors located throughout the skin and other soft tissues. These sensory channels include: **tactile, vibrotactile (vibration), force, and thermal**. (Rubin, 2016)

The haptic feedback channel is the main source of information about the fine shape and surface characteristics of objects. It also aids in the perception of weight, size and texture. For most interactions, haptic feedback is the most important component of haptic perception. Haptic feedback devices require a certain resolution and refresh rate to produce a smooth feel.

Like tactile feedback devices, vibrotactile feedback devices consist of one or more actuators that are in contact with the skin. The construction of haptic feedback devices is challenging because these actuators must be closely spaced and must exhibit high displacement relative to their size. Vibrotactile feedback has low requirements for both aspects. Of course, this also results in the often very limited authenticity and richness of vibrotactile feedback itself.

At the same time I take into account the cost of thermal sensors and mechanical sensors and the cost of experiments.

In the end I chose to **use vibrotactile feedback** as the haptic technology used in this project.

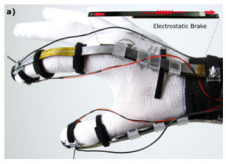
	tactile	vibrotactile	force	thermal
Requirements for actuator	no more than 2-3 mm needs to offer up to about 2 cm of displacement	several millimeters thick can get away with just a fraction of a millimeter of displacement	Usually larger and located in more parts of the human body	takes a lot more power than to create tactile and vibrotactile feedback
Built into electronic device?	No (motor used in cell phones, several millimeters thick, and offers no more than a few tenths of a millimeter of displacement)	Yes (Often used in various electronic devices such as mobile phones and gamepads)	No	No
Haptic feedback effect	The upper limit is very high, and the highest level simulates real touch sense (depends on the number of actuators in a range)	Quite limited in its realism and richness.	Perception of the overall shape, weight, and impact	Heat changes convey very little information and usually do not exist alone.
Cost	High	Low	High	High
Existing technology development	Immature & developing	High-quality hardware already exists	Developing	Developing
Other restrictions	Fingers are extremely sensitive to touch. If you want to simulate a more realistic haptic effect, and the position of the actuator is on the hand, you need to install a lot of actuators in a small space.	Because vibration is only part of the sense of touch, it is difficult for light to use vibrotactile feedback to simulate the real environment and transmit figurative information. Especially when the motor is built into the device.	Unlike the first three, the receptors are not entirely on the skin, and the muscles and ligaments also have receptors. So the force feedback equipment may be completely different from the first three. But it must be very large, it is impossible to be built into the electronic device, need to wear.	Its mechanism is different from the former, where these actuators do not produce physical motion, but rather move heat. The technology is still in development and does not often exist alone.
Applications	 DextrES: Wearable Haptic Feedback for Grasping in VR(2018)	 Gesture-recognizing hand-held interface with vibrotactile feedback(2009)	 Compressables: A Haptic Prototyping Toolkit(2021)	 TherModule: Wearable and Modular Thermal Feedback(2019)

Figure 2.1.14 Comparion of tactile, vibrotactile (vibration), force, and thermal

2.2 Comparison of printed and e-book

In the field of reading, although e-books are developing very rapidly, they still can not completely replace printed books. This subchapter describes the reading experience and the long-term memory of the content that account for readers' personal preference for printed books, and summarizes what kind of touch perceptions or behaviors may be caused by this. This provides a theoretical basis for later chapters thinking about how to apply good haptic experiences in e-reading process and haptic behaviors to help readers to memory the content of books.

2.2.1 What causes readers to prefer printed books?

There are numerous studies on whether people prefer to read print books or e-books, with slightly different findings. But in general, there are still more people who prefer print reading, and readers are more willing to use print books for long-term reading activities (Jain, 2021). This result remains unchanged even among the student groups, those who have the most acceptance of e-reading and reading experience by using electronic devices (Sage et al., 2019). Whether in daily reading (Jeong & Gweon, 2021) or academic material (Baron, 2017), printed books are the preferred reading medium for students (Sharma, 2020).

Then, in addition to the differences caused by different reading media, such as reading experience and memory of the content, there are three additional reasons why readers prefer printed books *(see Figure 2.2.1)*:

1. **Readers' familiarity with electronic reading media**
2. **For what purpose does the reader read**
3. **The material the reader reads**

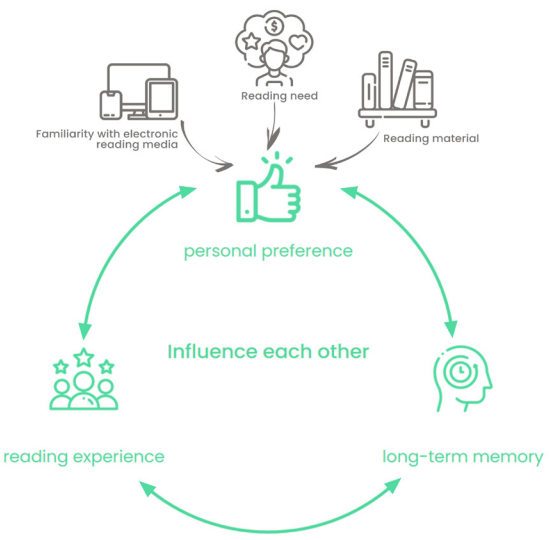


Figure 2.2.1 Reasons why readers prefer printed books

Familiarity with electronic reading media

The reason why many readers prefer paper is that they are far more familiar with paper than computers or tablets (Jeong & Gweon, 2021).

If we compare readers with and without tablets, tablet owners use tablets more frequently than non-owners. Because familiarity with electronic media affects readers' comprehension when reading e-books, when they are very familiar with e-reading, they will have more positive perceptions during e-reading (Sage et al., 2019).

Therefore, it is not difficult to find that readers' familiarity with electronic media greatly affects their personal preferences for reading media. As readers become more familiar with the electronic reading medium, their preference for electronic books will gradually increase, and tend to be in line with or even surpass those of printed books.

Among college students or some young groups, they are more accepting of electronic screens, and most of them own or have access to electronic reading devices (Jain, 2021).

Therefore, in the follow-up user research and design phase, my project should **target students or those young people** who **own electronic reading devices** to eliminate the preference for printed books caused by unfamiliarity or never owning electronic reading devices.

Reading purpose

In addition to the reader's familiarity with the medium, the purpose of reading also significantly affects readers' preference for

printed books as well as e-books.

When reading for academic or purpose, they prefer printed material because of better concentration. And digital media can cause them distraction and eye strain. (Soroya et al., 2022)

When the purpose of reading changes to entertainment and information, they prefer to use e-books for reading (Zhang & Kudva, 2014).

Reading material

Furthermore, 81.0% selectively use media depending on the reading materials. (Jeong & Gweon, 2021)

When reading graphic novels, magazines, and comic books, readers prefer electronic reading materials (Nazhari et al., 2016). For academic reading materials, popular science books, readers prefer printed reading materials (Alsaeedi et al., 2021).

Fiction is the most controversial among them. Some survey results show that readers prefer to read fiction through electronic media (Foasberg, 2014), while others show that readers prefer to read through print media (Nilsson, 2016).

Summary of reading purpose & material

Combining the differences in reading purposes and reading materials, we can see that, in general, readers prefer to use print media for serious reading with learning purposes, which requires readers to be more focused, more engaged, and not be distracted by other information. And when the reading materials are shorter, mostly leisure books, and the reading purpose is more relaxed, the electronic medium will also gain more favor because of its portability, easy access, etc.

Among them, most people **read fiction for pleasure and relaxation** (Zhang & Kudva, 2014), and few readers do not accept reading fiction on electronic devices at all (Alsaeedi et al., 2021), so **in the follow-up user research and design, fiction will also be the reading material that I choose.**

2.2.2 Differences in reading experience

After excluding readers 'familiarity with the media, reading purpose and reading materials, what else affects readers' personal preference for printing books and e-books?

The first is the difference in reading experience. Reading is a complex cognitive process, so many factors can affect the reading experience.

These factors can be divided into **objective performance** (reading time and reading comprehension) and **subjective attitudes** (perceived difficulty, perceived comprehension, perceived confidence, perceived fatigue and immersion) (Jeong & Gweon, 2021).

Objective performance is the reading performance that can be tested and quantified when a reader reads. There are many such measures, such as reading speed, reading endurance, and so on. (Rubin, 2013)

Subjective attitudes are self-assessments and subjective perceptions, which may not be measurable from objective data. But it has also been shown to affect reading comprehension and reading performance (Agler, 2019). And this perception question is usually "Do you think...?". The answer to this question may not be consistent with the actual measured data, but this reading attitude can also reflect readers' preferences for different reading media, as well as overall The feeling of reading experience.

The reader's process of reading a printed book is multi-sensory. Not just the look and feel of the book, but the weight of the book and the feel of the pages, but also the unique smell. In fact, one might also want to consider the specific sounds the pages make when they are turned. (Spence, 2020)

Today, most e-book reading is still based on sight, and a small part of hearing (like some audiobooks), and only a few are related to haptic. In practice, however, the importance of

haptic perception for reading continues to be validated (Alam, 2011).

So then I'm going to introduce the different reading experience of reading printed books and e-books due to haptic behavior and experience.

The impact of haptic on reading experience

First of all, readers need to scroll or click frequently when reading digital text, which will increase their cognitive needs and make readers unable to read content with more concentration and immersion (Kaufman & Flanagan, 2016). The experience is far weaker than flipping through the pages of a printed book (Alam, 2011).

Second, printed text can provide physical, haptic, spatiotemporal cues to the length of the article (Mangen et al., 2013). This can help readers relate their memory of what they read to the depth of the book or position on the page (Baron, 2021). For example, when a reader recalls a sentence, he will remember that the sentence appeared near the bottom of the page. So when reading content is described in chronological order and story development sequence, paper books have a more coherent situational model than e-books.

Third, compared to electronic texts, paper texts leave more haptic interactions, allowing for richer sensorimotor involvement in the reading process. (Mangen & Schilhab, 2012)

Finally, when people use mobile digital technology, they are prone to multitasking, distraction, information overload, etc., which will make them inclined to low-level information processing (Singer & Alexander, 2016). Electronic reading devices will receive some information from social media when readers read, such as the vibration of mobile phones received information, which can easily distract readers and let them do things unrelated to the reading activity.

2.2.3 Differences in long-term r

In addition to the reading experience, print books and e-books also differ in how readers remember the content. The reader will use many tools, or use many ways to assist him in content memory. The use of these behaviors or tools is very different between the two mediums.

I have summarized the memory techniques and tools in various articles (Bold & Wagstaff, 2017), (Liesaputra & WitteN, 2012) , (Marshall & Brush, 2002) , (O'Donnell, 2004), (Baron, 2021), and finally, I roughly divided the ways to help readers to remember into the following 12 ways (see Figure 2.2.2)and made a table (see Figure 2.2.3) to compare the haptic behaviors of these ways in reading printed books and e-books..

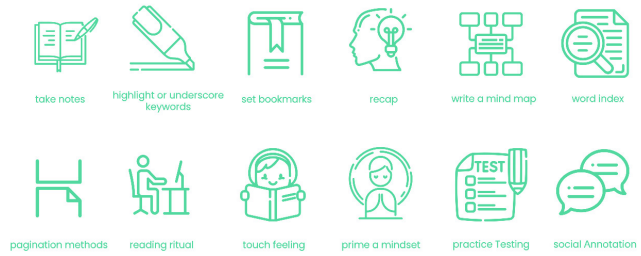


Figure 2.2.2 Twelve ways to help memory

Of these in these 12 ways, some are done only when reading a printed book, some are done only when reading an e-book, and some are done when reading both a printed book and an e-book (see Figure 2.2.3).

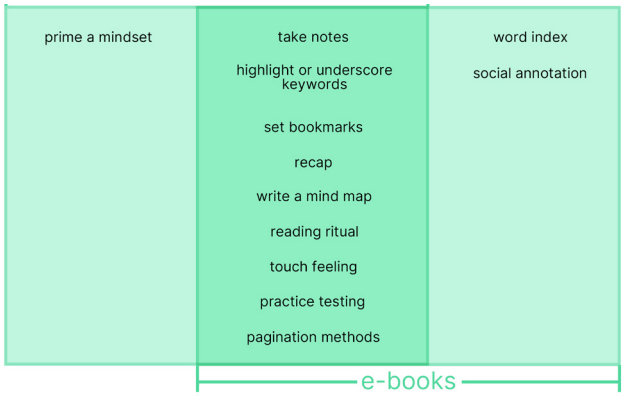


Figure 2.2.3 Difference between print books and e-books

Many of the reasons why these 12 ways of reading print books and e-books are different are related to tactile behaviors and manipulations. For example, the memory skills most commonly used by readers—note-taking

memory

or highlighting keywords (Bold & Wagstaff, 2017), are all by handwriting and touching real paper and pen when reading printed books; and when reading e-books, it is almost interacting with the screen, by typing, clicking, etc. And this difference has led to a significant change in the memory effect and the reader's feeling.

I haven't found any articles that test in detail the comparison of memory effects when using the same memory method when reading print books and e-books. But when reading a printed book, readers remember the content better than when reading an e-book (Szalavitz, 2012).

	print books	e-books
take notes	1. Put a notebook or ipad next to the book, and write on the notebook or ipad with a pen or apple pen. 2. Take notes on sticky notes and stick them in the book 3. Directly to the blank of the book page or Write in margins	1. Select the text, type on the keyboard and take notes 2. Organize all recorded notes into a note column by time or chapter.
highlight or underscore keywords	1. With a pen in hand, write and draw at any time. 2. Can use various types of pens, highlighters, pencils, etc. 3. Don't want to draw pictures on the text.	1. Many electronic reading software cannot directly draw pictures, but can only highlight the text by selecting the text. 2. When re-reading, focus on the highlighted part.
set bookmarks	1. Can make dog-ear page, use bookmarks, or paste blank sticky notes to make bookmarks	1. Directly click the button to add bookmarks 2. All added bookmarks will be integrated into bookmarks bar by time and chapter 3. The electronic reading software will automatically save the reading progress and automatically jump to the next reading
recap	1. When reading professional books, each chapter will be summarized in the chapter introduction to help recap content and secondary memory.	1. Open the bookmarks bar or note bar and browse it again to view the key information left at that time.
write a mind map	1. First browse the table of contents and frontiers, then list the outline, and make a mind map in the process of reading	
word index		1. Set up jump links to search words at any time
pagination methods	1. Paper page turning effect 2. Grab the paper ahead of time and prepare to turn the page	1. There will be a short refresh time during the page turning process 2. Click or scroll to page 3. Some electronic software will simulate the flipping effect of paper
reading ritual	1.cherish the new book very much, especially the process of tearing the package is very ceremonial	1. The reading scene is more casual
touch feeling	1. The weight of the book, the touch of the paper, the friction between the fingers and the pages when turning pages 2. As reading increases, the weight of the pages held in the left hand becomes heavier and heavier 3. Read back and forth	1. Scroll through, or click to turn the page, or drag the progress bar 2. Inability to perceive the thickness of the book 3. Inability to understand reading progress through touch
prime a mindset	1. Prepare a glass of water or a glass of milk 2. Go to a specific location, such as sitting at a desk 3. Read reminders in advance before reading	
practice testing		
social annotation		1. Interact with other readers, comment 2. Loading of real-time cloud documents 3. Read other people's notes

Figure 2.2.4 Different use of the same memory skills when reading print and e-books

LITERATURE REVIEW TAKEWAYS

Haptic has two main functions:
1.Express emotions and promote communication.
2.Improve cognitive ability.

TA1

TA2

Haptic is difficult to function independently and requires a **combination of multisensory**, such as sight or hearing. Experiences formed in combination with other senses in turn enhance haptic functions.

The final design should take account **the combination of multiple senses**.

TA3

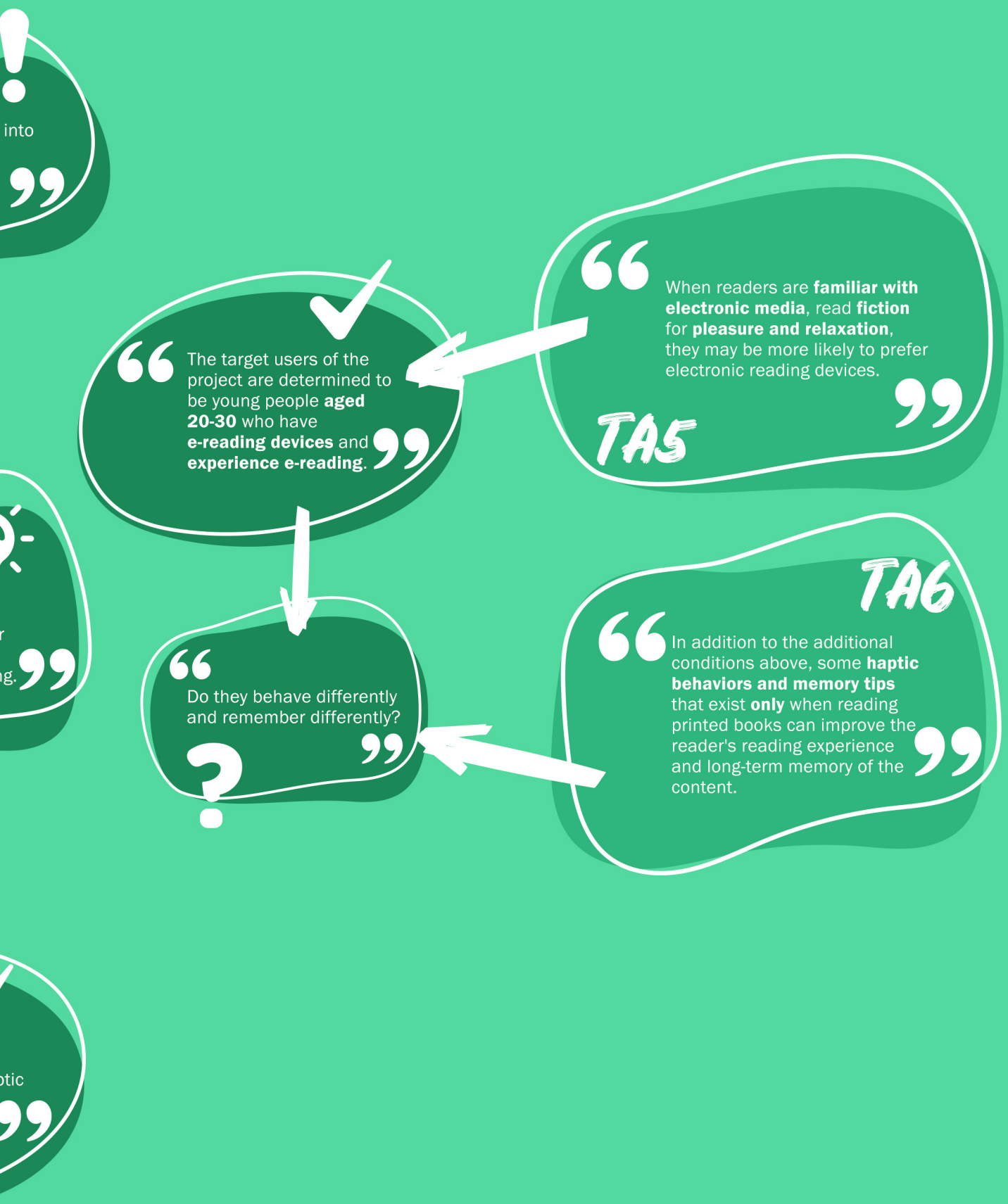
At present, the application of haptic in e-reading has the following four directions: 1. Help users better **immerse** themselves in the story. 2. **Learn and understand** new things and **recognize** old things through haptic. 3. **Memorize** textual information through **haptic behaviors or methods**. 4. **Feedback** to user commands or guide user behavior through haptics.

The future design can be considered from these fou directions, how to apply haptic in the field of readir

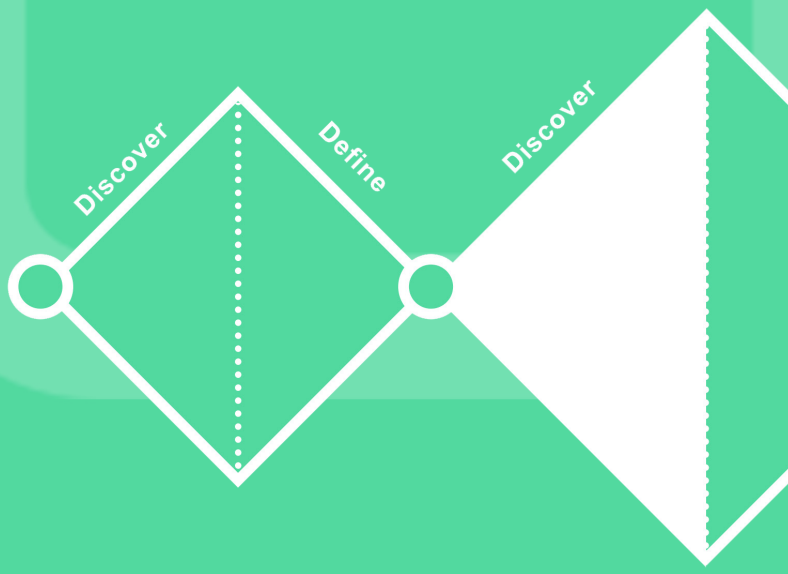
TA4

Among the **4 haptic sensory channels** on the market, **vibrotactile** is the **most mature** in technology, the **easiest** to obtain, and the one with the **lowest requirements for actuators**.

Chose **vibrotactile** as the hap technology for my project.

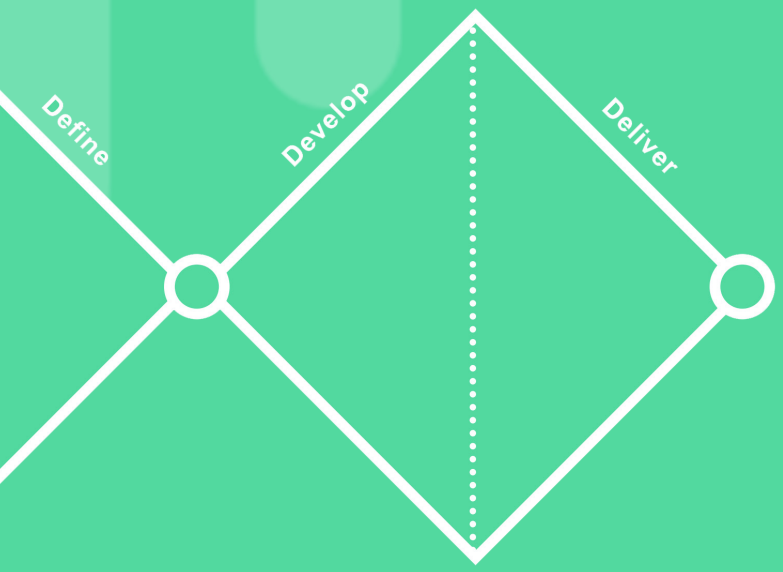

into
The target users of the project are determined to be young people **aged 20-30** who have **e-reading devices** and **experience e-reading**.
When readers are **familiar with electronic media**, read **fiction** for **pleasure and relaxation**, they may be more likely to prefer electronic reading devices.
TA5
Do they behave differently and remember differently?
TA6
In addition to the additional conditions above, some **haptic behaviors and memory tips** that exist **only** when reading printed books can improve the reader's reading experience and long-term memory of the content.

During the literature review process, I found
that need to be explored or verified through u
target users, so in this chapter, we through us
observations to obtain missing data from literat
and provide data support and guidance for later



CHAPTER 3
USER RESEARCH

d that there are still some remaining issues
ser research. In chapter 2.2.1, I identified the
ser research — questionnaires, interviews, and
ure reviews, collect feedback from target users,
r design stages.



3.1 Understand target users' behaviors

First of all, in chapter 2.2.1, I learned that familiarity with electronic devices will greatly affect readers' reading experience and memory ability on electronic devices. So I will interview 10 young users who have at least two e-reading devices with long-term e-reading experience.

I need to know from their conversations and observations whether the target users have changed in their personal preferences and choice of reading medium, and whether there are some new tactile behaviors and memory skills during the reading process.

At the same time, in order to have more accurate information in the later design stage, I also need to filter out the determined target users according to the main purpose of reading and the materials that he likes to read. Learn from more precise target users what types of books they like to read, what they want to memorize when reading different kinds of books, what is important to them, and what kind of reading is effective for them. Finally, find out how receptive they are to the new way of reading.

3.1.1 Research paticipants

In this survey, the selection of participants is very important. Familiarity with devices affects readers' personal preferences for electronic devices, reading experience, and long-term memory, according to literature research. Therefore, testers must be familiar with electronic reading equipment and have experience in using electronic reading equipment.

In the end, I selected **10 young people aged 20-30 who have e-reading devices and experience e-reading** to participate in my user research. (see Appendix B for the specific information of the participants).

3.1.2 Research methods

After understanding the factors that influence reader's reading experience and the haptic behaviors and memory tips while reading, I have developed a list of user research questions for user research.

To answer these research questions of mine, I conducted three separate research activities to answer different research questions. Questions explored by each activity are marked with differently color.

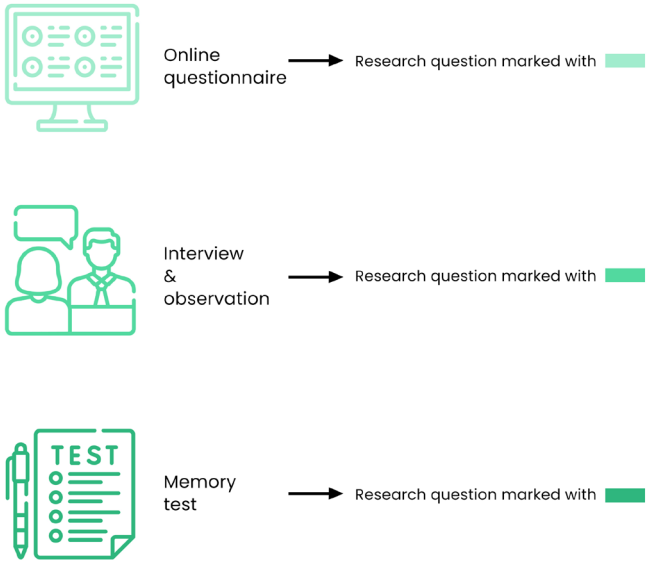


Figure 3.1.1 Three research activities and corresponding research question

3.1.3 Research questions

User reading habits

1. What is the readers' favorite reading medium? And why?
2. What is the readers' most commonly used reading medium?
    - If it is different from favorite reading medium, why?
3. What types of books do readers like to read? What is the purpose of reading these books?
4. What types of books do readers read most often? For what purpose?
5. Does the choice of reading medium make any difference when reading different types of books?
    - What type of books do they prefer to use e-books for?
    - When reading for what purpose, would they prefer to use e-books?

Current user behaviour, experience and memory tips

1. How do they behave differently when reading on different reading devices?
    - Which of these are haptic behaviors?
2. What methods or tools do they use when reading to help them read and remember the content?
    - Is there any difference between print books and e-books?
    - Why do they use this method when reading print books but not when reading e-books?
3. How do they feel differently when reading on different reading devices?
    - What are the advantages of printed books that can improve the reading experience?
    - Are any of these reasons related to touch?
4. Are they satisfied with their current reading experience? Especially when reading e-books?
    - When reading e-books, what experiences did they find unsatisfactory?
    - Are they satisfied with various features, such as note-taking, highlighting or underlining?

Ability and motivation to remember content

1. How well do they remember the contents of the book?
    - How much can they review when they finish reading a book?
    - Which part of the book impressed them?
2. Why are their memory skills good/bad?
3. Are they satisfied with their current memory abilities?
    - Can they remember what they want to remember?
4. When reading different types of books, what do they usually want to remember?
5. Why do they want to memorize this content?

Ideal reading experience for users

1. What would their ideal e-reading experience look like?
2. When reading, what do they pay most attention to?
3. How do they think the new ways of reading? Like audiobooks, podcasts, etc.?

3.1.4 Research results

1. Questionnaire results

First, through a questionnaire survey, to find out whether the personal preferences of these young people who are familiar with electronic devices for reading media have changed compared with the results in the literature review. Also the kinds of books they like and actually read and the purpose of reading them. Finally let them choose which different memory techniques they would use when reading print and e-books.

Reading materials they like and the purpose of reading them

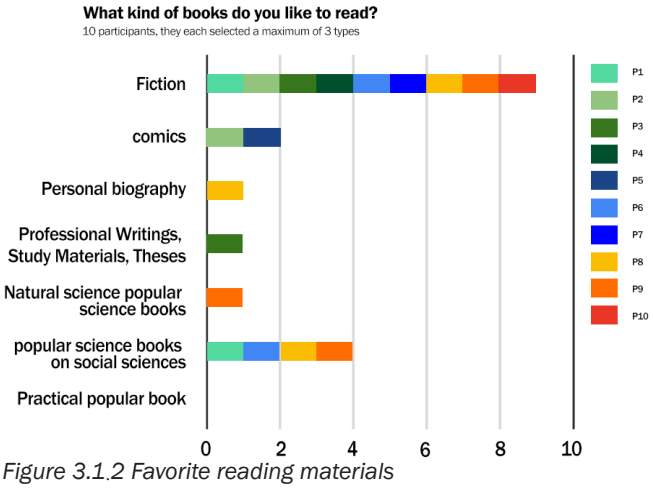


Figure 3.1.2 Favorite reading materials

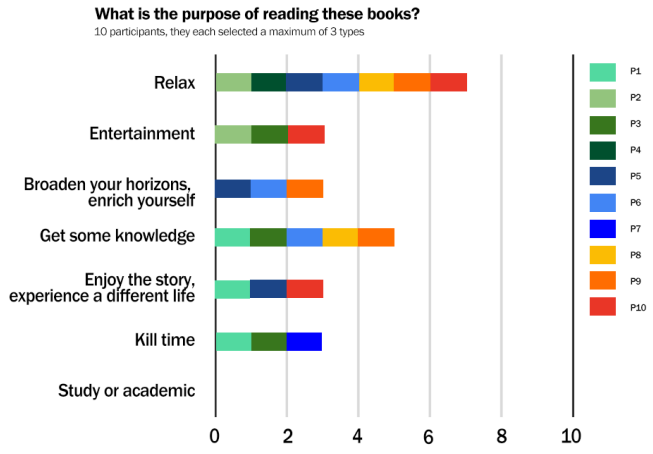


Figure 3.1.3 The purpose of reading favorite books

Frequent reading materials and the purpose of reading them

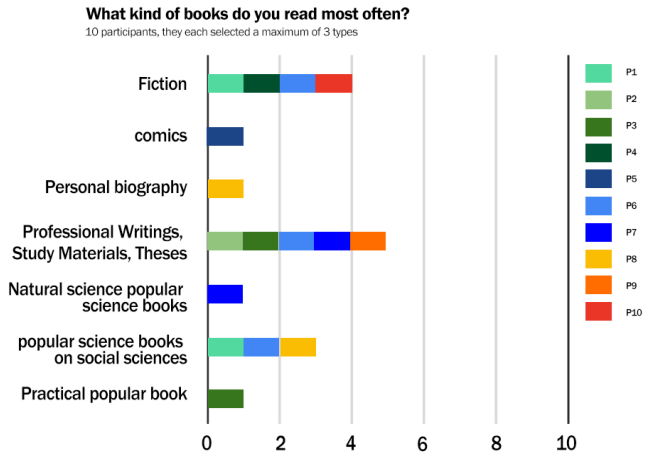


Figure 3.1.4 Frequent reading materials

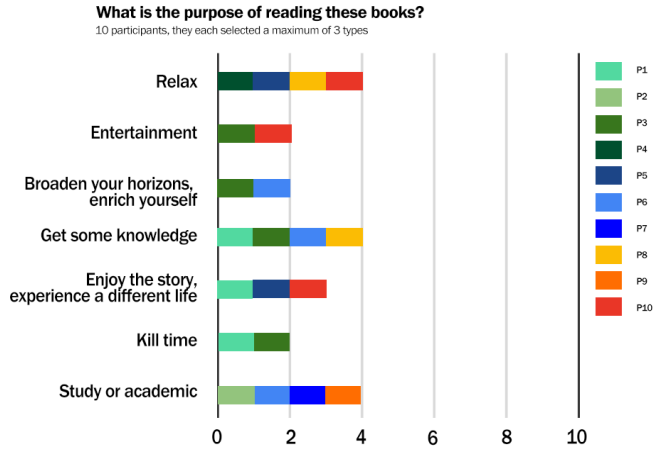


Figure 3.1.5 The purpose of reading frequent materials

As can be seen from the results, when the testers chose reading materials according to their own preferences, **fictions** became the first choice, followed by **social science books.** And their main purpose of reading these two types of books is to **relax** and simply **get some knowledge**. But when the test takers are students, they will be put under some external pressure. They are not completely independent in choosing their reading materials. They will read some professional-related books or papers for academic or learning purposes.

Favorite reading medium

Comparing printed books, ipads and mobile phones, everyone's personal preference.

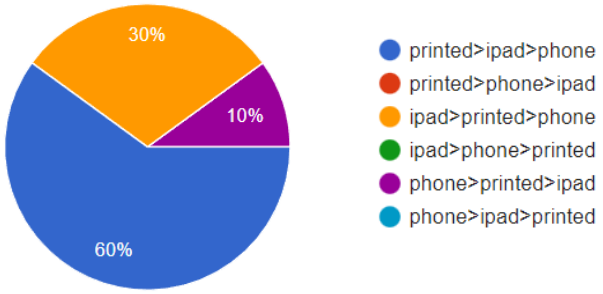


Figure 3.1.6 Favorite reading medium

Most commonly used reading medium

Comparing printed books, ipads and mobile phones, everyone's personal preference.

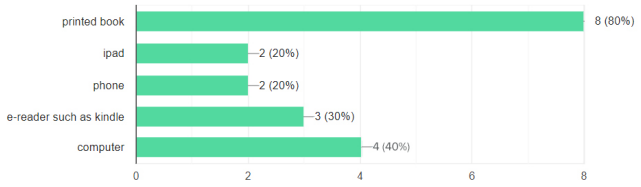


Figure 3.1.7 Most commonly used reading medium

Although the testers were all readers who owned and were familiar with electronic reading media, their favorite was **printed books**. Among electronic reading devices, **ipads are more preferred than mobile phones**. The reason I asked about it was that they felt that **marking and taking notes** on the iPad would be **easier,** and it could be used with the iPad pencil, which is closer to **the feeling of reading a printed book**.

And when testers compared their most commonly used reading devices, printed books were still the most commonly used. In addition to the printed books, ipads and mobile phones that I originally compared, many testers also mentioned e-book devices such as kindle, and computers (almost all participants with academic learning purposes will choose to use computers frequently for reading papers or professional related articles.)

Selected memory methods

Comparing printed books, ipads and mobile phones, the memory method the participants will choose

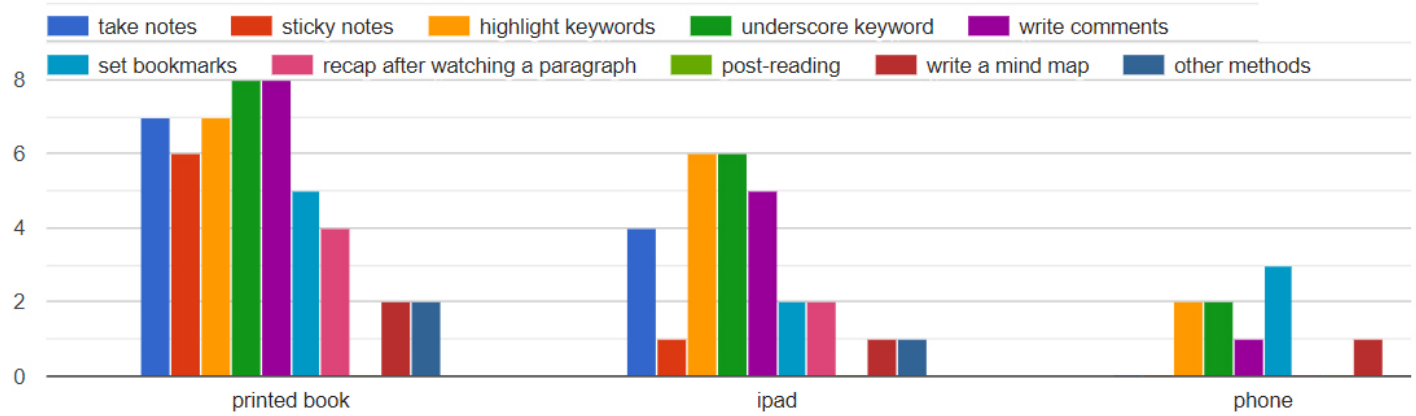


Figure 3.1.8 Selected memory methods when reading with printed book, ipad, mobile phone

I let the participants vote in the methods learned in chapter2.2.3 to help the long-term memory of book contents. It was found that when the participants were reading the printed book, except for writing after reading, all other methods are chosen, **especially marginalia** (writing comments, writing notes, highlighting or underlining key words, making notes, etc.). When using the iPad, the number of people who choose these methods is significantly **reduced**; when using the mobile phone, **fewer** people use the methods than using an iPad. The reason is that participants thought it would be **more difficult to perform these operations on a mobile phone**.

All the other methods proposed by the participants were read ahead, that is, first read the catalogue to understand the general content of the book and then start to read.

2. Interview & observation results

During the interview and observation phase, I asked participants to read both the printed and electronic versions of the same book. The book I used was Design strategies and methods (Zijlstra et al., 2014). I provided them with a lot of reading tools, such as pencils, pens of different colors, highlighters, sticky notes, bookmarks, etc., let them simulate the process of normal reading. Then I observed them as they read and interviewed them after they read.

Figure 3.1.9 Various materials and tools prepared

I gained a lot of rich insights from interviews and observations, and those conversations were transcribed as raw data. These data were then analyzed and integrated by using statement cards (Sanders & Stappers, 2013). Then, according to research questions, I grouped and clustered related cards into the following 3 directions: 1) **Different experiences and behaviors** of readers when reading print books and e-books. 2) **Different memory tips** that readers use when reading printed and e-books. 3) Readers' **ideal reading experience and views on new reading methods**. Thus, these raw data have a clearer interpretation.

Finally, I learned about the difference between their reading experience and their long-term memory of their content when reading printed books and e-books, and their views on some new multimedia reading, such as audiobooks, podcasts, and multimedia materials, to explore their acceptance of new ways of reading books.

Findings related to current readers' behaviour and experience:

Before reading

Print books

1. Get into the reading status quickly through some preparation.

Before reading, readers will look for a quiet environment, a comfortable chair, prepare a cup of coffee and some snacks for themselves, away from the crowd and noise, and enter the reading transition.

"When I read printed books, I read at a much slower pace, and I usually read in a more formal setting, on a chair or at the head of my bed." - Participant 1

"I'll make a cup of coffee before reading, and prepare a small packet of walnuts before I start reading." - Participant 8

Before reading, readers will use some timing application to set a reading target time to use external force to keep themselves focused while reading.

"I would set an alarm for 20 minutes, read for 20 minutes at a time, and take a break every 20 minutes." - Participant 10

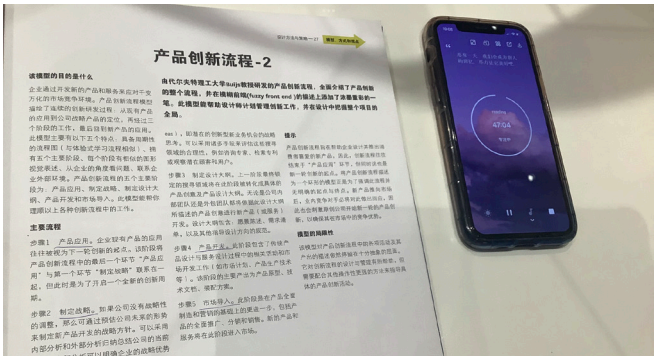


Figure 3.1.10 Set a reading alarm

E-books

1. Prepare extra paper and pens

When reading e-books, especially when studying academic materials, readers will first prepare paper notebooks for manual note-taking.

"I'm not used to taking notes in electronic books. I still use paper and pen to take notes, so before reading, I will prepare a notebook in advance." - Participant 1

During reading

Print books

1. Have some involuntary touch behavior.

When reading a printed book, readers experience some unique touch behaviors that vary from person to person. These behaviors are often done subconsciously, but they have become good reading habits, making their reading process more coherent, reducing the possibility of reading back, and these touch behaviors do not usually occur during e-reading.

"When I'm reading a paper book, I like to hold the next page in my hand when I haven't finished the page." - Participant 4

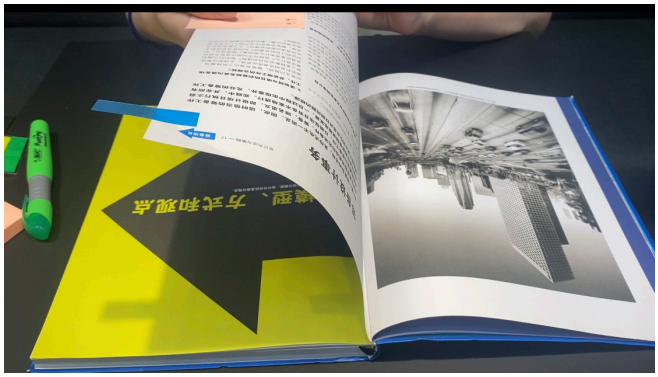


Figure 3.1.11 Hold next page

"When I'm reading, I like to point my pen to where I'm reading, and then my eyes follow my pen to read." - Participant 7

Figure 3.1.12 Guide the eye to read with a pen

"When I am reading a paper book, I am used to holding a pen in my hand and writing and drawing at any time." - Participant 3

"When I read something interesting, I like to draw an emoji next to it." - Participant 6

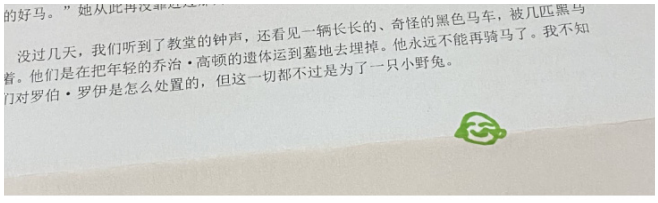


Figure 3.1.13 Draw an emoji to share feelings

2. Stay focused and calm becoause touch feelings.

When reading paper books, readers are basically not disturbed by too many factors. They are fully immerse into the story for a period of time and focus on reading. The weight of the book, the material of the pages, and the friction between the fingertips and the pages when turning the book, and other touch elements keep them quiet and settle down to read.

When reading a printed book, readers flips back and forth, and the process is completely free. Great freedom of reading will also make readers more comfortable and unbound.

"When I was reading a paper book, I didn't know why, but I quickly calmed my mind." - Participant 1

"I prefer the heaviness of printed books and the feeling of flipping through the books. Maybe it's because of touch? Most of the books I can only read in paper books. If I read e-books, only novels can make me keep reading them. Maybe because paper books engage all the senses to it."- Participant 9

“When reading a printed book, I flip through the pages quickly, looking for the title, and flagging snippets that I think are worth reading. I can flip through the printed book freely, and then I can flip to the front and read it again.”- Participant 5

E-books

1. Reading in a casual way.

The environment for readers to read e-books is much more casual than reading printed books. Because of the portability of e-books, they can be read anytime, anywhere, so they think that mobile phones are very suitable for reading novels. When they do not need other tools to read, mobile phones can be the perfect choice, very portable.

However, easy availability and portability also mean a decrease in the quality of reading and a change in reading attitudes. They don't think that reading is a very involved activity anymore, and fragmented reading can be seen everywhere.

“I read ebooks a lot more casually, lying on the bed, or sitting on the train. It also affects how much I value the book. If my posture was more serious, I would read more carefully , remember the content more accurately."- Participant 2

"I often read books on my mobile phone, but I read mostly about novels. While reading, I can remember the general content of the novel without using any tools. So for a novel, the mobile phone is the best reading tool, which automatically records where I last read it, and automatically jumps the next time I open it." - Participant 6

2. Lack of some touch cues.

E-books cannot perceive the geographical location of the text in the book, can not directly feel where to read and the change in the weight of the pages has been read. This prevents readers from understanding their reading progress through touch cues, while also missing some memory cues.

"The biggest difference between reading with an ipad and reading a printed book is that the ipad can't flip freely, feel the specific thickness, and feel more pages after reading. You cannot know the progress of reading, let alone where an important word or plot is in a particular place in the book."- Participant 8

3. The touch feeling is much worse than printed books.

Many interactions on e-books are much worse than on print books. For example, e-books cannot turn pages, only by clicking or scrolling. The refresh process of e-reading apps can make the reading process incoherent. It will also make readers not accumulate the sense of achievement of reading.

When the reader uses an electronic pen to mark and write, the feeling of writing cannot fully simulate the feeling of writing with a real pen and paper, and it is even better to tap the screen directly with a finger. There are even reading apps that can't write and draw yet, and when they want to record something, they need to type on the keyboard.

"When reading e-books, it is usually done by pulling the progress bar or jumping to the directory."- Participant 4

"When I was reading e-books, because many softwares could not handwrite, I had to click and draw, and at the same time I had to type. I didn't write fast, and it was very troublesome to draw."- Participant 2

"The process of flipping through the printed book will accumulate my sense of accomplishment. Every time I turn a page, I feel that I have read one more page, but the e-book cannot give me this sense of accomplishment. Every time I click it, I feel like a brand new page." - Participant 3

"I usually prefer to use my fingers, because using the apple pencil requires constant tool change, which is cumbersome." - Participant 10

4. There are many apps and functions to assist in reading.

When reading e-books, electronic devices can provide readers with more applications to assist them in reading, such as translation apps and website query. Even when using ipad to read, one screen can be cut into dual-screen operation mode, one side is the reading interface, and the other is other application interfaces. When readers find something or vocabulary they do not understand, they can inquire in time, which is very convenient.

At present, many reading apps can also provide functions such as comments and reader communication platforms. This makes it easy for readers to check other people's readings and gain knowledge and inspiration from them. Readers can also view other people's notes in real time, providing a platform for exchanges between readers. At the same time, it also supports readers to share books with others.

"When I read on the iPad, I usually do a split screen operation and then split the dictionary in half so that I can translate words I don't understand."- Participant 6

"You can look up something right away if you don't understand it."- Participant 3

"My most commonly used reading app can see other people's notes, some of which are very interesting, which is a feature I like very much."- Participant 8

After reading and read again

Print books

1. The reading progress needs to be manually recorded for rereading.

After reading, the reader needs to mark it through bookmarks, dog-ear, etc.

"When I finish reading, I usually fold a dog-ear so I can easily find the place when I read again."- Participant 1

Findings related to current readers' memory tips:

Before reading

Print books

1. Read with the purpose

Before reading, readers browse the table of contents and outline first, and have a basic understanding of the book's content before intensive reading of specific chapters. The first thing to do when opening a book is to memorize and analyze the table of contents carefully. Analyze the overall design of this book into several chapters, each chapter is divided into several dimensions, and each dimension can be condensed into several keywords.

Then read with purpose ("something I want to know").

"When reading a book, I like to browse the following table of contents and frontiers first, so as to have a general grasp of the content of the book. When necessary, I will list the outline."- Participant 1

During reading

Print books

1. The touch sensation brought about by the writing can strengthen the memory.

In the first time reading, readers put a notebook or ipad next to it and record what they consider important. This process helps the reader to remember by adding touch senses through writing. This memory effect is much better than the pure vision.

In addition to taking notes, they may also use pens or markers to highlight or underscore keywords directly on their books, which will also help them remember.

What is more, after reading a paragraph, they write summary and mind map. This process combs the content through writing, and form the content in the book into a logical line or knowledge network, which can help readers to effectively build a knowledge framework. Such a writing process is also a process of reflection and rememory.

