Adrian Røstgård Flatner, Ola Holde

Wearable Memory Augmentation

The Design, Implementation, and Empirical Investigation of a Wearable Memory Augmentation System for Amplifying Memory Recall

Master's thesis in Informatics
Supervisor: Michail Giannakos
Co-supervisor: Evangelos Niforatos
June 2022

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Summary

This thesis describes the design, implementation, and empirical investigation of a wearable memory augmentation system for amplifying memory recall. The study was conducted to evaluate the effectiveness of handheld, wrist-worn, and heads-up devices in enhancing memory recall when used to project relevant information as memory cues. The comparison was done on 19 university students in a multi-week, within-subjects research design. Wearable Memory Augmentation lies at the intersection of Memory Theory from Cognitive Psychology, and Wearable Computing from Computer Science. While these fields are well documented in literature, their integration still has much ground to cover. However, it is evident that research in the area is full of promise. *Research question:* How does cue delivery modality (no cue vs. smartphone vs. smartwatch vs. smart-glasses) affect participants' recall scores at the end of the day/after a week? There were two parts to the research: how the participants performed at the end of the day after using the system, and how they performed a week later. In addition, a set of independent variables were recorded to establish a preliminary model for the design of wearable memory augmentation systems. The participants were exposed to three activities: priming (reading a text with semantic information), memory augmentation (using the system), and evaluation (responding to a multiple-choice questionnaire related to the information). Questionnaires and in-app behavior analytics generated quantitative data for analyzing how the devices performed. A repeated-measures ANOVA was used to compare the means of the conditions and find significant differences. The analysis found that cue delivery modality affected the participants' recall scores at the end of the day. Specifically, there was a significant difference in scores between the participants who used the smart-glasses and those in the control group (no memory augmentation). Participants' recall of semantic information was improved by 16% when the system was used on the heads-up modality. Other significant differences were not observed. Nevertheless, the trends indicate that the systems were successful in amplifying memory recall at the end of the day and after a week.

Keywords: *Wearable Memory Augmentation, Memory Cues, Wearable Computing, Cued Recall, Android.*

Sammendrag

Denne avhandlingen beskriver designet, implementasjonen og den empiriske utforskningen av et wearable minneforsterkende system for gjenkalling av minner. Studiet var gjennomført for å evaluere effekten av systemet i kombinasjon med håndholdte, arm-, eller hodemonterte enheter. Sammenligningen ble gjort på 19 universitetsstudenter i et to ukers ”within-subjects” studie. Wearable minneaugmentering ligger i skjæringspunktet mellom minneteori fra kognitiv psykologi, og wearable computing fra datavitenskap/informatikk. Disse forskningsfeltene er godt dokumentert i litteratur, men integrasjonen av dem har fortsatt mye forbedringspotensiale. Forskning på feltet viser likevel til oppløftende resultater. *Forskningsspørsmål:* Hvordan vil leveringsmodaliteten for memory cues (ingen cues vs. smarttelefon vs. smartklokke vs. smartbriller) påvirke deltakernes resultater på slutten av dagen/etter en uke? Studien var delt i to: hvordan deltakerne gjorde det ved slutten av dagen etter å ha brukt systemet, og hvordan de gjorde det en uke senere. I tillegg ble det registrert et sett av uavhengige variabler for å etablere en modell for hvordan wearable minneforsterkende system kan bli designet. Deltakerne var gjennom tre aktiviteter: priming (lesing av en tekst med semantisk informasjon), minneforsterking (bruk av systemet), og evaluering (svare på en flervalgsquiz relatert til informasjonen). Spørreskjemaer og automatisk registrering av applikasjonsinteraksjon genererte kvantitativ data for å analysere hvordan de ulike enhetene presterte. En repeated-measures ANOVA ble brukt til å sammenligne gjennomsnittet av de ulike betingelsene og finne signifikante forskjeller. Analysen fant at leveringsmodaliteten for memory cues påvirket deltakernes resultater ved slutten av dagen. Det var spesielt en signifikant forskjell i poengsum mellom deltakerne som brukte smartbrillene og de som var i kontrollgruppen (ingen minneforsterking). Deltakernes gjenkalling av semantisk informasjon var forbedret med 16% når systemet ble brukt på smartbriller. Andre signifikante forskjeller ble ikke observert. Trendene indikerer at systemene var vellykkede i å forsterke gjenkalling av minner ved slutten av dagen og etter en uke.

Nøkkelord: *Wearable Memory Augmentation, Memory Cues, Wearable Computing, Cued Recall, Android.*

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Chapter 1

Introduction

1.1 Overview

The Wearable Memory Augmentation study aims to explore and evaluate how handheld, wrist-worn, and heads-up devices can deliver memory cues (sensory stimuli that help us remember) in the wild to enhance students' memory recall (retrieval of information from the past) when studying a topic. It entails the development of three applications that are designed to provide memory cues for amplifying the learning of a theme or curriculum. Each device has its own application, namely a smartphone app, a smartwatch app, and a smart-glasses app.