"For example, some popular science books or books related to majors (with more proper nouns), I tend to use printed books because I rely a lot on hand-eye movement to read and memorize during the reading process. Usually, the notebook or ipad is placed in the book beside, read and write auxiliary memory. And every time I read a paragraph, I make a summary (mark 1234)"- Participant 6

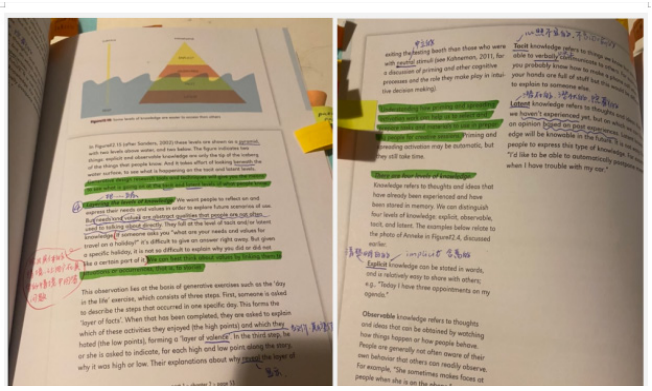


Figure 3.1.14 Make summary after reading a paragraph

"When I encounter something that needs to be memorized, I will excerpt the original words in the notebook. The process of excerpting is also the process of secondary memory."- Participant 2

"I prefer to stick the sticky notes directly and write the content on the sticky notes. The writing process is also a sorting of the content. I will remember the content I have sorted out better. Especially the learning and academic content, which is more useful."- Participant 10

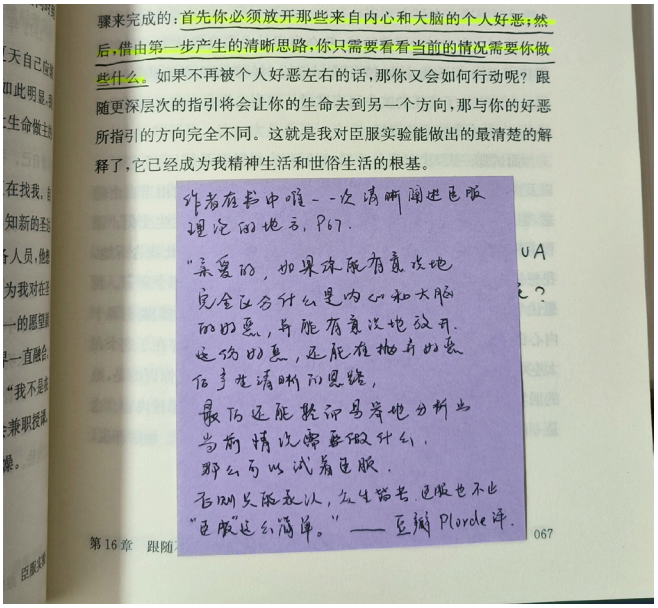


Figure 3.1.15 Stick the sticky notes

"I like to write a mind-map according to the table of contents, and make the focus of each chapter into a logical framework diagram."- Participant 7

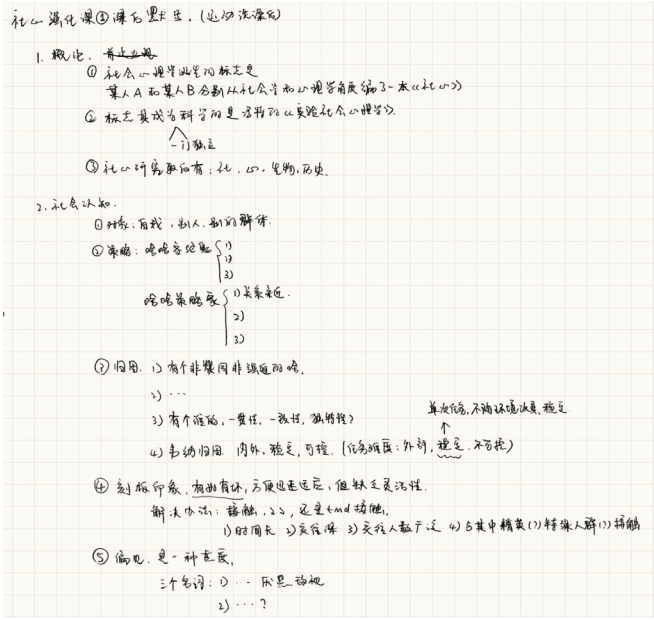


Figure 3.1.16 Write a mind-map

E-books

1.Highlight underlined keywords, setting bookmarks, and taking notes are the three most commonly used memory tips. And these tips are far less used than when reading printed books.

When readers use ipad to read, they will record some meaningful notes and content through finger operation typing or apple pencil writing. Some of the readers are very proficient in the use of these tools and methods, they feel no difference in memorization ability compared to reading a printed book. But there are some readers who are not used to using these markup functions in e-books, and they often forget to mark up, and the amount of markup is far less.

When readers use mobile phones to read, these tips and methods are used less. They hardly use mobile phones to mark and take notes, and the reading process is not paused, so they think mobile phones are more suitable for reading some things that do not need to be memorized, such as novels, and recreational, informational books.

They reported that when they read e-learning materials, they took few notes down the whole book and felt that they didn't remember much. But when reading the printed book, the marked content is roughly remembered.

"I hardly stop when I read e-books, especially on my mobile phone."- Participant 8

After reading and read again

Print books

1. Turn short-term memory into long-term memory through review.

After reading it, they asked themselves: "What did I learn? " Review immediately.

Suitable for the inspection and review link or self-test link. Use several key words to retell what they have read. Be able to test whether they really have the key points of reading information. Try to convert short-term memory into long-term memory.

"After I read a chapter, I will take a break and review what I have read in my mind, relaxing my mind and allowing me to reflect and self-test."- Participant 4

2.The markers made at the first reading can provide clues for the second reading.

When reading again, readers focus on the mark-up content and the listed outline listed, and they can quickly recall the mark-making ideas and quickly find the key content in the book.

"The second time I read, I'll focus on where I'm highlighting, and I'll probably be able to recall what I thought at the time."- Participant 1

"After reading a paragraph, make a summary, and record the summary on the label paper and stick it in the corresponding position of the book. When reading again, the information is prompted by the position of the label paper."- Participant 2

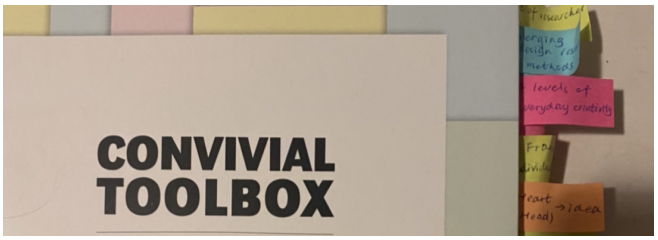


Figure 3.1.17 Stick the label on the book

E-books

1.Look at the notes directory for the second reading.

When readers read the book again, they will prioritize the notes catalogue, see what information they focus on in the first reading, and quickly recall their thoughts and highlights during the last reading. The content clues left by

the first reading can greatly reduce the workload of the second reading. Readers can quickly extract the key information, roughly recall the content of this article, and avoid forgetting.

"When I am reading an e-book, when I see some meaningful and important words, I will use the keyboard to type and record my understanding. When I read the book again, I will open the note directory first , revisiting the notes and I recall the general content of the book. Because my reading speed is very fast when I read it for the first time, so this kind of notes can help me recall the content of the material very well. " - Participant 2

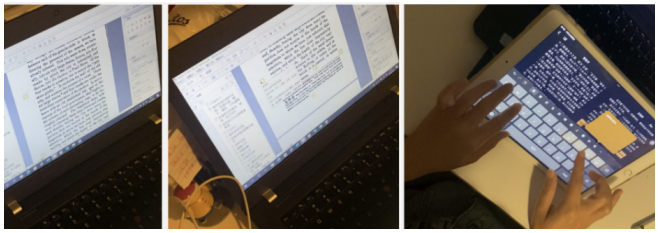


Figure 3.1.18 Look at the notes directory

Readers' ideal e-reading experience and views on new reading methods:

Ideal e-reading experience

1. Simulate the reading experience of printed books.

Many readers believe that printed books are irreplaceable. Their most ideal e-reading experience may be infinitely close to the print reading experience. The screen display effect is the same as the paper quality of traditional books, and the electronic pen writing process is consistent with the real writing experience. There is even an animation to simulate a real flip book effect. Some functions and tools, such as note-taking and highlighting underlined keywords, can support readers to write and scribble directly on the electronic screen, and also have the convenience of electronic applications, which can better summarize and categorize these marks and notes.

Especially when reading academic articles, a large screen with high resolution, multiple functions and convenient input, and the fastest page turning (very short refresh time) are the most important things for readers.

"I like kindle best in electronic devices. Electric ink makes its screen effect the closest to reading a printed book."- Participant 6

2. A vivid way of presenting stories through multisensory.

With the development of multimedia technology, readers have come into contact with some new reading methods. They do not rely solely on text to read, but enrich their reading experience through various methods such as sound, video, and dynamic illustrations. These multi-sensory experiences make them enjoy more pleasant and fresh feelings. They believe that the text in the content of future reading can even be dynamic and fluid, no longer trapped by printed books or screens.

Maybe there will be more technologies in the future, like AR or VR, etc., to provide readers with an immersive or interactive reading experience. Even they imagine that reading in the future will allow them to really enter into the story, talk to the characters in the story, feel their emotions, and experience the real scene.

"If I could, I would like reading to be like watching a 4D movie, so that when I'm looking at a history book, I'm going through time, that would be great."- Participant 7

Views on new reading methods

Audiobook

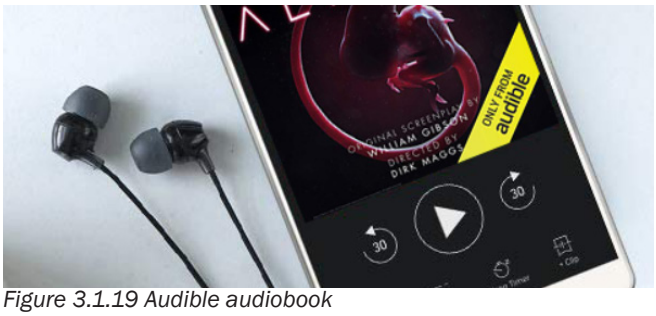


Figure 3.1.19 Audible audiobook

Good comments:

1.It is good in some specific situations, such as when there is no free hand, readers can read anytime and anywhere.

2.At the same time, some good dubbing, as well as a very appropriate soundtrack, can make readers imagine a whole scene.

Bad comments:

1.It's hard to concentrate on listening.

2.Not accustomed to the way sound conveys information, it must not include an audiovisual experience at the same time, or it is pure text.

3. Memory test results

In this part, I first asked participants to read two articles, one fiction and one nonfiction. As they read, they can mark places they think are important or interesting. I counted the parts they marked and summarized them on one graph *(see Figure 3.1.20)*

After each reading, have them answer the following 3 questions to test their reading quality:

1. After reading the news, retell the general content of the news

2.Which part of the whole news impressed you the most?

3.What parts of your reading do you think are important and worth remembering?

After each test they were able to read normally, roughly what they wrote down (question 1). What details will catch their attention and get them to notice (question 2) and, ideally, what they want or expect to remember (question 3)

Finally, compare the reading test results of fiction and nonfiction to understand what the testers want to memorize when reading these two types of books, and the gap between the expected and actual memory parts, which is convenient for exploring the reasons for this gap in the later design stage.

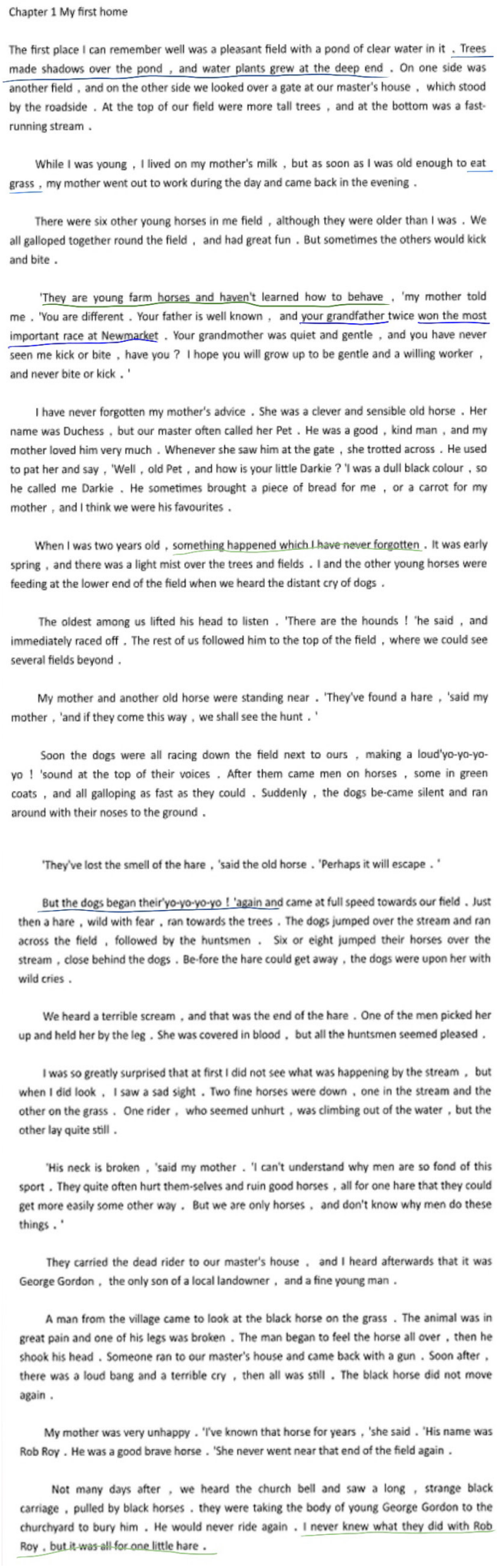
Result of reading fiction

First by marking and my observation and questioning, participants did not like marking when reading fiction. At most, when there is a major turning point in the plot or a major change in the character image, it may be drawn casually. They believed that **pausing to mark while reading fiction can disrupt reading fluency.**

8/10 participants felt that there was **nothing need to remember in particular** when reading fiction. At the same time, 5 participants suggested that if they can **focus on reading and immerse themselves in the story**, they will naturally remember the content of fiction.

When reading fiction, what they actually remember is **the overall plot structure or some climax.** And what impressed the participants the most was **character deciphering, plot reversal or some climax**.

In expectation, what participants want to remember is the moral and sublimation.



Chapter 1 My first home

The first place I can remember well was a pleasant field with a pond of clear water in it . Trees made shadows over the pond , and water plants grew at the deep end . On one side was another field , and on the other side we looked over a gate at our master's house , which stood by the roadside . At the top of our field were more tall trees , and at the bottom was a fast-running stream .

While I was young , I lived on my mother's milk , but as soon as I was old enough to eat grass , my mother went out to work during the day and came back in the evening .

There were six other young horses in me field , although they were older than I was . We all galloped together round the field , and had great fun . But sometimes the others would kick and bite .

'They are young farm horses and haven't learned how to behave , 'my mother told me . 'You are different . Your father is well known , and your grandfather twice won the most important race at Newmarket . Your grandmother was quiet and gentle , and you have never seen me kick or bite , have you ? I hope you will grow up to be gentle and a willing worker , and never bite or kick . '

I have never forgotten my mother's advice . She was a clever and sensible old horse . Her name was Duchess , but our master often called her Pet . He was a good , kind man , and my mother loved him very much . Whenever she saw him at the gate , she trotted across . He used to pat her and say , 'Well , old Pet , and how is your little Darkie ? 'I was a dull black colour , so he called me Darkie . He sometimes brought a piece of bread for me , or a carrot for my mother , and I think we were his favourites .

When I was two years old , something happened which I have never forgotten . It was early spring , and there was a light mist over the trees and fields . I and the other young horses were feeding at the lower end of the field when we heard the distant cry of dogs .

The oldest among us lifted his head to listen . 'There are the hounds ! 'he said , and immediately raced off . The rest of us followed him to the top of the field , where we could see several fields beyond .

My mother and another old horse were standing near . 'They've found a hare , 'said my mother , 'and if they come this way , we shall see the hunt . '

Soon the dogs were all racing down the field next to ours , making a loud'yo-yo-yo-yo ! 'sound at the top of their voices . After them came men on horses , some in green coats , and all galloping as fast as they could . Suddenly , the dogs be-came silent and ran around with their noses to the ground .

'They've lost the smell of the hare , 'said the old horse . 'Perhaps it will escape . '

But the dogs began their'yo-yo-yo-yo ! 'again and came at full speed towards our field . Just then a hare , wild with fear , ran towards the trees . The dogs jumped over the stream and ran across the field , followed by the huntsmen . Six or eight jumped their horses over the stream , close behind the dogs . Be-fore the hare could get away , the dogs were upon her with wild cries .

We heard a terrible scream , and that was the end of the hare . One of the men picked her up and held her by the leg . She was covered in blood , but all the huntsmen seemed pleased .

I was so greatly surprised that at first I did not see what was happening by the stream , but when I did look , I saw a sad sight . Two fine horses were down , one in the stream and the other on the grass . One rider , who seemed unhurt , was climbing out of the water , but the other lay quite still .

'His neck is broken , 'said my mother . 'I can't understand why men are so fond of this sport . They quite often hurt them-selves and ruin good horses , all for one hare that they could get more easily some other way . But we are only horses , and don't know why men do these things . '

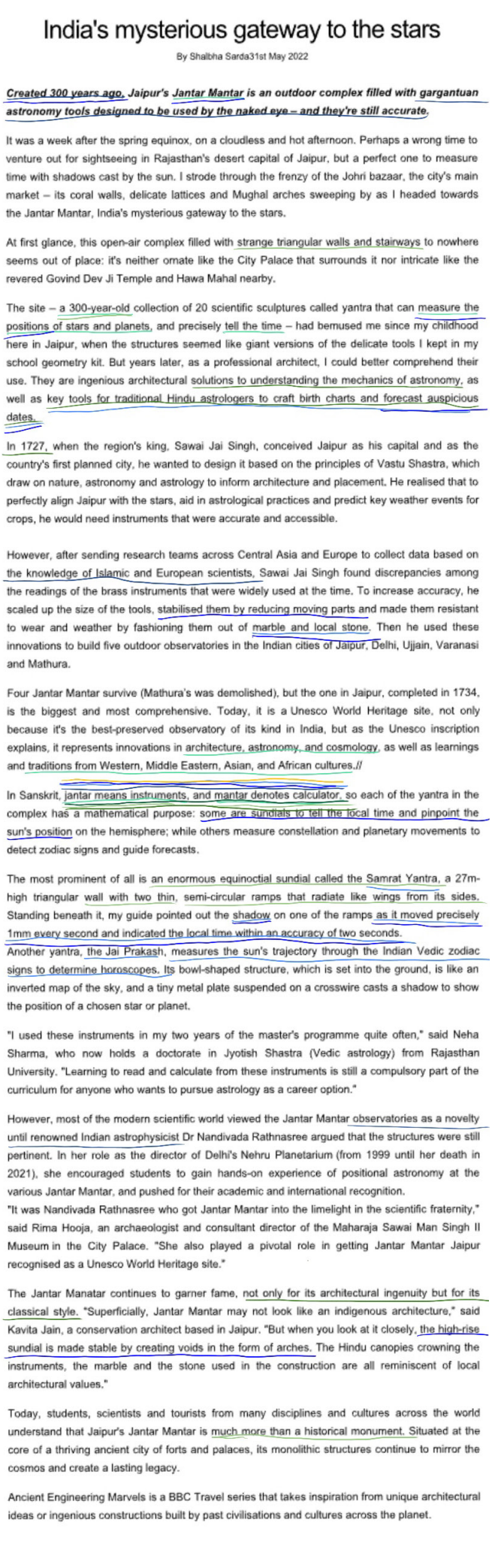
They carried the dead rider to our master's house , and I heard afterwards that it was George Gordon , the only son of a local landowner , and a fine young man .

A man from the village came to look at the black horse on the grass . The animal was in great pain and one of his legs was broken . The man began to feel the horse all over , then he shook his head . Someone ran to our master's house and came back with a gun . Soon after , there was a loud bang and a terrible cry , then all was still . The black horse did not move again .

My mother was very unhappy . 'I've known that horse for years , 'she said . 'His name was Rob Roy . He was a good brave horse . 'She never went near that end of the field again .

Not many days after , we heard the church bell and saw a long , strange black carriage , pulled by black horses . they were taking the body of young George Gordon to the churchyard to bury him . He would never ride again . I never knew what they did with Rob Roy , but it was all for one little hare .

Figure 3.1.20 Reader's mark summary



India's mysterious gateway to the stars

By Shalbha Sarda31st May 2022

Created 300 years ago, Jaipur's Jantar Mantar is an outdoor complex filled with gargantuan astronomy tools designed to be used by the naked eye – and they're still accurate.

It was a week after the spring equinox, on a cloudless and hot afternoon. Perhaps a wrong time to venture out for sightseeing in Rajasthan's desert capital of Jaipur, but a perfect one to measure time with shadows cast by the sun. I strode through the frenzy of the Johri bazaar, the city's main market – its coral walls, delicate lattices and Mughal arches sweeping by as I headed towards the Jantar Mantar, India's mysterious gateway to the stars.

At first glance, this open-air complex filled with strange triangular walls and stairways to nowhere seems out of place: it's neither ornate like the City Palace that surrounds it nor intricate like the revered Govind Dev Ji Temple and Hawa Mahal nearby.

The site – a 300-year-old collection of 20 scientific sculptures called yantra that can measure the positions of stars and planets, and precisely tell the time – had bemused me since my childhood here in Jaipur, when the structures seemed like giant versions of the delicate tools I kept in my school geometry kit. But years later, as a professional architect, I could better comprehend their use. They are ingenious architectural solutions to understanding the mechanics of astronomy, as well as key tools for traditional Hindu astrologers to craft birth charts and forecast auspicious dates.

In 1727, when the region's king, Sawai Jai Singh, conceived Jaipur as his capital and as the country's first planned city, he wanted to design it based on the principles of Vastu Shastra, which draw on nature, astronomy and astrology to inform architecture and placement. He realised that to perfectly align Jaipur with the stars, aid in astrological practices and predict key weather events for crops, he would need instruments that were accurate and accessible.

However, after sending research teams across Central Asia and Europe to collect data based on the knowledge of Islamic and European scientists, Sawai Jai Singh found discrepancies among the readings of the brass instruments that were widely used at the time. To increase accuracy, he scaled up the size of the tools, stabilised them by reducing moving parts and made them resistant to wear and weather by fashioning them out of marble and local stone. Then he used these innovations to build five outdoor observatories in the Indian cities of Jaipur, Delhi, Ujjain, Varanasi and Mathura.

Four Jantar Mantar survive (Mathura's was demolished), but the one in Jaipur, completed in 1734, is the biggest and most comprehensive. Today, it is a Unesco World Heritage site, not only because it's the best-preserved observatory of its kind in India, but as the Unesco inscription explains, it represents innovations in architecture, astronomy, and cosmology, as well as learnings and traditions from Western, Middle Eastern, Asian, and African cultures.//

In Sanskrit, jantar means instruments, and mantar denotes calculator, so each of the yantra in the complex has a mathematical purpose: some are sundials to tell the local time and pinpoint the sun's position on the hemisphere; while others measure constellation and planetary movements to detect zodiac signs and guide forecasts.

The most prominent of all is an enormous equinoctial sundial called the Samrat Yantra, a 27m-high triangular wall with two thin, semi-circular ramps that radiate like wings from its sides. Standing beneath it, my guide pointed out the shadow on one of the ramps as it moved precisely 1mm every second and indicated the local time within an accuracy of two seconds.
Another yantra, the Jai Prakash, measures the sun's trajectory through the Indian Vedic zodiac signs to determine horoscopes. Its bowl-shaped structure, which is set into the ground, is like an inverted map of the sky, and a tiny metal plate suspended on a crosswire casts a shadow to show the position of a chosen star or planet.

"I used these instruments in my two years of the master's programme quite often," said Neha Sharma, who now holds a doctorate in Jyotish Shastra (Vedic astrology) from Rajasthan University. "Learning to read and calculate from these instruments is still a compulsory part of the curriculum for anyone who wants to pursue astrology as a career option."

However, most of the modern scientific world viewed the Jantar Mantar observatories as a novelty until renowned Indian astrophysicist Dr Nandivada Rathnasree argued that the structures were still pertinent. In her role as the director of Delhi's Nehru Planetarium (from 1999 until her death in 2021), she encouraged students to gain hands-on experience of positional astronomy at the various Jantar Mantar, and pushed for their academic and international recognition.
"It was Nandivada Rathnasree who got Jantar Mantar into the limelight in the scientific fraternity," said Rima Hooja, an archaeologist and consultant director of the Maharaja Sawai Man Singh II Museum in the City Palace. "She also played a pivotal role in getting Jantar Mantar Jaipur recognised as a Unesco World Heritage site."

The Jantar Manatar continues to garner fame, not only for its architectural ingenuity but for its classical style. "Superficially, Jantar Mantar may not look like an indigenous architecture," said Kavita Jain, a conservation architect based in Jaipur. "But when you look at it closely, the high-rise sundial is made stable by creating voids in the form of arches. The Hindu canopies crowning the instruments, the marble and the stone used in the construction are all reminiscent of local architectural values."

Today, students, scientists and tourists from many disciplines and cultures across the world understand that Jaipur's Jantar Mantar is much more than a historical monument. Situated at the core of a thriving ancient city of forts and palaces, its monolithic structures continue to mirror the cosmos and create a lasting legacy.

Ancient Engineering Marvels is a BBC Travel series that takes inspiration from unique architectural ideas or ingenious constructions built by past civilisations and cultures across the planet.

P1
P2
P3
P4
P5
P6
P7
P8
P9
P10

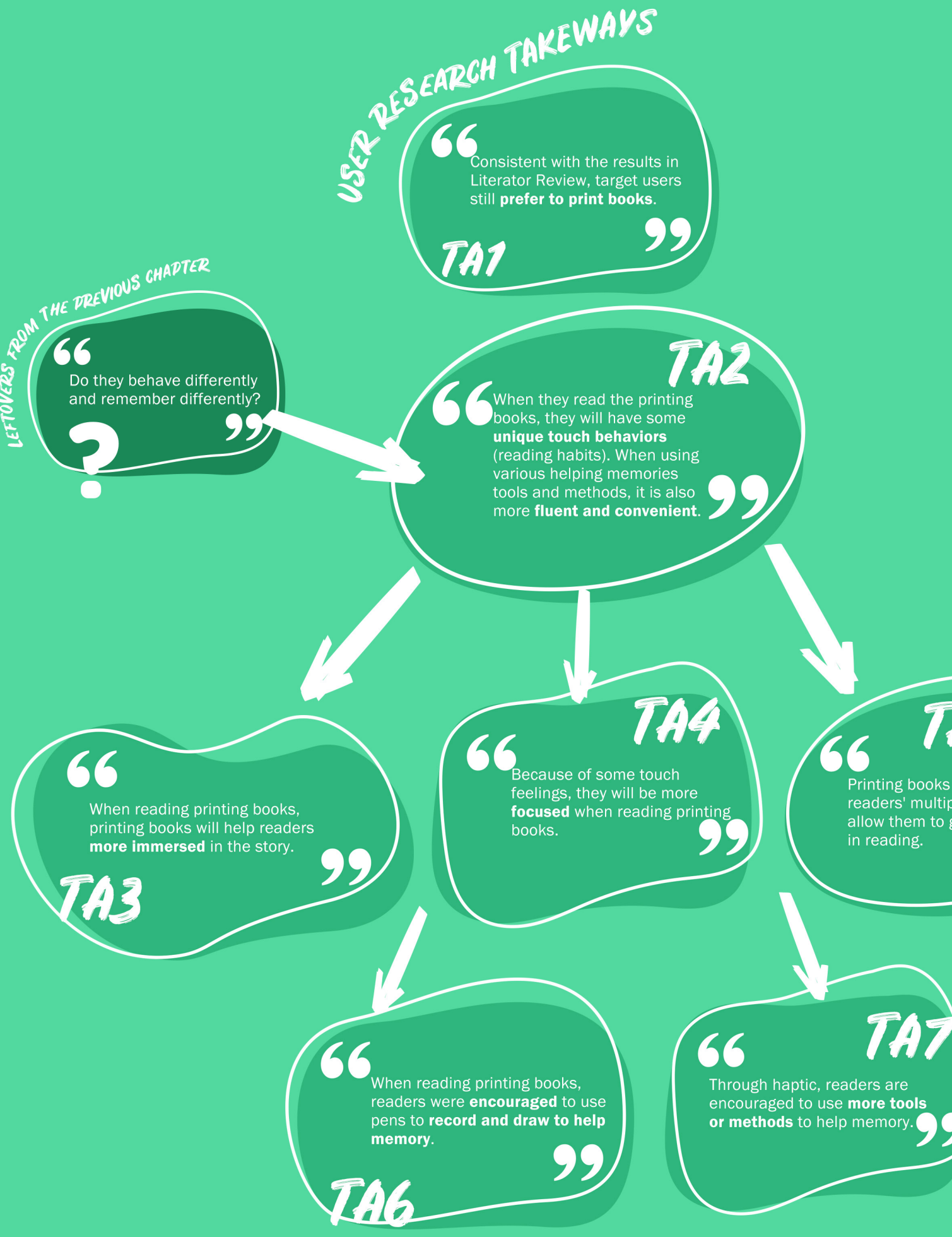
Result of reading nonfiction

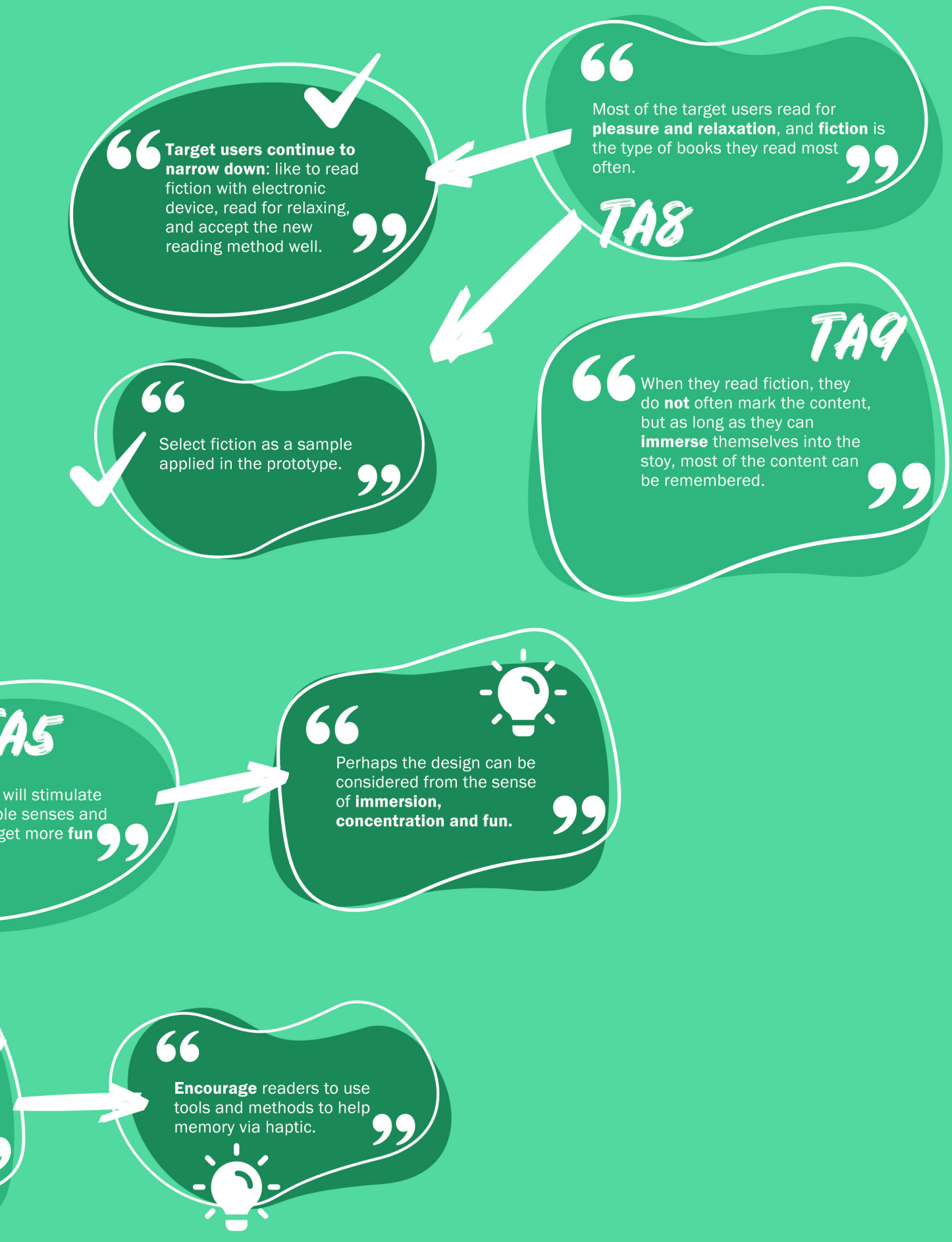
Compared with fiction, there are many **more markers** in nonfiction. Most participants will mark some concluding remarks in the text about **definitions, unknown words, names of instruments, time and place**. The largest of these was an explanation of an **unrecognized word**, which was marked by 7/10 of the participants. They generally believed that **marking some important words would help them memorize** important content.
When reading non-fiction (in this case, a popular science article in the social sciences), what they actually remember is what the whole article is mainly about, how it was built, how it works, and what it means. Most of the things that the participants r**emembered most were consistent with what they marked**, the names of specific instruments, the interpretation of unknown words, the overall value and meaning, and so on.
What the participants expected to remember was the same as what they were most impressed with in practice, but the difference was that it was difficult for them to remember some unknown words and details after passing a mark.

Summary

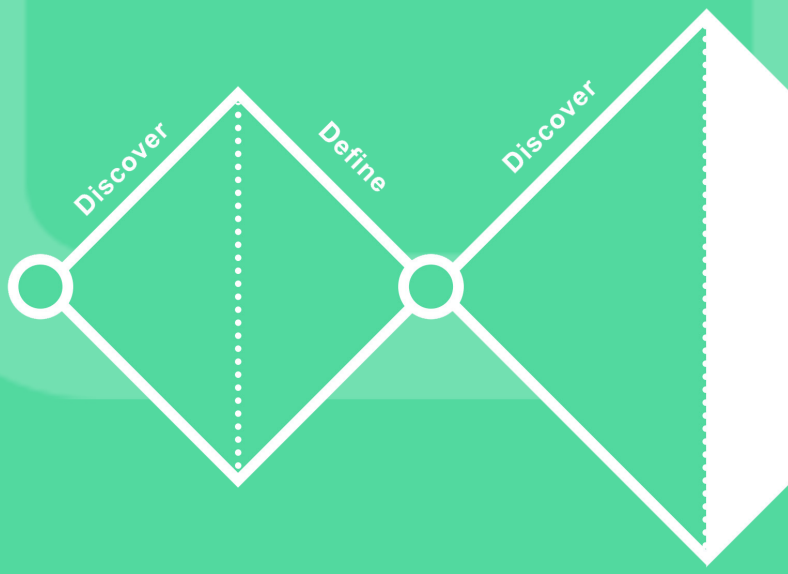
From this test results, we can see that when looking at fiction, readers do not need to help remember with markers, taking notes and other ways. Their motivation to remember the content is not strong, and they usually read fiction to **relax, and enjoy the story**. They think that if they are interested in the fiction and can **immerse** themselves into the story, they can probably remember the story content. What the reader actually remembers **matches** what he wants to remember.

When reading nonfiction, **the marked part** matches what is expected to be remembered. The purpose of reading nonfiction is usually to understand the knowledge and expand their horizons, so what they want to remember most is the **explanation or popularization of their unknown proper nouns,** but the reality is, they may remember that they marked the keyword or sentence, but the explanation or definition can **not** be fully **understood** by marking it, so it is easy to mark it, but actually it is difficult to remember it.


USER RESEARCH TAKEWAYS
Consistent with the results in Literator Review, target users still **prefer to print books**.
TA1
LEFTOVERS FROM THE PREVIOUS CHAPTER
Do they behave differently and remember differently?
?
TA2
When they read the printing books, they will have some **unique touch behaviors** (reading habits). When using various helping memories tools and methods, it is also more **fluent and convenient**.
When reading printing books, printing books will help readers **more immersed** in the story.
TA3
TA4
Because of some touch feelings, they will be more **focused** when reading printing books.
Printing books
readers' multip
allow them to
in reading.
When reading printing books, readers were **encouraged** to use pens to **record and draw to help memory**.
TA6
TA7
Through haptic, readers are encouraged to use **more tools or methods** to help memory.

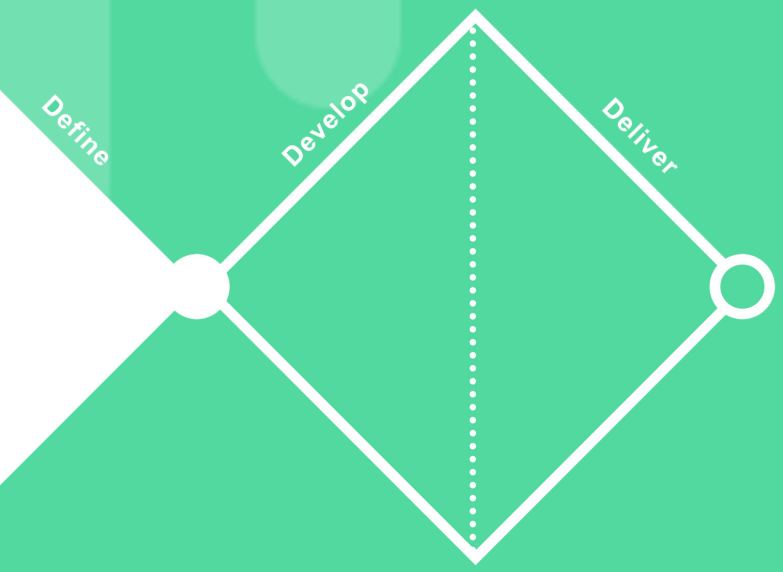

Most of the target users read for **pleasure and relaxation**, and **fiction** is the type of books they read most often.
TA8
Target users continue to narrow down: like to read fiction with electronic device, read for relaxing, and accept the new reading method well.
TA9
When they read fiction, they do **not** often mark the content, but as long as they can **immerse** themselves into the stoy, most of the content can be remembered.
Select fiction as a sample applied in the prototype.
Perhaps the design can be considered from the sense of **immersion, concentration and fun.**
will stimulate
ple senses and
get more **fun**
Encourage readers to use tools and methods to help memory via haptic.

So far, a lot of information about e-reading an
literature review and user research. Therefore,
and determine the design objectives as well as



CHAPTER 4
DESIGN BRIEF

d tactile applications has been found through
this chapter will further refine the target group
the interaction vision I expected.



4.1 Target group

In the beginning, the target group is very large, as long as the readers who like to read are the target group. However, after conducting literature review and user research, I found that users' familiarity with electronic devices greatly affects their experience of e-reading. Generally, users who are familiar with and own e-reading devices will be more willing to use and like e-reading. Second, most users read for relaxation and pleasure, so most of them want to maintain a smooth, immersive, and focused reading experience. If on this basis, they can memorize more content and acquire more knowledge, all the better. But overall, they should still be people who read for relaxation and pleasure. Also, because my project focuses on haptic reading, they also need to have some receptiveness to new ways of reading. So, in the end my target group is 20-30 year olds who are familiar with and own electronic reading devices *(see Figure 4.1.1).*

The reading materials have also changed. In the preliminary research, I also learned that more users tend to use e-reading to read novels, information, comics and other types of materials. Fiction is also the type of book that the target group likes and reads most often. And the results in chapter 2.1.3 Haptic Application Cases show that it is difficult for vibration to convey meanings that are too abstract or complex. So, in the end I will choose the novel genre as the interaction prototype in the design phase.

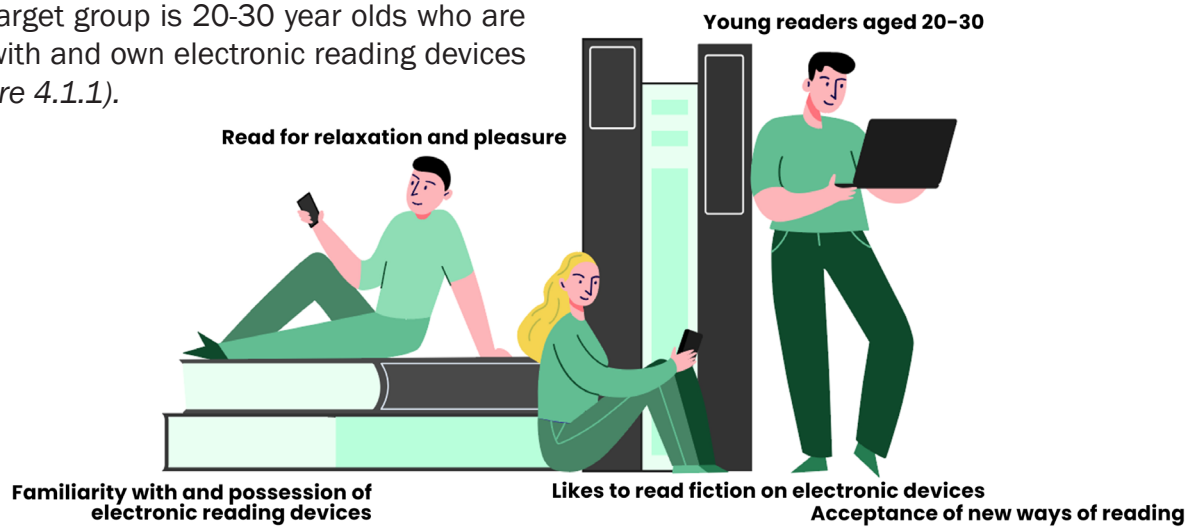


Figure 4.1.1 Characteristics of target users

4.2 Design goal & Interaction vision

"My design goal is to improve the readers' e-reading experience and the long-term memory of the content through haptic technology."

4.2.1 Interaction vision

Interacting with my design should feel like visiting an immersive light exhibit.

Figure 4.1.2 North Forest Lights (Moment Factory, n.d.)

The corresponding interaction qualities are:

Immersed

When people enter the exhibition, a series of immersive light and sound installations are paired with mesmerizing views, allowing people to quickly immerse themselves in the exhibition world.

My design should immerse the user in reading the story through haptic, arouse their emotions, and allow them to tune in with the characters of the story.

Focused

The dim environment and rhythmic lighting make people concentrate on the tour.

My design should let people focus on the reading process through haptic, not distracted, and better remember the content of the story.

Playful

The sensory light installation breathes with the pace and notes, as if communicating with the visitors.

My design should allow people to have interesting interactions with the interface through haptic, making the reading process more vivid.

These interaction qualities will become important indicators for concept formation and testing in the design phase.

4.3 Design opportunities

Simulate real-world dynamic haptics through haptic component, so as to achieve a more immersive effect for readers.

It can be seen from the literature review that vibration can assist visual and auditory information transmission. There are also a lot of haptic technologies that want to simulate the tactile feeling brought by real objects, and then program them into haptic symbols, just like sound effects. There are often similar applications in AR and VR.

So is it possible to transmit some simple tactile information through vibration feedback, so that the e-reading process can be transformed from a more obvious visual activity to a multi-sensory experience?

While transmitting information through touch, it enhances the reader's understanding and feeling of this thing, character or event, thereby enriching his reading experience, and at the same time enhancing the long-term memory of the content.

This direction will be reflected in Concept 3 in the first iteration.

Through the interactive feedback of the vibration expression system, it is communicated that the electronic device has received the user instruction.

Through the interactive feedback of the vibration expression system, it is communicated that the electronic device has received the user instruction.

Expressing system commands or feedback through vibration is now the most common application of haptic technology on smart devices. Whether it is the vibration received by the text message of the mobile phone, or the interactive feedback of some games on the game console, they will tend to use vibration. Many times this vibration also appears together with visual and auditory information, but there is no doubt that vibration makes the experience more diverse. , and even let interactive feedback convey emotional information.

So is there such a situation of interactive information transmission in reading? I think this is also a direction to think about.

For example, when the reader makes a record or makes a mark, the system will give him some vibration feedback, which means that he has received the mark information; or when the system wants to remind the reader of a certain information, it will use vibration to do so. Tips and more.

Perhaps this process will make the communication of information more emotional and interesting, and will react to the reader's marking instructions and make them remember the process deeply.

This direction will be reflected in Concept 2 in the first iteration.

Put the haptic behaviors that only exist in reading printed books into the e-reading process.

In the previous survey, we can find that more people like to read printed books. I have also conducted an in-depth analysis of the reasons for this. Some of the factors that influence this preference come from the tactile experience of reading printed books. For example, reading freely, judging the progress of reading by looking at the thickness of the pages, using pencils to draw and paint, etc. These haptic experiences enrich the reading process and make more people prefer printed books.

So is it possible to simulate some tactile behaviors through vibration technology, and put these behaviors that can only occur on printed books in the electronic reading process?

Then to monitor whether such a similar tactile experience can bring the same tactile experience to the e-reading process as reading a printed book, thereby enhancing the reader's reading experience? And whether this behavior is helpful for memory can also continue to be verified.

This direction will be reflected in Concept 4 in the first iteration.

Use touch to implement only some of the help memory tips that appear in the print text.

I've found that there are so many ways to help readers memorize what's in a book that can only be used when reading a print book, or a very different process than reading an e-book. Such as taking notes, highlighting or underlining keywords, setting bookmarks, etc.

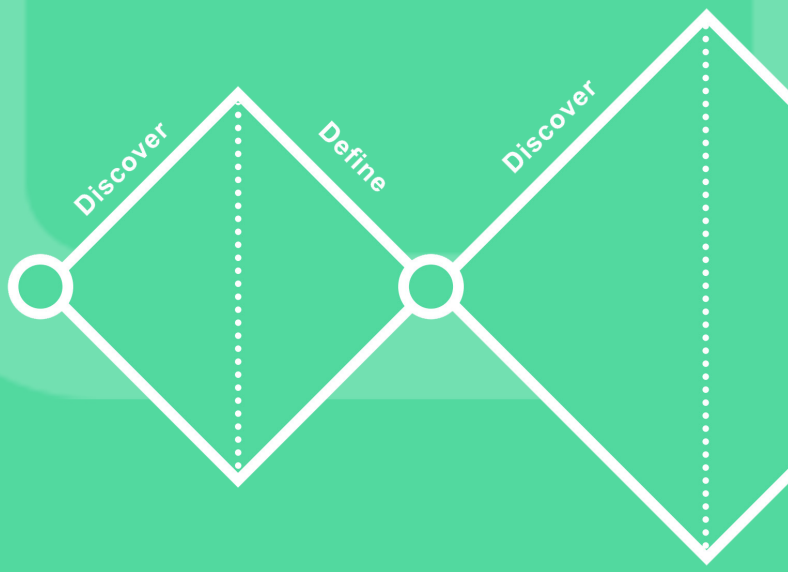
These methods are very helpful for reading and memory, but many operations are inconvenient when reading e-books, so that readers do not like to use it when reading e-books. This also often leads to better long-term memory of book content when readers read printed books.

So I was wondering if I could optimize these tools and methods in a tactile way, or if I could use these memory tricks that can only happen in the process of reading a printed book to the e-reading process. Let readers use these memory skills freely when reading e-books.

From this perspective, readers can improve their reading experience and improve their long-term memory.

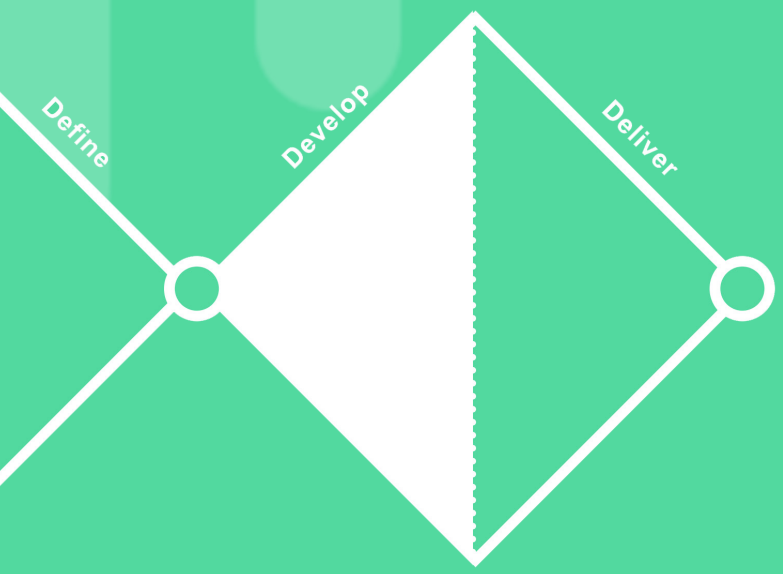
This direction will be reflected in Concept 1 & 5 in the first iteration.

According to the four design directions found
classify and summarize the scheme obtained
subsequent concepts. At the same time, I also
applications.



CHAPTER 5
IDEATION

in Chapl 5, I made several brainstorms. Then
by brainstorming to provide inspiration for the
tested several different vibration actuators and



5.1 Ideation sessions

I conducted a self-ideation session starting from the 4 directions presented in design opportunites in chapter 5 to generate initial design ideas to accomplish my design goals.
In this session, I try to come up with as many ideas as possible to explore more possibilities in the future.

1.Simulate real-world dynamic haptics through haptic sensors, so as to achieve a more immersive effect for readers.

2.Through the interactive feedback of the vibration expression system, it is communicated that the electronic device has received the user instruction.

3.Put the haptic behaviors that only exist in reading printed books into the e-reading process.

4.Use touch to implement only some of the help memory tricks that appear in the print text

Because I didn't prepare a group session, I didn't design a logical mind map in this part. Instead, start from 4 directions and write down as many design ideas as possible on the miro board, or whether there are any possibilities other than 4 directions.

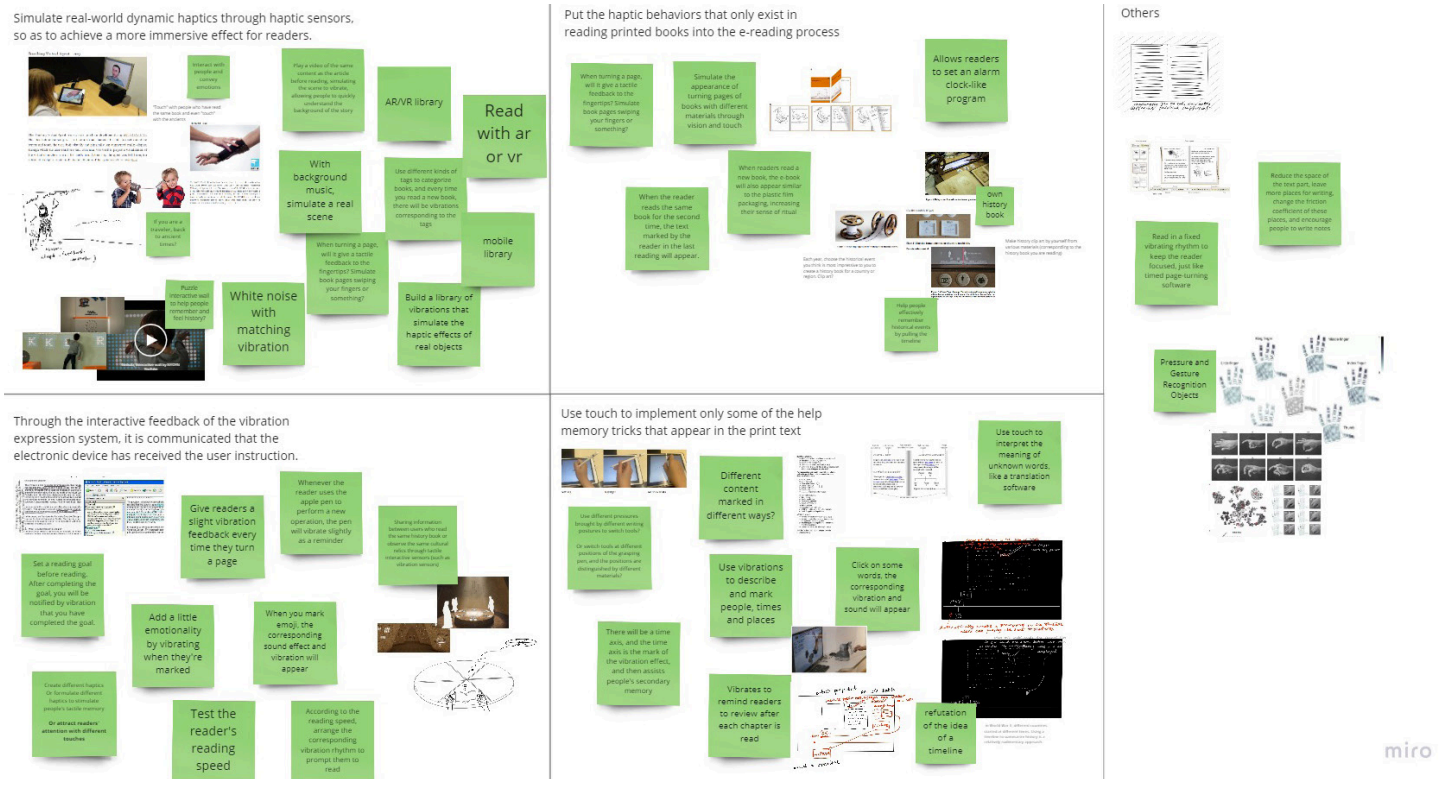


Figure 5.1.1 Ideation sessions in Miro board

5.2 Idea clustering and selection

5.2.1 Six idea clusters

I summarize these ideas into 6 clusters.

1. Vibration to get people to focus on reading

Regular vibration keeps the reader at a constant reading speed
By testing the reading speed of different readers, the readers can keep reading at a stable or even fast speed through a fixed vibration rhythm. Keep them focused while reading. At the same time, the reading process becomes rhythmic. By increasing the reader's concentration, it improves the quality of their reading, thereby improving the long-term memory of the content.

Vibration reading on white noise background
Make different scenes of white noise and matching vibration patterns, let people read in this environment, avoid being disturbed by external noise or other.

2. Immerse people in the story through vibration

Build a virtual vibration library
By simulating the tactile frequency of real objects in the real world, the vibration effects that these words can produce are programmed and put together. Whenever the same word appears in the article, the reader will have a corresponding vibration when touching the word.

Read the previous vibration summary
Every time you read a new book, there will be a vibration and video introduction about the background of the book, so that readers can quickly enter the reading state and understand the background of the book. An alternative to a simple textual background introduction.

Immersive Vibration Reading
If there are some scenes in the background of the story, there will also be background music and vibrations that match the scenes.

3. Vibration to mark and annotate

Differentiate different content with different markup
Mark people with circles, mark time and place with boxes, and after marking, let readers describe the content with vibration, so as to deepen the memory of this content. Or choose one of the various vibrations.

Retrace the vibrations between markers through the timeline
Arrange the characters, times, and places in the order of chapters. The vibrations marked in different chapters will appear on the timeline. Click the vibration markers on the timeline to recall the marked content.

Replace words with vibration
For example, this person has a quarrel with another person in this chapter, then when you click on this character, a quarrel label will appear, and when you click the label, the quarrel sound effect and vibration will appear. Select Vibration to tag people.

4. Simulate real page turning and reading progress through vibration

4. Simulate real page turning and reading progress through vibration
By changing the vibration amplitude to prompt the reading progress, when the reader first starts to read a book, there will be some slight vibrations when turning a page without turning it. But when the reader is about to finish a book, there will be obvious vibrations when turning the page to remind the reader, "You are almost finished!"

5. Realize the interactive feedback of the system through vibration

Vibration prompts readers to turn pages
When the reader turns a page, there will be a slight vibration at the moment of turning the

the page to prompt.

Vibration feedback emoji tags

When the reader makes a mark, he can choose one of the many emoji expressions that he thinks best expresses his emotions at that time. The system will then give him feedback, through sound and vibrations, alerting the reader that the system has received and responding to his mark. The interesting interactive process allows the reader to leave a deeper impression on the content he marked.

6. Explain some proprietary words by vibration

Vibrate jump link

When some different proprietary words appear, it will establish a jump link and jump directly to the Wikipedia interface or other popular science interface for explanation, during which there will be vibration prompts.

vibrate word index

Just like the reading pen used by children, when there are words that you do not understand, you can click, and it will emit corresponding sounds and vibrations to explain the meaning of the words, just like a different translation software. More suitable for non-native speakers.

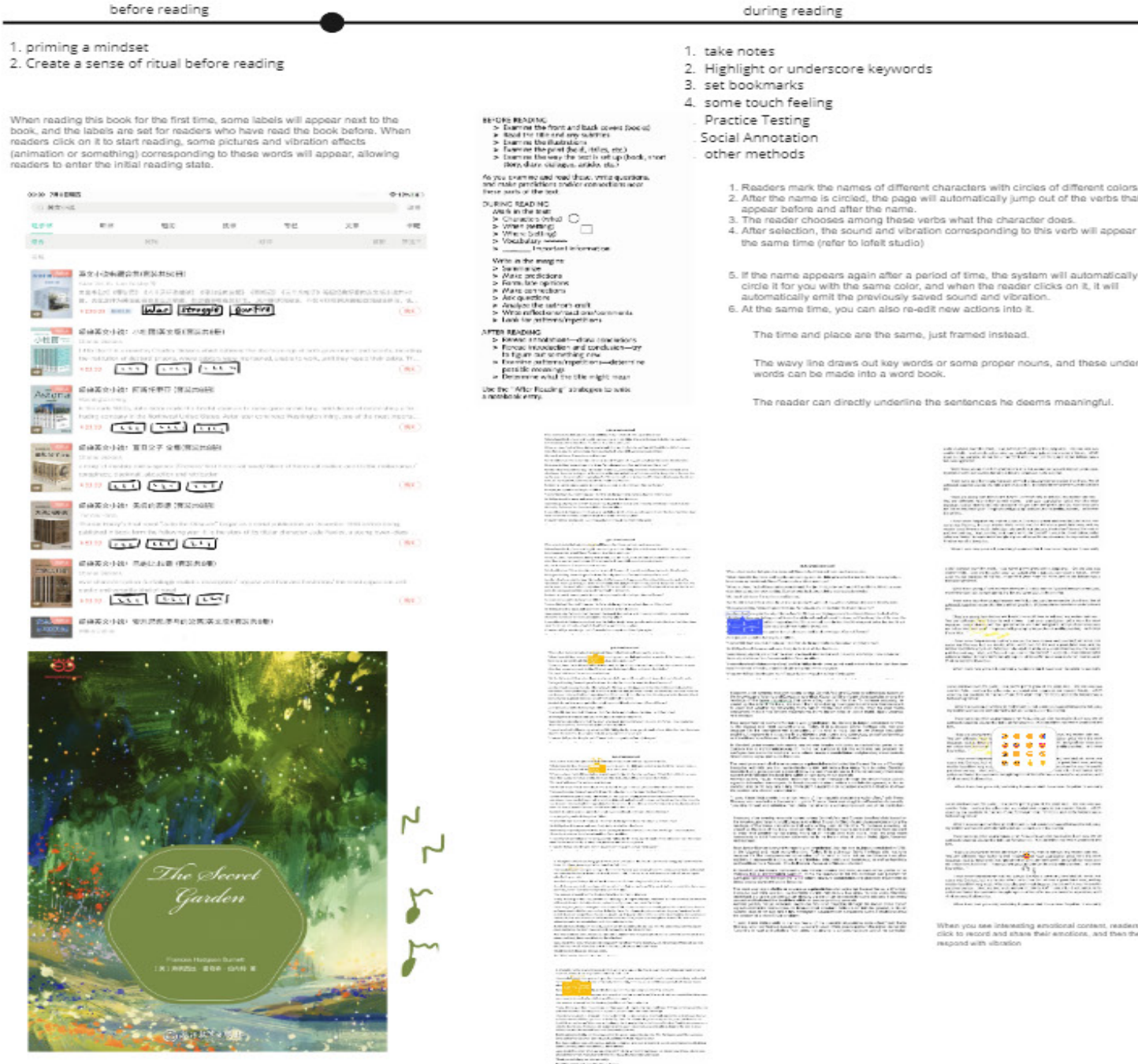


Figure 5.1.2 Idea selection in Miro board

5.2.2 Idea selection

Finally, I choose ideas by building a timeline *(see Figure 5.1.2)* that is categorized according to the complete flow of reading: before reading, during reading, after reading and reading again. *(see Figure 5.1.3)*

In consultation with my advisory team, I chose to focus on the stage of during reading to design. Finally, I selected 5 of my favorite concepts from these ideas. The subsequent iteration stage is given to follow-up design.

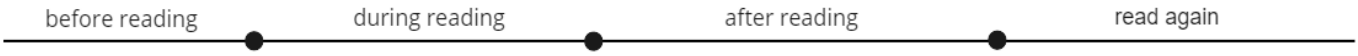
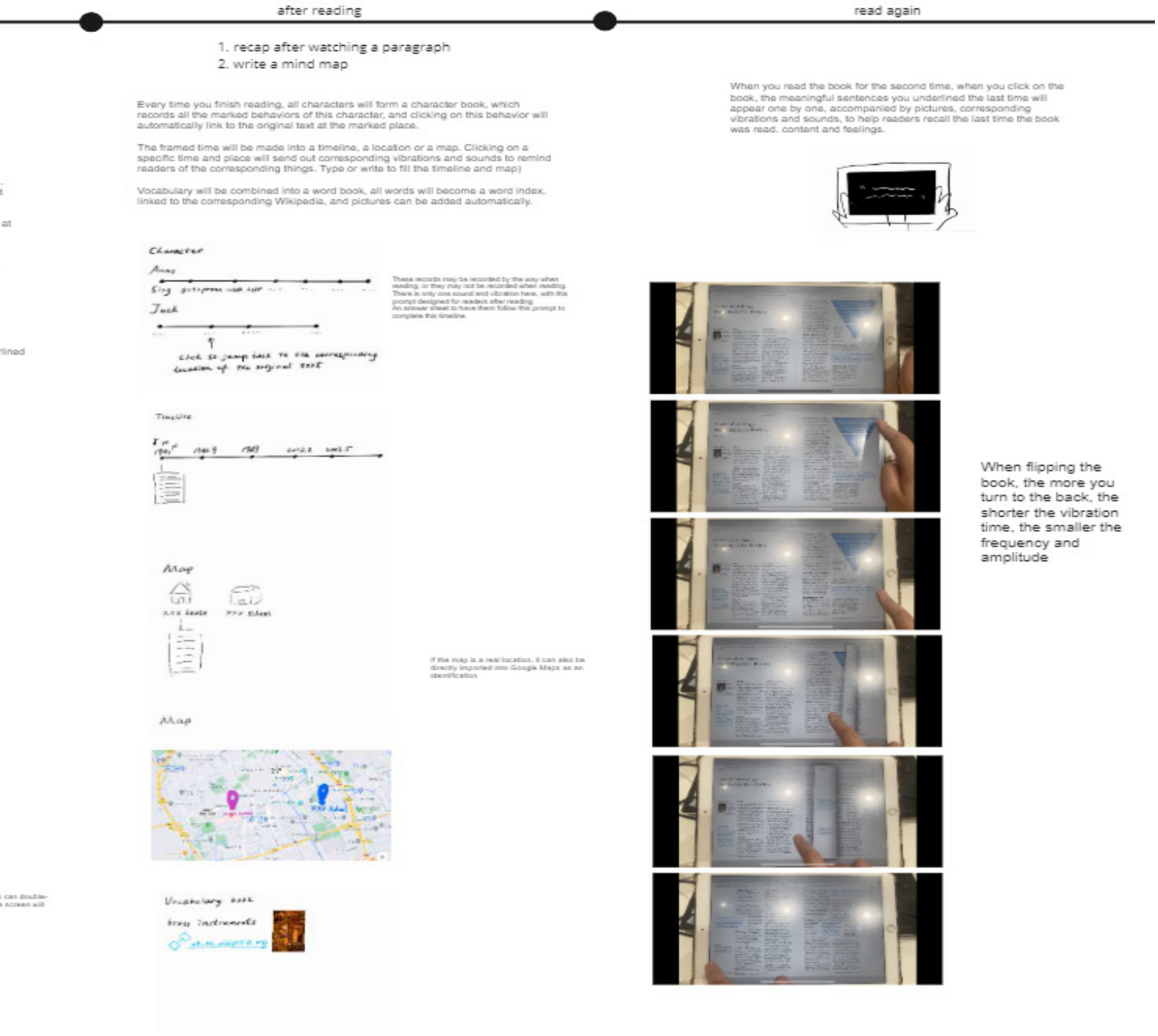


Figure 5.1.3 Ideas selection standard via timeline



5.3 Testing different vibration actuators

5.3.1 Hapticlabs

Hapticlabs is a no-code development toolkit for haptic interactions.
It allows users to freely create vibrations, rhythm or pulses by dragging visual components on the computer or mobile interface without programming. And the output of vibration can be directly performed by inserting any type of electro-magnetic actuators can be used, such as ERM, LRA and Voice Coil actuators, without soldering.

My use experience:
Like:
Getting started is very simple. Installation is very easy. Great for short-duration vibrating effects.

Unlike:
The overall editing interface is not very easy to use.
Not suitable for long-duration vibration effects.
The vibration effect is a little single.
The effect of "fade in" and "fade out" is not obvious.
When the vibration intensity is low, difficult to perceive. When the vibration intensity is high, hands will feel numb.

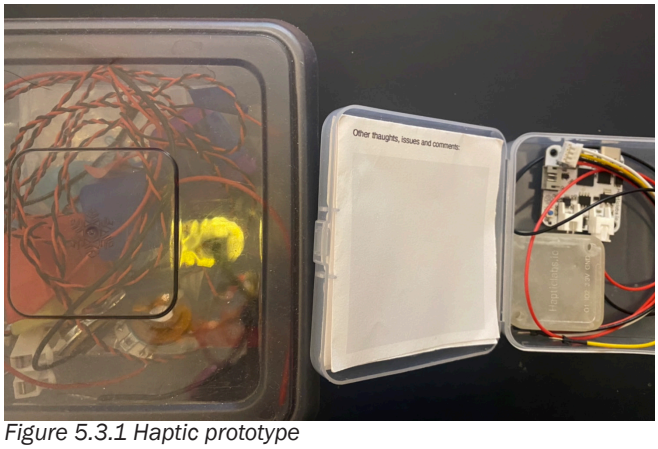


Figure 5.3.1 Haptic prototype

Figure 5.3.2 Prototype interface (https://www.hapticlabs.io/)

5.3.2 Lofelt Studio

Lofelt Studio offers drag-and-drop simplicity that lets user rapidly translate audio files into haptic clips (Büttner, 2020).

It optimizes the process of manually designing haptics. Studio calculates the audio files that users drags into the interface through advanced algorithms, and automatically converts the audio data into matching haptic envelopes and emphasis points, which can then be immediately output to the mobile phone for experience.

But since Lofelt Studio was announced to be closed to the public when I learned about it, It cannot be used now. Only vibration cases that others have done before can be experienced. Therefore, it will not be considered in the subsequent prototype design.
My use experience:
Like:
Combined with sound, it can create a very real feeling.
It fits perfectly with the sound.
No need to manually adjust the vibration intensity, frequency, duration, all haptic data are automatically converted from audio files by the system.
Vibration can exist alone in silent conditions.

Figure 5.3.3 Lofelt studio in phone

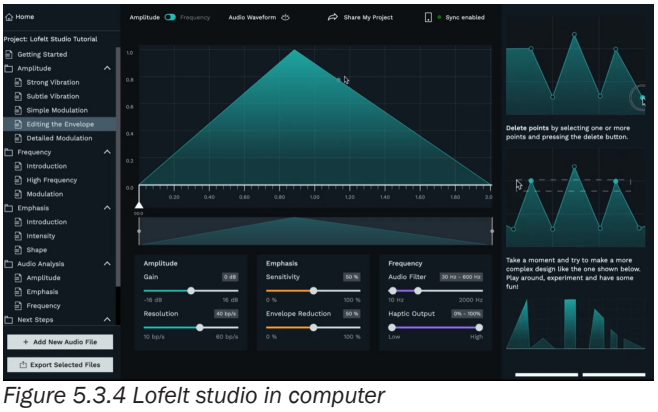


Figure 5.3.4 Lofelt studio in computer

5.3.3 Bluetooth connection and plug-in vibration actuator

Both are vibration actuators that can be connected to electronic devices via Bluetooth or direct insertion. When audio is played in an electronic device, the vibration actuator automatically converts the sound signal into vibration feedback.

Bluetooth Connected Actuator

The first is composed of M5Stack (a tiny programmable smart speaker based on ESP32) (ATOM Echo, 2020) and a vibration actuator (product number 639897) from Foster. (see Figure 5.3.5)

A soldered connection is required between the vibration actuator and the smart speaker. After the welding connection, connect the speaker to the mobile phone or computer through Bluetooth, and play music on the mobile phone or computer, and the vibration actuator will have the corresponding vibration effect in real time, completely converting the sound into vibration. When the vibrating actuator works, the sound is almost reduced by half.

■Specifications

Size	ϕ25mm
Impedance	5.7Ω
Rated Input Voltage	1.0Vrms
Maximum acceleration frequency	65Hz
Vibration acceleration	2.61Gp-p at 65Hz (200g)
Net Weight	28.0g

Figure 5.3.5 Component information

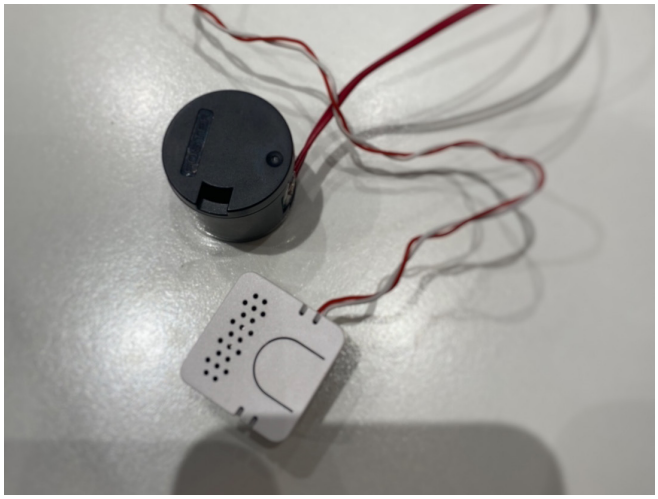


Figure 5.3.6 Bluetooth Vibration motor

My experience:

Like:

It is very convenient to convert sound into vibration signal in real time.

Allows to adjust the vibration effect by adjusting the audio.

It can be connected to electronic devices such as computers, mobile phones, ipads, etc.

Unlike:

The actuator is a little too large and not easy to grip.

When the vibrating actuator is working, the acoustic signal cannot be present at the same time.

Plug-in vibration actuator

Basically the same as the Bluetooth connection actuator, it is a contact speaker of BE STAR which is directly connected to the electronic device by wiring with a 3.5mm mono jack plug.

The use experience is basically the same, except that it cannot be connected to the iphone.

Figure 5.3.7 Component information

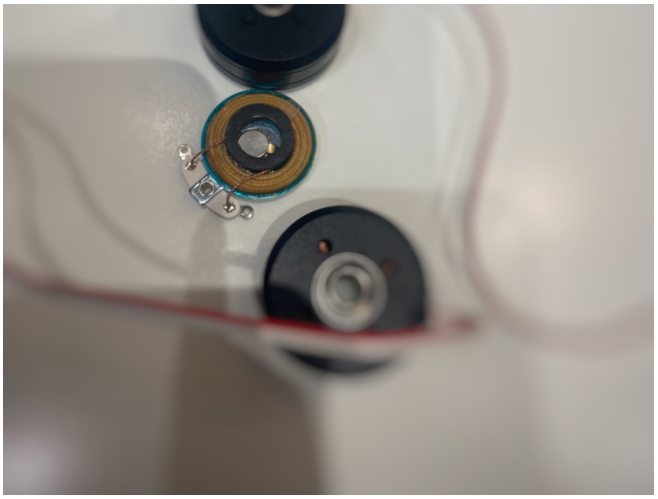
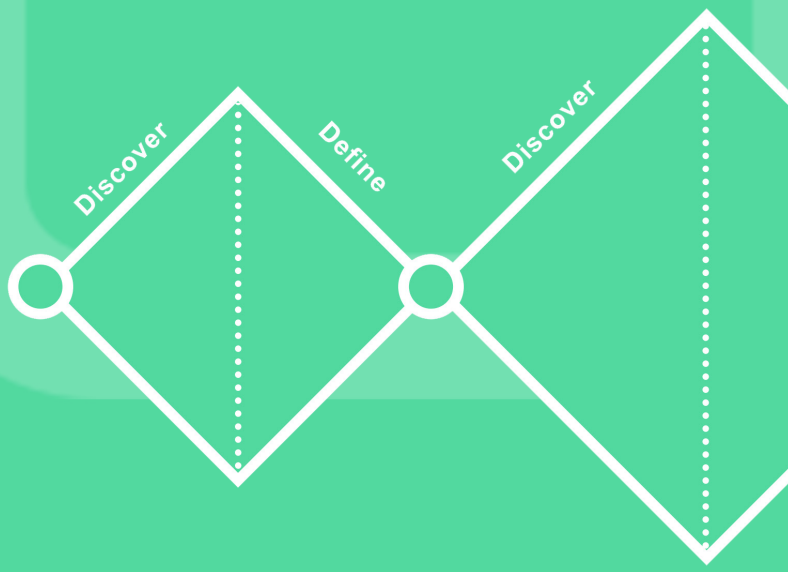


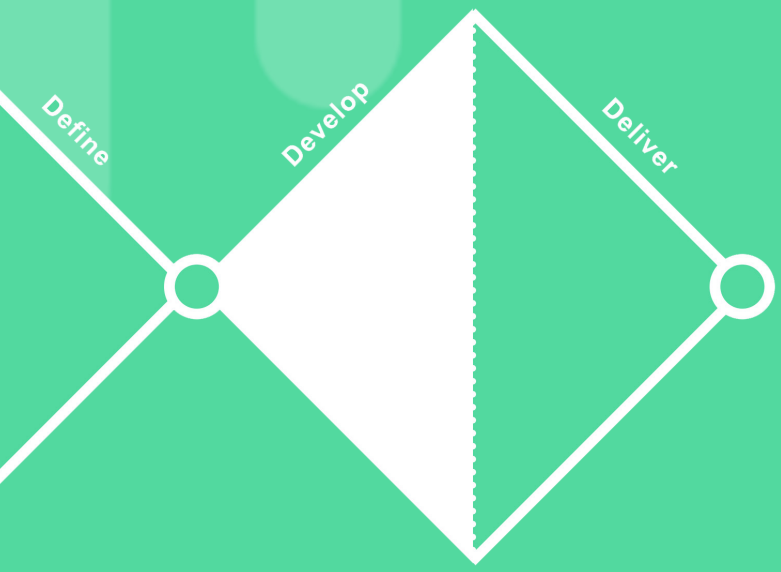
Figure 5.3.8 Another direct plug-in sound-to-vibrator

This chapter describes the iterative process of
device technologies in Chapter 5, and then bu
This chapter then tests and evaluates the targe
a prototype. Finally, the evaluation results are a



CHAPTER 6
FIRST ITERATION

f concepts, which uses the strategy and haptic
uilds on which five different concepts are born.
et user and the the supervisory team by making
nalyzed to provide support for the next iteration.



After finishing the ideation, I did the first concept iteration. Five feasible concepts were extracted and prototype from the brainstorming results. For the next concept iteration, I searched for 11 target users for testing and evaluation, and I collected their feedback on the five concepts.

6.1 Concept#1 Vibration Curve

6.1.1 Concept generation

The concept actually takes advantage of the previously acquired function of touch to improve cognition and enhance memory. At the same time, in this concept, I chose to replace the information that should be expressed by vision with touch, so that users can increase the time to convert visual information into tactile information, and provide multi-sensory channels for information storage. The memory aids of highlight or underscore keywords and recap were selected.

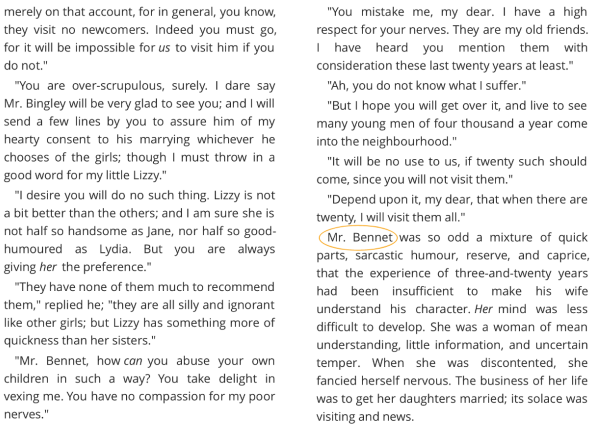
This transformation is divided into 3 steps:
(1) highlight or underscore keywords
(2) Imagine and create
(3) Recap information

It first highlights or underscores keywords in different ways, allowing readers to have a longer-term memory and thinking about the information they feel is important. Then, by converting visual information into tactile information, it allows readers to associate information and consolidate their understanding and memory of information again. Finally, a timeline helps readers retrace the information.

Step #1
highlight or underscore keywords

The first step is to highlight and underline important information that you want to remember through different annotation methods. According to the information in the previous chapter2, different types of information can be divided through different annotation boxes. Let readers pay more attention to key information while labeling, and effectively classify information through different labels.

Highlight key points with different annotations



merely on that account, for in general, you know, they visit no newcomers. Indeed you must go, for it will be impossible for *us* to visit him if you do not."

"You are over-scrupulous, surely. I dare say Mr. Bingley will be very glad to see you; and I will send a few lines by you to assure him of my hearty consent to his marrying whichever he chooses of the girls; though I must throw in a good word for my little Lizzy."

"I desire you will do no such thing. Lizzy is not a bit better than the others; and I am sure she is not half so handsome as Jane, nor half so good-humoured as Lydia. But you are always giving *her* the preference."

"They have none of them much to recommend them," replied he; "they are all silly and ignorant like other girls; but Lizzy has something more of quickness than her sisters."

"Mr. Bennet, how *can* you abuse your own children in such a way? You take delight in vexing me. You have no compassion for my poor nerves."

"You mistake me, my dear. I have a high respect for your nerves. They are my old friends. I have heard you mention them with consideration these last twenty years at least."

"Ah, you do not know what I suffer."

"But I hope you will get over it, and live to see many young men of four thousand a year come into the neighbourhood."

"It will be no use to us, if twenty such should come, since you will not visit them."

"Depend upon it, my dear, that when there are twenty, I will visit them all."

Mr. Bennet was so odd a mixture of quick parts, sarcastic humour, reserve, and caprice, that the experience of three-and-twenty years had been insufficient to make his wife understand his character. *Her* mind was less difficult to develop. She was a woman of mean understanding, little information, and uncertain temper. When she was discontented, she fancied herself nervous. The business of her life was to get her daughters married; its solace was visiting and news.

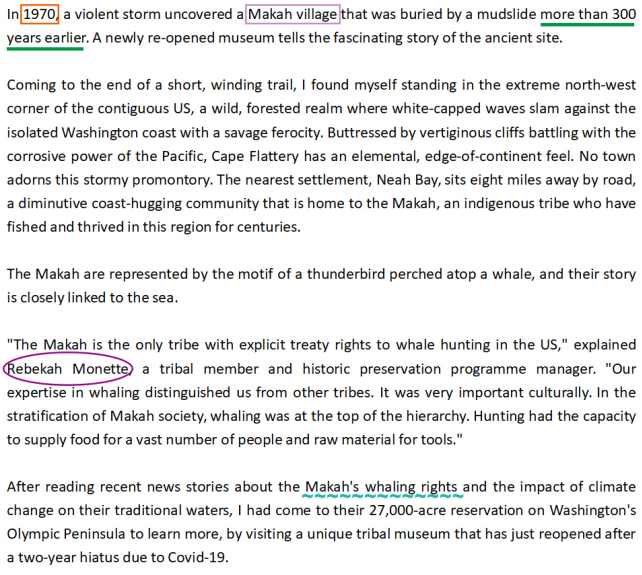
Figure 6.1.1 Mark Character with circle

Mark in the text:

Characters(who)

Time(when)
Location(where)

Vocabulary
Important information



In 1970, a violent storm uncovered a Makah village that was buried by a mudslide more than 300 years earlier. A newly re-opened museum tells the fascinating story of the ancient site.

Coming to the end of a short, winding trail, I found myself standing in the extreme north-west corner of the contiguous US, a wild, forested realm where white-capped waves slam against the isolated Washington coast with a savage ferocity. Buttressed by vertiginous cliffs battling with the corrosive power of the Pacific, Cape Flattery has an elemental, edge-of-continent feel. No town adorns this stormy promontory. The nearest settlement, Neah Bay, sits eight miles away by road, a diminutive coast-hugging community that is home to the Makah, an indigenous tribe who have fished and thrived in this region for centuries.

The Makah are represented by the motif of a thunderbird perched atop a whale, and their story is closely linked to the sea.

"The Makah is the only tribe with explicit treaty rights to whale hunting in the US," explained Rebekah Monette, a tribal member and historic preservation programme manager. "Our expertise in whaling distinguished us from other tribes. It was very important culturally. In the stratification of Makah society, whaling was at the top of the hierarchy. Hunting had the capacity to supply food for a vast number of people and raw material for tools."

After reading recent news stories about the Makah's whaling rights and the impact of climate change on their traditional waters, I had come to their 27,000-acre reservation on Washington's Olympic Peninsula to learn more, by visiting a unique tribal museum that has just reopened after a two-year hiatus due to Covid-19.

Figure 6.1.2 Highlight key points with different annotations and color

Step #2
Imagine and create

The second step is to convert visual information (people, place, time, key information, etc.) into tactile information by selecting, searching or creating 3 ways. This process requires the reader's imagination, and this imaginative process will in turn deepen the reader's memory of the information. It also makes the reading process interesting through interesting transformations.

Select a vibration that represents the character from the template

Selecting, this step requires the reader to connect his understanding of the character (character, mood or behavior at that time) with one of the vibration curves in the template through his own understanding and imagination, and then click on the curve to feel Sound and vibration feedback corresponding to the curve. Finally, choose the one that is closest to the character you understand.

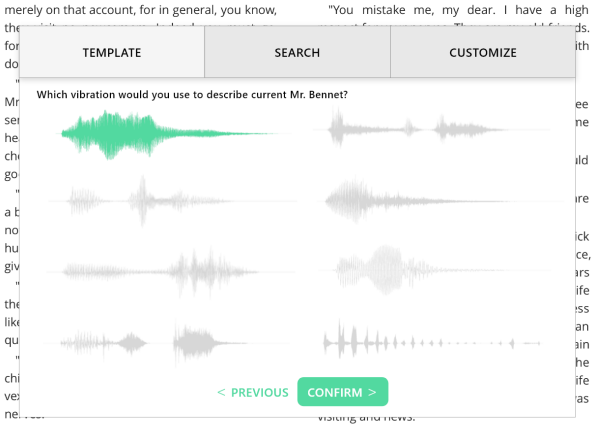


Figure 6.1.3 Select a vibration from the template

Search for the vibration curve of a most representative person

Searching, in this step, based on the template, the sound effects and vibrations are divided into three more detailed parts. For example, for characters, they are divided into character, emotion and behavior. Information is classified and transformed into tactile information.

Create a vibration curve yourself

Creating, this step, is to jump out of the original vibration library, but to create characters that you understand by drawing or adjusting the turning points yourself. This step requires more imagination, and at the same time, it will be more fresh for the reading experience.

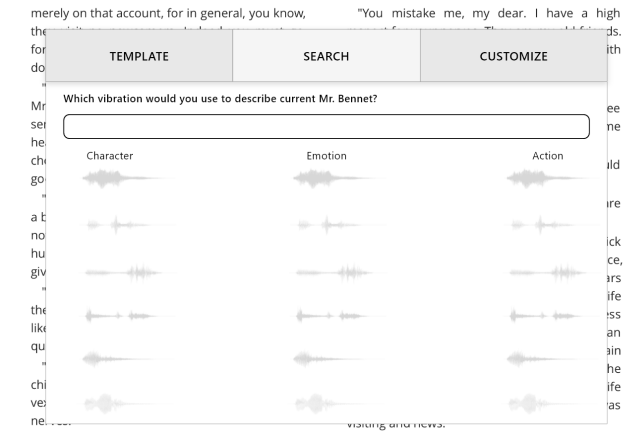


Figure 6.1.4 Search for the vibration curve

Figure 6.1.5 Draw a line to create vibration curve

There are two ways to create, one is that the reader directly draws the curve according to his own understanding of the character, (for example, a person with a violent personality is a curve with a very large change in amplitude), and then the system will automatically identify the curve drawn by the reader as similar to the curve. Sound and vibration feedback.

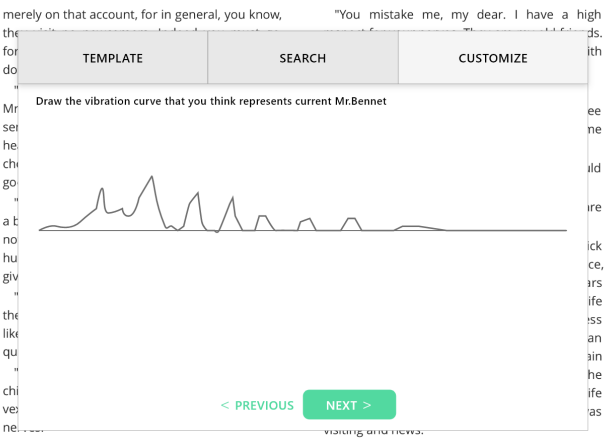


Figure 6.1.6 The drawing line

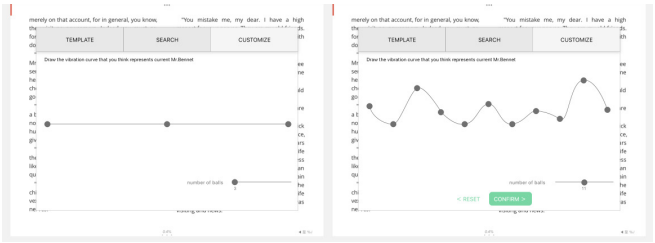


Figure 6.1.7 Create multiple inflection points

The other is to create multiple inflection points, like notes in a piano score, that alter the amplitude and frequency of vibrations by adjusting the height and distance of these "notes" by the reader themselves.

Step #3
Recap information

The third step is the recap information. General e-books will have a bookmark-like function, which summarizes all the information marked by readers during the reading process, and helps readers to review and review the information. But in my concept, the retrospective information will be classified and displayed in the time axis according to the different labeling methods.

Category timeline

On the timeline of the category, all the person annotations are divided into one page, all the time annotations are divided into one page, and the location, keywords and important information are all divided into a separate page. At the same time, the marked visual information will be hidden, leaving only the vibration curve selected according to the visual information at that time, and arranged according to the chapters. The reader clicks on the vibration curve on the timeline and can again get sound effects and vibration feedback. In this way, it helps readers to recall the imagination and thinking at the time when this information was marked.

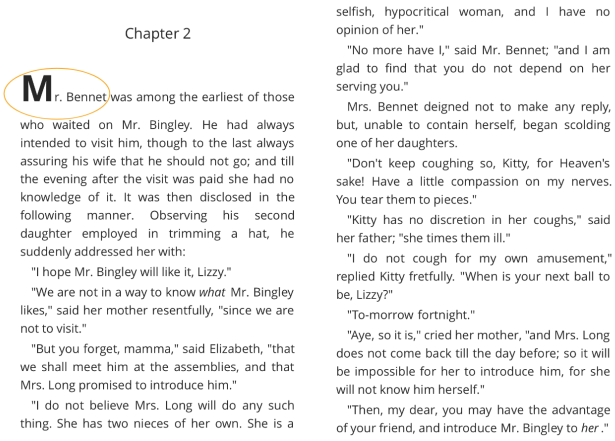
Figure 6.1.8 Character timeline

And about the location timeline, if it's a real location, it can be turned into a map. Strengthen the reader's spatial imagination.

Figure 6.1.10 Generate a new vibration curve on the timeline

Repeat steps
When reading the previously marked information again

When reading the previously marked information again, such as the same person. The reader does not need to mark the person by drawing a circle or a frame, the system will automatically recognize that you have marked the person. The reader only needs to click, and the callout mark used by the same character you marked before will appear, along with the sound effect and vibration feedback you selected (or searched or created) when you last marked. This again helps the reader review the information, recalling what happened to the character before. You can also reselect (search/create) a new sound effect and vibration feedback.



Chapter 2

Mr. Bennet was among the earliest of those who waited on Mr. Bingley. He had always intended to visit him, though to the last always assuring his wife that he should not go; and till the evening after the visit was paid she had no knowledge of it. It was then disclosed in the following manner. Observing his second daughter employed in trimming a hat, he suddenly addressed her with:

"I hope Mr. Bingley will like it, Lizzy."

"We are not in a way to know *what* Mr. Bingley likes," said her mother resentfully, "since we are not to visit."

"But you forget, mamma," said Elizabeth, "that we shall meet him at the assemblies, and that Mrs. Long promised to introduce him."

"I do not believe Mrs. Long will do any such thing. She has two nieces of her own. She is a selfish, hypocritical woman, and I have no opinion of her."

"No more have I," said Mr. Bennet; "and I am glad to find that you do not depend on her serving you."

Mrs. Bennet deigned not to make any reply, but, unable to contain herself, began scolding one of her daughters.

"Don't keep coughing so, Kitty, for Heaven's sake! Have a little compassion on my nerves. You tear them to pieces."

"Kitty has no discretion in her coughs," said her father; "she times them ill."

"I do not cough for my own amusement," replied Kitty fretfully. "When is your next ball to be, Lizzy?"

"To-morrow fortnight."

"Aye, so it is," cried her mother, "and Mrs. Long does not come back till the day before; so it will be impossible for her to introduce him, for she will not know him herself."

"Then, my dear, you may have the advantage of your friend, and introduce Mr. Bingley to *her*."

Figure 6.1.9 Automatically recognize original annotations

Repeat steps
After annotating a new vibration information for the character

When the reader marks a new vibration curve for the same character, the reader can immediately press and hold the marked position to enter the timeline, and can see that the new mark has appeared on the character timeline in order.

6.2 Concept#2 Set a goal

6.2.1 Concept generation

The concept is to use the tactile vibration feedback mechanism (a tactile channel commonly used in electronic interfaces) and to improve focus through rhythmic vibrations. By setting goals, satisfy the reader's sense of accomplishment after reading the reading goals. And through two vibration rhythms (the fastest reading speed and the most comfortable reading speed), users are prompted to maintain a stable reading speed and a focused reading state.

The concept is divided into three stages:
(1) Set reading goals and complete reading goal, vibrate prompt to rest
(2) Test the reading speed of the two states
(3) Read in two vibrational rhythms

In this process, the reader's reading quality is improved by improving concentration and stimulating brain movement. And it is a very fresh reading experience for the reader to read under the continuous vibration mode.

Step #1
Set reading goals and comlete it to rest

The first step allows the reader to calculate the approximate amount of time they will spend reading this time by choosing which chapters to read at a time. Then when the reader finishes reading the goal he has set, the interface will automatically jump to the interface where the goal is completed and can be rested.

Set goals by reading chapters

Figure 6.2.1 Interface for setting goals

Goal completed, can rest

Figure 6.2.2 Interface for prompting rest

Figure 6.2.3 Vibration audio for rest

Prompt to rest In addition to the interface, there will be vibration prompts, the vibration is a continuous, steady rhythm for 21 seconds.

Step #2
Test the reading speed

The second step is to test the reader's fastest reading speed and the most comfortable reading speed in the most scientific way. Provide data support for readers to read at this speed later. This page only appears the first time the reader uses the app.

Pre-test and in-test

After setting the reading goal, the system allows the reader to read a fixed text (216 words) at his fastest reading speed and the most comfortable reading speed, click the start button to start the test, and then test that they have finished reading the text Elapsed time, click the stop button to end the test, and calculate their fastest/most comfortable reading speed. Finally, prompt the reader to continue reading at this speed.

Figure 6.2.4 Start testing

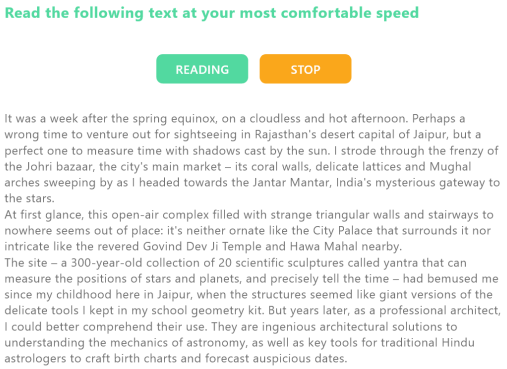


Figure 6.2.5 In the testing process

Test result

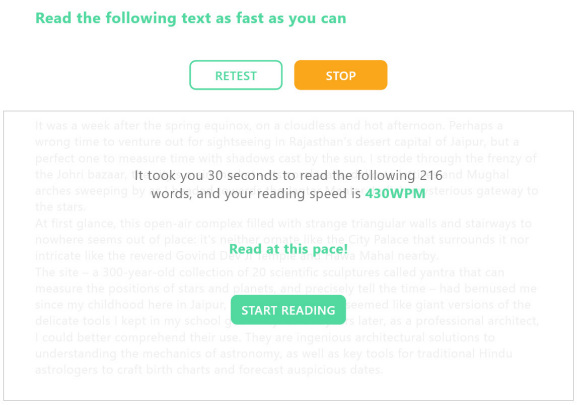


Figure 6.2.6 Get the reading pace when read at the fastest speed

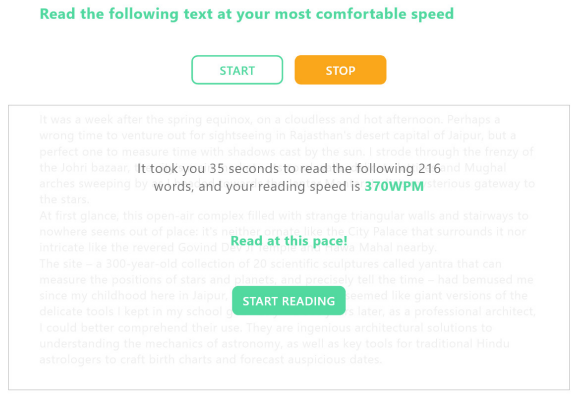


Figure 6.2.7 Get the reading pace when read at the most comfortable speed

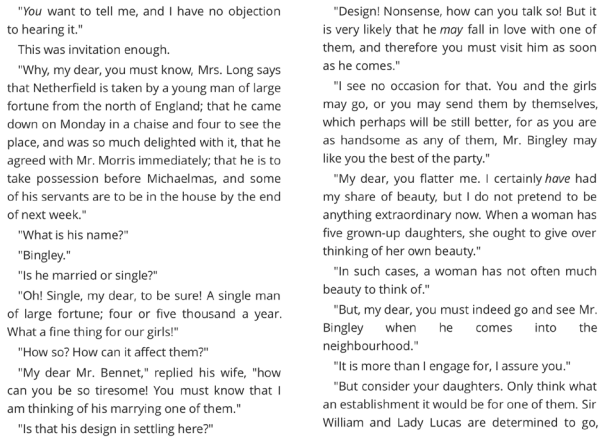
Reading speed is often measured in "words per minute", or WPM. This is the number of words read in a minute, similar to how "miles/ kilometers per hour" is the number of miles/ kilometers traveled in an hour.

Step #3
Read at a fixed vibrational rhythm

The third step is to ensure that the reader reads at a regular vibration frequency, so as to improve the reader's concentration, keep reading at a constant speed, and it is not easy to drift off and repeat reading. At the same time, the reading speed is tested by yourself, the data is accurate, and it is suitable for the reader's personal situation.

In the reading process

After the reading speed is measured, the system will automatically program a vibration melody that matches the reading speed, that is, when the reader finishes reading a line of content on a page, one cycle of the vibration melody is completed. Prompt the user to complete the reading of a line of content in one vibration cycle.



"*You* want to tell me, and I have no objection to hearing it."

This was invitation enough.

"Why, my dear, you must know, Mrs. Long says that Netherfield is taken by a young man of large fortune from the north of England; that he came down on Monday in a chaise and four to see the place, and was so much delighted with it, that he agreed with Mr. Morris immediately; that he is to take possession before Michaelmas, and some of his servants are to be in the house by the end of next week."

"What is his name?"

"Bingley."

"Is he married or single?"

"Oh! Single, my dear, to be sure! A single man of large fortune; four or five thousand a year. What a fine thing for our girls!"

"How so? How can it affect them?"

"My dear Mr. Bennet," replied his wife, "how can you be so tiresome! You must know that I am thinking of his marrying one of them."

"Is that his design in settling here?"

"Design! Nonsense, how can you talk so! But it is very likely that he *may* fall in love with one of them, and therefore you must visit him as soon as he comes."

"I see no occasion for that. You and the girls may go, or you may send them by themselves, which perhaps will be still better, for as you are as handsome as any of them, Mr. Bingley may like you the best of the party."

"My dear, you flatter me. I certainly *have* had my share of beauty, but I do not pretend to be anything extraordinary now. When a woman has five grown-up daughters, she ought to give over thinking of her own beauty."

"In such cases, a woman has not often much beauty to think of."

"But, my dear, you must indeed go and see Mr. Bingley when he comes into the neighbourhood."

"It is more than I engage for, I assure you."

"But consider your daughters. Only think what an establishment it would be for one of them. Sir William and Lady Lucas are determined to go,

Figure 6.2.8 Reading interface

down on Monday in a chaise and four to see the place, and was so much delighted with it, that he agreed with Mr. Morris immediately; that he is to take possession before Michaelmas, and some of his servants are to be in the house by the end

Figure 6.2.9 Read line by line

Regular vibrational rhythm

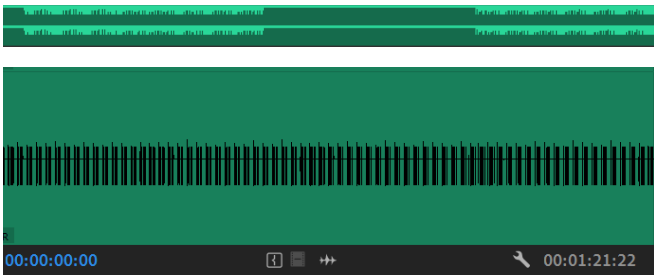


Figure 6.2.10 Fastest-paced vibrating audio

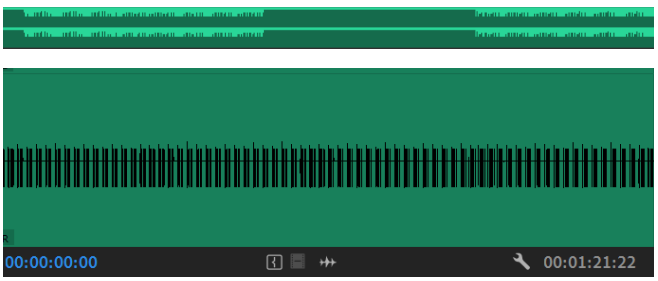


Figure 6.2.11 Most comfortable-paced vibrating audio

6.3 Concept#3 Context reading

6.3.1 Concept generation

The concept is to use the capabilities of current haptic technology to make readers more immersed in the story. The whole concept provides readers with a multi-sensory reading experience. Tactile vibrations, corresponding auditory music, and accompanying visual reading background pictures. The auxiliary memory method of prime a mindset is selected, and readers can quickly enter the reading state through the friendly white noise background or the situational music corresponding to the story. In this concept, the vibrations are automatically generated by the sensor along with the music.

There are two modes of this concept:
(1) Fixed Context Mode
(2) Immersive Story Situation Mode

In this process, readers should either not read under white noise (a background that many users like), so that they can quickly calm down and start to focus; or they should read in the context of the story to help readers quickly understand the story and immerse in the story. Provide readers with an interesting multi-sensory reading experience, and at the same time, improve readers' memory in the process.

Mode #1
Fixed Context Mode

Choose a fixed reading situation

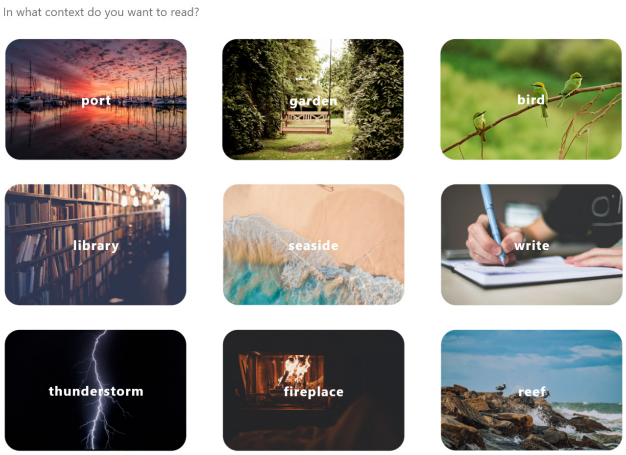


Figure 6.3.1 Nine fixed reading situations

At present, 9 reading situations are set in the interface, all of which are relatively friendly white noise backgrounds. Such as the sound of rain, birdsong, stove, writing and so on. Experiments have shown that white noise slightly improves the tester's learning ability and recognition memory. (Rausch, V. H., 2014) And in this concept, in addition to the original pure auditory sense of white noise - audio, it also adds the corresponding tactile vibration and visual background. I want readers to be more immersed in this background, so that they can block other outside interference and quickly enter the reading state.

Matching visual background

And as to whether the addition of the visual background piece was effective and necessary, or if it would be distracting, or affect the role of haptics in the concept, I'm not sure yet. So, I made a control group, one with the corresponding background, and one with the original pure white background.

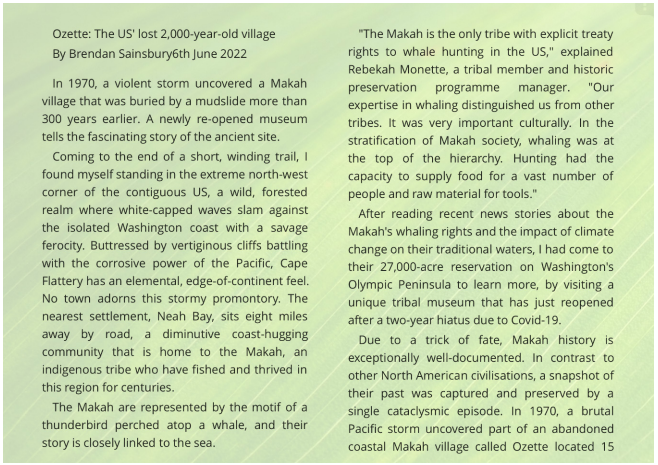


Figure 6.3.2 Bird background

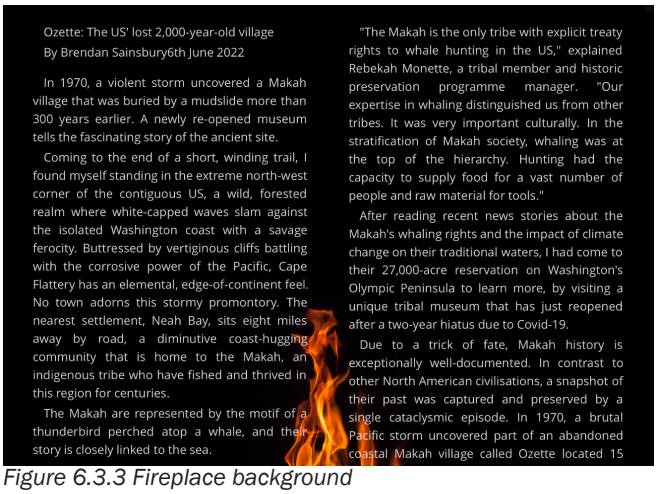


Figure 6.3.3 Fireplace background

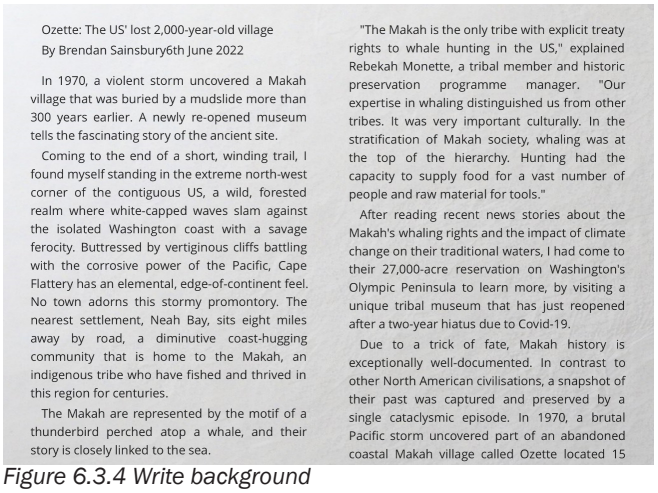


Figure 6.3.4 Write background

Figure 6.3.5 fireplace Waveform

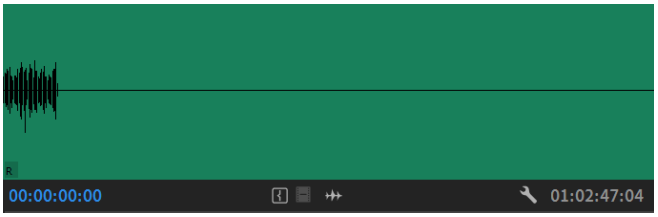


Figure 6.3.6 Seaside Waveform

Mode #2
Immersive Story Situation Mode

Turn on immersive reading mode

The difference between this interface and the fixed situation is that it is not a fixed white noise background, but will change according to the change of the storyline and situation. It remains slight overall. It can also achieve the function of shielding external interference, and at the same time make readers feel immersive through multi-sensory experience. I want to use this to improve the reader's reading experience, as well as the understanding and memory of the scene. Each chapter will have a new situation. The background music and vibrations associated with the situation are voted by other readers who have read the same book. The scenarios with the highest votes are automatically applied to new readers' first readings.

Figure 6.3.7 Start immersive reading interface

Change the story audio context

After reading each chapter, the reader can reselect the story context. If readers feel that the current music and vibration do not fit the context of the content they are reading, they can choose one of four contexts to replace after reading this chapter. Then the next time the reader reads the chapter again, the music and vibration used will be the reader's choice. And his votes are also recorded, affecting the situational patterns of subsequent readers.

Figure 6.3.8 Change audio interface(vote)

Figure 6.3.9 The first audio waveform

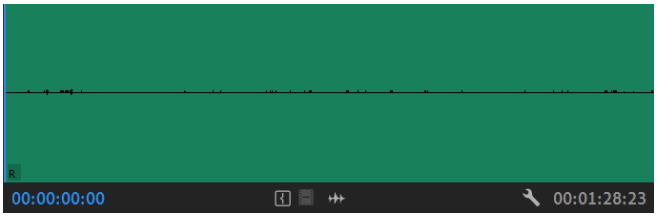


Figure 6.3.10 The second audio waveform

In order not to disturb the reader, not only will the reader not be immersed in the story, but it will make the reader unable to concentrate on learning. Each immersive situational vibration is relatively mild, and the sound is relatively small, because they will continue throughout the reading process, such as the first paragraph is 3 minutes, the second paragraph is 1 and a half minutes.

6.4 Concept#4 Emotion express

6.4.1 Concept generation

This concept is to use the function of touch to convey emotions, and to combine the memory aid of highlight or underscore keywords. Make tag bookmarks emotional, not just a bookmark. Let readers express their emotions at the same time when marking, and the system will give them feedback of vibration and sound, increasing the interactivity of the interaction.

In this concept, different from the general label that remembers the content of the label, in addition to remembering the content of the label, it also allows the reader to remember the emotional feeling when the label is marked, making the memory process easier and emotional. Simultaneous vibration and sound feedback make the marking process experience more interactive.

Tagging with emoji

First, according to the general labeling method, highlight or underscore keywords or sentence, and then the emoji selection box will automatically jump out. The reader can arbitrarily select the expression representing the emotion at this time to mark it, and the screen then gives vibration and sound feedback after the reader has selected it.

"*You* want to tell me, and I have no objection to hearing it."

This was invitation enough.

"Why, my dear, you must know, Mrs. Long says that Netherfield is taken by a young man of large fortune from the north of England; that he came down on Monday in a chaise and four to see the place, and was so much delighted with it, that he agreed with Mr. Morris immediately; that he is to take possession before Michaelmas, and some of his servants are to be in the house by the end of next week."

"What is his name?"

"Bingley."

"Is he married or single?"

"Oh! Single, my dear, to be sure! A single man of large fortune; four or five thousand a year. What a fine thing for our girls!"

"How so? How can it affect them?"

"My dear Mr. Bennet," replied his wife, "how can you be so tiresome! You must know that I am thinking of his marrying one of them."

"Is that his design in settling here?"

"Design! Nonsense, how can you talk so! But it is very likely that he *may* fall in love with one of them, and therefore you must visit him as soon as he comes."

"I see no occasion for that. You and the girls may go, or you may send them by themselves, which perhaps will be still better, for as you are as handsome as any of them, Mr. Bingley may like you the best of the party."

"My dear, you flatter me. I certainly *have* had my share of beauty, but I do not pretend to be anything extraordinary now. When a woman has five grown-up daughters, she ought to give over thinking of her own beauty."

"In such cases, a woman has not often much beauty to think of."

"But, my dear, you must indeed go and see Mr. Bingley when he comes into the neighbourhood."

"It is more than I engage for, I assure you."

"But consider your daughters. Only think what an establishment it would be for one of them. Sir William and Lady Lucas are determined to go,

Figure 6.4.1 Underscore sentence

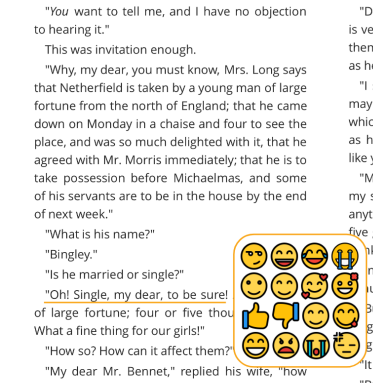


Figure 6.4.2 Emoji selection box

Each emoji has a corresponding sound and vibration. This vibration is matched by sound. The sound of each expression is controlled within 2 seconds, about 1 second. Appears automatically after the reader selects and clicks the emoji. Click again and it will reappear.

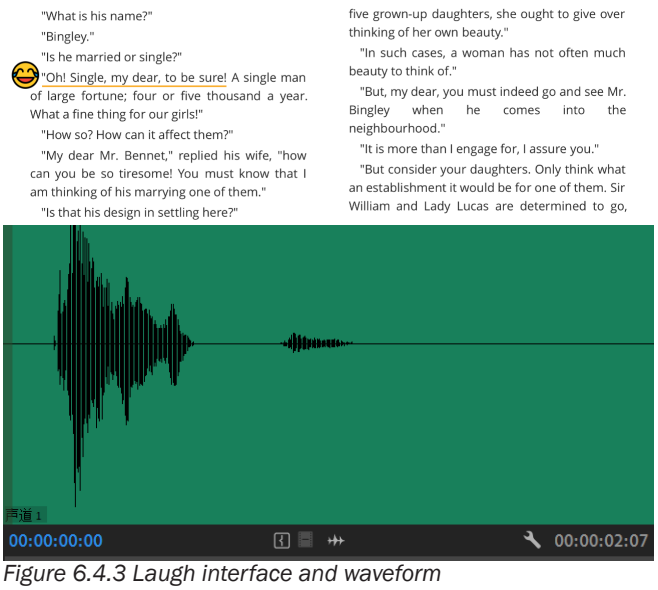


Figure 6.4.3 Laugh interface and waveform

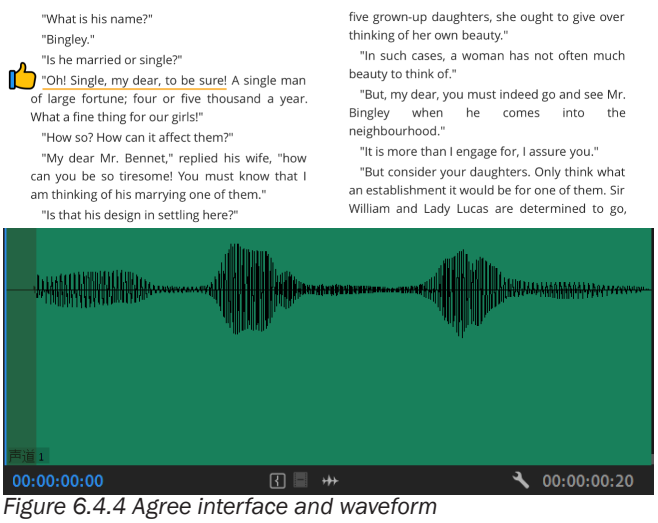


Figure 6.4.4 Agree interface and waveform

6.5 Concept#5 Word index

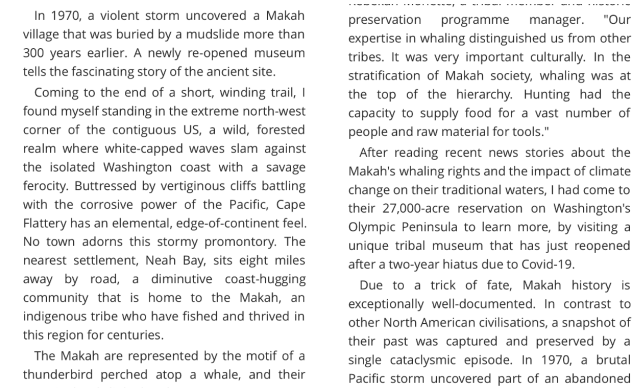
6.5.1 Concept generation

The concept is to use word index for auxiliary memory. Similar to an aural tactile dictionary. It helps readers understand and remember new vocabulary. Of course, because of the feature of this function, it is suitable for non-native language readers or younger readers, or articles with more uncommon vocabulary.

In this concept, different from the general word index, the words are explained by sound and vibration, and the words or pictures are explained by listening and touching instead of visual. Let the reader understand vocabulary from another angle.

Unmarked words/triggerable words

In the actual reading interface, there are no marks and prompts. The reader can click on any word during the reading process. As long as the word has a sound effect stored in the sound effect library (soundsnap), it can generate sound and vibration. of. Neither sound nor vibration will trigger automatically if the reader doesn't click.



In 1970, a violent storm uncovered a Makah village that was buried by a mudslide more than 300 years earlier. A newly re-opened museum tells the fascinating story of the ancient site.

Coming to the end of a short, winding trail, I found myself standing in the extreme north-west corner of the contiguous US, a wild, forested realm where white-capped waves slam against the isolated Washington coast with a savage ferocity. Buttressed by vertiginous cliffs battling with the corrosive power of the Pacific, Cape Flattery has an elemental, edge-of-continent feel. No town adorns this stormy promontory. The nearest settlement, Neah Bay, sits eight miles away by road, a diminutive coast-hugging community that is home to the Makah, an indigenous tribe who have fished and thrived in this region for centuries.

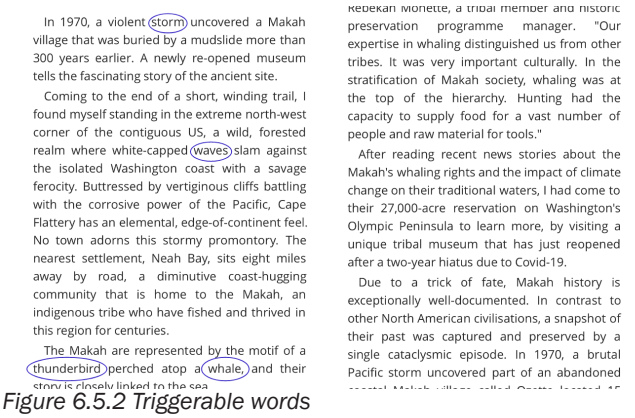
The Makah are represented by the motif of a thunderbird perched atop a whale, and their

preservation programme manager. "Our expertise in whaling distinguished us from other tribes. It was very important culturally. In the stratification of Makah society, whaling was at the top of the hierarchy. Hunting had the capacity to supply food for a vast number of people and raw material for tools."

After reading recent news stories about the Makah's whaling rights and the impact of climate change on their traditional waters, I had come to their 27,000-acre reservation on Washington's Olympic Peninsula to learn more, by visiting a unique tribal museum that has just reopened after a two-year hiatus due to Covid-19.

Due to a trick of fate, Makah history is exceptionally well-documented. In contrast to other North American civilisations, a snapshot of their past was captured and preserved by a single cataclysmic episode. In 1970, a brutal Pacific storm uncovered part of an abandoned

Figure 6.5.1 Unmarked words reading interface



In 1970, a violent storm uncovered a Makah village that was buried by a mudslide more than 300 years earlier. A newly re-opened museum tells the fascinating story of the ancient site.

Coming to the end of a short, winding trail, I found myself standing in the extreme north-west corner of the contiguous US, a wild, forested realm where white-capped waves slam against the isolated Washington coast with a savage ferocity. Buttressed by vertiginous cliffs battling with the corrosive power of the Pacific, Cape Flattery has an elemental, edge-of-continent feel. No town adorns this stormy promontory. The nearest settlement, Neah Bay, sits eight miles away by road, a diminutive coast-hugging community that is home to the Makah, an indigenous tribe who have fished and thrived in this region for centuries.

The Makah are represented by the motif of a thunderbird perched atop a whale, and their

preservation programme manager. "Our expertise in whaling distinguished us from other tribes. It was very important culturally. In the stratification of Makah society, whaling was at the top of the hierarchy. Hunting had the capacity to supply food for a vast number of people and raw material for tools."

After reading recent news stories about the Makah's whaling rights and the impact of climate change on their traditional waters, I had come to their 27,000-acre reservation on Washington's Olympic Peninsula to learn more, by visiting a unique tribal museum that has just reopened after a two-year hiatus due to Covid-19.

Due to a trick of fate, Makah history is exceptionally well-documented. In contrast to other North American civilisations, a snapshot of their past was captured and preserved by a single cataclysmic episode. In 1970, a brutal Pacific storm uncovered part of an abandoned

Figure 6.5.2 Triggerable words

For example, in the interface below, there are four words "storm", "waves", "thunderbird", and "whale" that can trigger sound and vibration.

The sound and vibration time of these words are very short, the sound is not too loud, and the vibration is not too intense, so as not to suddenly appear and affect the reader's reading. A few seconds at most.

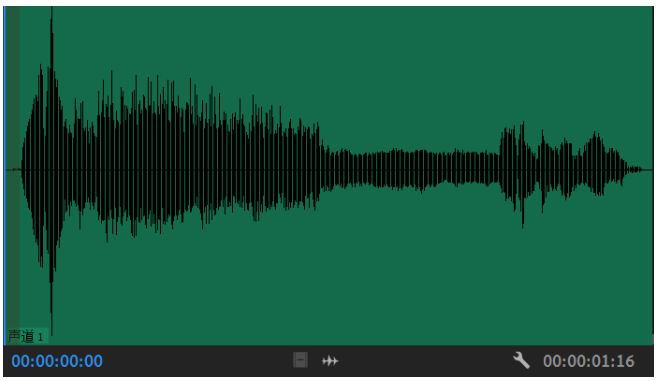


Figure 6.5.3 storm waveform

Figure 6.5.4 thurderbird waveform

Figure 6.5.5 wave waveform

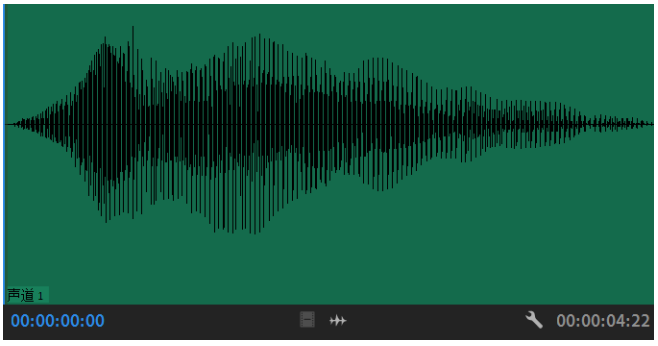


Figure 6.5.6 whale waveform

6.6 Evaluation

6.6.1 Evaluation approach

Test objectives

The goal of iterative testing is to understand people's overall experience and understanding of the functionality of several concept prototypes. Scored from three perspectives: usability, logic, and simplicity. It's also about understanding whether these five conceptual prototypes can help with my design goals, and getting potential actionable directions for improvement from user feedback.

Questions to answer by iterative testing:

1. How do people perceive the overall experience (functionality and interaction)?

What do you think is the purpose of this interaction?

2. How usable, logical, and simple is the concept prototype?

How useful does this prototype seem to you on a scale from 1 to 5?
How logical was the order of the steps in this prototype for you, on a scale from 1 to 5?
Do you think the process of using this prototype is easy, on a scale from 1 to 5?

3. Does the concept prototype improve my design goals (enhancing the reading experience and improving long-term memory of the content)?

Do you think this prototype will improve your reading experience? Why(not)?
Do you think this prototype will improve your memory of the content? why (not)?

4. Do people want to use my concept prototype?

Would you use this prototype to help you read? Why(not)?

5. What other potential improvement points are there for the concept prototype?

Where do you think this prototype could be improved?

Participants

11 participants took my test, the first and eleventh testers were from supervisory team, while the other 9 testers are all students between the ages of 20-25, which fits my target user. They love to read and have experience reading on ipads.

Test set-up

Test environment

Testing environments are in quiet, separate rooms, such as offices, testers' homes, and quiet corners of the library.

Test device

The prototype was built using adobe XD, which can be simulated on an ipad, and uses a Bluetooth vibration motor, which can almost restore the quality of the audio itself and turn it into vibration feedback.

Test procedure

Participants were first introduced to the project, including the context and activities they would experience.

Then the tester will put the vibration sensor on the hand, and use the iPad to simulate the grasping method of reading with the iPad. Test the concepts in the order of 1-5. After completing the test of a concept, complete the corresponding content in the questionnaire and conduct a simple interview, and then proceed to the test of the next concept.

Finally, the entire process will be recorded. Feedback and quotes from each participant are summarized, categorized and analyzed.

Figure 6.7.1 Bluetooth Vibration motor

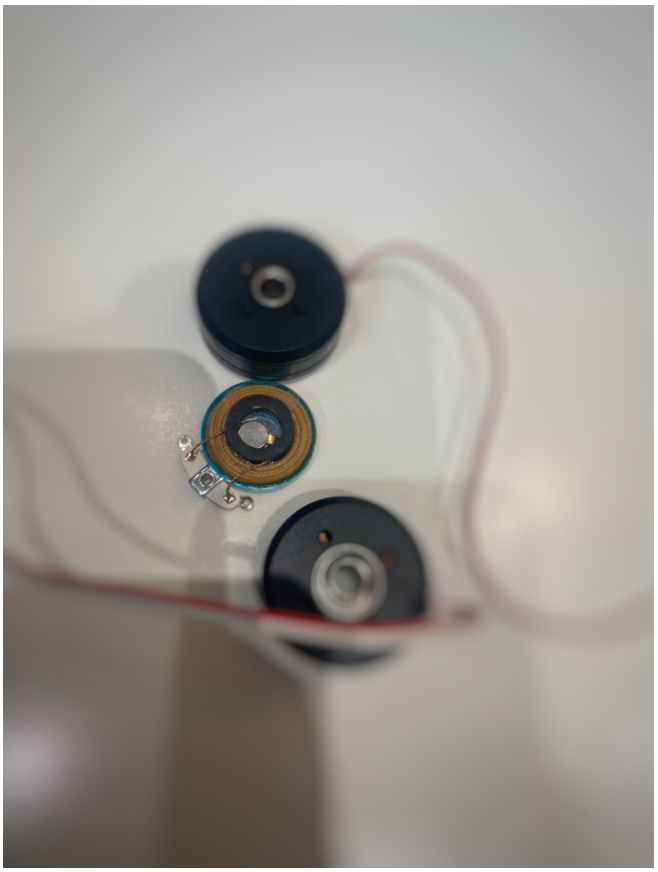


Figure 6.7.2 Another direct plug-in sound-to-vibrator

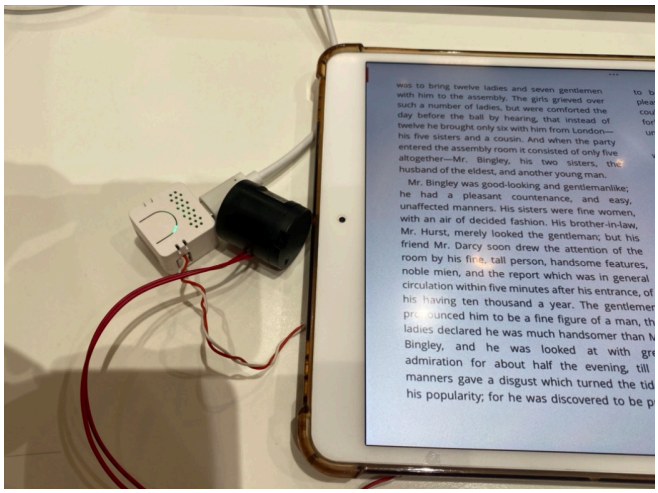


Figure 6.7.3 Bluetooth Vibration motor connected to ipad

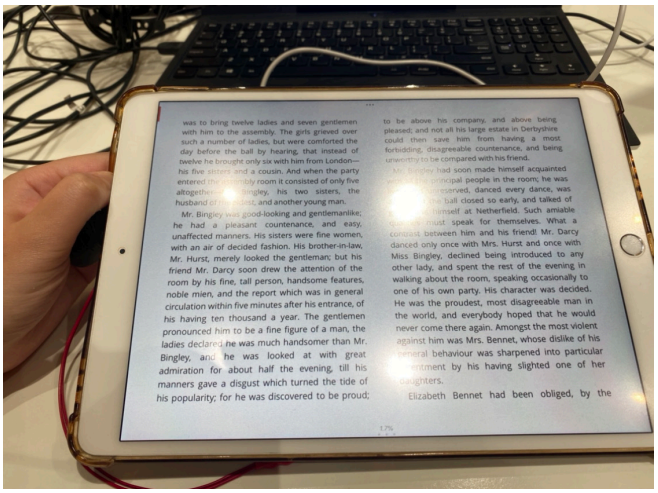
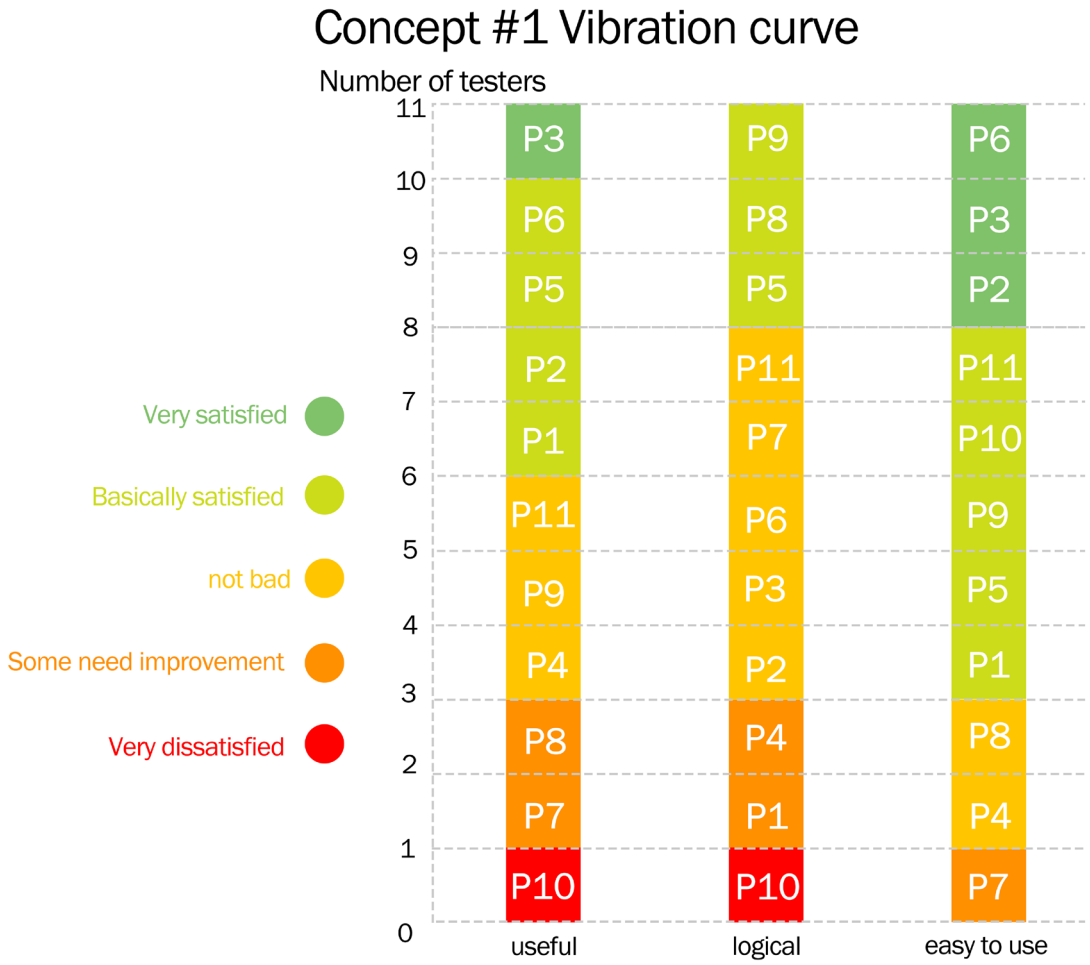


Figure 6.7.4 Handheld during testing

After conducting 11 user tests, I visualized the answers to the 1-5 questions on utility, logic, and ease of use from the questionnaire results. P+x above is the participant's number. The 1-5 scale represents a range from very dissatisfied to very satisfied. Visual analysis ensures that the entire prototyping process is practical, logical, and easy to use. And the answers to the other interview questions, I recorded it and categorized it into some key takeaways.

6.6.2 Evaluation results for concept #1



Utility, logic, and ease of use analysis

An overview of Concept 1 shows that the majority of participants rated the concept prototype as having a moderate level of utility (most scores were 3.0-4.0), and 3 participants even considered it to be of poor utility (scores below 3.0). The logical acceptance of this conceptual prototype is even lower than the practicality. However, the recognition for the difficulty of use is slightly higher. Overall, the overall concept was rated as fair by testers.

In this concept, the subsequent opinions of participants 4,7,8,10, who scored less than or equal to 3 in two of the three items, and none were scored out of 5.and none of them has a full score of 5 points.

Key takeaways for design goals

About reading experience:

-For reading efficiency, it will be reduced.

-For the reader, this interaction interrupts the continuous reading process.

-The meaning expressed by vibration and sound will be more vague and abstract, and not as easy to understand as vision.

"It feels more suitable for some simple readings, and complex readings are likely to cause confusion. Because it is very necessary to train the meaning of complex texts to be defined by simple vibrations and sounds. If there is no uniform standard, for vibration and sound The feeling of sound varies from person to person, so it is easy to cause me to think that this vibration is the meaning at the time, but I will not feel it when I look at it later." -P7

-The fun of reading is improved.

About reading memory:

-The time it takes to mark the word may make the word more memorable for the reader.

"I like that it collects data. You can circle the same person in an article, or the same place, timeline, etc., and then make statistics, and finally get a more or less number of occurrences of a place in the article" -P3

"I think it is helpful, but it is more suitable for children. For me, it will reduce my reading efficiency. I have to draw lines from the reading process, which requires imagination." -P4

-Multi-sensory stimulation can indeed help readers remember the marked content.

-When using a list for review, if the article is too long, those tags may not be as effective.

Improvements

-Various forms of interaction are open to discussion.

"I would like to add gaze capture, which automatically plays sounds and vibrations with gaze instead of clicking." -P3

-The last thing on the list should be more than just a one-line list of who, when, and where. However, the current vibration curve cannot express more complex content.

"I think in addition to characters' characters, behaviors and emotions, what I want to remember more should be character relationships. What is the intersection between characters." -P2

"I think when I read a book, in addition to the characters, I also want to record the interesting content and words in the novel, and then I will automatically establish a connection in my brain when I read it for the second time. But at present I can't imagine how to use sound and vibration to to express a long paragraph." -P6

·There are some complex vibration reading methods that need to be learned for those who are used to visual reading.

"Maybe there's a tutorial for beginners or some guidance? At the same time, I don't feel like the vibration and sound can directly remind me of the text I marked." -P3

"I don't want to have too many vibrations because it puts a cognitive load on me. I need to spend a lot of time understanding and imagining the meaning of each vibration and sound before connecting it to words." -P4

"Vibration and sound are very weakly related to words for me at the moment. Just looking at the description of Mr. Bennet, I can't imagine how it should sound and how vibration should be." -P9

Summary

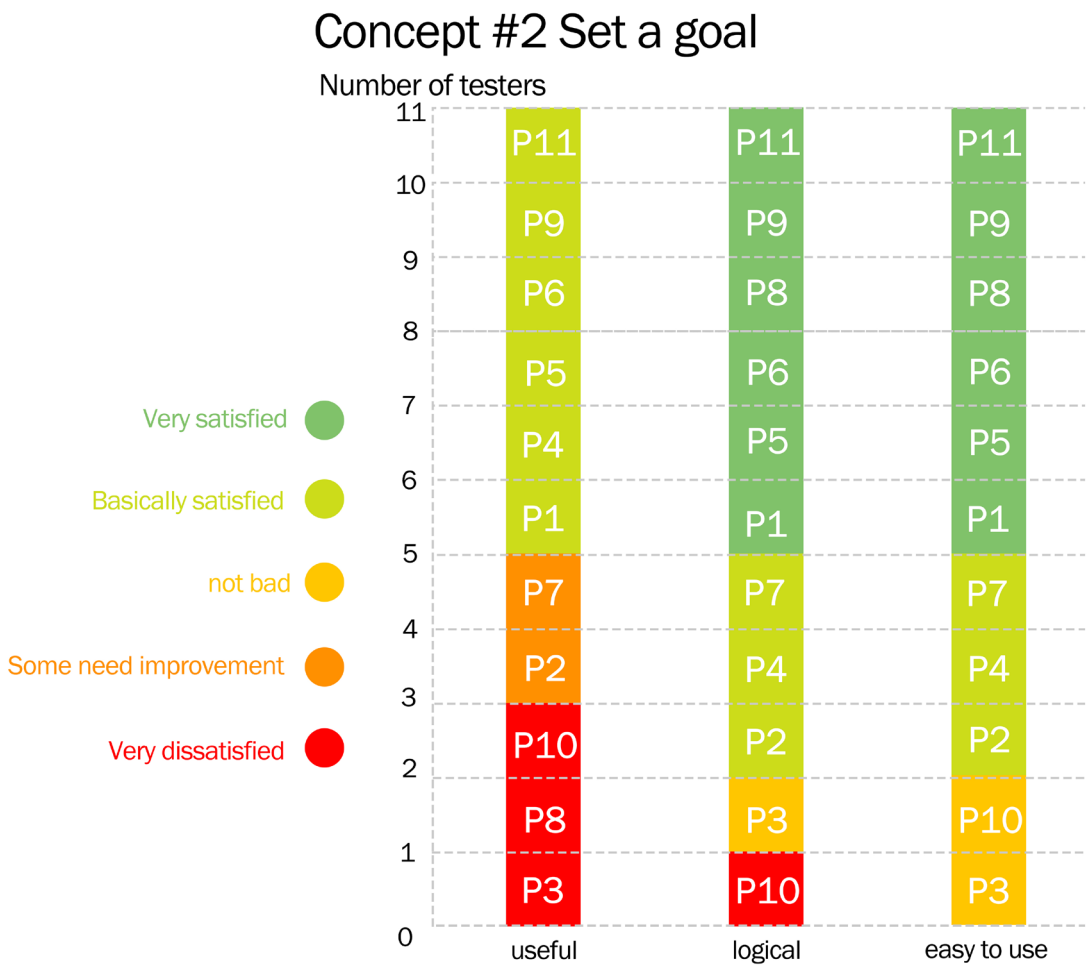
1.The behavior of marking through vibration and sound is a brand new experience for readers. At present, some of the feedback they give is very fresh and interesting, and when recording, it is a secondary memory of the marked content, which will deepen their understanding of the content. Revisiting it again is three memories, allowing them to **reorganize the entire outline of the story**. But it's also a weird experience for some people, who aren't used to using touch for memory and association. Many testers were unable to fully adapt to the transition from visual marking to auditory and haptic marking, **thinking that the correlation with textual descriptions was weak**. It depends very much on the reader's own imagination.

2.At the same time, the discrimination of vibration is not enough at present, and it is difficult to establish a connection between the vibration curve and the text, and it is also difficult to establish a connection with the sound vibration. Just looking at the picture that represents sound and vibration, it's hard to imagine how it has anything to do with the characterization. When the text is *very long and the meaning expressed is very complex*, it is difficult for vibration and sound to **represent the meaning**.

3.However, the interaction of sound effects in the process of drawing lines is interesting, but sound dominates the concept, and vibrations appear dispensable. *The sound is what distinguishes whether I choose this sound and vibration*, it doesn't matter whether there is vibration or not.

4.If the story is very *long and has a lot of characters*, these added vibrations and sounds will become *less meaningful in retrospect.* Because it is *difficult to recall the text description* at the time of recording through a specific tone of voice.

6.6.3 Evaluation results for concept #2



Utility, logic, and ease of use analysis

The overview of Concept 2 shows that the test results of this concept prototype compared to Concept 1 are more polarized, people who like it more like it, and people who don't like it more dislike it. Approval of utility for this prototype was also polarized (6 participants rated it 4.0, 5 participants rated it 1.0-2.0). Although the logic and difficulty acceptance of this concept prototype are also polarized, the average score is better (both 6 participants rated 5.0, 3 participants rated 4.0). Overall, the whole concept was polarized among testers, and it was recognized by more than half of the participants, but the existing problems also exacerbated the dissatisfaction of a small number of participants with the concept.

The follow-up comments of participants 3, 10 in this concept are of great concern, and they disliked the concept very much. At the same time, participants 1, 5, 6, 9, and 11 all gave high scores to this concept. You can also pay more attention to their opinions to see if the advantages of this concept can be retained in the future.

Key takeaways for design goals

About reading experience:

-Readers love the process of making plans and find it motivating. But some interaction details can still have room for improvement.

"I love the interaction of setting goals and building a sense of accomplishment." -P6

-Readers don't like the process of testing their reading speed, which makes them nervous.

"I didn't like the process of the test, it was very stressful like taking the IELTS test." -P3

-The vibration and sound instead interfere with the reader's reading or give the reader a lot of pressure. They prefer free and relaxed reading situations.

"I won't use it, it's like an automatic page turning software, it's urging me, but actually I want to be relaxed during the reading process, maybe not focus enough, but I don't want to feel the pressure." -P5

"It's like the phone is vibrating next to me all the time, which makes me very nervous. And for me, reading is not a constant movement, and some important content I will automatically slow down reading." -P10

-Keep a constant and fast reading speed, so that the reader's reading process becomes rhythmic.
"I really like the concept, especially having me read at the fastest speed, which makes my reading more rhythmic and focused. On the contrary, reading this at the speed I am most comfortable with will not feel so good."- P1

"My reading speed is very slow, it really allows me to read with a sense of rhythm." -P4

About reading memory:
-It is not very good at improving the memory of the content of the article. Because it is almost always a cursory reading. Fast reading at the expense of intensive reading comprehension.
“No, it makes focus on reading pace rather than content.”-P7

"If I've read for a long time, if I can refocus my attention through this, it may improve my memory for the content at this time." -P9

Improvements

-The testing process can be more natural. should not be completely disconnected from the process of reading.
"I think the process of the test should be done automatically after the first page is read. When I read the first page, it will automatically help me calculate how many words there are in this page, how long it takes you, and then Figured out the reading speed that works best for me." -P3

-A slight vibration is much better than music like an alarm. Complete silence would be a little better.
"And it's better to be silent, that sound is like an alarm, it makes me very anxious, it would be better if it was just a slight vibration." -P3

-There can be a function to stop vibration and sound.
"This kind of reading will make me miss a lot of difficult words, and I will pass when I encounter the content I don't understand. Because there is no time for me to think, it will make me read it all in one go. Maybe it will allow me to stop it." -P2

-Vibrations and sounds that prompt rest may be improved.
"The vibration that reminds me that I can rest should be more comfortable, just like the vibration feedback sound of the game in Nintendo, ps5, such as the haptic feedback that I collected gold coins, the vibration is short but the vibration is more accurate." -P6

-Perhaps the vibration may not be strong at the beginning of reading, and it is only used as a reminder and encouragement after the user's page turning speed slows down.
"There can be no sound at the beginning, and then as I read more and more slowly, for example, I turn the pages more slowly. The vibration can become more and more obvious."-P9

Summary

1.People who like the concept feel that it is a rhythmic reading that encourages focused reading. People who don't like it think it's a rush, but it's very disturbing to read.

2.At the same time, almost everyone believes that this way of reading will sacrifice the memory of the content. Therefore, this method is more **suitable for reading news and information articles.**

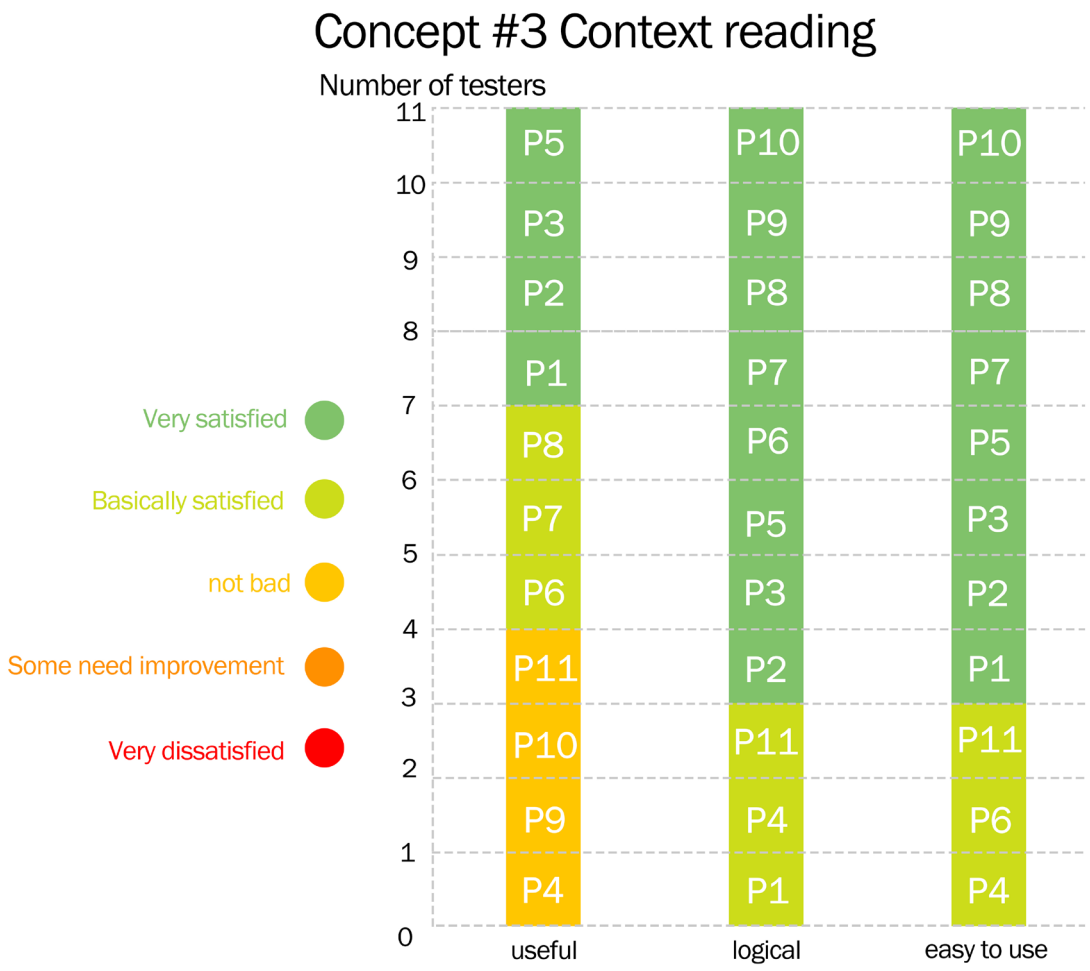
3.At the same time, they believe that the process of testing reading speed can be more natural and integrated into reading, rather than a special test, which will make them feel nervous.

4.Most people like the concept of setting goals, but the vibrations of the cues **can be more concise and short.**

5. To suit different reading situations, readers should **be able to turn on and off** this function freely. At the same time, if it is for the purpose of increasing the reader's attention, perhaps this function should only be available when the reader's reading speed drops significantly.

6. Contrasting sounds, **regular vibrations won't interfere too much with reading. No sound and only vibration**, the user experience will be better.

6.6.4 Evaluation results for concept #3



Utility, logic, and ease of use analysis

An overview of Concept 3 shows that this concept prototype tested the best of the 5 concepts. The 11 testers were very satisfied with the approval of this prototype in all three dimensions (all scores were greater than or equal to 3.0). The recognition for logic and ease of use was even higher, reaching a good level for all staff (all scores greater than or equal to 4.0).

In this concept, one can mainly focus on the opinions of participants 4, 11, who are rated as low. And the direction of future iterations of this concept can be subtle, adjusting some details.

Key takeaways for design goals

About reading experience:

-Through vibration and sound, the story becomes more vivid and the reading immersion is enhanced. Especially novel themes.

-Sound will be more important than vibration.

-White noise helps me relax and get into a state quickly. The sound that fits the content of the story makes reading more immersive.

"This is better than the second concept. I think that reading should be a quiet and relaxing environment. White noise can give me such a feeling, and white noise that matches the background of the story is even better." -P3

"I like to use white noise when I study. White noise can help me enter the learning state. Compared with choosing the scene myself, I prefer to fit the scene." -P6

About reading memory:

-Sound may be helpful, but not sure.

"Maybe the sound can help me, but I'm not sure if it helps me remember the details of the specific article." -P10

Improvements

-During use, the user should be allowed to stop the background sound and vibration.
"If so, maybe other senses can be used to increase the immersion of reading? Like smell?" -P3
"I feel that the sound is a little too small, and at the same time, the discrimination of the vibration is very small, and I don't feel that there is a big difference" -P6

-During use, sound and vibration do not appear throughout the entire process, but only appear naturally at critical moments or when scenes are switched. To help users quickly enter the reading situation, but do not disturb the user's degree.
"Follow my reading progress by using eye-catching technology to automatically appear with corresponding contextual sounds and vibrations?" -P2

"Only sound when I read the highlight?" -P4

-The discrimination of vibration is not enough, and the sound is a little too small.
"Because there are sounds that can't be heard, only vibrations. There are only vibrations. In fact, I don't really realize what the vibrations mean. I can't tell the difference between the vibrations of the stove and the thunder in the situation." -P6

-There are more options.
"There could be more options for white noise." -P7

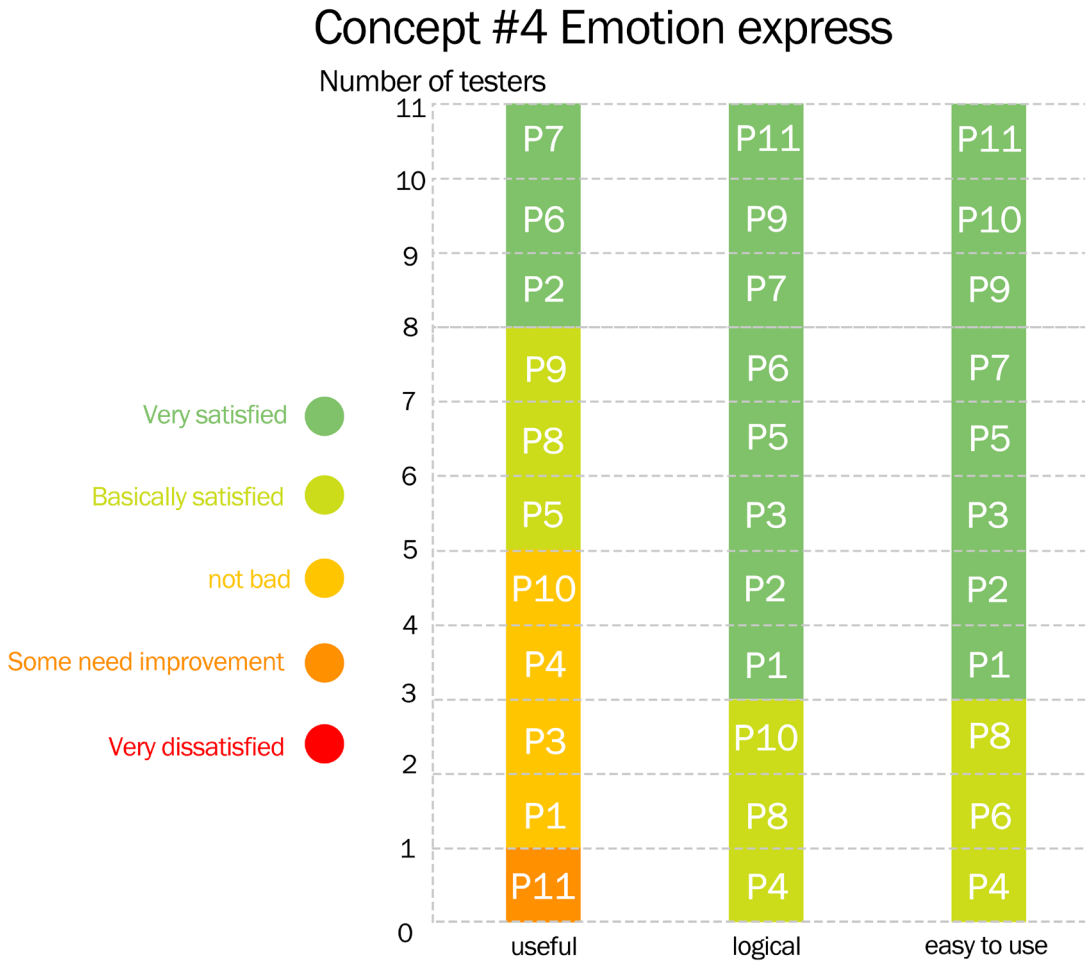
Summary

1.They felt that such background sounds and vibrations could make them more **immersed in the story**, and if the sounds and vibrations weren't too loud, they wouldn't greatly interfere with reading.

2.But in this concept, if there is sound and vibration for a long time, they will become dispensable. On the contrary, it is more suitable to **add some naturally during scene switching or highlight clips**, rather than appearing all the time.

3.And the distinction of sound is very large, but **the vibration will appear a little thin**, can the distinction of vibration be made more obvious.

6.6.5 Evaluation results for concept #4



Utility, logic, and ease of use analysis

An overview of Concept 4 shows that this prototype tested only slightly worse than the third concept in usability approval (one participant rated it 2.0), and was on par with Concept 3 in terms of logic and ease of use , are all good.

In this concept, you can refer to the follow-up comments of 1, 3, 4, 10, and 11. Their scores on usability are low, and there may be good guidance for functional corrections.

Key takeaways for design goals

About reading experience:

-This concept can convey emotions.

"It's like a sticky note with sound and vibration! It's so much fun, it's great as a diary and handbook aid." -P2

-Give me a pouring channel, very interesting

"Yes, when I read and hear interesting sentences, I have a mood and want to send an emoji."-P6

About reading memory:

-It helps me recall my thoughts and emotions when I made it.

"When I re-read, I see the marks, or just have a list of marks, and it helps me recall why I made the mark. It's a process of repeating the memory." -P1

"It's hard to say, I may remember the emotional stuff left at the time. But maybe not." -P3

"Helps me recall how I felt when I made the mark." -P6

Improvements

-More than just an expression of emotion, it can be turned into a quick sorted sticky note.

"Be sure to have something like a note list, and categorize different emojis, such as those that I agree with, as one piece, which is very helpful for re-reading." -P5

"Maybe the sound of the feedback can be switched? Can you choose it yourself?" -P3

-For added marks, can have more meaning than just expressions.

"I think I can add some text. When I put a sticky note, I very much hope that I can write something. For example, when I see this piece, I think it is very important and needs to be read again. I will write Super important three words and three exclamation marks!!!" -P4

"I don't think I might read that list, but maybe I will follow me and like it a few times, and find it funny a few times. At the same time, in addition to expressions, there may also be emojis to express words that I think are inspiring to me. Then click When emotes, maybe a cutscene can appear that matches the sound effects and vibrations to fit the game animations." -P6

-Design a matching bookmark-like list, categorizing the different tags. When re-reading, you can re-read by different tabs.

"I think in addition to the emotional type label, there can also be a love-like label, which represents words I like; the light bulb label represents words that I think are inspiring." -P5

-In addition to the feedback from the screen to readers, can it also be extended to the communication between readers and other readers?

"I have a favorite app that has a feature that shows other readers' underlined sentences and their comments. I wonder if it's possible for this to become a kind of feedback on other people's comments?"- P10

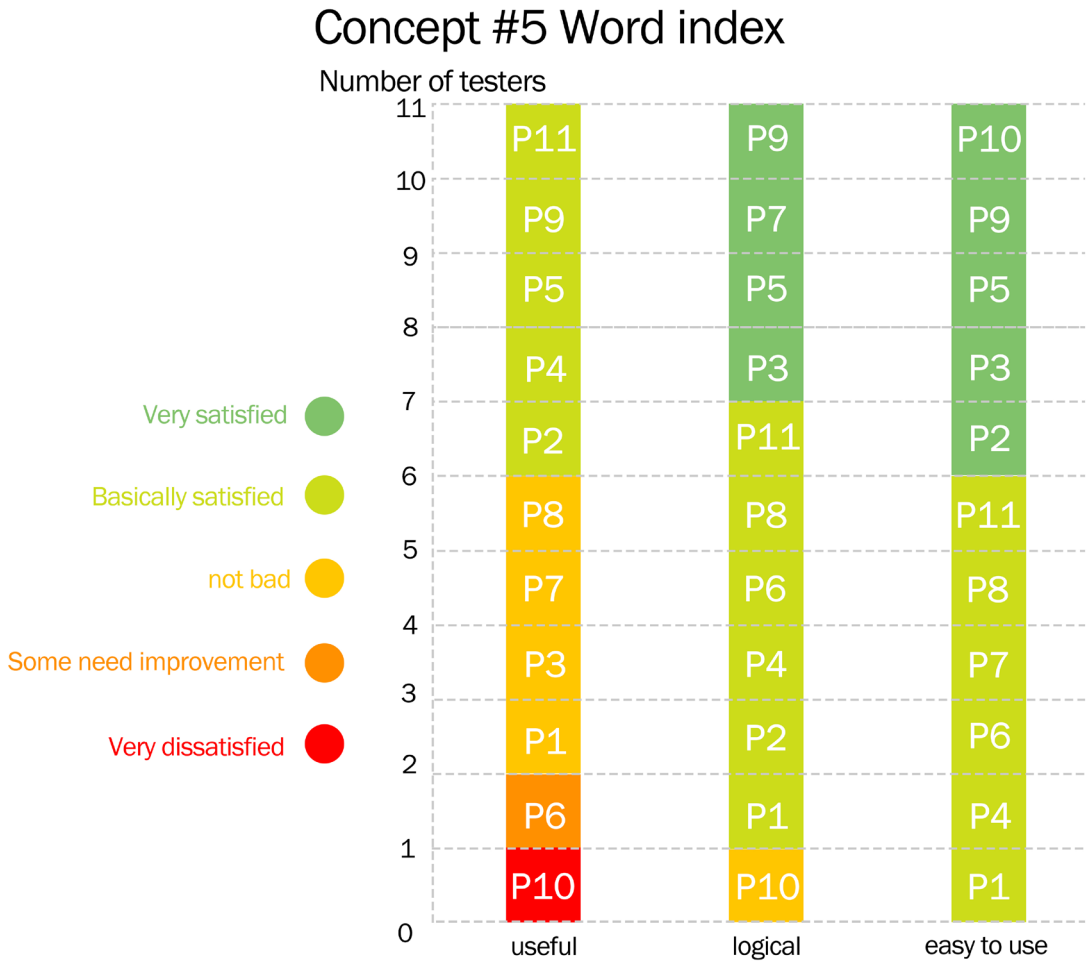
Summary

1.In addition to the emoji, they thought they could turn it into a sticky note with sound and vibration. Recording is not just about reading the mood at the moment, it can be words that **I like "love", or words that inspire me "lamp bulb".**

2.At the same time, can you **interact with other readers**? For example, readers can see the comments of other readers. Is the **vibration as a feedback for receiving a message**? Like a cell phone receiving a message? For example, if other readers evaluate or like your notes, you will receive vibration prompts.

3.Make a list similar to the bookmark bar, which can **classify different expressions and different markers**, and then make it easier for users to see them again.

6.6.6 Evaluation results for concept #5



Utility, logic, and ease of use analysis

The overview of Concept 5 shows that the majority of participants have a moderate level of approbation of the concept prototype (most of the scores are 3.0-4.0), and even 2 participants even considered it to be less useful (scores below 3.0). But The recognition degree of logic has been significantly improved, and only one is lower than 4.0. In terms of ease of use, it can achieve good results for all staff.

The follow-up comments of participants 1, 6, 10 in this concept are noteworthy. Especially participant 10 rated the concept very low. At the same time, the opinions of 1, 3, 6, 7, 8, and 10 are also worth referring to, because they are not very high in usability.

Key takeaways for design goals

About reading experience:

-This feature is well adapted as an acoustic-tactile translator.

"It's more suitable for some environments that need to be translated, such as words that I don't understand, or if a song is written in the text, or a description related to music, it can play a specific song, which is good." -P3

"This is great for non-native readers! It's like a translation software." -P1

"Useful for word learners, but the constant clicking process interrupts my reading process and the interaction doesn't make me feel very comfortable. So I don't think I'll be using it very often." -P2

-Not suitable for quiet use.

"It depends on the situation, but sometimes it feels like it's a little unnecessary. For example, when I was in a very quiet reading environment, it suddenly appeared such sounds and vibrations." -P3

-More suitable for young children.
"It doesn't feel particularly useful, it feels like a reading pen used by children." -P4

-It's hard to notice this function during reading.
"In the process of reading, I rarely notice to use this function. Few words need this function. For word index, I think the visual display will be more useful." -P6

Improvements

-The way of appearance is unnatural, and the way of interaction is childish.

-Links that make sounds should not be just some simple nouns.
"It would be very interesting to say what kind of song appears in the article, or the specific song name, or the name of some musical instruments, and then click to make the corresponding sound and vibration." -P3

-Vibration and sound alone are not clear enough, and visual presentation is still needed.
"I think it still needs to be combined with visual information to facilitate understanding." -P4

"I still prefer to be able to have a picture, such as the word is a thunderbird, if it can jump out of the picture of a thunderbird, and then there are sounds and vibrations, it will be more clear." -P6

Summary

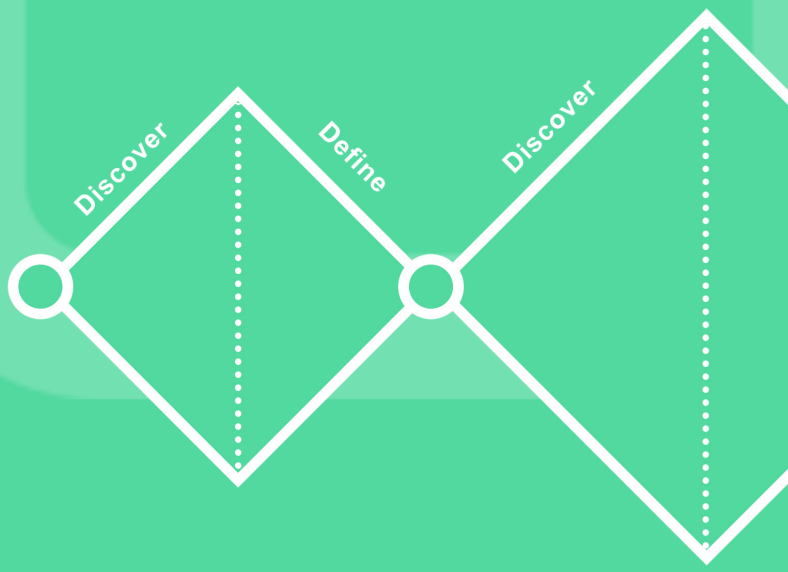
1.However, most people think that there is a paradox, that is, the sound and vibration of the recognized word is known, and there is no need to click, and the **unfamiliar word cannot be fully understood by the sound and vibration**, and it still needs to be **supplemented by visual** (text or pictures)

2.And more **suitable for children to use**. Because most of the content in the books they read is difficult to have concrete vocabulary, and **most of them are abstract**. If the sound or vibration is not accurate enough, it can cause a misunderstanding. Like, what is the sound of the leaves like? Maybe only the wind blows to the leaves.

3. The interaction between clicking words to make sounds and vibrations is not convenient or in line with general reading habits. People are completely immersed in the story, they **forget to click**. It might be better to **turn sight capture on automatically**, if possible.

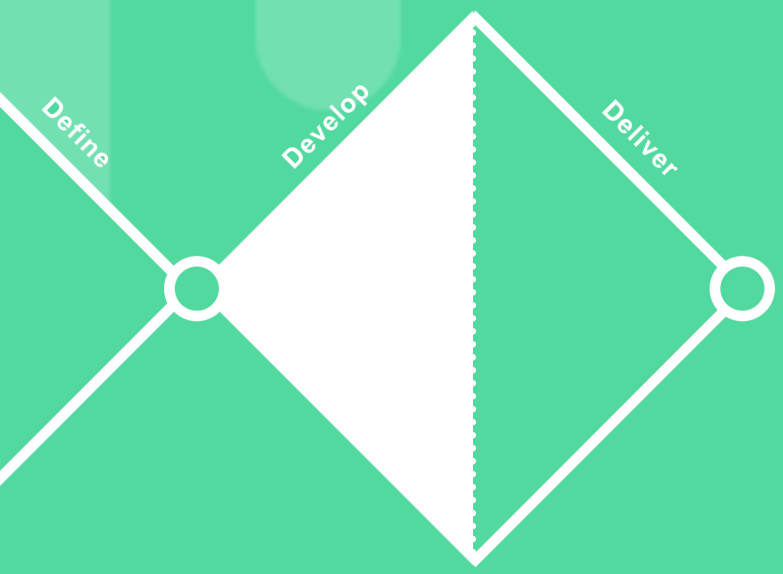
4.This function is more suitable for **specific sounds and vibrating words,** such as specific song names, fixed rhythm, language and so on.

This chapter presents the user feedback obtai
and analyzing it, iterates in this direction again.
optimized and iterated into new concept prototy
the supervisory team and worked out the desig



CHAPTER 7
SECOND ITERATION

ned after the first iteration, and after collecting
After that, the better concepts are merged and
ypes. Finally, I tested and discussed again with
n direction for the final design.



7.1 Defining final design direction

7.1.1 Summary of the first iteration

First, my final design needs to be able to meet my design goal of improving the e-book reading experience and improving the long-term memory of the e-book content.

Secondly, the whole concept should be user-friendly in interactivity, the interface is useful, each operation is logical, and simple to use.

Finally, because the focus of this project is on the application of touch, the prominent role of touch in electronic reading, the tactile technology must need to dominate in the final design, not auxiliary (auxiliary vision and auxiliary hearing)

Concept #1 Vibration curve

First of all, for the reading experience, some participants thought it was interesting, and the feedback of sound effects and vibrations was unseen before; but more participants thought that using touch to describe characters was a very strange experience, this The process has three transformations, transforming text (visual information) into vibration graphs (visual information), and then into sound effects and vibration feedback (listening to tactile information). This process is too imaginative and time-consuming. Not a very good reading experience.

For the long-term memory of the content, it depends entirely on the distinction between the sound effect and the vibration, and the current recognition of the vibration is still low (that is, the distinction between any two vibration feedback is not large). If the story is simple and short, the timeline can be a memory aid, helping the reader recall the marked content. But when the story is very abstract, it is difficult to use vibration curves to describe abstract words, and it is difficult to correctly mark the meaning. Or when the story is very long, it is difficult to recall it when it is finally recalled with the timeline.

When it comes to the recognition of the interface design, most participants think that it is a bit unclear just by looking at the vibration curve, and the whole operation process is very complicated, which is not very friendly for first-time users.

Then, in this concept, touch appears dispensable relative to sight and hearing. It is far less accurate and convenient than visual information in transmitting and recording information. In the sound effect and vibration feedback, the effect of vibration and no vibration is similar. If you turn off the sound, it's hard to tell the difference just by looking at the vibration without knowing what information it contains.

There is an additional point, the feasibility of prototyping, the most interesting of this concept. Creating personalized vibration curves by drawing curves is very difficult to program.

So finally for concept 1, I chose to give it up.

Concept #2 Set a goal

First of all, for the reading experience, most participants like the interaction of setting goals, which can give them a sense of accomplishment to a certain extent. As for the concept of reading at a constant pace with a fixed vibrational rhythm, half of the participants liked it very much, found it very interesting, kept them focused and had a sense of ups and downs in the process of reading. But the other half of users hate it very much, because the very fast rhythm urging them to read makes them tired, and the loud sound is very loud, which interrupts their thinking and does not match the reading environment they like to relax. The reading speed test was considered by almost all participants to be very bad and should be deleted, or done naturally in another, more natural way.

Second, for the long-term memory of the content, almost all participants believed that reading at a very fast pace would sacrifice memory for the content. But when the tempo is slowed down a bit, the nerf is greatly reduced.

In terms of the recognition of the interface design, the operation is very simple and logical, and it can be quickly understood after the first use. But differences in usability were also related to whether testers were comfortable reading with regular vibrations. Overall satisfaction is still high.

On top of that, touch is very important in this concept. There were even many participants who believed that the regular vibrations would not interfere too much with reading, but rather the sound was very annoying and disturbing reading. Maybe it would be better if the vibrations were only slight and silent. And regular vibration can really help readers focus on reading and improve efficiency.

The feasibility of the prototype is very simple.

So for Concept 2, I opted to keep its function vibrating regularly and optimize again on a basic basis.

Concept #3 Context reading

First of all, for the reading experience, the participants thought that it was very good, with little sound and vibration, hardly any major interference with reading, and it also helped them to quickly immerse themselves in the story and enter the reading state. But the concept is not very new, and if sounds and vibrations persist for a long time, they will become dispensable.

For the long-term memory of the content, participants were immersed in the story and were more attentive, but it was uncertain whether this actually improved long-term memory.

The entire interface operation is very smooth and reasonable. But some participants took issue with the voting mechanism and the immersive background music that lets previous readers' votes determine readers.

However, in this concept, the sense of touch is also easily overlooked, and the sound is very different, but the long-term vibration is irregular, and it is difficult to simulate the real situation based on the vibration alone, and it only appears with music as an auxiliary.

In terms of feasibility, interface programming is very simple and easy to operate in the early stage. But in the future, if every chapter of all books is used, it will still require a certain amount of work. However, for haptic technology, if the vibration feedback is irregular, it is very difficult to completely simulate a real situation through vibration. This kind of vibration is impossible to complete with only one vibration sensor, requiring very fine tactile points, and adding thermodynamics and other tactile feedback mechanisms. rather than pure vibration.

So for concept 3, I chose to keep it functional for immersing the reader in the story.

Concept #4 Emotion express

First of all, for the reading experience, labels with sounds and vibrations are interesting experiences, but some participants feel that just mere emoticons are relatively empty and relatively naive, and other more instructive labels can be added to express "interesting" "I like", "important" and "want to remember". The feedback from sound and vibration is not as meaningful. Sounds and vibrations appearing as feedback from the system are not very necessary, but it might be interesting if similar feedback appeared in other readers.

For the long-term memory of the content, it is not very helpful at present. However, you can add a bookmark bar-like list that categorizes different emojis and tags so that readers can review them again.

The whole interface is very reasonable.

At the same time, in this concept, touch is also an auxiliary meaning. Visual (emoji) and auditory (corresponding sound effects) are more suggestive than tactile vibrations, and when vibrations appear at the same time as them, It's

hard for readers to notice it.

In terms of feasibility, whether programming or haptic applications.

So for Concept 4, I chose to keep it's mechanism for vibrating feedback after receiving information and add social interaction features.

Concept #5 Word index

First of all, for the reading experience, its audience is relatively small, and it is not completely suitable for my target users. It is more suitable for children with small vocabulary or children. In most real reading situations, readers who do not understand the vocabulary that needs to be explained or inquired tend to be abstract and complex vocabulary, and it is difficult to describe it through simple vibration or sound. Vocabulary is often sound, and readers do not need vibration and sound annotations. And when readers concentrate on reading, without any prompts and marks, they often cannot find this function. Even if they are explained at the beginning, they will gradually forget this function after reading for a long time.

For the long-term memory of the content, this effect is also greatly reduced due to the limitation of the "must be vocal" vocabulary.

The whole interface is very reasonable.

In this concept, the tactile dilemma is similar to the third concept. A single vibration source alone cannot simulate the real touch of an object. Only vibration will cause interference and confusion.

In terms of feasibility, it is also similar to Concept 3. Almost all tactile experiences that need to simulate real situations, such as those in VR and AR systems, are quite complex and sophisticated.

So for Concept 5, I chose to give it up.

7.1.2 Select second iteration di

Based on this, I did another simple ideation.

Ideation on concept#2&3

According to the conclusions I have drawn, in this new concept, the questions I want to think about:
1. How to use a regular vibration rhythm to keep readers focused, but at the same time not affect their normal reading?
2. What kind of regular vibrational rhythm is friendly?
3. How to determine the speed of the vibration rhythm?
4. How can emotions be conveyed with a regular vibrational rhythm?
5. How to make the regular vibration rhythm adapt to different situations at the same time?
6. What reading situations should I set?

Ideation on concept#4

According to the conclusions I have drawn, in this new concept, the questions I want to think about:
1. How does this vibration feedback mechanism work?
2. When receiving what kind of information, is it more meaningful to receive vibration feedback?
3. Does the vibration feedback mechanism still occur when the reader does not open the reading software?
4. How to filter meaningful information?
5. Are there any differences between vibration cues and visual cues or auditory cues?
6. Where can this kind of reading communication feedback platform help in long-term memory?

Exclusion Concept #4

After the final preliminary discussion, I chose to give up the idea of a reading and communication feedback platform based on Concept 4.
What I can't solve is the following:
First of all, there are many existing reading and communication platforms, but this kind of communication should be quiet and optional. For example, underlining sentences allows you to see their comments from readers who also

underlined the sentence. Or before reading a book, you can browse other readers' evaluations of the book. But with the addition of vibratory feedback mechanisms, that communication has the potential to become very noisy. And if it is not screened by visual information, what kind of information can be received and what kind of information readers do not want to accept, this screening mechanism will become very difficult. Because once the feedback after receiving the information changes from simply appearing a line of text to feeling a vibration, the feedback itself becomes larger, so the information should be more important and cannot be ignored.

Secondly, most of the reading exchanges are not real-time information exchanges, and are time-lag. The reader's reading time is not synchronized, and visual information can solve this problem perfectly. It can retain the information, and even if it is not delivered in real time, the cost of missing is not very large. Reading exchanges can take place at different times and in different places. But most of the haptic information feedback is real-time, it is impossible to vibrate all the time to remind the reader, that is to say, the communication can only be achieved if you and other readers are reading the same book together at the same time, and it is not surprising. But this condition is very harsh. Even if there are other readers who are reading the same book at the same time as you, you can complete the matching and start communicating, but whether the matching readers have your heart and the same frequency as you Thoughts, whether it makes you want to continue to communicate, whether you have feelings for the same sentence, are all uncertain.

Finally, for most readers, the reading process is private, quiet, and continuous. Especially when reading a novel, maybe you have a desire to share when you see a piece of text or a plot, but most of the time, you still don't want your reading process to be interrupted by sudden information. So, how to design a vibration feedback mechanism that does not interrupt reading and allows readers to share ideas and receive information from other readers who have the same opinion really bothers me.

So, to sum up the above, after some thought, I chose to give up Concept 4.

Optimization for Concepts 2 & 3

As for Concepts 2 & 3 combined and optimized to be read in a regular vibrational rhythm in different situations, I conducted a brainstorm based on the questions I wanted to think about.

1. How to use a regular vibration rhythm to keep readers focused, but at the same time not affect their normal reading?
First of all, in order not to affect the reader's reading, this vibration should not be too obvious, its frequency should not be too fast or too slow, and it should be able to adapt to the reader and be customizable. In the process of reading at the same time, is it reasonable to use a line of text as a vibration cycle? Because a line of text may be the end of a sentence plus the beginning of a sentence, and the undulating vibration rhythm will make the reading focus stay at the beginning of each line, then when the beginning of each line is the end of the previous line, there may be Difficulty in reading comprehension. Therefore, it may be more reasonable to put the entire sentence on the same line, and the long sentence to be separated by commas or according to the meaning of the sentence.

2. What kind of regular vibrational rhythm is friendly?
In the research of chapter 2, an article wrote that the 15hz vibration rhythm can keep readers focused, promote the quality of readers' reading, and not affect their comprehension. So it is very necessary to test different vibration frequencies in the second iteration.

3. How to determine the speed of the vibration rhythm?
As for the way to determine the speed of the vibrational rhythm, I prefer to leave it to the reader to decide. The speed at which a line is read varies from person to person. At the same

time, because I plan to add different branching mechanisms, sentences of different lengths will be generated. Can the vibration rhythm be adjusted slightly with the length of the sentences? The duration of a cycle varies with the length of the sentence, but the amplitude and trend of the vibrations remain the same.

4. How can emotions be conveyed with a regular vibrational rhythm?
Similarly, according to the research in chapter 2, it can be seen that touch can convey emotions, and different vibration laws, vibration amplitudes, vibration speeds, etc. will affect the expression of emotions. Therefore, it is worth trying to change the speed of vibration in different situations to see whether it will bring different emotional senses to the reader.

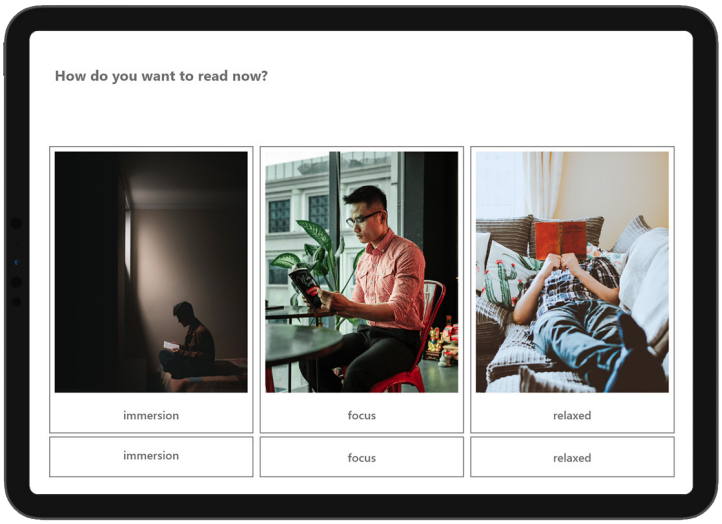
5. How to make the regular vibration rhythm adapt to different situations at the same time?
For a novel, the change of situation may occur in different chapters, or it may occur between a sentence or two. Therefore, it is difficult to ensure that readers read the moment of emotional change or the moment of situational change according to the original layout according to the almost uniform format, and the vibration rhythm can immediately keep up and make changes (unless eye-tracking technology is used). Therefore, it is better to change the original typesetting rules and perform pagination processing according to situational changes and emotional changes. Reduce the amount of emotional information each page represents, but at the same time make emotional processing more precise.

6. What reading situations should I set?
During the iterative process, participants repeatedly mentioned three key words for their ideal reading state during reading: "relaxed," "focused," and "immersed." These three words may change depending on the content of reading, the environment in which they are reading at the time, and their own mood, but it is undeniable that these three words may be able to satisfy most reading scenarios and reading needs. So in the second iteration of the concept prototype, I also consider these 3 reading situations.

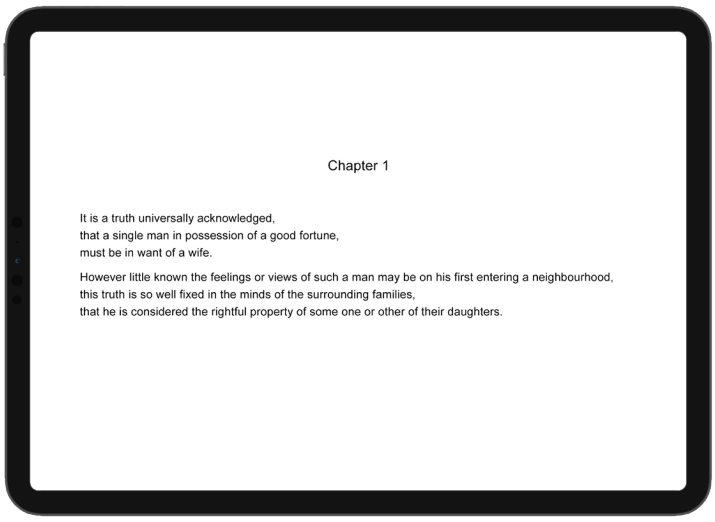
7.2 Second iteratio

7.2.1 Integrated concept

Based on the thinking in the previous chapter, I finally



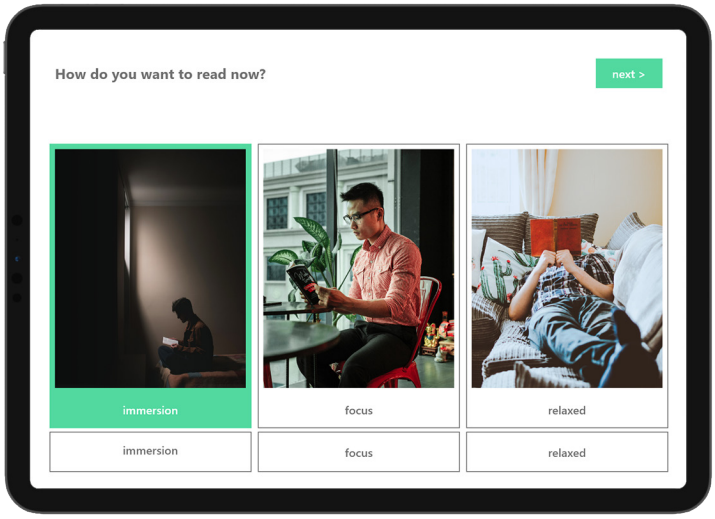
After opening the interface, readers can choos
two vibration rhythms to choose from.

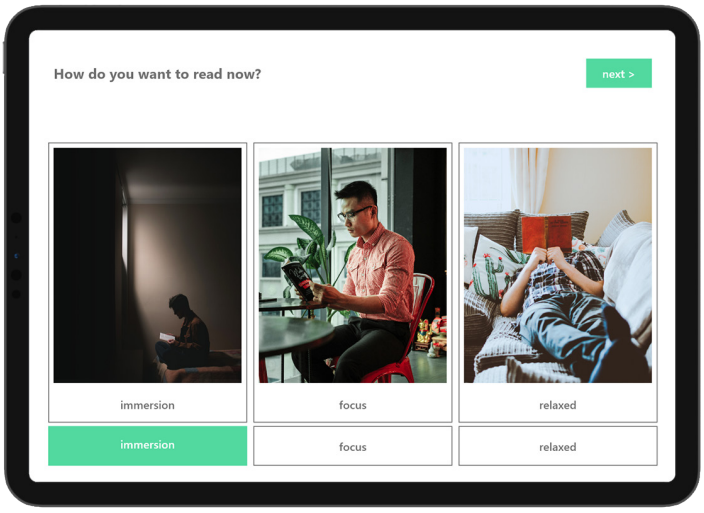


The paging and line-breaking methods have c
fixed typesetting on each page to paging acc
environment or plot or characters' emotions i
page; A line of fixed width, similar number of
meaning of the sentence in a complete senten

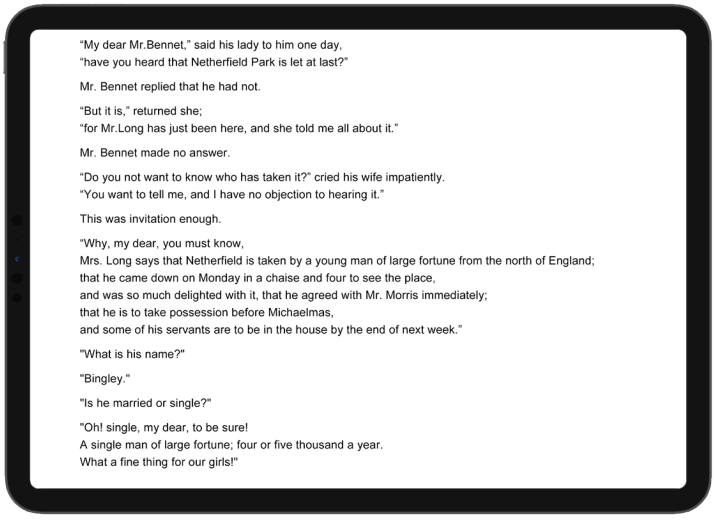
n

came up with a conceptual prototype for the second iteration.





se from three reading contexts, namely "immersion", "focus" and "relaxed". And each context has



"My dear Mr.Bennet," said his lady to him one day,
"have you heard that Netherfield Park is let at last?"

Mr. Bennet replied that he had not.

"But it is," returned she;
"for Mr.Long has just been here, and she told me all about it."

Mr. Bennet made no answer.

"Do you not want to know who has taken it?" cried his wife impatiently.
"You want to tell me, and I have no objection to hearing it."

This was invitation enough.

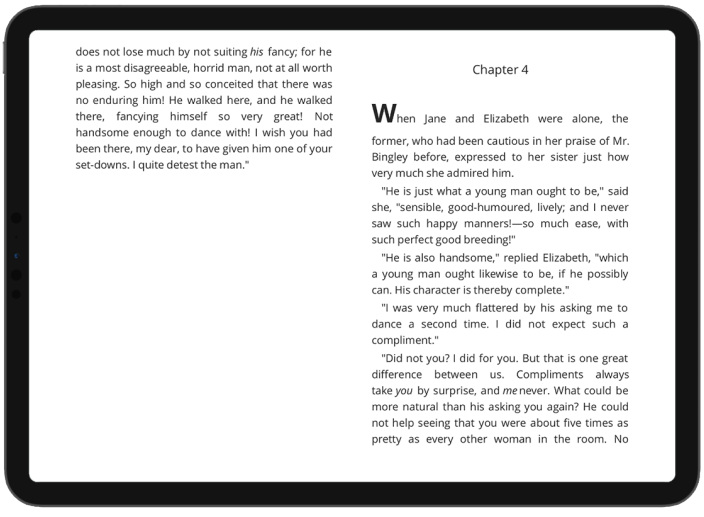
"Why, my dear, you must know,
Mrs. Long says that Netherfield is taken by a young man of large fortune from the north of England;
that he came down on Monday in a chaise and four to see the place,
and was so much delighted with it, that he agreed with Mr. Morris immediately;
that he is to take possession before Michaelmas,
and some of his servants are to be in the house by the end of next week."

"What is his name?"

"Bingley."

"Is he married or single?"

"Oh! single, my dear, to be sure!
A single man of large fortune; four or five thousand a year.
What a fine thing for our girls!"



does not lose much by not suiting *his* fancy; for he is a most disagreeable, horrid man, not at all worth pleasing. So high and so conceited that there was no enduring him! He walked here, and he walked there, fancying himself so very great! Not handsome enough to dance with! I wish you had been there, my dear, to have given him one of your set-downs. I quite detest the man."

Chapter 4

When Jane and Elizabeth were alone, the former, who had been cautious in her praise of Mr. Bingley before, expressed to her sister just how very much she admired him.

"He is just what a young man ought to be," said she, "sensible, good-humoured, lively; and I never saw such happy manners!—so much ease, with such perfect good breeding!"

"He is also handsome," replied Elizabeth, "which a young man ought likewise to be, if he possibly can. His character is thereby complete."

"I was very much flattered by his asking me to dance a second time. I did not expect such a compliment."

"Did not you? I did for you. But that is one great difference between us. Compliments always take *you* by surprise, and *me* never. What could be more natural than his asking you again? He could not help seeing that you were about five times as pretty as every other woman in the room. No

hanged. The paging method has changed from ording to situational transitions. Whenever the n the book change, it will be divided into a new words, to be divided into lines according to the ce or a long sentence, and punctuation marks.

Place a group of the original paging and rowing as a control group, and perform a control test in the subsequent test.

7.2.2 Vibration rhythm

I designed two rhythms for each of the 3 contexts, a total of 6 vibration rhythms.

The rhythm I designed for immersion is not regular.
The first vibrating rhythm is similar to Concept 3 in the first iteration, adding a piece of background music for each situation that occurs in the story, complemented by vibrations. But unlike Concept 3, it does not switch between different background sounds and vibrating melody through each chapter, but when the environment in the story changes, or the mood of the characters changes, or there is a big plot twist. When the page is turned, there will be background music and vibration for about 1-4 minutes to prompt the reader to switch the environment or change their mood, making it easier for the reader to enter the story.
The second vibration rhythm shortens the background music and vibration based on the first vibration rhythm. The duration is mostly within 10 seconds, and no more than 15 seconds at most. The timing of appearance does not change.

The following picture shows the time points of the four times of music and vibration in the content of the first to third chapters of Pride and Prejudice (the music and vibration of the first A and fourth times D are the same), respectively:
A.when the story begins, a family living in the countryside talked about their new neighbors who had just moved in.
B.The Bennets had a heated argument about whether to visit.
C.The family was invited to a dance by the neighbors.
D.After the dance, the family returned to the village cottage to chat.

In each group, the top picture is the waveform of the first vibration rhythm (long duration), and the bottom picture is the waveform of the second vibration rhythm (short duration).

A(D). Vibration waveform of countryside

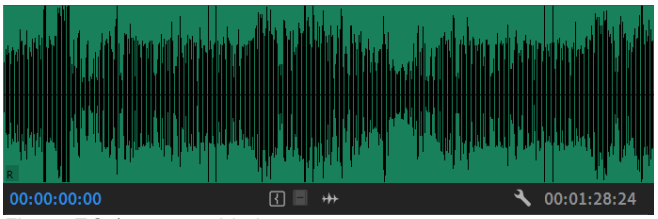


Figure 7.2.1 countryside long

Figure 7.2.2 countryside short

B. Vibration waveform of countryside

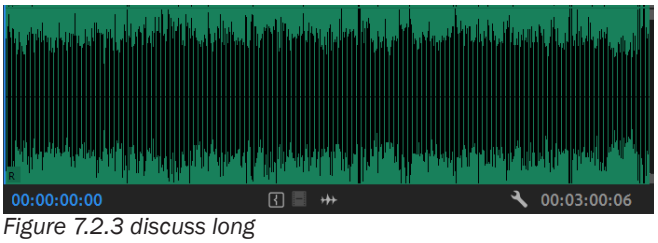


Figure 7.2.3 discuss long

Figure 7.2.4 discuss short

C. Vibration waveform of ball

Figure 7.2.5 Ball long

Figure 7.2.6 Ball short

Next is the rhythm I designed for focus, and every cycle of it is the same melody. And in this situation, I adjusted the volume to a very low level, which is difficult to capture in a normal environment, almost only the sense of pure vibration.

The first vibrating rhythm is inspired by 2/2 Beats in music, take the half note as one beat, and there are two beats in a bar, and the law of strength is one strong and one weak, the previous note is heavy shoot. This beat feels faster and more intense when played. So I used it to express the rhythm of focus. The purpose is to allow readers to accurately capture the timing of line break reading and maintain reading concentration.

The first vibrating rhythm waveform

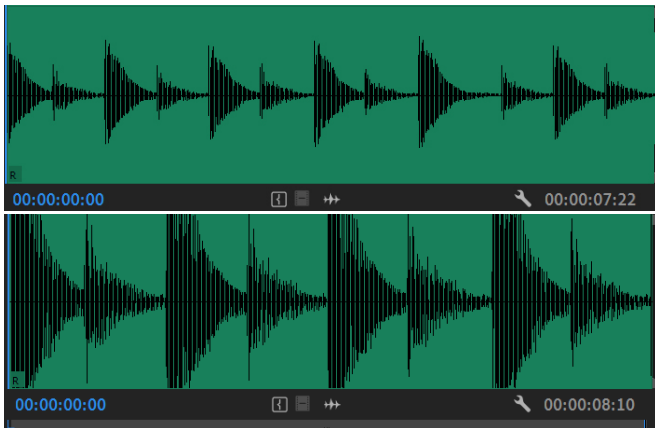


Figure 7.2.8 2/2 beats

I designed 4 velocities for this vibrating rhythm, the waveform graph and the duration of one cycle are shown below.

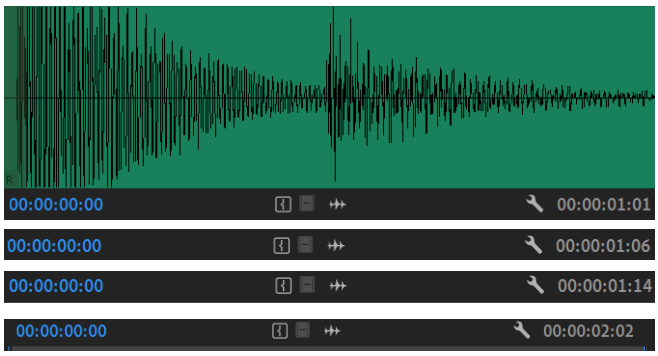


Figure 7.2.9 Four speeds for 2/2 beats of a cycle

The second vibration rhythm is completely different. Whenever the reader turns to a new page, it will not have any vibration for the first 25 seconds, but when the reader reads a page for more than 25 seconds (indicating that the reader possible distraction), it will gradually increase, prompting the reader to return to the book and continue reading.

The second vibrating rhythm waveform

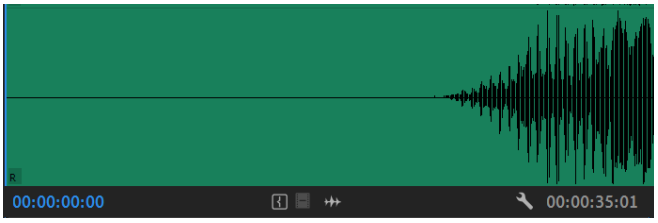


Figure 7.2.10 22 FOUCUS

Lastly, the rhythm I designed for relaxed. Also, every cycle of it is the same melody, and the sound is very small and negligible, just pure vibration.

The first vibrating rhythm was also inspired by 3/4 Beats in music. This rhythm is usually used in waltzes, emphasizes the accent on the first beat, the melody is smooth, and the rhythm is obvious. At the same time, it brings a brisk and rhythmic experience to the audience. So I used it to represent relaxed rhythms. The purpose is to allow readers to read in a rhythmic and relaxed manner.

The first vibrating rhythm waveform

Figure 7.2.11 3/4 beats

I designed 4 velocities for this vibrating rhythm, the waveform graph and the duration of one cycle are shown below.

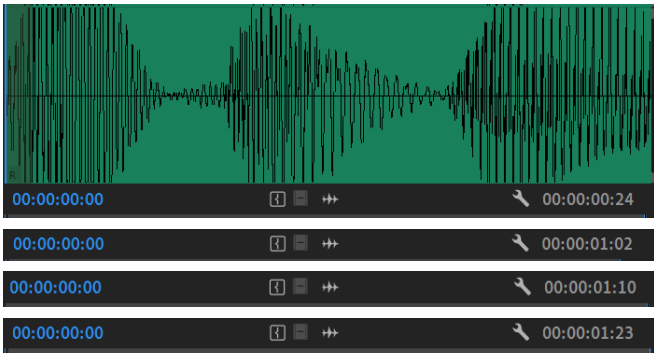


Figure 7.2.12 Four speeds for 3/4 beats of a cycle

The second vibration rhythm is the fluctuating breathing rhythm. The breathing rhythm is integrated into the reading. The vibration changes from light to heavy and finally returns to light as a cycle. I want the reader to also breathe, slow down and relax with the rhythm of the vibrations.

The second vibrating rhythm waveform

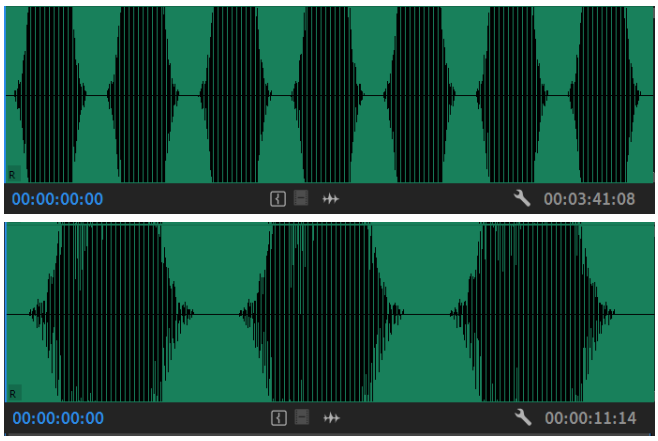


Figure 7.2.13 Fluctuating breathing waveform

Similarly, I designed 4 velocities for this vibrating rhythm, the waveform diagram and the duration of one cycle are shown in the figure below.

Figure 7.2.14 Four speeds for fluctuating breathing of a cycle

7.2.3 Set up a test control grou

For focus context and relaxed context, in order to ma
different treatments for the three chapters of Pride an

In the first chapter, the speed of the vibrating section
is used.
In the second chapter, a new paging and line-breaking
will change slightly with the length of each line. (The cl
8.2.)
In the third chapter, the vibration speed is restored an

Overall interface

Figure 7.2.15 Different paging and line-breaking for 3 chapters

New page

"But it is," returned she;
"for Mr.Long has just been here, and she told me all about it."

Mr. Bennet made no answer.

"Do you not want to know who has taken it?" cried his wife impatiently.
"You want to tell me, and I have no objection to hearing it."

This was invitation enough.

"Why, my dear, you must know,
Mrs. Long says that Netherfield is taken by a young man of large fortune from the north of England;
that he came down on Monday in a chaise and four to see the place,
and was so much delighted with it, that he agreed with Mr. Morris immediately;
that he is to take possession before Michaelmas,
and some of his servants are to be in the house by the end of next week."

"What is his name?"

"Bingley."

"Is he married or single?"

"Oh! single, my dear, to be sure!
A single man of large fortune; four or five thousand a year.
What a fine thing for our girls!"

Figure 7.2.16 Different line breaks

So in order to deal with the vibrating rhythm in the
sentences, I recreated the vibrating rhythm that matc
second chapter. As shown below.

Chapter 2 Vibration Waveform

Figure 7.2.17 Variable 2/2 beat vibration rhythm

Figure 7.2.18 Variable 3/4 beat vibration rhythm

Figure 7.2.19 Variable breathing vibration rhythm

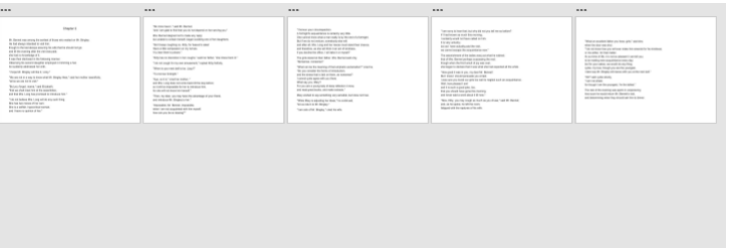
p

ake the test results more obvious, I have done three
d Prejudice.

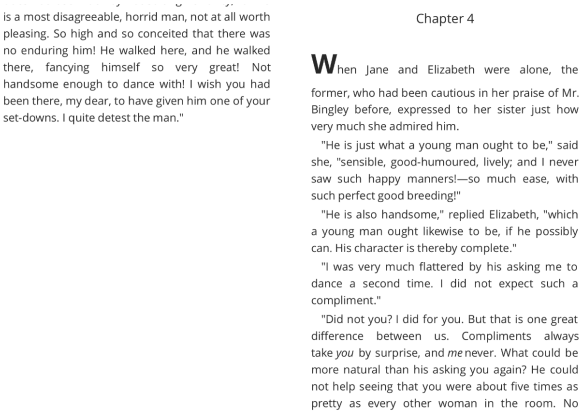
is fixed, but the new paging and line-breaking method

g method is used, but the vibration speed of each line
hange in the vibration waveform can be seen in Figure

d fixed, and the original page and line method is used.



Original page



is a most disagreeable, horrid man, not at all worth pleasing. So high and so conceited that there was no enduring him! He walked here, and he walked there, fancying himself so very great! Not handsome enough to dance with! I wish you had been there, my dear, to have given him one of your set-downs. I quite detest the man."

Chapter 4

When Jane and Elizabeth were alone, the former, who had been cautious in her praise of Mr. Bingley before, expressed to her sister just how very much she admired him.

"He is just what a young man ought to be," said she, "sensible, good-humoured, lively; and I never saw such happy manners!—so much ease, with such perfect good breeding!"

"He is also handsome," replied Elizabeth, "which a young man ought likewise to be, if he possibly can. His character is thereby complete."

"I was very much flattered by his asking me to dance a second time. I did not expect such a compliment."

"Did not you? I did for you. But that is one great difference between us. Compliments always take *you* by surprise, and *me* never. What could be more natural than his asking you again? He could not help seeing that you were about five times as pretty as every other woman in the room. No

e second chapter that constantly changes with the
ches the new paging and line-breaking method of the

7.3 Evaluation

7.3.1 Evaluation approach

Evaluation sessions were conducted with 3 target users, who had previously participated in user research and the supervisory team separately.

The evaluation with the supervisory team was aimed at discussing the feasibility of the concept and the direction of the final design.

User testing is designed to discuss which vibration rhythm is the most suitable and to inform my final choice.

Research questions

In this assessment, the core questions I need to know are:

Evaluation meeting with the supervisory team:

1. Do these contexts need to exist at the same time? Or choose to focus on one in the final design?
2. Which vibrational rhythm is the most suitable?
3. How could the final trade-off regarding vibrational rhythm be better?

Evaluation meeting with target users:

1. Do you feel that this vibrational rhythm makes you focus?
2. Do you find this vibrational rhythm to relax you?
3. Do you feel that this vibrational rhythm makes it easy for you to immerse yourself in the story?
4. Which vibration rhythm experience do you think is the best?
5. Do you like the new paging method?
6. When reading these three chapters, which chapter do you like the most?

7.3.2 Key takeaways from the evaluation

"Immersion" context

(Feedback from the user test)

-Vibration still cannot transmit information effectively. Concrete music but can't match precise vibrations.

“Although it is more in-line with the content of the reading than the context reading in the first iteration, and the point of occurrence is more subtle. But the information in the vibration is still not discernible through the vibration. I mainly listen to the background music to identify what the vibration represents. the meaning of."

- The information conveyed by music and vibrations is not exactly what the reader expects. Instead, it interferes with reading.

"It feels like the background music + vibration doesn't quite fit the reading content. For example, the first chapter is a conversation between a family in a country house, but I don't think the background music and vibration you added are very consistent."

- Sudden vibrations and music are annoying to readers. Perhaps a continuous vibrational rhythm is more appropriate.

"Both vibration rhythms in Immersive Mode bothered me a bit because it came out of nowhere. When it came up suddenly, I was terrified because it didn't have any vibration or music on the front and back pages. ."

- It's a very good idea to increase the vibration during environment switching and mood changes. It's a lot of fun for the whole reading experience.

"I can still feel the changes from this, such as the environment switching to the dance party, and the Bennets getting excited because of the quarrel. At this time, I can still have some touches."

"Focus" context

(Feedback from the user test)

- The first vibrating rhythm will make the reader read faster.

"At this vibratory rhythm I tend to have a faster vibratory rhythm that will keep me reading efficiently."

"But when the sentences get very long, it's still a bit difficult to read at this rhythm."

- The second vibrating rhythm which is starting to vibrate after 25 seconds may cause some confusion.

"My first impression of using it was that I was a little confused about what it meant. There are pages where nothing happens, and there are pages that vibrate. What does it mean? I might need to have some introductory pages ."

(Feedback from the supervisory team)

-The first vibrating rhythm is really rhythmic.

"beng, bong; beng, bong; this rhythm is really strong. Although the rhythm is a bit too fast."

- The second vibration rhythm is debatable whether it is appropriate to start vibrating gradually without turning the page for 25 seconds.

"I feel that this is not necessarily suitable, because there may be many situations when reading, such as leaving for a short time, but because of this, it is not good to continue to vibrate to remind."

- The second vibration rhythm If there is no prompt when you first use it, it is difficult for readers to respond to the meaning of the vibration.

"It may be necessary to guide or prompt the reader to tell the reader that this vibration means that you are watching slowly, and you should turn the page! Otherwise, the vibration may make the reader feel that something is wrong."

"Relaxed" context

(Feedback from the user test)

- The first vibration may need to be slowed down a bit more, and the retake should be a bit more pronounced to achieve a relaxing waltz-like effect.

"dong, qia, qia; dong, qia, qia; the rhythm of this vibration is very strong, so it may need to be slowed down a little to have a relaxing effect, otherwise it may be the same as the first iteration of concept2, not only will it not let I'm focused, and it makes me feel distracted."

"I can't tell where I should read the line breaks. The rebeats of the line breaks are not particularly noticeable in this vibrating rhythm. Maybe it would be better to strengthen one of the beats a bit?"

- The second vibration is ideal for relaxation.

"Breathing with the vibration and then reading is a

fun experience, and I'll adjust my breathing rate so that I can breathe with the vibration. But that's what I need the vibration frequency to be stable, at least the vibration rhythm should be the same in one page"

- The speed of the second vibration should be set at the reader's choice, or there is some natural way to make it fit the human breathing rhythm.
"For me, if the breathing rhythm is too slow, it is not good. It will make me feel like I have to lift up in one breath and exhale very slowly."

(Feedback from the supervisory team)
- The first vibrating rhythm does not make the reader feel relaxed.
"Under this vibration rhythm, perhaps because the speed of a cycle is too fast, I still don't feel relaxed. The relaxation should be slower."

-The second vibration rhythm, when the speed becomes slower, does make people feel very relaxed.
"Slow breathing, it does make me feel relaxed."

Overall experience

(Feedback from the user test)
- Line breaks make the overall typography unsightly. And sentences of different lengths will make readers feel uncomfortable.
"Line wrapping doesn't really help me understand the meaning of the sentence, but it most obviously makes the whole interface less beautiful."

- Pagination is very nice. But the amount of content on each page should not vary too much.
"I like this pagination method very much, but there is a problem. For example, the first page and the second page, the first page has only 6 lines of words, but the second page has a full 22 lines of words. The gap is too large, which is a bit strange."

- This way of paging is not very suitable for ipad, may be more suitable for mobile phone.
"The content capacity of one page of the iPad is very large. If you want to paginate carefully and start each transition on a new page, then the entire interface will be very empty."

- The preference for breathing vibration rhythm is the highest.
"This vibratory rhythm is the most relaxed option, and it's really relaxing."

- The vibration rhythm changes too fast and is not very suitable.
"It is very inconspicuous to change every sentence. Only when the fastest rhythm immediately becomes the slowest rhythm will you have a very obvious feeling, but at the same time, this change will be a bit abrupt."

(Feedback from the supervisory team)
- This whole new way of wrapping is unnecessary. On the contrary, the length of the sentence varies, causing difficulty in reading. It is better to keep the original wrapping method.
"I don't think this line break is better than the original line break. I don't have a situation where I can't understand the meaning of the sentence because of the line break."

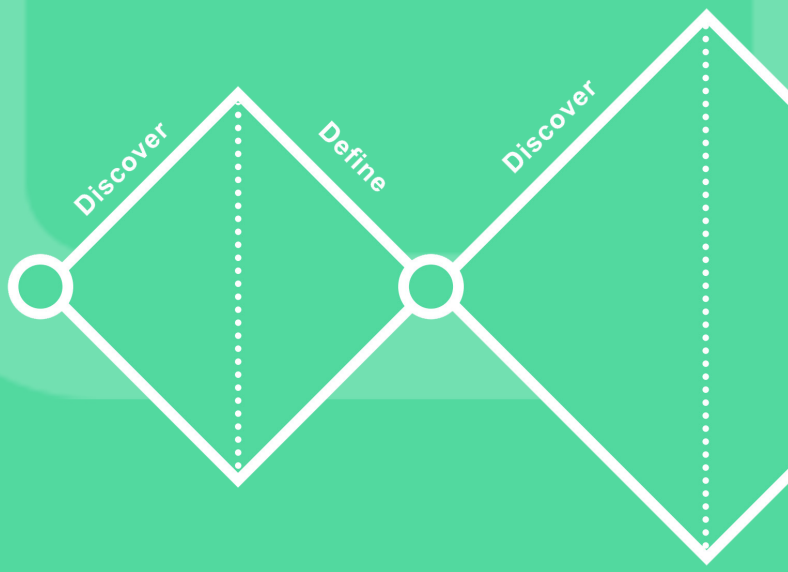
"Only when the rhythm of the vibration is too fast, I feel that the original line breaking method will make me a little unable to read the meaning of the sentence. But as long as the rhythm is controlled more reasonably, then the new line breaking method is unnecessary."

- The new paging method is still very good.
"The content of each page is reduced, and it is a very good idea to split pages at important plots or environment switching. You can accurately find the reader's reading progress without eye tracking and add appropriate vibration rhythms."

- For the vibration mode, it is not necessary to keep all three, but only one of the 6 vibration rhythms can be selected for refinement.
"For the final design, it is not necessary to consider every situation, you can focus on one of them, and then make an outlook for other contexts, such as which direction can be expanded in the future. Because if every context is considered However, it will make the concept blurred, and each one is not detailed enough. It will also cause trouble for users."

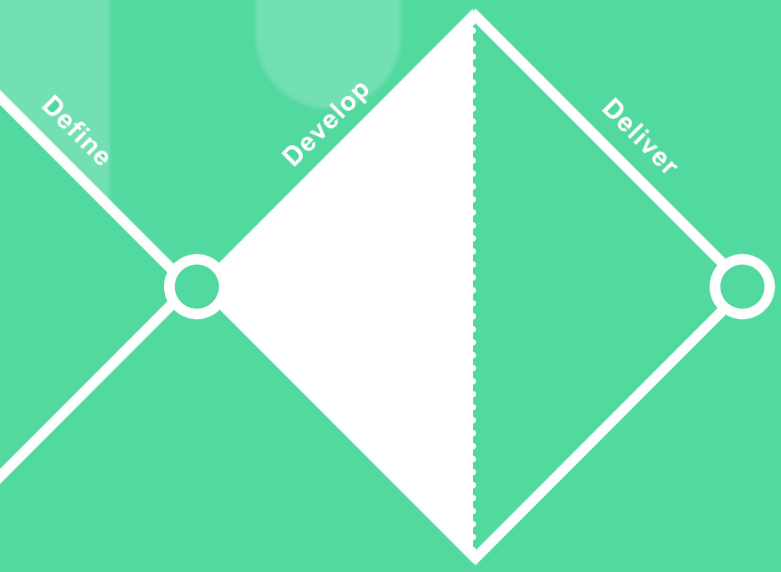
- The vibrating rhythm feeling that every line changes in the second chapter is not very obvious. A constantly changing vibrational rhythm is not very necessary.
"Actually, I can't feel the feeling that the vibration rhythm you introduced changes with the length of the sentence. The vibration rhythm changes a little between each sentence, so this vibration rhythm is suitable for medium-length sentences, but for For long sentences, it is difficult for me to read a whole long sentence in one cycle."

After the second iteration, I reflected the test
prototype of my final deign.



CHAPTER 8
FINAL ITERATION

results. Finally, the Final Iteration is also the



8.1 Defining final design direction

8.1.1 Summary of the second iteration

First, the reflection process and questions for the second iteration of the conceptual prototype were consistent with the conceptual prototype for the first iteration. But because the concept has been concreted, I have refined the judgment dimension:

1. Completion of design goals

A. Does the entire prototype help readers stay focused while reading? More immersed in the story?

B. Can this immersion and focus help better memorize the content of the story?

C. Does the vibrational rhythm help them stay focused?

D. Which vibratory rhythm works best in this concept?

2. Readers' acceptance of the prototype's usability, logic, and ease of use

E. Are the 3 contexts and 6 rhythms reserved for the entire prototype for readers to choose from, is it easy to use and logical?

F. Can the choice of vibrational rhythm be personalized?

3. For the application of haptic technology (ie whether haptics play a dominant role in this concept)

4. Feasibility of the concept

Improved reading experience

The two vibrational rhythms of the **Immersion context** help readers quickly understand the context in which the story takes place. Short-term vibrations are much less disruptive to reading than long-term vibrations. After the first few seconds of long-term vibration, subsequent vibrations are not very meaningful for reading, but will divert the reader's attention and be disturbed by the vibration. At the same time, the result of conveying figurative information through vibration, but it is not accurate enough to make the transmission process meaningless, has not been greatly improved.

The two vibration rhythms of the **Focus context,** the second vibration rhythm appears at a fixed time, but it does not actually have much effect on the reading experience during the test process, and there are many factors that affect the reader's reading speed. There may be some special situations due to some unexpected situations. So this function doesn't make much sense. The first vibration rhythm is a regular vibration rhythm, which does not convey concrete information, but can convey emotions through a fixed vibration rhythm. But there is a problem that this vibration rhythm was originally designed to keep readers focused during the reading stage, so the initial speed is relatively fast. A faster frequency may make the reader focus, but it may also convey nervousness. At the same time, the reader will be too busy scanning the text and lack time to think and imagine, and this frequency will make them unable to concentrate because the light It takes a lot of energy to keep up with the vibrational rhythm.

The two vibration rhythms of the **Relaxed context** are similar in setting, helping readers to read at a constant speed through regular vibration rhythms. The vibration frequency is relatively slow, and the duration of one ups and downs cycle is longer, which helps readers to complete a line of reading in one cycle, and it is not easy for them to get distracted. Compared with the first vibration rhythm (waltz), the second vibration rhythm (breathing) is more relaxing, and the reader will try to maintain a similar breathing rate when reading, and the reading process is more comfortable.

The new paging and line break methods, the new paging mode can be retained, but there is a problem that for such a large screen as an iPad, if there is only one or two sentences in the entire interface, the screen utilization rate will be too low, and the time to click on the screen to turn pages will also be too low. Will be too close, keeping the reader busy tapping the screen,

sacrificing read coherence. There is no need to retain the new line break method. By changing the vibration frequency to match sentences of different lengths, the entire reading rhythm is disrupted.

Long-term memory of the content

In fact, whether these three situations, the six vibrational rhythms, allow readers to focus on reading or immerse themselves in reading can really improve the long-term memory of the content can not be measured by science. But subjectively speaking, readers feel that this way allows them to read attentively without interference from the outside world, and that this reading atmosphere will make them improve the memory of the content. But the vibration rhythm can't be too fast, too fast will cause them to be carried away by the vibrational rhythm, and they need to pay different attention to the vibration rhythm at the expense of thinking and memory of the content.

Usability, logic and ease of use

The first is a relatively basic idea based on this concept, that is, readers can freely choose different reading situations according to their own needs, whether to immersion, focus, or relax. However, there is a relatively logical problem in this choice. The reader does not feel the vibration before using it, and the current concept prototype cannot achieve a high degree of personalization. All readers can choose from the vibration rhythm, which is still in the 6 templates. make a selection. Then, in the case that the effects of different vibration rhythms are quite different, it is better to place the reader's choice on a customizable vibration frequency of the most suitable vibration rhythm. At the same time, the opening and closing of vibration and the selection of vibration frequency need to be increased.

Then there is a basic establishment of other functions of the whole reading application.

The application of haptic technology

First of all, instead of conveying concrete information through vibration, emotions are conveyed through regular vibration rhythms at different speeds to control reading speed, subjectively improve perceived immersion, and reduce perceived fatigue.

Feasibility

Not transmitting concrete information through vibration will make the entire programming more feasible. As mentioned before, the transmission of figurative information requires a tactile feedback mechanism in the tactile channel, which is difficult to achieve only by tactile vibration feedback and a small number of vibration sensors that are not accurate enough. But it is relatively easy to simply change the vibration speed, but the only problem is how to realize the customizability of the vibration rhythm. There needs to be a code that can change the speed, which can change the audio playback speed corresponding to the vibration rhythm in real time.

Summary

1. Only keep one vibration rhythm of one of them, and make it more detailed. The regular vibration rhythm performed better than the irregular vibration, and among the three regular vibration rhythms, the breathing rhythm performed better.

2. Think about the customization of vibration speed.

3. The new paging method can be retained, but maybe ipad is not suitable.

4. The new line wrapping method is not so necessary in the test results, because the vibration rhythm cannot be guaranteed to be stable. And for people who read in their native language, this way of line breaks is already accustomed to, and only very fast reading will affect reading comprehension.

5. The overall function of the app is not yet complete, and it should be completed later.

8.1.2 Select final iteration direction

For the final iteration, I did a simple ideation:
In the final iteration, the questions I need to think about:

1. How to refine the breathing vibration rhythm? How to realize the customizability of this vibration speed, so that the vibration speed can match the reading speed of each reader?

2. Does the breathing vibration rhythm need to be improved in any way? Does its fluctuation, vibration amplitude, and one-cycle vibration change still need to be optimized?

3. Ipad is not suitable for the new paging method. If only the vibration feedback mechanism is needed, is there any other better carrier?

4. If the new paging method is matched with a constant vibration frequency, can readers still feel the change according to the paging method of scene switching and emotional changes? Does it need to be matched with the change of vibration frequency to be more obvious? Or does it need to be paired with something else?

5. What other functions do the whole app need to make a usable e-reading software in the end? How should the adjustment and switch of the vibration function be reflected?

So I brainstormed these questions and came up with the final iteration direction.

First of all, for the functionality of the overall app, I need to complete the functions of the entire app to make it an e-reading software, adding basic functions such as searching for books, personal library and so on. Then I need to perform a function exploration and selection for the functions that the app needs to have.

Second, for the aesthetics of the app, I need to choose a good color for the app. I want to choose **green**, and I want to give the reader a feeling of natural freshness and free breathing, which corresponds to the vibration rhythm of the

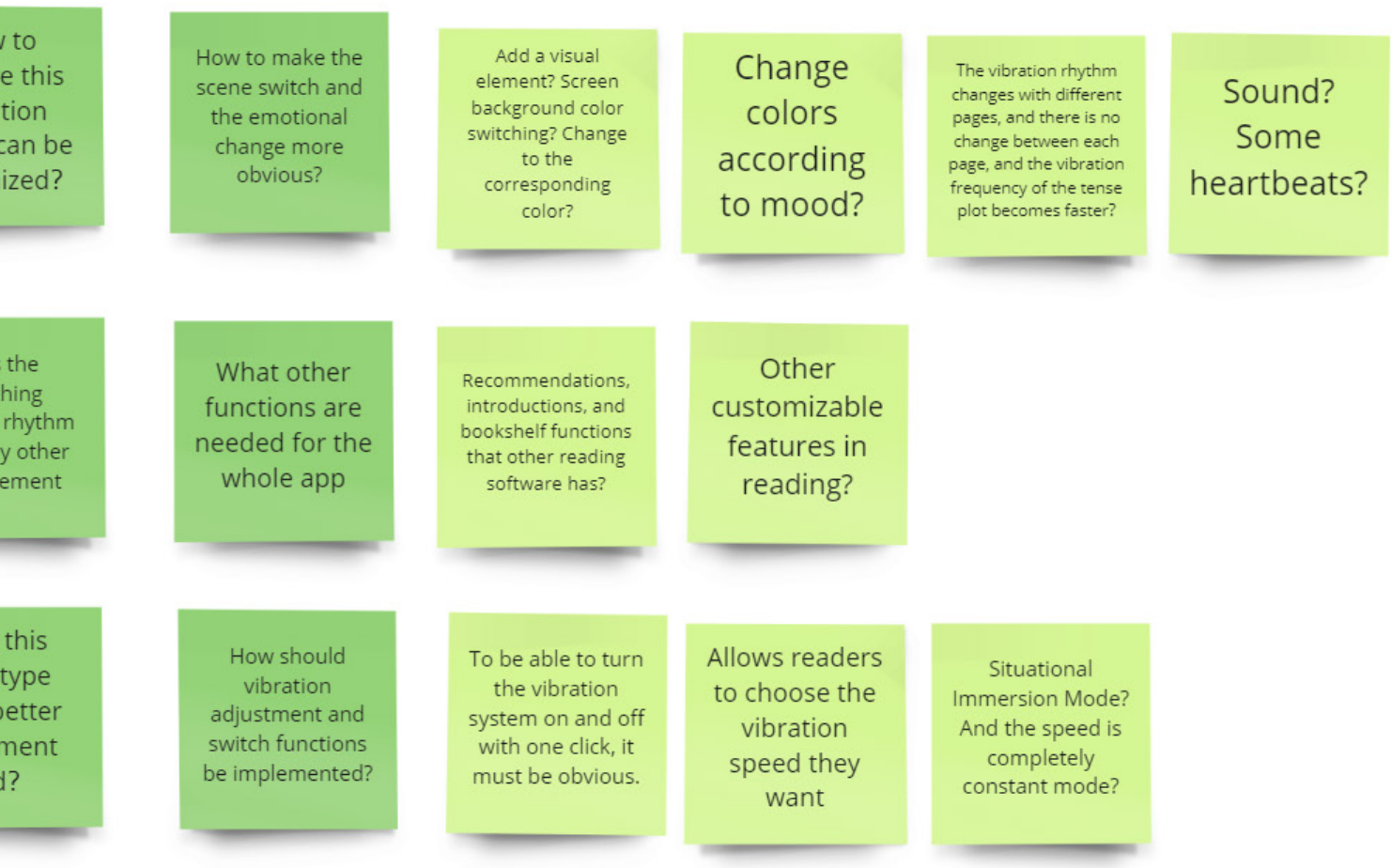
Figure 8.1.1 Cluster of second iteration

breath I choose.

Third, regarding the overall page turning method, page turning is performed according to plot changes, emotional changes, or scene switching.

Fourth, in order to match the new page change method and the meaning of page change, we want to make this change more obvious, so we need to change the vibration frequency of each page. When the plot is gentle, the vibration rhythm can be slow. When the plot reaches its climax, the vibrating rhythm increases. Change every time you turn the page, don't let the change become too drastic and unnatural.

Fifth, in addition to this, additional visual



elements are added to create a gradient reading background. The background color will change with the mood, plot, and environment, deepening the sense of immersion.

Sixth is the vibration itself, which is set for the reader to choose the vibration speed independently, or turn on the immersive mode. As well as designing a very obvious switch to control the start and pause of the vibration.

Finally, because if it is only a vibration function, there is no need to implement operations such as note-taking highlights through the app, and in order to make the new page change method adapt to the screen size. I choose to use my **mobile phone** as the carrier of the app instead of the ipad.

8.2 Final iteration

8.2.1 Functions

In order to determine what other functions need to be included in my final design, I researched the functions of most reading software on the market, and asked my testers to choose among them, and finally determined a more rational combination of functions.

The functions are divided into main functions and functions when reading, and then let testers put their own emoji avatars in the function sections they need. The board will be emptied again every time you test to prevent testers' test results from affecting each other.

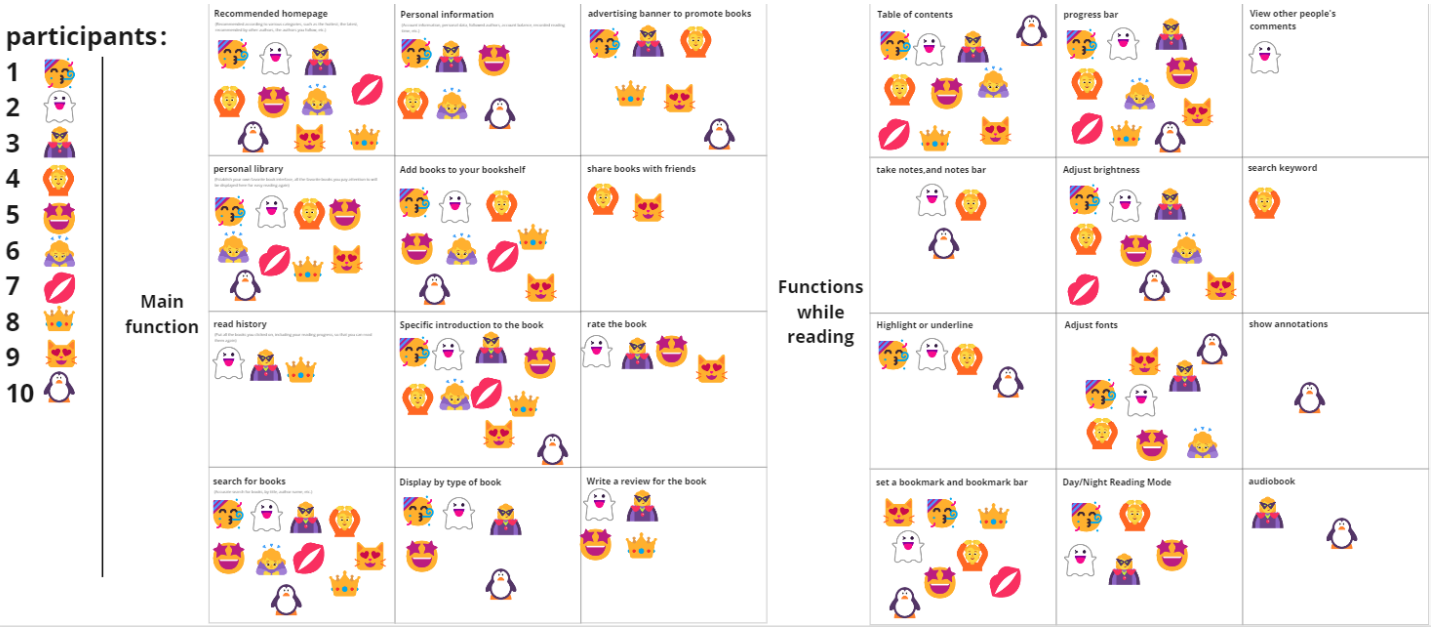


Figure 8.2.1 Function selection

Finally, put features selected by more than 50% of the votes (i.e. with at least 6 participants) in my final iteration prototype.
The main functions reserved are to recommend the homepage, personal library, search for books, personal information, add books to your own bookshelf, specific introduction of books.
The functions reserved while reading are table of contents, bookmarks, progress bar, adjust brightness, adjust font.

As for the vibration function, I currently have 3 settings, turn on/off the vibration mode, choose the vibration speed independently and turn on the immersive vibration mode (because the exploration of the vibration function is still in progress, and the function I am currently envisioning is These three are then prototyped to see how the test results do the final adjustment on the vibration function in the final adjustment.)

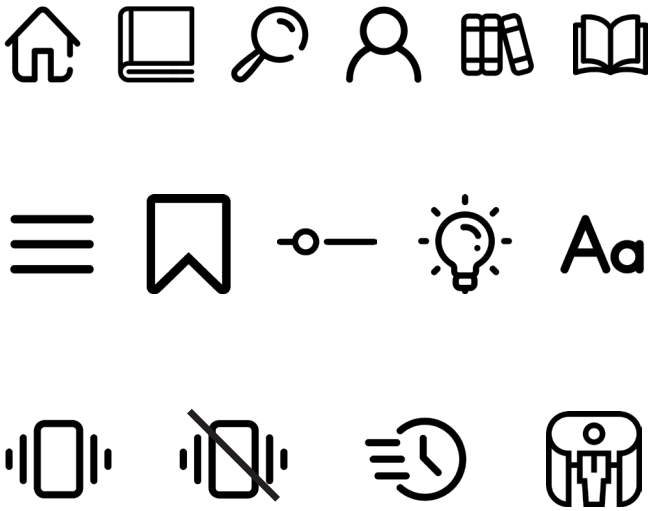


Figure 8.2.2 Icons

8.2.2 Look and feel

One of the main goals of the interface design of our application is to make it as simple and friendly as possible, since the functions of the application are relatively many. To create a consistent look and feel for the app, we used Google's Material Design Guidelines (Material Design, n.d.) as a basis. This provides information such as spacing, font size, and style, which helps improve the readability, accessibility, and clarity of the interface. A key component of Material Guidelines is the use of a state system to display a specific state of an element (for example, clicked or deselected). Use these guidelines to help users distinguish certain common elements (for example, toggle switches or sliders).

Additionally, we used green (#52D9A0) as the base of the color palette to improve the consistency and recognizability of the app, while still having a friendly appeal. Then it is matched with 4 shades of gray from black to white, keeping the simplicity of the whole app. Don't clutter the whole software with various colors.

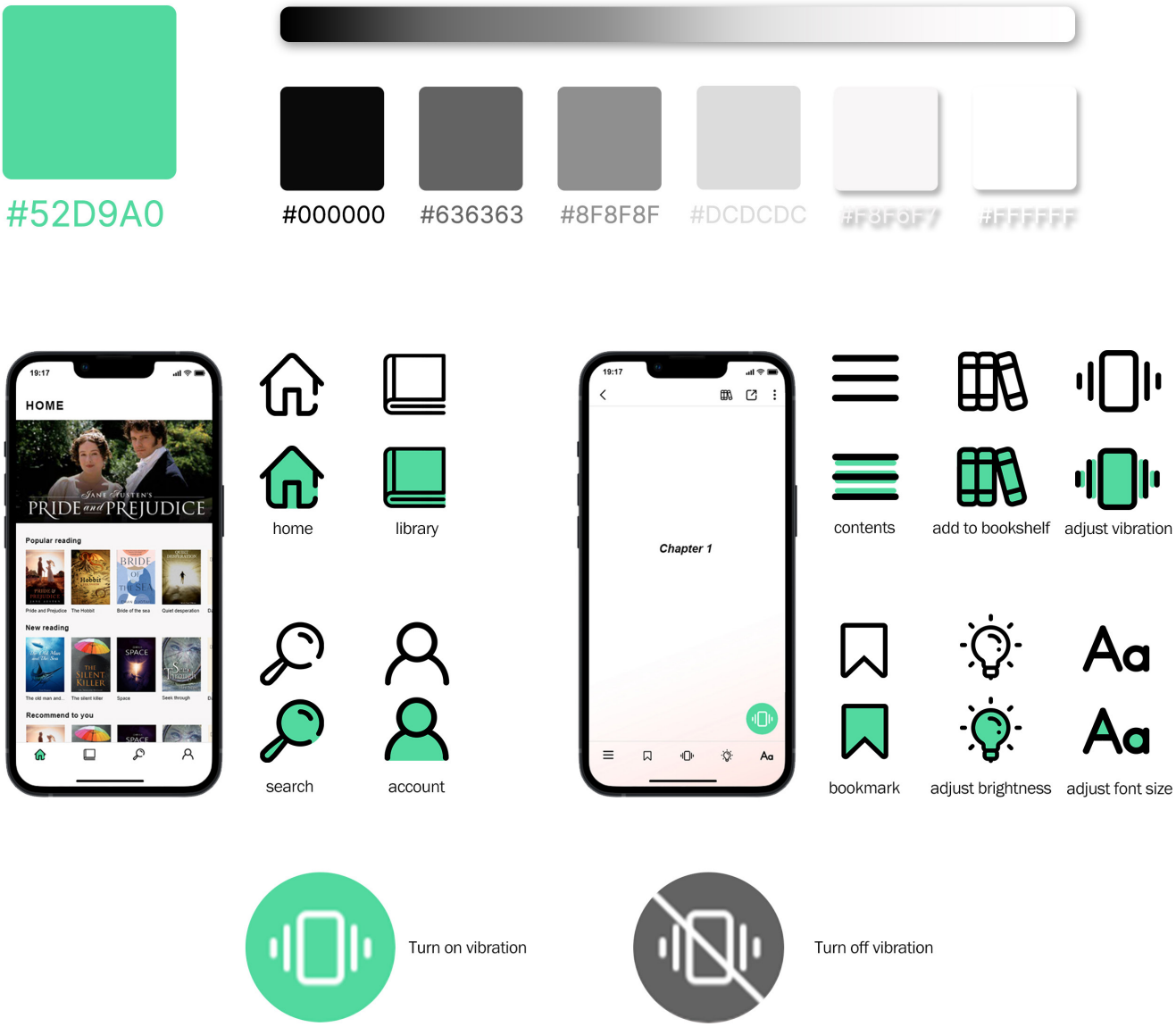


Figure 8.2.3 22 Look and feel

8.2.3 Prototype

In the process of making the prototype, I first simply built the basic functions of the app, home page, library page, search page, account page, book information page, and then focused on making one of the functions, and found a book I wanted from the home page. After reading the book, check the specific information of the book, add it to your library, and find the newly added book in the library.

Then there is the most important function of vibration in this project. First of all, when you click on the reading interface, click in the middle of the screen, and a function bar will appear. There will be a very obvious vibration button in the lower right corner, gray means off, click once, the button will change It turns green, and the icon changes at the same time.

The bottom function bar houses all the adjustment functions when reading, and the vibration function is placed in the middle of the bottom bar, where it is most easily noticed. At the same time, the vibration button is to adjust the details of the vibration mode, adjust the vibration speed by dragging the slider and choose whether to turn on the immersive vibration mode.

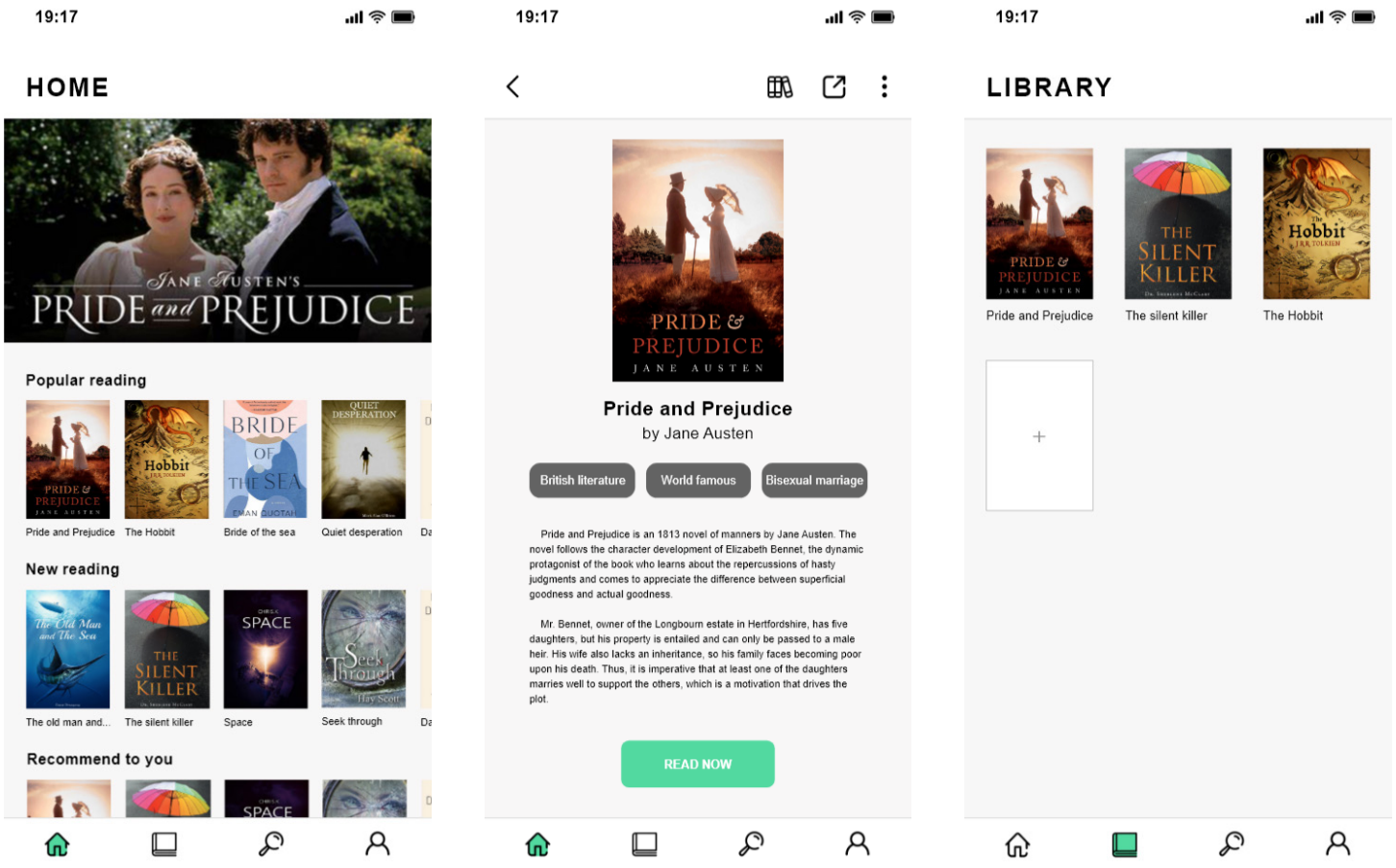


Figure 8.2.4 Search for books

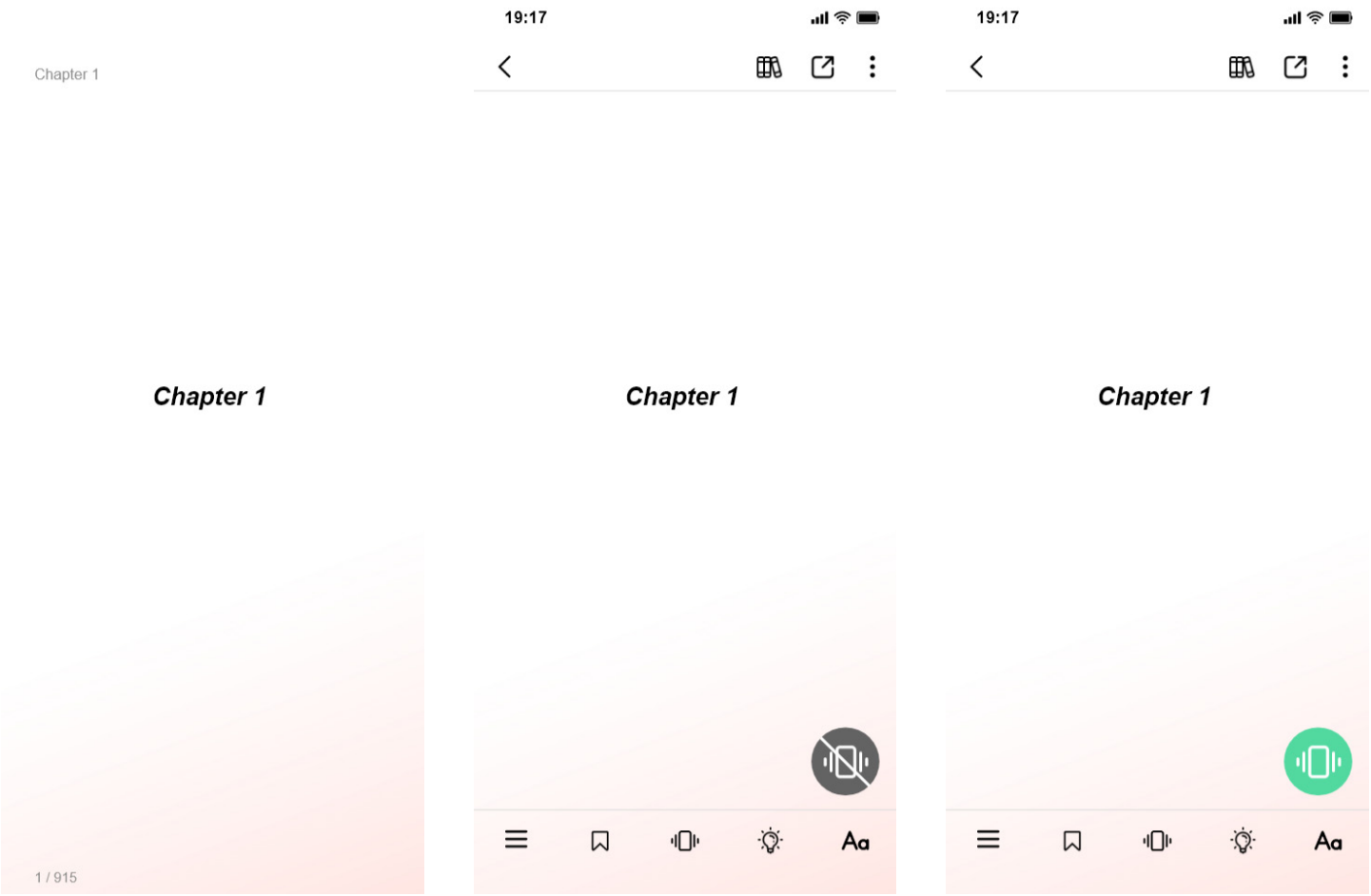


Figure 8.2.5 22 Turn on/off vibration

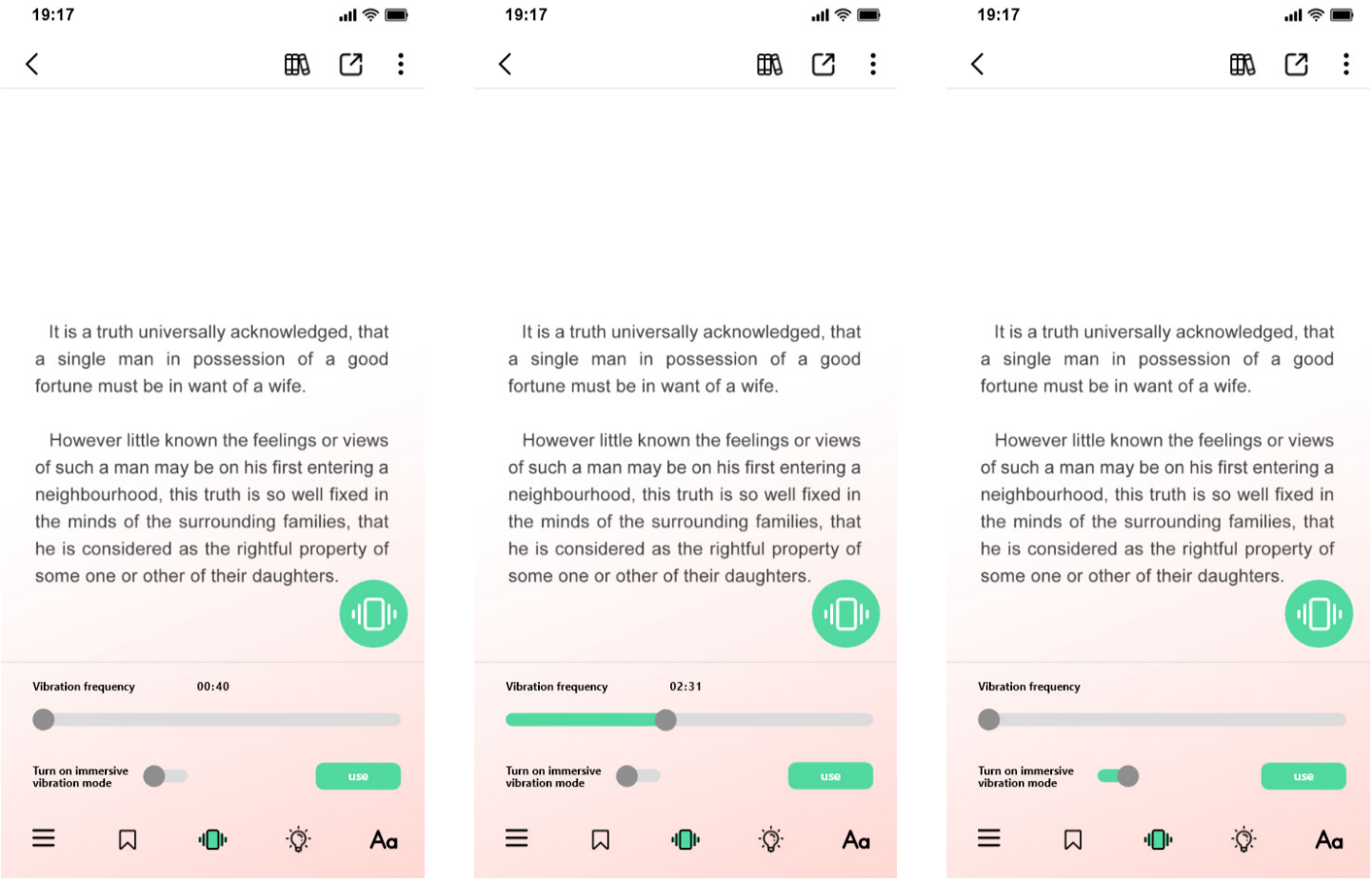


Figure 8.2.6 Adjust vibration frequency

8.2.4 Prototype details

Vibration rhythm

In the final iteration, I first optimized the breathing rhythm in the second iteration to make the undulating gradient more natural, and at the same time adjusted the volume so that when using the prototype on the phone, I would only feel a slight vibration but not hear the background music the size of.

At the same time, in order to enable users to choose the vibration speed independently, I set 8 speed files for them on the premise that they can not automatically generate different speeds as the readers adjust the slider, from 1 second per cycle to 3.24 seconds per cycle , which roughly simulates an arbitrary speed that the reader can choose.

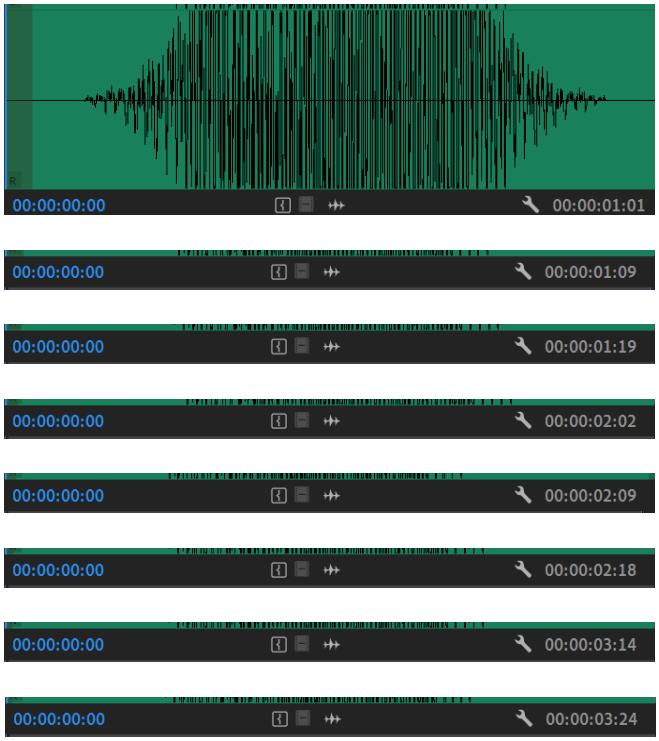


Figure 8.2.7 Vibration waveforms with different frequencies

As for the immersive story vibration mode, my considerations are:

Because in the second iteration I tested when the vibration speed changes once per line with the length of the sentence, that is, once per cycle, it is obvious that this result is not good. Either the change between the two sentences is not large enough, and the tester cannot easily feel the change of vibration; or the change between the two sentences is too large, jumping from the longest sentence to the shortest sentence, and the vibration speed changes greatly. Makes them feel very strange and unnatural, and instead interrupts their breathing rhythm.

Learning from the previous experience, this time I adjusted the change of the vibration speed to one change per page, that is, when reading the same page, the vibration speed remains constant, but if the mood of the next page changes, the vibration The speed will also speed up or slow down as the mood changes, this change is to maintain a full page until the next page turn. Moreover, the vibration changes between every two pages will not be too large, and it will only give people a feeling of slow acceleration and slow deceleration. I hope it can bring readers a feeling that as the plot changes, the reader's breathing rhythm is also changing.

In order to achieve this, I divided the emotions on each page according to the development of the storyline (the smaller the number, the more intense the emotion), such as the fierce quarrel between the bennet couple in chapter 1 (level 3), chapter 3 The dance party begins (level 5), in chapter 46, Elizabeth reads the letter, rests on her head, and hurries out the door (level 1), and then matches the 8 designed vibration rhythms one by one, with level 1 corresponding to the fastest vibration cycle (1 seconds), I stitched the waveforms of the 8 rhythms together for comparison.

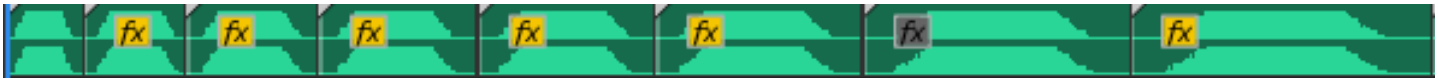


Figure 8.2.8 Vibration waveforms with different frequencies

Background color gradient

And about the background color will change as the plot changes, the characters' mood changes and the scene changes. So what colors should be matched with different emotions or different scenes? I did a simple research. The survey found that deep reds or some dark, saturated reds can make people feel angry and nervous; vivid and pastel yellows, oranges, and reds or some light warm colors can make people feel happy; dark blue or dark green Gray or some cool colors can feel sad; white or some very light blue-green can feel calming. (Stephen E. Palmer, 2012)
And according to the article (Pride and Prejudice) paragraph I chose in the archetype:
Chapter 1 From a quiet family conversation to a disagreement between the bennet couple (change from white to red)
Chapter 2 From the heated conversation immediately after the last chapter to Mr.Bennet secretly fulfilling his wife's wish, everyone made peace and the family was happy (change from red to yellow)
In chapter 3, it is a scene transition, from a happy rural hut to a gorgeous aristocratic ballroom. I refer to the color matching of the aristocratic ballroom: gold, brown, and the shape of the hanging crystal lamps, and designed such a golden brown For the background, there are some argyle patterns on it. (changes from yellow to golden brown with argyles)

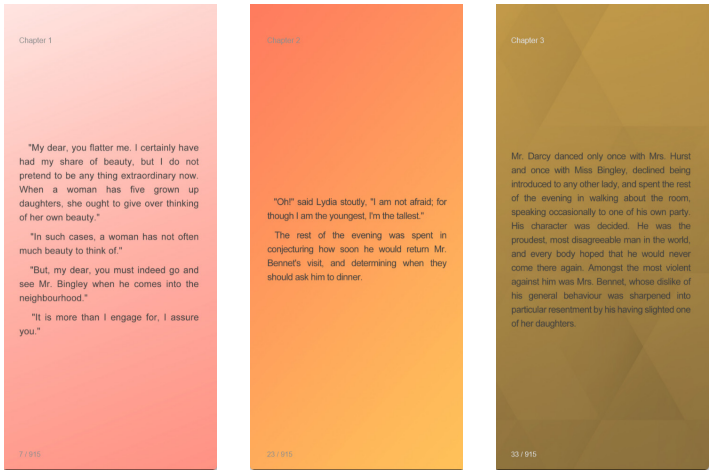


Figure 8.2.9 Background color of chapter 1,2,3

Figure 8.2.10 Reference to the Palace Ballroom

And in chapter 46, I specially chose this chapter as a test, because the content of this chapter, the protagonist Elizabeth, has a lot of emotional ups and downs, and there are many color changes. From the beginning of interacting with Darcy (happy yellow), to receiving a letter from my sister that my sister is running away with someone, I feel more and more nervous and anxious (from yellow to dark red), and then I want to go out in a hurry But she met Darcy, Darcy comforted her and calmed her down (from red to white), and then when Darcy left, Elizabeth fell into the sadness, fearing that her love with Darcy would never be possible again (from white to blue).

Figure 8.2.11 Changed background color for chapter 46

8.2.5 Prototype implementation

My final iteration is an interactive prototype made by adobeXD to show on the iphone and connect the vibration actuator through a bluetooth speaker.

The reader feels the vibration in real time by grasping the vibrating actuator by hand.

Because the last e-reading device is based on the iPhone, the direct plug-in vibratory actuator cannot be used. Therefore, although the bluetooth-connected vibration actuator is a bit large for the palm of the hand and uncomfortable to hold, this vibration actuator is still selected on the whole.

In terms of cost and user experience, it is best to connect the built-in vibration actuator of the mobile phone in the future, or use a smaller vibration actuator.

Figure 8.2.12 Prototype

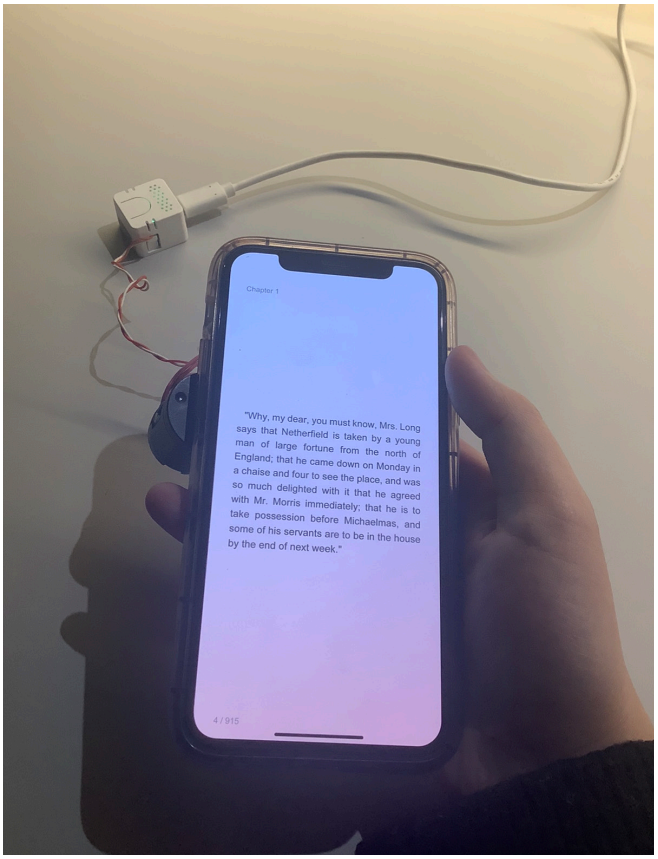
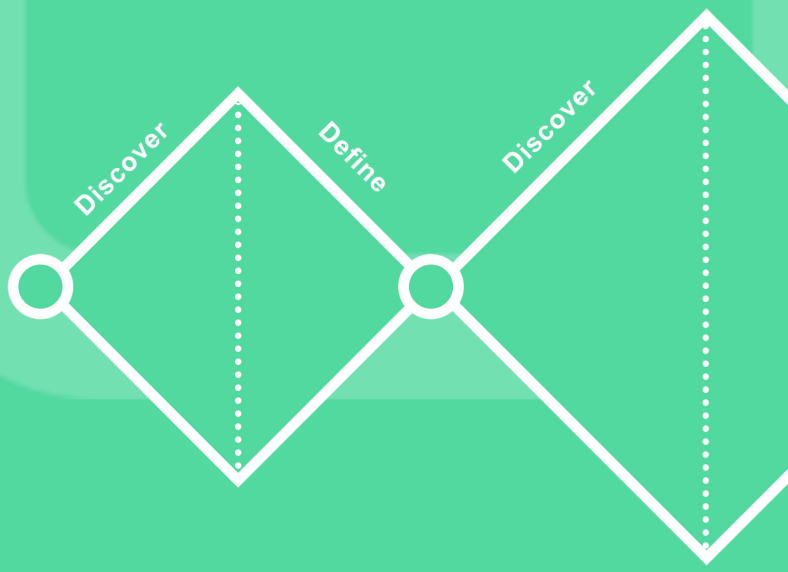


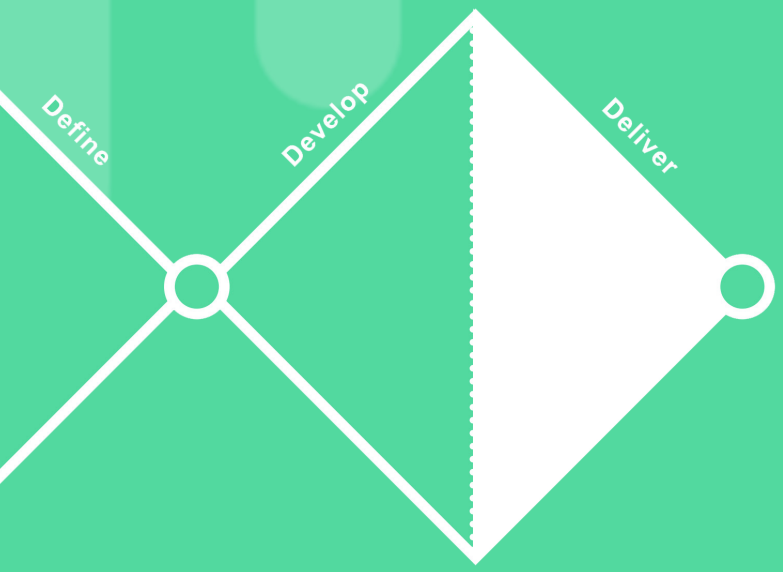
Figure 8.2.13 Hold the prototype

For the final design prototype, I evaluate from 4
optimize the prototype, and the final design.



CHAPTER 9
USER TESTING

angles to get the final modification opinion. And



9.1 Evaluation

9.1.1 Test objectives

The goal of the evaluation test is to evaluate whether my design solution meets the design goals and interaction vision. Due to the limitations of the test conditions, it was not possible to objectively assess whether participants were able to improve their long-term memory of the content with this concept. Beyond that, the following questions should be answered by user testing:

1.Design goal:
How can my concepts help readers have a better reading experience during the e-reading process?
How immersed, focused, and playful do participants feel?

2.Difficulty
In the process of using the prototype, which functions and steps do readers think difficult?

3. Usability
How usable is the concept perceived by participants?

4.Overall desirability
How eager did the participants feel about the concept?
How likely are participants to use this design concept to read?

9.1.2 Test participants

The final test was conducted by 6 participants, aged 20-30, who had read for relaxing and pleasure, had multiple electronic devices, and had a lot of e-reading experience. Four of them had participated in previous user research or prototype tests, and the other two were new participants who had never known about the project before. Details about the participants is shown in Appendix B: Participants information.

9.1.3 Test methods

During user testing, participants were first introduced to the project, including the context and activities they would experience. Participants then tested the final prototype of the mobile app on their phones by completing several tasks, and I observed their actions it to see if they made any mistakes or misunderstandings. The test process details are shown in Appendix K: Final user test task order.

Then, they were asked to rate the design's **difficulty, usability,** and **overall desirability.**

Participants were asked to rate the difficulty of each task. The difficulty of each step in order from 0 (very difficult) to 5 (very easy).
The usability of the concept was assessed using the System Usability Scale (SUS) (Kortum & Miller, 2008). Participants were asked to express "strongly disagree" to "strongly agree" for each usability test question (10 in total) on a scale from 1 to 5. It can differentiate whether the final design is usable on small sample sizes. AttrakDiff (Hassenzahl et al., 2003) is used to measure overall desirability. Participants were asked to scale from -3 to 3 for each assessment question (21 total). Removed pragmatic quality part to avoid overlapping with SUS. The interaction vision (immersed, focused, and playful) in design goals is also included in AttrakDiff.

In addition to the ratings, there was a semi-structured interview to collect user feedback. This section was recorded for analysis. Insights and quotes from each participant were summarized and categorized to help better explore whether the concept could bring readers a better reading experience, as well as to suggest revisions for my final design. Details of the interview questions are shown in Appendix C: Final user test questions.

Observations and interviews were used to collect **qualitative data**. **Rating** was used to collect **quantitative data**.

9.1.4 Test results

Qualitative Data

The important insights and quotes collected from observations and interviews are summarized and summarized as to whether my design achieved my design goals and to what extent I expected interaction vision.

1. Design goal

How immersed, focused, and playful do participants feel?

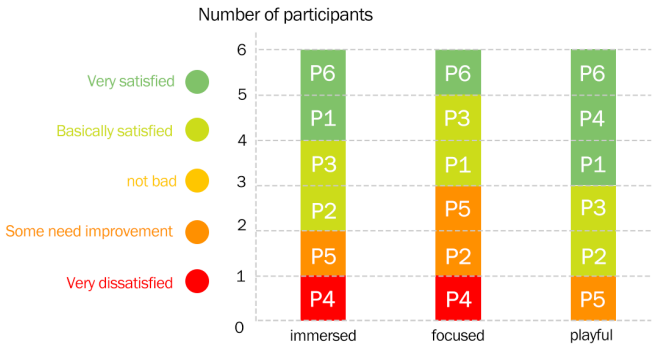


Figure 9.1.1 Rating results for design goal

Immersed

Participants (4/6) felt that the different vibrational frequencies in the app conveyed emotional information and made them more immersed in the story. The change of the background color is matched with the vibration frequency that changes with the situation, providing an immersive reading experience from the visual and tactile senses.

There were also participants (2/6) who felt that it was difficult for them to feel changes in mood during vibrational changes. One participant felt that the change in vibration frequency did not mean much to her, while another participant felt that she could not understand the participation of vibration while reading, and the constant vibration itself was something that would make her feel uncomfortable. .

Only the vibrational frequency changes, and the emotional information conveyed is not rich and accurate enough. Participants can understand that an increased vibrational frequency represents anger, but when the frequency is also increased, but it is intended to express happy emotions, this vibrational change can be misunderstood. In the same way, it also occurs in the sad mood, the frequency is also slowed down, calm and sadness seem to have the same vibration effect. This same vibrational change represents a different emotion and can confuse participants.

In addition, participants (4/6) reported that the increased vibration frequency made them feel that the vibration intensity was also higher, and when the vibration frequency was too fast, the palms would feel numb while holding the vibrating actuator continuously.

Finally, the participants (5 / 6) could feel the emotional information conveyed by the change of background color, and believed that this way provided clues for the change of vibration rhythm. The combination of the two made the emotional transmission more obvious. On each new page, readers can detect subtle changes, strengthening the emotions in the written description.

"Faster vibrations are suitable for themes like war, and have little relevance to romance novels. Why is the vibration faster? I find this connection to emotion very weak."- Participant 4

"Sadness is a little less felt. Feeling like calm?"- Participant 2

"Sometimes the vibration intensity is too high. It made my hands numb."- Participant 5

"Sadness and anger are indistinguishable. The vibration of anger should be fast and heavy, the vibration of sadness should be slow and heavy. Different emotions should be distinguished. Anger and sadness should be distinguished."- Participant 3

'The appearance of red should be somewhat related to the plot. Maybe more nervous? But his mood will not change, but it can convey the meaning of tension in the plot."- Participant 6

Focused

Participants (3/6) felt that a regular vibrational rhythm led them to focus on rhythmic reading. In the short-term test, they thought they would stay focused to keep up with the rhythm of the vibrations while using the app to read. However, for long-term use, whether it is still effective and comfortable, most participants cannot give an answer.

There were also participants (3/6) who felt that vibration did not allow them to focus on reading. One participant (P4) felt that when she was fully immersed in the story, she ignored the vibrational effect and did not read to the vibrational rhythm. Two other participants (P2, P3) believed that the vibration frequency they chose at the beginning could make them focus, but in the later immersive reading mode, the vibration frequency would keep changing and they would not be able to keep up with the vibration frequency.

In addition, participants believed that guiding reading through vibrational rhythm was a process that required learning.

At the same time, it is unreasonable to force participants to read one line per cycle. They will adjust themselves as they read. For example, in a cycle, read from the middle of the previous line to the middle of the next line, not from the beginning to the end of a line.

Finally, the optional vibration frequency can ensure that the reader can read at a relatively constant speed, and it is better to maintain a line of text in one cycle. However, in the immersive reading mode in the back, with the continuous change of the vibration rhythm, it is difficult for readers to read in full accordance with the vibration rhythm.

"Actually I can't keep up with that vibration reading a little bit. I don't know if it's because I'm not a native speaker or what. I usually break sentences at the end of a sentence."- Participant 5

"The function that needs to read a line of words in one vibration cycle needs to be guided, otherwise I don't know. My reading speed is still at my own pace, slowly ignoring the vibration."- Participant 4

"Vibration is not very comfortable at first, but I can find the reading rhythm later and get used to it. It will be slightly slower than normal reading rhythm."- Participant 1

Playful

Participants (5/6) rated the experience of incorporating vibration into the reading process as novel and interesting. They see it as an attempt that has not been seen in previous e-reading processes. Multisensory (a combination of sight and touch) makes reading more fun, interactive, and encourages readers to read.

Only one participant (P5) had a vibrating actuator vibrating in the palm of the hand during the reading process that was not very acceptable. He thinks reading should be a quiet, relaxing process, and vibrations can make him feel irritable and distracting.

Participants indicated that this vibration reading method may be more suitable for some specific fictions, accompanied by illustrations or some pictorial visual elements.

Finally, the participants believed that there could be more than one vibrational rhythm, and different types of novels could have different vibrational rhythms. In addition to this breathing rhythm, there could also be heartbeats, or some natural ones. This may also be a good development direction.

"I prefer the immersive reading mode and find it very interesting."- Participant 1

"I find it really fun to read at a regular rhythm, making sure I don't over-read it, and it feels like I'm singing B-box."- Participant 3

"I would like to experience it for a short time, but I don't know if I will be willing to use it for long-term reading. And this feeling is more suitable for reading fiction, especially some fiction with very large emotional changes and very intense scenes. But declarative Popular science articles are useless. And it's better to have a native language book."- Participant 2

2. Overall desirability

How likely are participants to use this design concept to read?

Most of the participants (4/6) felt that the whole prototype experience process was very good. Improve their reading experience.

It brings a whole new direction to the e-reading process, integrating the tactile experience into reading. At a time when the market is exploring the role of hearing and vision in reading, it provides an unexpected tactile experience. And it is not like the tactile feedback in the game that I have experienced before to transmit concrete information through touch, but to transmit abstract emotional information, which is very good.

At the same time, they believe that the final design is an alternative reading method, but cannot completely replace the current electronic reading application.

And in the future, if I want the design can meet the needs of various types of fiction reading, there should be more changes in vibration. And the vibration actuator should exist in a more natural form, such as a built-in sensor in a mobile phone, or an external comfortable glove.

"It's a direction I never imagined. I tried audiobooks before, using auditory instead of visual storytelling, but it's hard to imagine how to transmit information through touch. It feels like this only happens in Braille reading. So it feels very fresh to experience. ."- Participant 6

"I don't think it's very comfortable for me to hold this actuator to read, it would be better if there was a built-in vibrating actuator."- Participant 1

Regarding the experience of some details, the participants believed that there are more and more accurate vibration actuators in the market, such as the vibration motor in the gamepads, which can vibrate and convey information more accurately and user-friendly.

Participants (3/6) did not perceive this vibrational rhythm as breathing *(see Figure 9.1.2),* they felt that breathing should be more prolonged and relaxed. There should not be only one ups and downs, there should be inhalation, exhalation, and two ups and downs. So sometimes, they can't breathe with the vibrational rhythm.

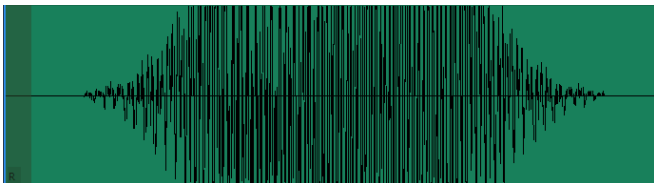


Figure 9.1.2 Original vibration rhythm

Secondly, the vibration frequency should fluctuate within a more reasonable range. Participants believed that in the immersive vibration mode, when the vibration was too slow, it would affect their reading, and when the vibration was too fast, it was difficult to keep up with the rhythm. At the same time, when the vibration is too fast, the vibration intensity will also increase. But when the vibrations are too strong, they are distracted and distressed.

Most of the participants (4/6) really liked the gradient background, believing that it adds to the appeal of the entire app. At the same time, the slight changes between each page are very clever, and the gradients are also very beautiful. And it is a very good idea to use a little color change to imply a change of emotions. But one participant felt that the choice of background color might also need to be scrutinized. The font color stays the same, it's always black, so when the background color gets darker, the black font gets a little blurry. And reading under different background colors, the contrast between the font and the background will be different, and reading for a long time may cause visual fatigue. Also, the background chosen for the scene of "Prom" is too abstract, and some decorative embellishments will make her misunderstood.

"Can I choose the decoration of this background? Can the color remain the same in the mode of self-selecting vibration frequency?"- Participant 3

"The abstract patterns represented by figurative scenes are very different from person to person. It is difficult to unify."- Participant 2

Quantitative Data

Through the participants' scores on the difficulty of using the prototype, usability, and overall desirability, the design details of the entire prototype need to be modified and adjusted.

1. Difficulty

In the process of using the prototype, which functions and steps do readers think difficult?

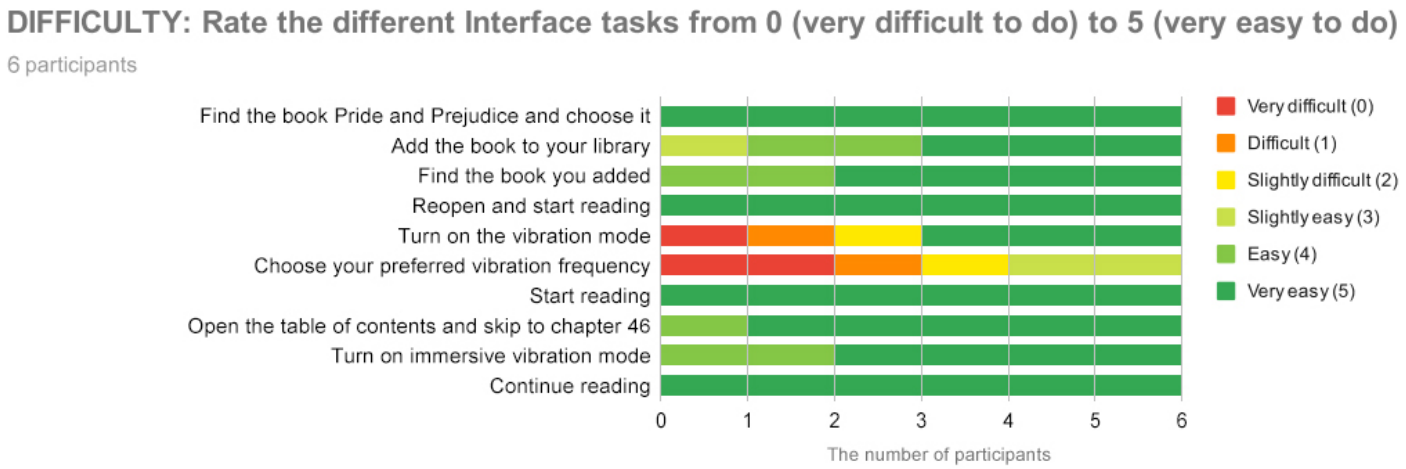


Figure 9.1.3 Rating results for difficulty

Participants were asked to rate the difficulty of each task. It was determined that only 2 tasks (out of 10) were not rated as easy by the participants.

When "Turn on the vibration mode", one participant believed that the gray color means disabling vibration which is the opposite of the original expression of turning on vibration mode. Two participants selected the vibrate button in the tab bar, finding the presence of two vibrating icons puzzling.

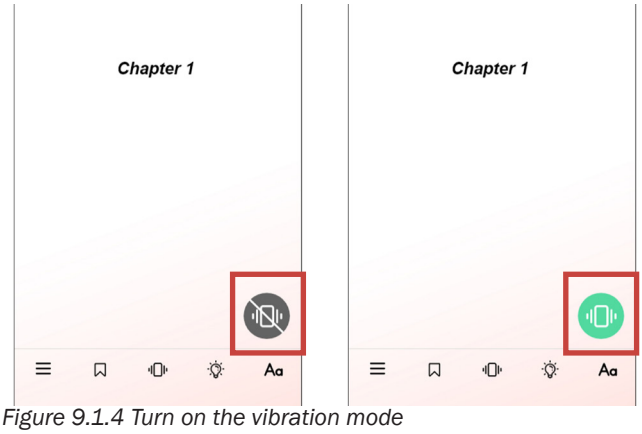


Figure 9.1.4 Turn on the vibration mode

In addition, four participants felt that it was unreasonable to separate the functions of turning on/off the vibration system and adjusting the vibration frequency into two buttons, and it was more logical to have full control of the vibration function through one button.

Finally, five participants believed that the number indicating the vibration speed that appeared above when sliding the slider to select the vibration frequency was meaningless, and when sliding the slider, the vibration did not appear, and they had to click the "use" button to apply it and changes in vibration frequency cannot be sensed in real time.

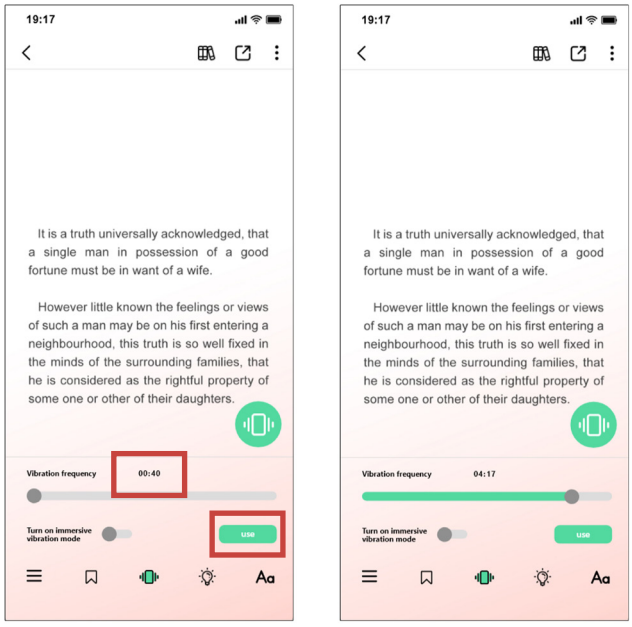


Figure 9.1.5 Choose preferred vibration frequency

2. Usability

How usable is the concept perceived by participants?

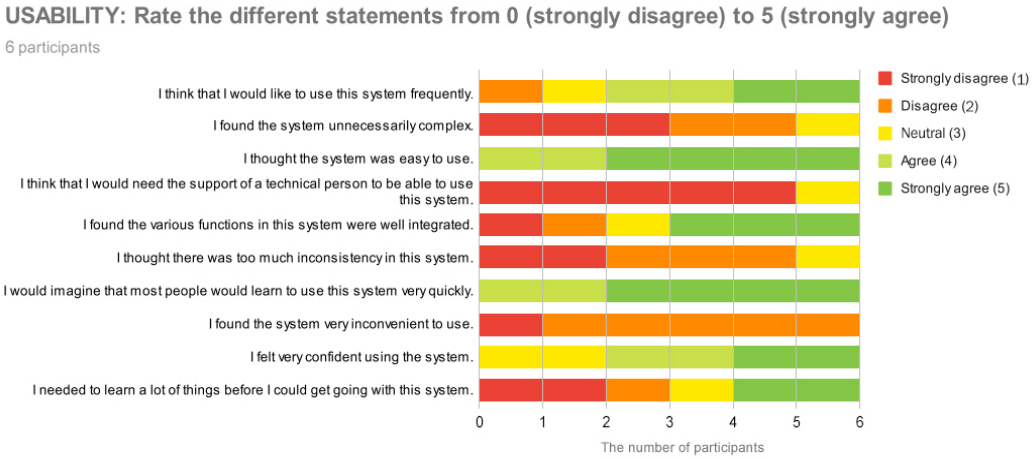


Figure 9.1.6 Rating results for usability

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

Figure 9.1.7 Interpretation of the SUS scores

In the SUS, odd-numbered questions are all in a positive tone, and even-numbered questions in a negative tone. The rationale behind the calculation is very intuitive (T, 2020):

X = Sum of the points for all odd-numbered questions – 5
Y = 25 – Sum of the points for all even-numbered questions
SUS Score = (X + Y) x 2.5

The SUS score was 77.9 (n=6).
The usability of the final iteration can thus be assessed as good.

One of the most dissatisfied participants felt that the integration of functions was not good enough. The self-selected vibration frequency mode wanted readers to focus, and the vibration immersion mode wanted readers to immerse themselves in the story. These two functions should not be placed in the same app.

3. Overall desirability

How eager did the participants feel about the concept?

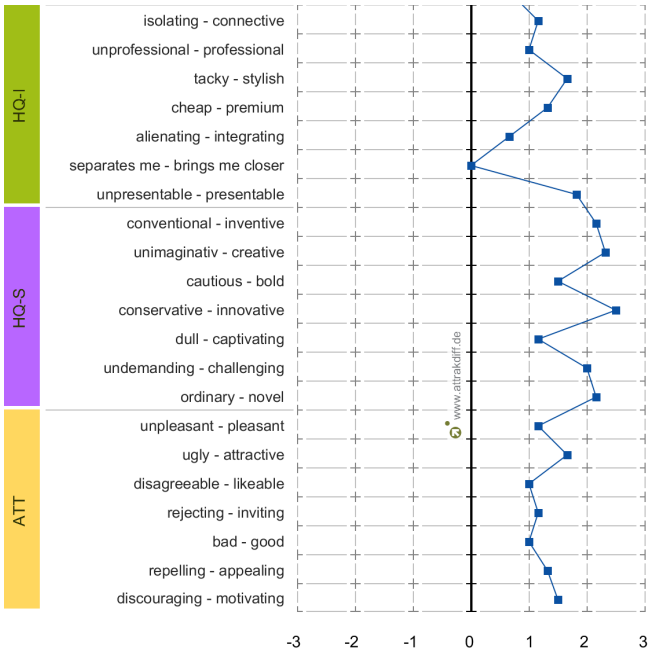


Figure 9.1.8 Results of Attrakdiff

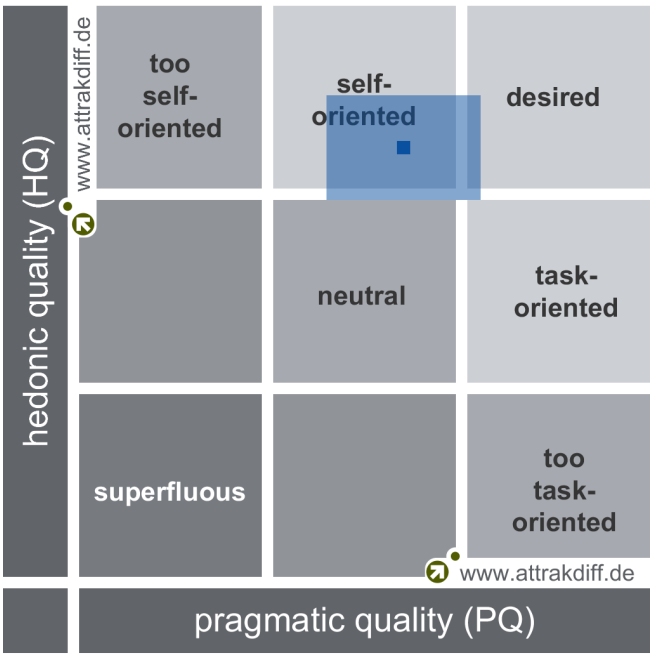


Figure 9.1.9 Results of Attrakdiff

The results of AttrakDiff show that, overall, the final design is located in the "self-oriented" region of the analysis matrix. Overall, the participants were satisfied and willing to try the final design, and its functionality was attractive. But whether it is willing to use it for a long time still needs to be examined.

9.2 Final adjustments

9.2.1 Interface adjustment

From the results of the evaluation of our final concepts with users, a few last adjustments were made to create our final design.

First, **combine** the original the 'Vibration On/ Off 'button and the 'Vibration Mode Selection' button **into one button** *(see Figure 9.2.1)*. Because the user feels that it is not logical to divide the vibration function into two buttons, and it is easy to cause operation errors.

Then, we still retain several advantages of the original interface: users can turn on the vibration mode with one click; users can first note the vibration function from various functions; and users can distinguish whether the vibration mode is on or not by color. On this basis, it has been optimized so that after the users click the vibration mode button, it will directly open the vibration detail adjustment interface.

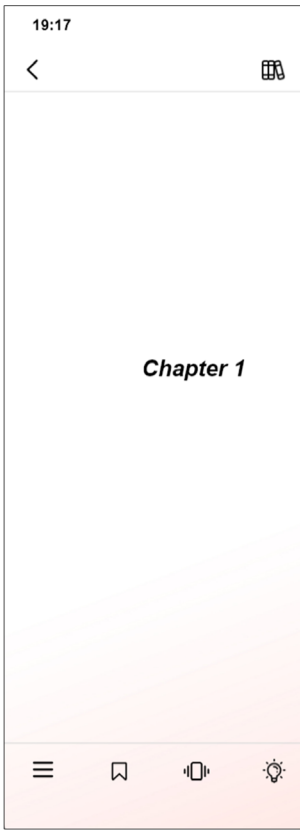
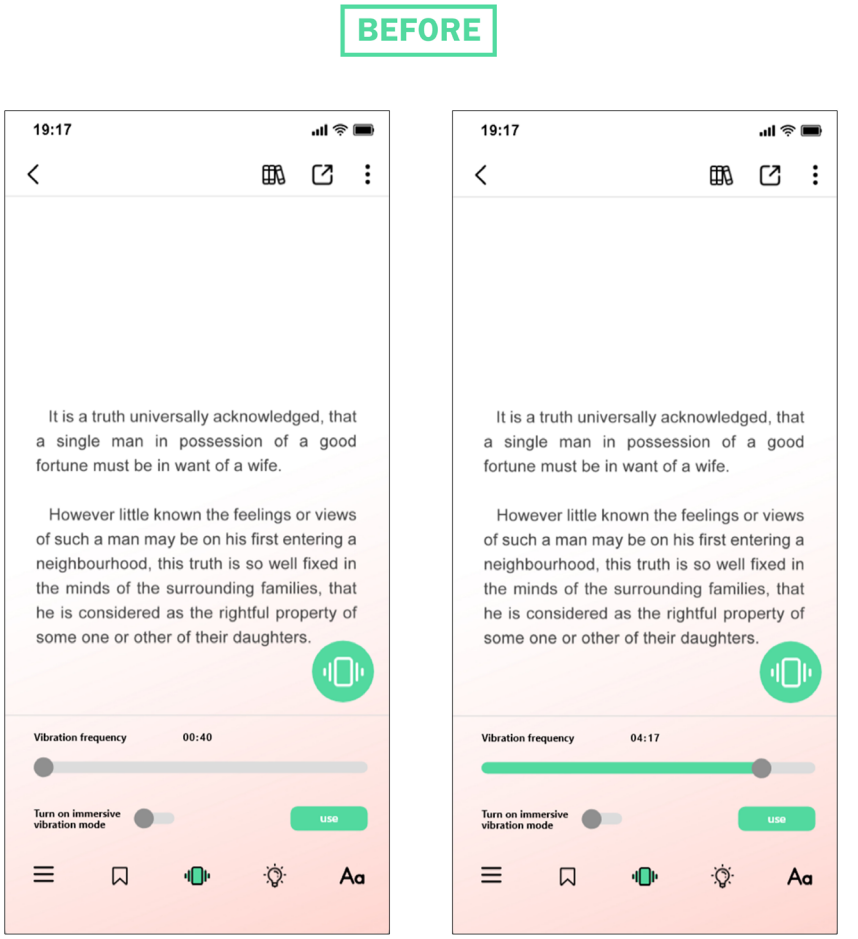
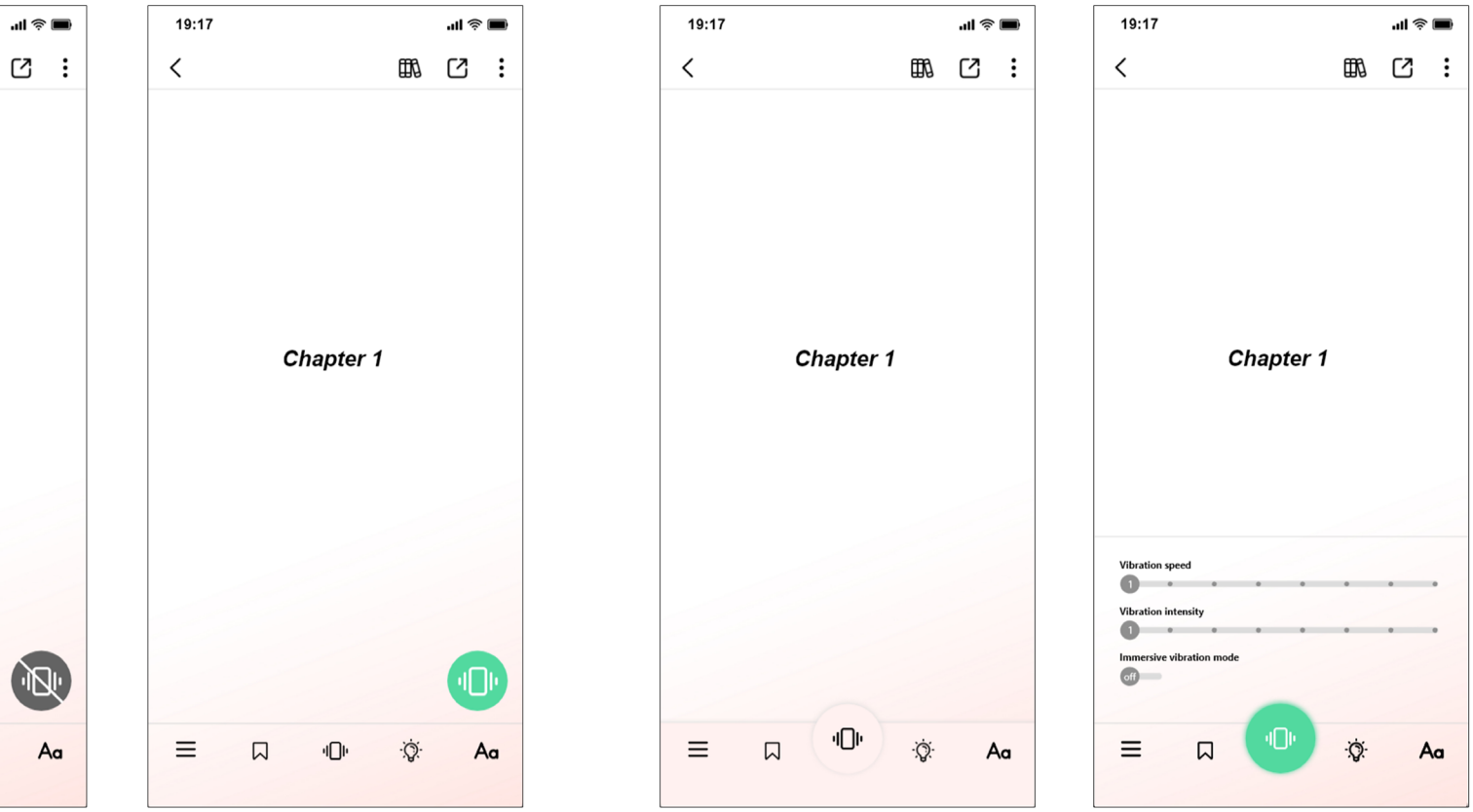


Figure 9.2.1 Adjustment 'vibration' button



BEFORE

AFTER



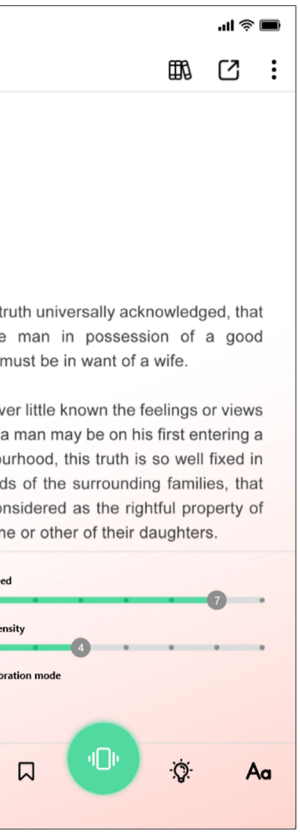


Figure 9.2.2 Adjustment breathing mode interface

In the adjustment vibration mode interface, **delete the 'use' button**, because the users think that the vibration should change when the slider is slid.

At the same time, **delete the number representing the vibration speed**. Because this number has no unit, the users cannot understand what it means. It is more reasonable to directly tell the user whether it is fast or slow. **(eg speed rating)**

Finally, **the vibration intensity (amplitude) is added** as another vibration change criterion, because the user feels that if only a single vibration speed (frequency) change cannot fully express emotions, it is easy to lead to different emotions but the same vibration effect. While there are four different parameters that can affect the vibrotactile information, namely frequency, amplitude, time and location. Frequency and amplitude are the easiest to encode as emotion type and intensity. (Rehman & Liu, 2008)

9.2.2 Vibration rhythm adjustment

Expression design

As mentioned in chapter 9.2.1, in order to transmit emotions more accurately, users can better distinguish the vibration effects of different emotions. I added vibration intensity as a criterion for vibration variation.

In the evaluation, because the vibration effect is only the difference in speed, it is difficult to show a big difference in the face of the current 4 types of emotions (calm, angry, happy, sad) in the prototype. Calm and sad are low frequency vibrations, angry and happy are high frequency vibrations. Users can understand that calm emotions are low-frequency vibrations, and angry ones are high-frequency vibrations, but when they are happy (like when they are angry) it is a high frequency vibration and when they are sad (like when they are calm) it is a low frequency vibration, causing them to misunderstand the emotional expression of the vibration.

So, in the final design, I introduced a circumplex model of emotion *(see Figure 9.2.3)*, which states that all emotional states arise from two fundamental neurophysiological systems, one related to valence (a pleasure–displeasure continuum) and the other to arousal, or alertness (Russell, 1980), while all emotions are linear combinations of these two dimensions,or varying degrees of valence and arousal (Posner et al., 2005). In this recurrent model, the horizontal axis representing the valence dimension and the vertical axis representing the arousal or activation dimension.

I refer to the test results of a robot expressing emotions through vibration (Song & Yamada , 2017), focusing on four emotions, relaxation (positive low arousal), happiness (positive high arousal), sadness (negative low arousal) and anger (negative high arousal). And **the higher the vibration intensity, the more negative emotions it expresses.**

In the end, I use the **vibration intensity** as an expression of **valence**, the more positive emotions, the lower the vibration intensity; the more negative emotions, the higher the vibration intensity. The **vibration speed** is used as an expression of **arousal**, the higher the aroused emotion, the faster the vibration speed; the lower the aroused emotion, the slower the vibration speed.

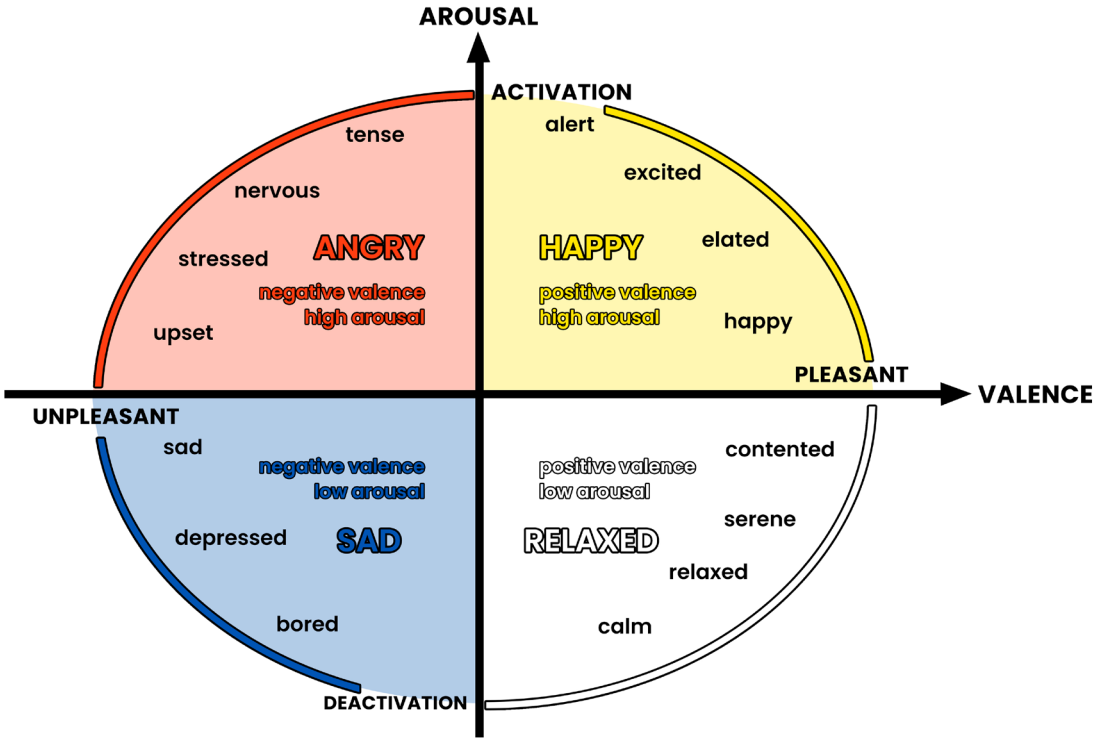


Figure 9.2.3 The circumplex model and the four focusing emotions

Vibration rhythm adjustment

First, I adjusted the vibration rhythm again, and chose one that is closer to the rhythm of breathing fluctuations. Make users feel more immersive. (see Figure 9.2.4)

Then I designed 8 levels of vibration speed and 8 levels of vibration intensity. (see Figure 9.2.5) And in contrast to the final iteration prototype, the lower the level, the lower the speed and intensity. The difference between each vibration intensity level is 4dB; the difference between each vibration speed is 0.6s. In the mode of choosing the vibration effect, the user can adjust the vibration speed and vibration intensity. In the immersive vibration mode, vibration intensity is added to express richer emotions.

According to the article (Pride and Prejudice) paragraph I chose in the prototype: (see Figure 9.2.6)
Chapter 1 From quiet family conversations to disagreements between the Bennets (from low-frequency low-amplitude vibrations to high-frequency high-amplitude vibrations)
Chapter 2 From the heated discussion after the last chapter to Mr. Bennet secretly fulfilling his wife's wish, everyone gets along in harmony, and the family is happy (from high-frequency high-amplitude vibration to high-frequency low-amplitude vibration)
Chapter 3 has little change in emotion, it is always happy, but the degree of happiness is different. (Maintain high frequency low amplitude vibration, but gradually increase the frequency)
Chapter 46, from the very beginning of the relationship with Darcy (maintaining high-frequency low-amplitude vibration), to receiving a letter from my sister saying that my sister ran away with someone, I became more and more nervous and anxious (from high-frequency low-amplitude vibration to high-frequency high-frequency vibration) Amplitude vibrations), then wanted to go out the door in a hurry but met Darcy, Darcy comforted her and calmed her down (maintained high-frequency high-amplitude vibrations, but gradually decreased in frequency and amplitude), and then when Darcy left, Elizabeth Trapped in anxiety, worrying that my love with Darcy will never be possible (middle frequency vibration to low-frequency high-amplitude vibration).

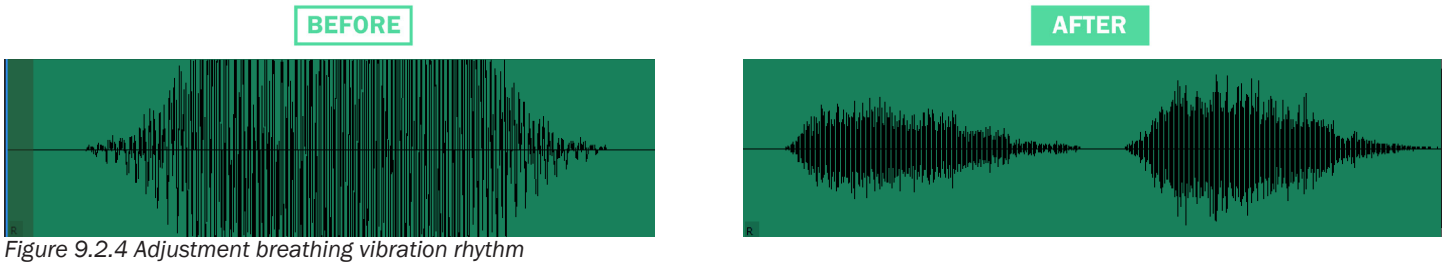


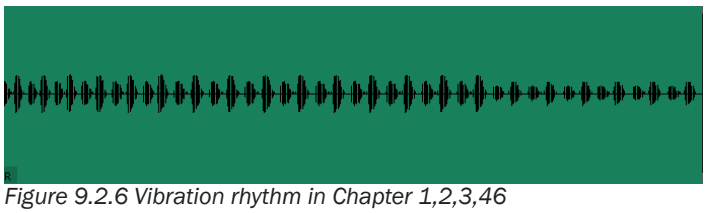
Figure 9.2.4 Adjustment breathing vibration rhythm

Figure 9.2.5 Eight levels of vibration intensity

chapter 1

chapter 2

chapter 3



chapter 46

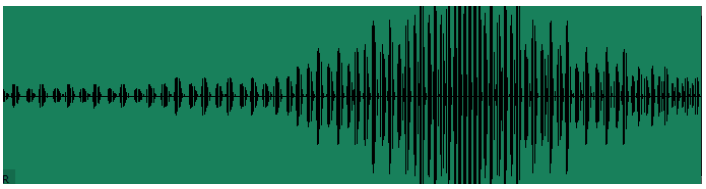
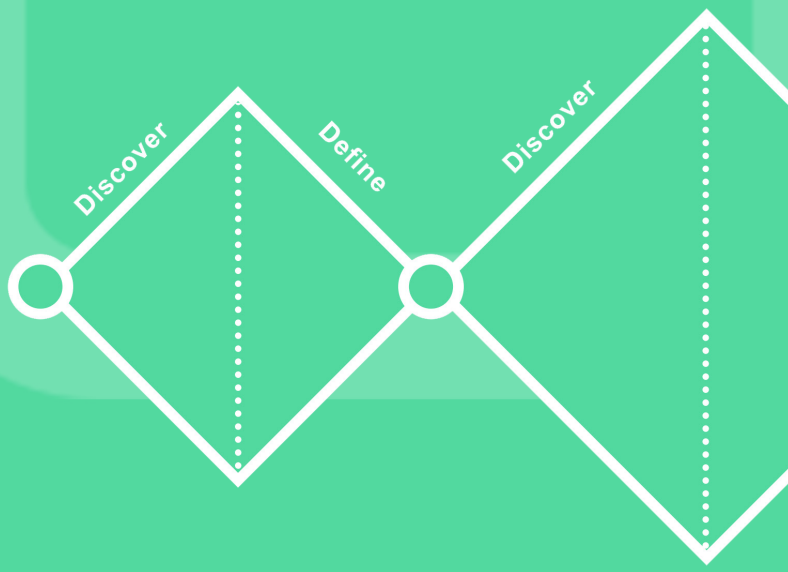


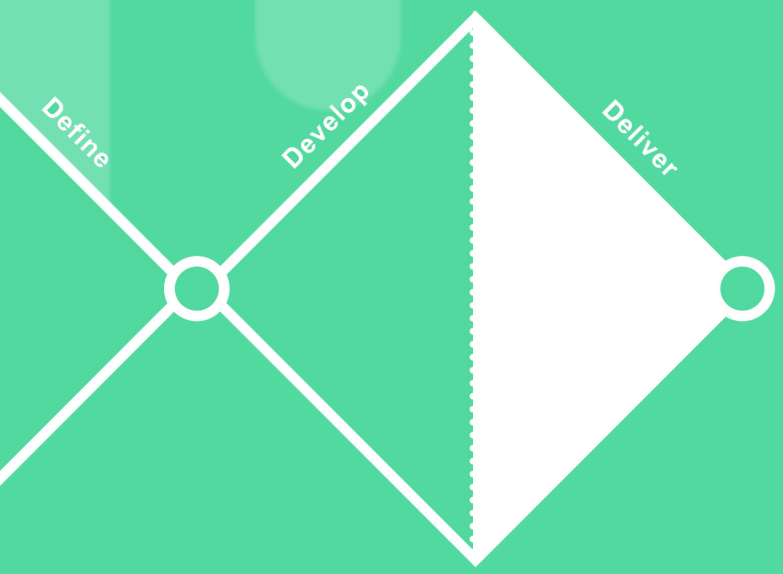
Figure 9.2.6 Vibration rhythm in Chapter 1,2,3,46

After finishing the ideation, I did my first conce
viable concepts were extracted and prototyped
out 10 target users for testing and evaluation, c



CHAPTER 10
FINAL DESIGN

ept iteration. From the brainstorming results, 5
. For the next iteration of the concept, I sought
ollecting their feedback on the five concepts.



10.1 Final concept overview

The final design result of this project is an application with external vibration actuators.

The app is designed to provide young readers with a more interesting e-reading experience, allowing them to enjoy the process of reading novels more focused and immersed, and naturally improve the memory of the content of the story in the process.

The whole application is divided into two parts: searching books part before reading and a browsing content part during reading.

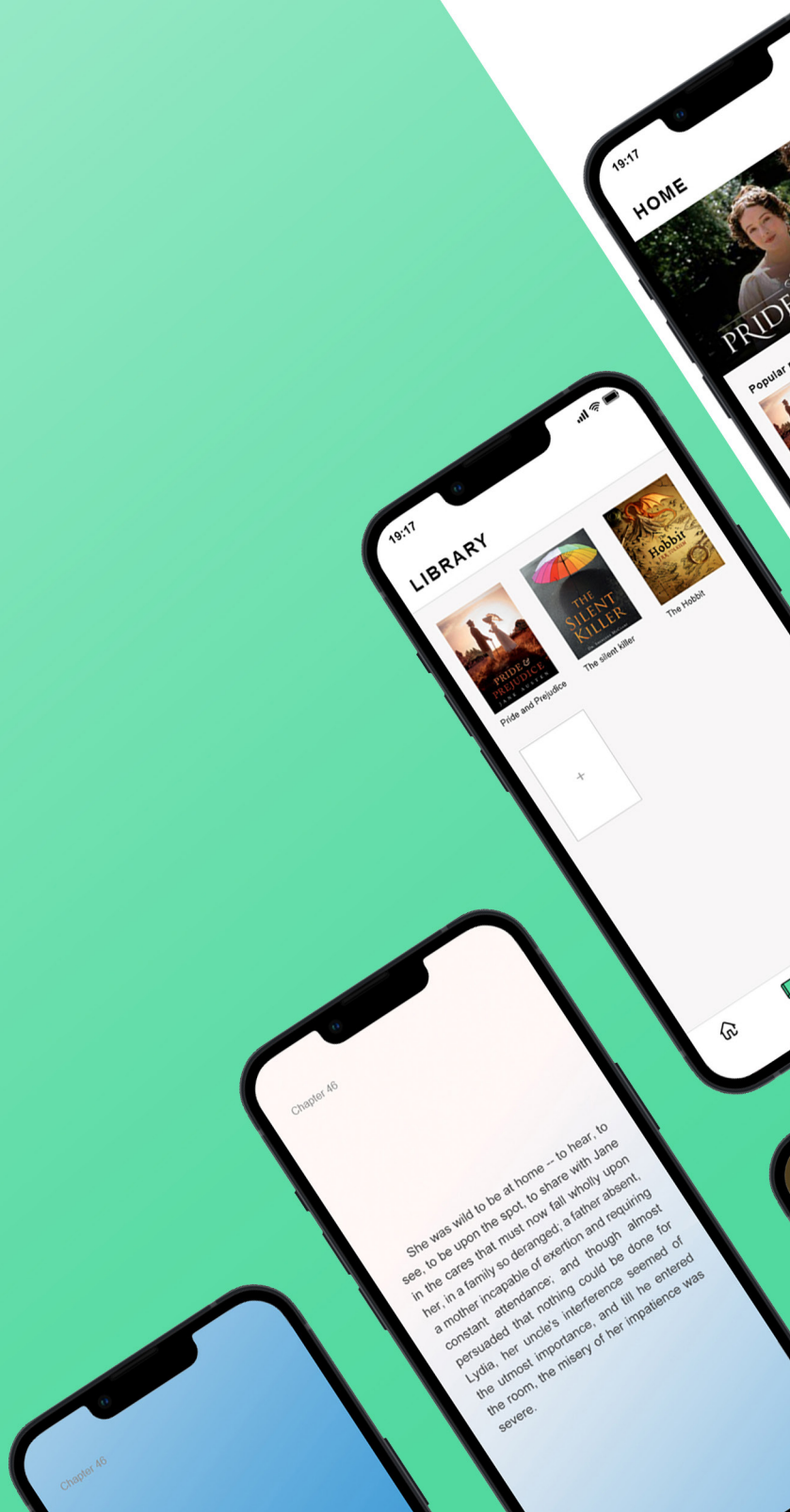
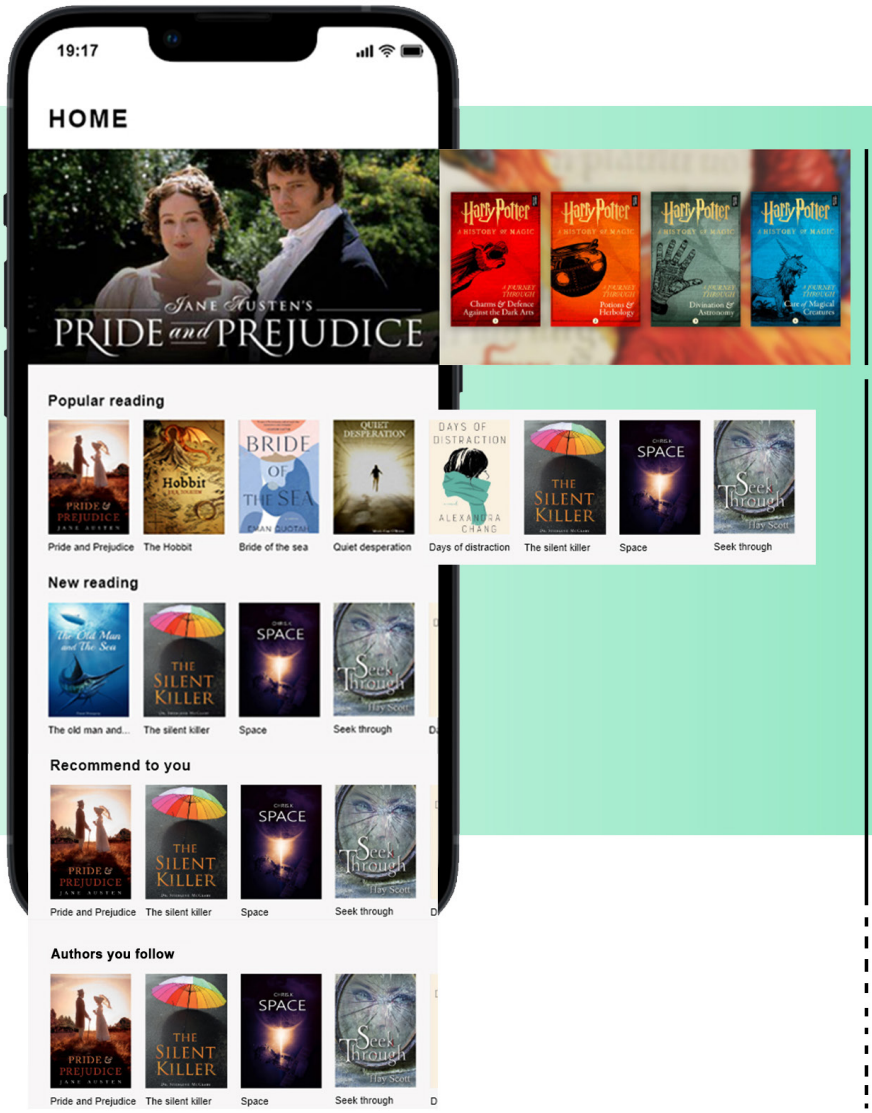


Figure 10.1.1 General overview of the app interface


19:17
Pride and Prejudice
by Jane Austen
British literature
World famous
Bisexual marriage
READ NOW
Recommend to you
New reading
Chapter 3
Chapter 1
Chapter 46
Pride and Prejudice
Chapter 1
Chapter 2
Chapter 3
Chapter 4
Chapter 5
Chapter 6
Chapter 7
Chapter 8
Vibration speed
Vibration intensity
Immersive vibration mode

10.2 Interface —— searching books

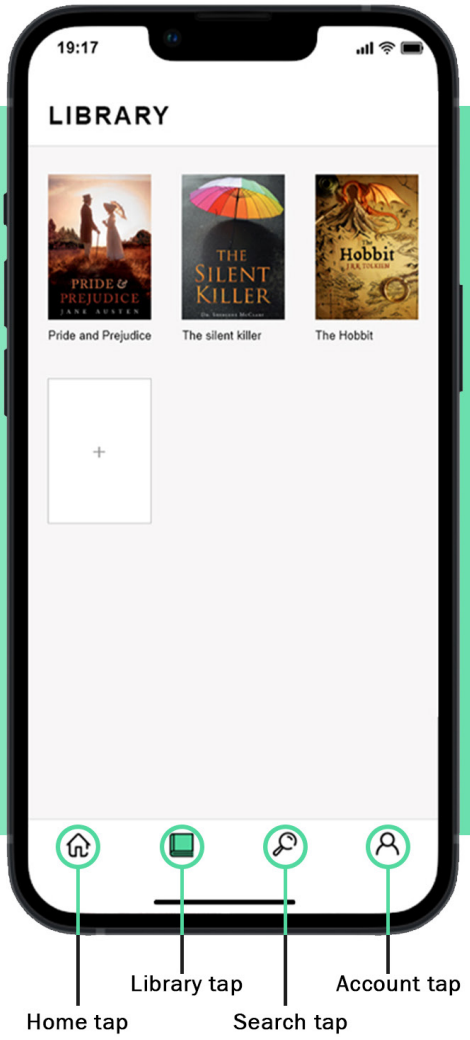


(a)
Home

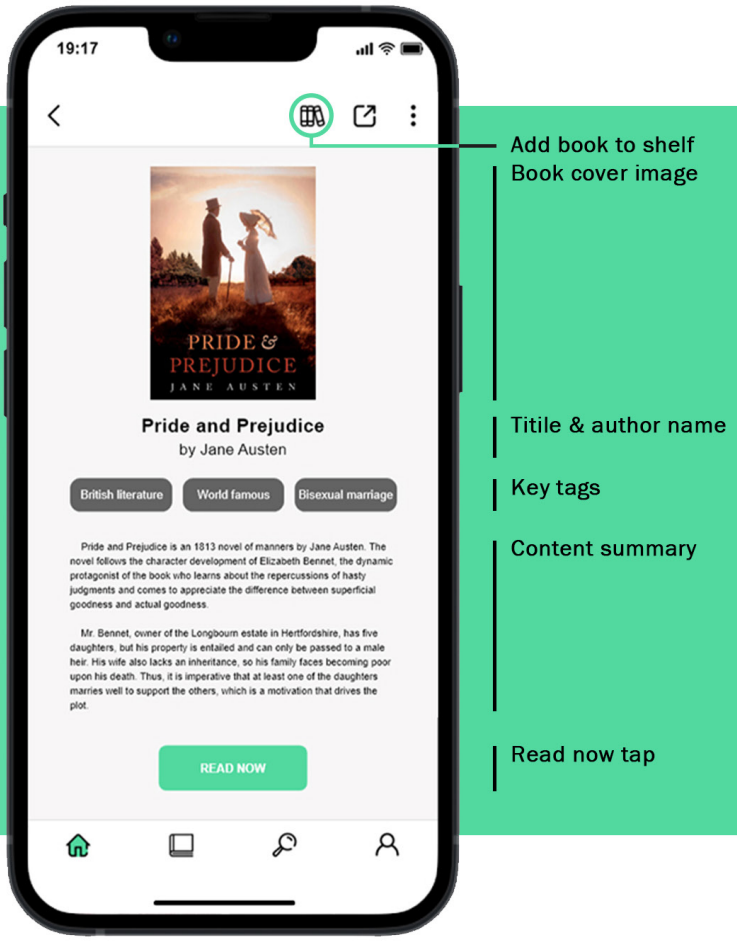
Figure 10.2.1 Searching books page

Like most common e-reading apps, the interface I designed has a basic book recommendation by genre, personal library, search book, and personal information interface. In this process, readers can easily find the book they want to browse, learn the basic information of the book, and finally collect the book they are reading. *(see Figure 10.2.1)*

The login interface of the application is the **home page** (a). Its main function is to recommend different books to readers in different ways and types. There is a recommended banner at the top, and different book posters are used to attract readers to read. Readers can swipe up and down to get books recommended in different ways of popular, new, recommended or following, and swipe left and right to get more books of the same type.



(b)
Library



(c)
Book information

In addition to the home page, the searching books part has 3 functions. The **library page** (b) displays the readers' favorite books, so that readers can quickly find it and retain the previous reading progress when rereading the book. The other two functions, one is the search page, readers can freely search for books by author and title; the other is the account page, where readers can view information about the account.

When the reader clicks on any book, the basic introduction of the book will appear on the **book information page** (c), which includes the title of the book, the name of the author, key tags, and an introduction to the content. In this interface, readers can also quickly add books to their personal library, or share books with friends. Finally, there is an obvious "read" button at the bottom, which is convenient for readers to start reading immediately.

10.3 Interface —— browsing content

10.3.1 Reading mode adjustment interface

Browsing content interface is the focus of my entire project and the biggest feature of the entire application.

There are two **bright spots** in this interface. The first one is the **vibration mode adjustment function** in the reading mode adjustment interface. *(see Figure 10.3.1)*

In this interface, in addition to the same directory function, bookmark function, brightness adjustment function, and font and size adjustment function (a) as the regular e-reading application (common functions refer to chapter 8.2.2), there is also the most important function — vibration mode adjustment function in this project.

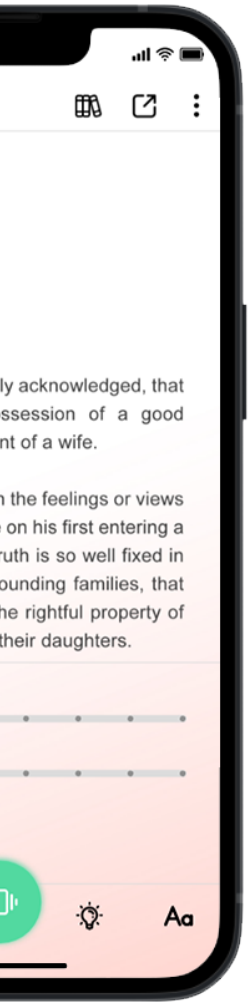
The vibration mode adjustment button is located in the center of the tab bar below the interface, and is highlighted with a circle-shaped button. After the reader clicks, the **vibration mode adjustment interface** (b) will appear, and the vibration mode will be turned on at the same

Figure 10.3.1 Mode adjustment page

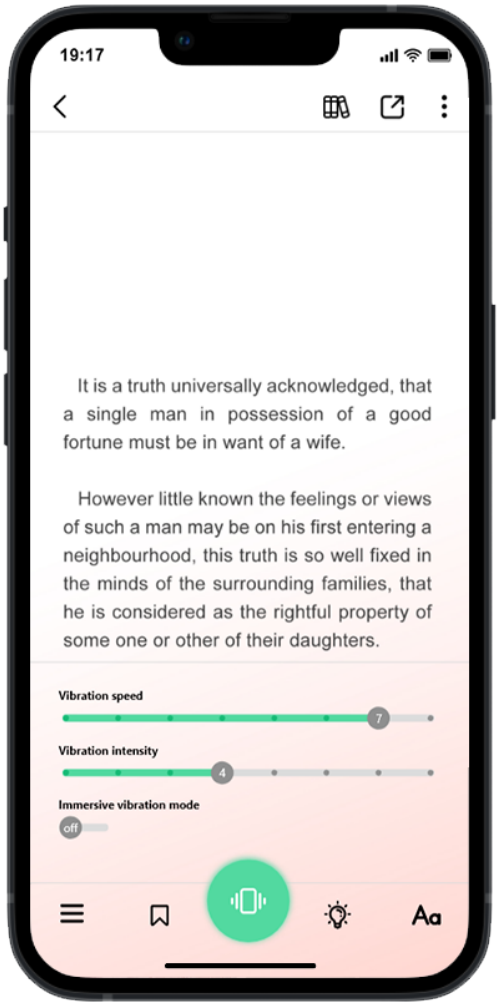
time; and click this button again to turn off the vibration mode. A prominent vibrate button and one-tap to turn vibration mode on and off ensure readers can easily find and use this function. In this interface (b), readers can click to **select different levels of vibration speed and vibration intensity** (c, d). Each vibration level corresponds to the number on the slider to remind the reader of the current vibration effect, and the vibration effect will also change in real time with the reader's click, so that the reader can choose the most suitable vibration effect for them.

At the same time, the reader can also turn on the **immersive vibration mode** (e), then the application will change the vibration speed and intensity based on the vibration effect currently selected by the reader. The purpose is to allow readers to feel the emotional changes represented by the changes in the storyline of the book, the changes in the emotions of the characters, the switching of scenes, etc. through the changes of the vibration effect.

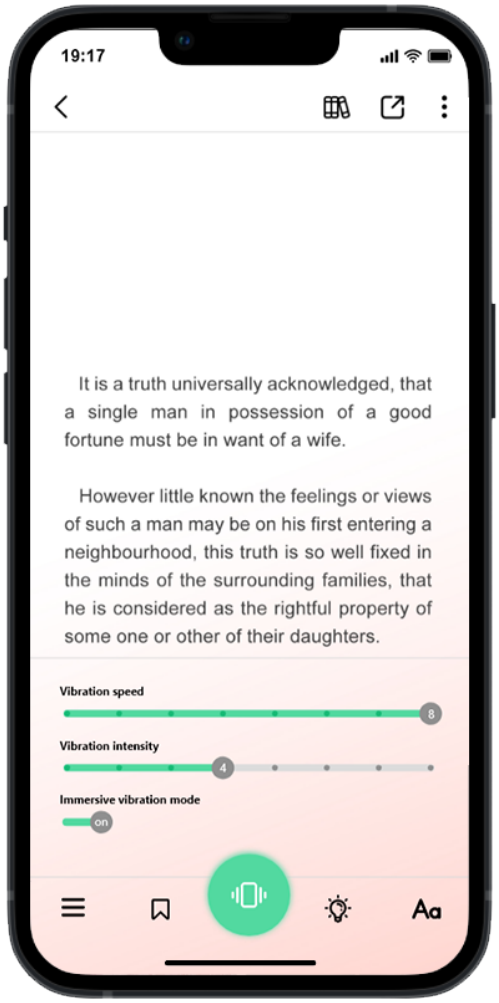
Finally, the entire reading mode adjustment interface is very easy to turn on and off. Just tap the middle of the screen to enter the adjustment mode, and tap the middle of the screen again to exit the adjustment mode and enter the reading mode.



(c)



(d)



(e)

10.3.2 Reading interface

The second highlight on the browsing content interface is that the **background color** in the reading interface **changes with the emotion** of the content. *(see Figure 10.3.1)*

The vibration effect alone is difficult to accurately convey emotions (Song & Yamada, 2017), and some visual or auditory effects are often required. In the evaluation results, users also reported that when the vibration effect changed, the background color also changed, which would make them more able to feel the emotions brought by the vibration.So in the final design I still keep the design of the background color change.

According to the circumplex model of emotion in chapter 9.2.2, I choose to use **white** to

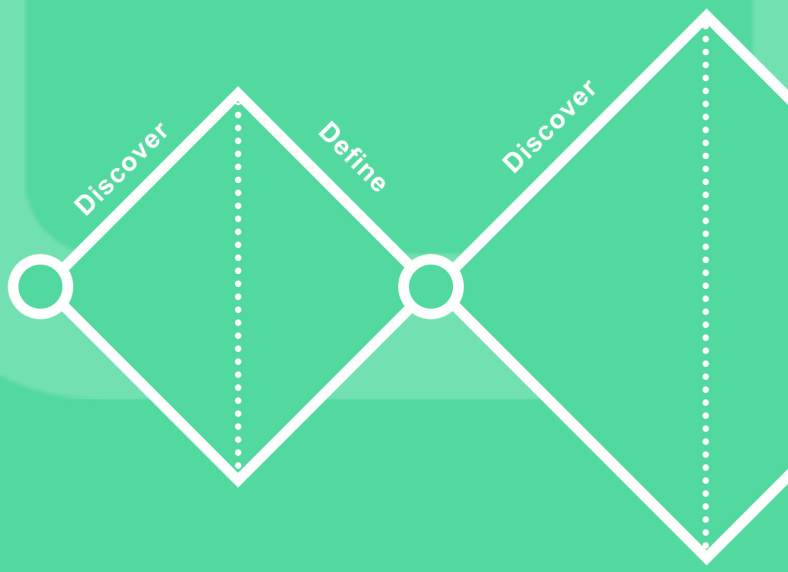
Figure 10.3.2 Reading page

represent relaxed and peaceful emotions, **red** to represent angry and anxious emotions, **blue** to represent sad and depressed emotions, and **yellow** to represent happy emotions , excitement. At the same time, I designed these background color changes as **gradient effects** to ensure that the changes of each page will not be very sudden, and there will not be a sudden big difference in color between each page. At the same time, for some key scene transitions, I choose to use **abstract shapes and corresponding color schemes** to represent them, instead of using figurative images and similar illustrations as the background, so as to avoid the reader's attention being too transferred to the background.

The paging method in the final iteration is retained in the final design, so the text length of each page varies, but it is controlled within a reasonable range - between 6 and 16 lines. When the immersive vibration mode is turned on, the vibration effect of each page remains stable, and a refurbished page may have some changes in the vibration effect, but each change will not be too large (the change in the vibration speed does not exceed 0.6s/cycle, and the vibration The change in intensity does not exceed 4dB), ensuring that the reader will not be startled or disturbed by the sudden change of vibration effect.

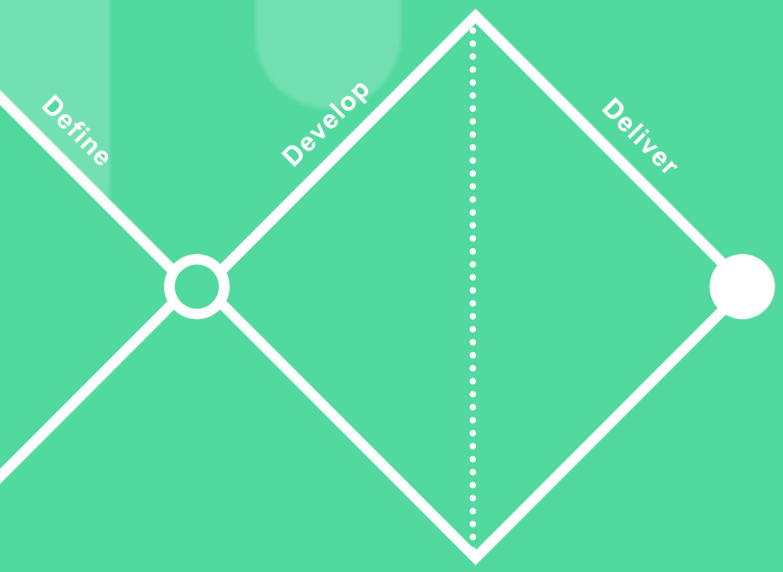
CONCLUSION &

Summarize the final design of the design go
limitations of the project, which can improve
possibility of future development.



CHAPTER 11
RECOMMENDATION

pals and interaction vision, and propose the
the plan, possible application areas and the



11.1 Conclusion

To evaluate the results of this project, I reviewed my design goals - to improve the readers' e-reading experience and the long-term memory of the content through haptic technology.

Except that because of the limited testing conditions, it is impossible to objectively measure whether participants can improve long-term memory of the content through my concept,
My design goals and desired interaction vision were initially realized. Most participants felt that my design created an immersed, focused, playful e-reading experience.

Immersed

With the scene switching, the vibration effect and background color that change with the characters' emotions can make readers feel emotional information, and provide multi-sensory perception, immersing them in the story situation. Different vibration speeds and intensities give readers different haptic feelings, and it has also been proven to arouse readers' emotional perceptions.

Focused

The regular vibrating rhythm guides the reader to concentrate and read at an even pace. Readers choose the vibration frequency to determine the vibration speed that suits their reading habits, and read at an average speed below this speed to ensure that readers will not be distracted or reread during the reading process. This improves their reading concentration. Subjectively, readers recognize that by increasing focus, the long-term memory of the content is improved. However, no objective memory ability tests have been conducted, so there is no definitive answer to the goal of whether this concept can improve long-term memory by getting readers to focus on reading.

Furthermore, the vibrational rhythm of "breathing" can indeed make readers focused, but whether there is a more suitable vibrational rhythm remains to be explored.

Playful

Incorporating haptic technology into reading is a very interesting and fresh attempt. Readers' feedback on the vibration application in reading is mixed. Some people feel that it will make their reading process more playful, and some people can't adapt to the vibration effect when reading. Choosing vibrotactile feedback as the haptic technology for this project really brings more fun and multi-sensory experience to readers.

Summary

Overall, the participants liked the concept. They are willing to try this e-reading with vibrotactile feedback. However, when using it for a long time, whether the reading experience is still as good as the test stage remains to be verified.

This project is generally an attempt to use haptic technology in the electronic reading process, and it has also been confirmed that haptic can transmit emotional cognition during the reading process and improve readers' immersion and concentration. The application of haptic in reading is worth further exploration.

11.2 Limitations

Prototype completion

Book in prototype

First of all, because I only made and tested the final design based on the book "Pride and Prejudice", although the choice of this book is based on chapter 5, in different novels, the effect of emotional transmission and vibration must be different. What's more, even for this book, I only made chapters 1, 2, 3 & 46 (the chapter with the most obvious emotional changes and the most emotional changes), whether this design can be applied to all types of novels remains to be tested.

Haptic technical conditions

The haptic element in the prototype is composed of ATOM Echo speaker and Foster vibration actuators. Its function is to convert music into vibration signals, but its vibration effect is more direct and simple, and it cannot simulate more vibration effects. When the project itself needs to transmit figurative information (concept in the first iteration) and emotional information (final design) through vibration, it will not be able to achieve a more precise effect due to the limitations of the vibrator itself.

Validity of test results

Participant's limitations

In the whole project, whether it is the preliminary user research, the mid-term iterative test or the final evaluation test, the participants are students from Delft University of Technology or friends who have a similar educational background with me and have experience in e-reading. Their educational background may affect their perception of the entire archetype and their receptivity to new ways of reading.

Secondly, it is the number of participants. I have found about 10 people in the research and iterative testing process, but the number of people is too small for both qualitative and quantitative research, which also leads to certain deviations in the test results.

Time limit

Both iterative testing and evaluation testing are done in a short period of time. But whether it is the reading experience in the design goal or the effect of long-term memory is a long-term process. For almost all the testers, it is the first time to use the tactile experience to read, which is a new experience for them, which may lead them to have a more positive evaluation of it, but it is also possible that they are not used to it. tactile experience, which resulted in poor reviews. As for whether touch can improve long-term memory, a very scientific, objective, and long-term testing process is required. However, due to the limitation of time and testing methods, the quantitative test results for the improvement of long-term memory are very lacking. I can only learn from some Possibilities derived from subjective questions.

About the application of haptic technology

First of all, about the sense of touch, especially the application of vibrotactile in reading is less, mostly Braille reading, or some children. So haptic applications in reading are a relatively unknown area. For me, how to choose the right haptic technology and how to apply it in the reading process is a very challenging thing. In addition, most of the haptic elements are still in the experimental stage or expensive, so there are also great limitations in the choice of haptic technology.

Secondly, for most readers, they have almost never experienced the application of vibration in the reading process, and it is quite different from the general reading experience, and other senses are also involved in this process, so in the test process these senses The resulting impact also affects the test results, not all of which are haptic. So this is also worth exploring and verifying again.

11.3 Recommendations

Prototype improvements

Use the phone's built-in vibration actuator

My final design prototype is still to choose an external vibration actuator, but in the actual ideal, I want the vibration actuator to be built-in. No need to hold or wear other equipment. However, because the currently known audio-to-vibration signal application - Lofelt Studio is no longer in operation, only external actuators can be selected. So in the future, if there are other thinner, portable vibration actuators, or applications that can automatically recognize audio files and convert them into vibration signals with built-in vibration actuators, the concept prototype will be improved.

Explore more vibration effects

In the final prototype, the vibration effect I chose was based on an audio file of a breath, and on top of that, the volume and playback speed were adjusted to achieve different vibration intensities and vibration speeds. Based on breathing, it is hoped that the user's breathing rhythm can resonate with vibration in order to convey emotional information. However, whether there are other vibrational effects that can better achieve emotional arousal and maintain focus still needs more exploration.

Potential applications

This project is currently an independent e-reading application, which focuses on the vibration function, bringing readers a different multi-sensory reading experience.

In the future, this project can be combined with traditional e-reading applications and integrated into one of the functions to ensure access to book resources.

It can also cooperate with some innovative e-reading applications, such as Immer mentioned in chapter 1.1.1, which displays the page-turning effect through color changes and sound effects, so it is possible to achieve a multi-sensory reading experience of sight, hearing and touch , and also add sound effects to convey emotional information; or combine with audiobooks, allowing readers to perceive emotions through vibration while "listening to the book".

Finally, it can also cooperate with public libraries, so that reading not only stays on the mobile phone interface, but also becomes an interactive space. For example, in the reading room of the library, readers are provided with wearable vibration actuators, and then read and perceive the emotional feelings brought by vibration touch.

Future possibilities

Exploration of other haptic technologies

As I mentioned in chapter 2.1.4, vibrotactile is far less informative and accurate than haptic. But because haptic components can transmit real and accurate information requires very high standards of actuators and programming. These haptic component technologies are either immature or too expensive to obtain. So in this project I did not consider the tactile sensory direction. So I chose to let haptic convey abstract information such as emotions, rather than concrete information. But if the technology matures and the price decreases in the future, I believe there will be more ways to use the tactile senses to improve the reading experience and long-term memory, such as:

Combine with VR and AR technology to realize immersive reading experience
Play as a story character and perceive through touch
Understand the background of the story through 4D animation

Simulate the experience of using a printed book

In the design brief, I proposed 4 directions for thinking about vibrotactile applications. Both of them hope to use touch to simulate real printed books, touch behaviors and memory skills when people read printed books. But also because of the choice of vibrotactile, the test results in these two directions are

not satisfactory. But if other tactile senses are added, not only these two directions are possible, but also a more effective way of reading may be brought about by touch on this basis, such as:

Simulate the friction of paper when flipping a book.
Simulate the touch feeling of real writing.
Highlight keywords by changing friction.
Interpret unknown words through touch, hearing, and vision.
Learn and read expertise by touching virtual 3D models.

REFERENCES

199it Chinese Internet Data Information Network.(2022, April 23). China Academy of Press and Publication: The 19th National Reading Survey in 2022. http://www.199it.com/archives/1423794.html

199it Chinese Internet Data Information Network.(April 21, 2017). Amazon: 2017 China Reading Survey, the richer you are, the more you love to read. http://www.199it.com/archives/584966.html

Naomi, S. B.(May 9, 2021). Why do we remember more by reading in print vs. on a screen? https://bigthink.com/neuropsych/reading-memory/

Hermans, M.(October 12, 2021).KB Onderzoekskroniek: De toekomst van taal is vloeibaar. https://informatieprofessional.nl/kb-onderzoekskroniek-de-toekomst-van-taal-is-vloeibaar/

Israr, A., Zhao, S., Schwalje, K., Klatzky, R., & Lehman, J. (2014). Feel effects: enriching storytelling with haptic feedback. https://dl.acm.org/doi/abs/10.1145/2641570

Rath J. H. (2013). The effects of visuo-haptic presentation on memory. http://hdl.handle.net/10211.3/10211.4_552

Forsberg, A., Guitard, D., & Cowan, N. (2021). Working memory limits severely constrain long-term retention. https://doi.org/10.3758/s13423-020-01847-z

Design Council. (September 10, 2019). What is the framework for innovation? Design Council's evolved Double Diamond. https://www.designcouncil.org.uk/news-opinion/whatframework-innovation-design-councils-evolved-double-diamond

Yang, Y., Li, D., Cui, Q., & Jiang, Z. Q. (July 13, 2022). Affective function of touch and the neurophysiological mechanism. https://doi.org/10.3724/SP.J.1042.2022.00324

Jean, A.D.L., Stack, D.M. (2007). Functions of maternal touch and infants' affect during face-to-face interactions: New directions for the still-face. https://doi.org/10.1016/j.infbeh.2008.09.008

Zhang, S., Wang, D., Afzal, N., Zhang, Y., & Wu, R. (2016). Rhythmic Haptic Stimuli Improve Short-Term Attention. https://doi.org/10.1109/TOH.2016.2531662

Novak, M., Phelan, S., Lewalter, D., & Schwan, S. (2020). There is more to touch than meets the eye: haptic exploration in a science museum. https://doi.org/10.1080/09500693.2020.1849855

Vi, C.T., Ablart, D., Gatti, E., Velasco, C., & Obrist, M. (2017). Not just seeing, but also feeling art: Mid-air haptic experiences integrated in a multisensory art exhibition. https://doi.org/10.1016/j.ijhcs.2017.06.004

Stein, B. E., Stanford, T. R., & Rowland, B. A. (2009). The neural basis of multisensory integration in the midbrain: its organization and maturation. Hearing research, 258(1-2), 4–15. https://doi.org/10.1016/j.heares.2009.03.012

Spence, C. (2021). Multisensory contributions to affective touch. https://doi.org/10.1016/j.cobeha.2021.08.003

Rath, J. H. (2013). The effects of visuo-haptic presentation on memory. http://hdl.handle.net/10211.3/10211.4_552

Bara, F., Gentaz, E., Colé, P., & Sprenger-Charolles, L. (2004). The visuo-haptic and haptic exploration of letters increases the kindergarten-children's understanding of the alphabetic principle. https://doi.org/10.1016/j.cogdev.2004.05.003

Lacey, S., Tal, N., Amedi, A., & Sathian, K. (2009). A putative model of multisensory object representation. Brain Topography, 21, 269-274. https://doi.org/10.1007/s10548-009-0087-4

Sanchez, S., Dingler, T., Gu, H., & Kunze, K. (07 May 2016). Embodied Reading: A Multisensory Experience. https://doi.org/10.1145/2851581.2892353

Yannier, N., Israr, A., Lehman, J. F., & Klatzky, R. L. (2015). FeelSleeve: Haptic Feedback to Enhance Early Reading. https://doi.org/10.1145/2702123.2702396

Heibeck, F., Hope, A., & Legault, J. (2014) . Sensory Fiction: A Design Fiction of Emotional Computation. https://doi.org/10.1145/2660579.2660585

Webb, M., Tracey, M., Harwin, W. et al. (2022). Haptic-enabled collaborative learning in virtual reality for schools. https://doi.org/10.1007/s10639-021-10639-4

Cingel, D., Blackwell, C., Connell, S., & Piper, A M. (2015). Augmenting children's tablet-based reading experiences with variable friction haptic feedback. https://doi.org/10.1145/2771839.2771900

Bau, O., Poupyrev, I., Israr, A., & Harrison, C. (2010). TeslaTouch: electrovibration for touch surfaces. https://doi.org/10.1145/1866029.1866074

Wang, Q., Ren, X., & Sun, X. (2016). EV-pen: an electrovibration haptic feedback pen for touchscreens. https://doi.org/10.1145/2988240.2988241

Rubin, J. (2016). What is haptics, really? Part 1: tactile feedback & Part 2: vibrotactile (vibration) feedback. https://www.linkedin.com/pulse/what-haptics-really-part-1-tactile-feedback-jake-rubin/

Hinchet, R., Vechev, V., Shea, H., & Hilliges, O. (2018). DextrES: Wearable Haptic Feedback for Grasping in VR via a Thin Form-Factor Electrostatic Brake. https://doi.org/10.1145/3242587.3242657

Kim, S., Park, G., Yim, S., Choi, S., & Choi, S. (2009) Gesture-recognizing hand-held interface with vibrotactile feedback for 3D interaction. https://doi.org/10.1109/TCE.2009.5277972

Endow, S., Moradi, H., Srivastava, A., Noya, E. G., & Torres, C. (2021). Compressables: A Haptic Prototyping Toolkit for Wearable Compression-based Interfaces. https://doi.org/10.1145/3461778.3462057

Maeda, T., & Kurahashi, T. (2019). TherModule: Wearable and Modular Thermal Feedback System based on a Wireless Platform. https://doi.org/10.1145/3311823.3311826

Jain, D. (2021). A Study on Readers' Preference between Physical Books and E-books in Indore City. https://jusst.org/wp-content/uploads/2020/11/A-Study-on-Readers-Preference-between-Physical-Books-and-E-books-in-Indore-City-1.pdf

Sage, K., Augustine, H., Shand, H. et al. (2019). Reading from print, computer, and tablet: Equivalent learning in the digital age. https://doi.org/10.1007/s10639-019-09887-2

Jeong, Y. J., & Gweon, G. (2021). Advantages of Print Reading over Screen Reading: A Comparison of Visual Patterns, Reading Performance, and Reading Attitudes across Paper, Computers, and Tablets. https://doi.org/10.1080/10447318.2021.1908668

Baron, N.S., Calixte, R.M., Havewala, M. (2017). The persistence of print among university students: An exploratory study. https://doi.org/10.1016/j.tele.2016.11.008

Sharma, L. R. (2020). Examining Education Students' Preference for Reading Medium, Resource and Time. https://doi.org/10.3126/irjmmc.v1i1.34116

Soroya, S. H., Rehman, M. A., Tariq, I., Khanum, A., & Bashir, F. (2022). E-reading consumption among Pakistani digital immigrants: A mixed-methods approach. https://doi.org/10.1177/01655515211061868

Zhang, Y., & Kudva, S. (26 February, 2014). E-books versus print books: Readers' choices and preferences across contexts. https://doi.org/10.1002/asi.23076

Nazhari, Hafiz A., et al. "A Study On English Reading Habits Of Students Of English Study Program Of Riau University." vol. 3, no. 2, Oct. 2016, pp. 1-8.

Z. S. Alsaeedi, N. B. M. Ngadiran, Z. A. Kadir and W. A. H. Altowayti, "An Overview of Reading Habits and Medium Preference Among University Students," 2021 International Congress of Advanced Technology and Engineering (ICOTEN), 2021, pp. 1-5, doi: 10.1109/ICOTEN52080.2021.9493486.

Foasberg, N. (2014). Student Reading Practices in Print and Electronic Media. doi:https://doi.org/10.5860/crl.75.5.705

Nilsson, S. K. (2016). Young Adults in Sweden on Reading Literary Fiction in Print and Electronic Media. https://doi.org/10.7771/1481-4374.3140

Rubin, G. S. (2013). Measuring reading performance. https://doi.org/10.1016/j.visres.2013.02.015

Spence C. (2020). The Multisensory Experience of Handling and Reading Books. https://doi.org/10.1163/22134808-bja10015

Alam, K. M., Mahfujur Rahman, A. S. Md., & Saddik, A. El. (2011). HE-book: A prototype haptic interface for immersive e-book reading experience. doi: 10.1109/WHC.2011.5945514.

Kaufman, G., & Flanagan, M. (2016). High-Low Split: Divergent Cognitive Construal Levels Triggered by Digital and Non-digital Platforms. https://doi.org/10.1145/2858036.2858550

Mangen, A., Walgermo, B.R., Brønnick, K. (2013). Reading linear texts on paper versus computer screen: Effects on reading comprehension. https://doi.org/10.1016/j.ijer.2012.12.002

Baron, N. S. (MAY 9, 2021). Why do we remember more by reading in print vs. on a screen? https://bigthink.com/neuropsych/reading-memory/

Mangen, A., & Schilhab, T. (2012). An embodied view of reading: Theoretical considerations, empirical findings, and educational implications. Skriv, 285-300.

Singer, L. M., & Alexander, P. A. (2017). Reading Across Mediums: Effects of Reading Digital and Print Texts on Comprehension and Calibration. https://doi.org/10.1080/00220973.2016.1143794

Bold, M. R., & Wagstaff, K. L. (2017). Marginalia in the digital age: Are digital reading devices meeting the needs of today's readers? https://doi.org/10.1016/j.lisr.2017.01.004

Liesaputra, V.,& Witten, L. H. (2012). Realistic electronic books. https://doi.org/10.1016/j.ijhcs.2012.02.003

Marshall, C., & Brush, A. J. (2002). From Personal to Shared Annotations. https://www.microsoft.com/en-us/research/wp-content/uploads/2002/01/p812-marshall.pdf

Carol Porter-O'Donnell. (2004). Beyond the Yellow Highlighter: Teaching Annotation Skills to Improve Reading Comprehension. https://doi.org/10.2307/4128941

Baron, N. S. (2021). How we read now: strategic choices for print, screen, and audio. Oxford University Press.

Szalavitz, M. (2012). Do e-books make it harder to remember what you just read?. http://healthland. time. com/2012/03/14/do-e-books-impair-memory

van Boeijen, A., Daalhuizen, J., van der Schoor, R., & Zijlstra, J. (2014). Delft Design Guide: Design Strategies and Methods.

Sanders, E.B., & Stappers, P.J. (2013). Convivial Toolbox: Generative Research for the Front End of Design.

North Forest Lights — themomentary. (n.d.). (2021). https://crystalbridges.org/calendar/north-forest-lights/

Büttner, D. (Dec 18, 2020). Better Haptics, 10x Faster with Lofelt Studio. https://medium.com/lofelt/better-haptics-10x-faster-with-lofelt-studio-42e491317ed6

ATOM Echo, Shanghai, China. (Jun 23, 2020). ATOM Echo: ESP32-based Miniature Programmable Smart Speaker by M5Stack. https://www.espressif.com/en/news/ESP32_ATOM_Echo

Aaron Bangor, Philip T. Kortum & James T. Miller (2008) An Empirical Evaluation of the System Usability Scale, International Journal of Human-Computer Interaction, 24:6, 574-594, DOI: 10.1080/10447310802205776

T, W. (2020, January 8). Measuring and Interpreting System Usability Scale (SUS). UIUX Trend. https://uiuxtrend.com/measuring-system-usability-scale-sus/#interpretation

Rehman, S. U., & Liu, L. (2008). Vibrotactile Emotions on a Mobile Phone. doi: 10.1109/SITIS.2008.72.

Russell, J. A. (1980). A circumplex model of affect. Journal of Personality and Social Psychology, 39(6), 1161–1178. https://doi.org/10.1037/h0077714

Posner, J., Russell, J., & Peterson, B. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. Development and Psychopathology, 17(3), 715-734. doi:10.1017/S0954579405050340

Song, S., & Yamada, S. (2017). Expressing Emotions Through Color, Sound, and Vibration with an Appearance-Constrained Social Robot. 2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI, 2017, pp. 2-11.