The preparatory work consisted of a literature review on related science in the field of human memory theory, as well as the state of art in memory augmentation and the delivery of memory cues. The design and subsequent implementation of the memory augmentation system are based on literature and sound design principles. To evaluate the three modalities' (handheld, wrist-worn, and heads-up devices) ability to successfully deliver memory cues, they were tested on 19 participants in a multi-week within-subject user study. This includes the reading of themed texts, memory augmentation through the applications, and answering multiple-choice tests for evaluation. Questionnaires and in-app behavior analytics generated quantitative data for analyzing how the cue delivery modalities performed in memory augmentation. To compare the means of conditions and find significant differences, a repeated-measures ANOVA was used. Results from the study indicate success concerning the system and are favorable for the heads-up approach.

In order to be concise in the formulation of the problem, it is crucial to define how the terms *memory* and *learning* are used in this thesis. First off, memory is the mental processes used to acquire (learn), store, or retrieve (remember) information (Spear and Riccio (1994), as cited in Radvansky (2017)). It is clearly related to learning, and even acts as the underlying process that supports it. For something to be learned, it has to be remembered, and vice versa. The term *learning* is accordingly *to acquire information* in the context of this thesis.

There is one more important distinction to make. Despite the fact that the term learning is diligently used throughout the text, the main contribution is not to the research field of learning. The field is made up of several theories, e.g. cognitivism, behaviorism, and constructivism, which all confirm that it is an active multi-step process. Interactivity is also highly credited in the process (Swan, 2002). Defining the term *learning* in the context of this theory would be ‘the act of acquiring information or skill such that knowledge and/or behavior change’ (Morris et al., 2006). This is not the scope of the thesis. It is rather directed at memory recall. Even so, it may be that the affinity between these two research fields warrants that the study has a significant impact on learning theory as well.

1.2 Motivation

The motivation for creating and evaluating a wearable memory-augmenting system for enhancing memory recall is threefold. The first motivator is to amplify memory recall with a marginal increase in effort, the second is the complete novelty of the research, and the third is the mission of moving cued recall out of the lab. These three main motivators are explained further in the next few paragraphs.

Memory is a fundamental part of humans. It gives the possibility to reflect on past experiences and knowledge and use it to make choices in the future. Over time, recalling memories becomes more difficult, and at a certain point memories are lost (Theodore Thudium, 2022). There is a strong motivation for the study to enhance memory recall in order to enable humans to retain memories that are otherwise likely to disappear. With the rise of new technology that can automate tasks and be worn, there is an opportunity to decrease the memory deprivation with little effort from the wearer.

While there exist countless tools for increasing retention when studying and several studies and solutions for augmenting human memory, there is little research on the use of wearable technology for enhancing memory recall when students are learning a new theme. This means that the study is backed by well-researched areas, but the angle is novel. The interesting areas to explore in this context is what kind of memory theory should be utilized, how the apps should be designed, how they should be used, and what kind of wearable cue delivery modalities are effective. How to create powerful memory cues may be one of the most critical aspects of the process. Answering these questions will potentially create a baseline for how to design and develop wearable devices and applications for augmenting human memory in the future.

Cued recall refers to recalling a list of items by the help of cues or guides (The Human Memory, 2022). A lot of research in cued recall take place in clinical or laboratory settings. It applies to work on for example dementia and amnesia, or experiments conducted in controlled settings to measure some effects of memory cues. One of the main motivations for the research is to move cued recall out of the lab and into generally applicable use cases by utilizing wearable technologies and feedback-collecting services like automated analytics and online forms. The results of seeing cued recall in the wild will most likely strengthen the findings by being applicable in real-life situations.

1.3 Goal

A few cutting-edge research projects already focus on increasing cognition through for example machine learning and wearable systems (Dingler et al., 2016; Khan et al., 2019). By taking advantage of this possibility and delivering memory cues that increase recall in a non-intrusive manner, students would potentially learn or perform faster with marginal increases in cognitive strain.

The research questions of the study concern how a typical smartphone, a smartwatch, and a pair of smart-glasses perform in amplifying memory recall when a student is learning new material. A memory augmentation system will be deployed on the three devices, delivering memory cues to help remember the content. By comparing the modalities' abilities to amplify memory recall, the study will make a valuable contribution to joining the fields of memory theory and wearable computing.

The first research question goes into how the results are at the end of the day:

RQ1 How does cue delivery modality (no cue vs. smartphone vs. smartwatch vs. smart-glasses) affect participants' recall scores at the end of the day?

It concerns whether the manner in which the memory cues are delivered will affect the participants' results on the multiple-choice quiz they will receive after a day of memory augmentation. The objective is to compare the performances of the control group, the smartphone group, the smartwatch group, and the smart-glasses group, and identify which modality performs most favorably. The hypothesis is accordingly that cue delivery modality will have an effect on the participants' recall scores at the end of the day.

One of the assumptions regarding the outcome of the study is that the more immersive the cue delivery modality is, the more likely participants are to remember the study contents. The assumption is based on that it is an in-the-wild study that brings about a range of distractions. It should therefore be easier to be attentive if the experience is all-consuming when a cue is received. The smart-glasses should be the most advantageous device in this scenario (always in the field of vision), followed by the smartwatch (always on the arm) and smartphone (probably on the table).

The second research question concerns how the participants perform after a week:

RQ2 How does cue delivery modality (no cue vs. smartphone vs. smartwatch vs. smart-glasses) affect participants' recall scores when a week has elapsed?

The objective for RQ2 is to compare the performances of the groups a week after they have undergone memory augmentation. The purpose is to determine which modality is best for strengthening the memory in order to avoid the process of forgetting over time. In this regard, it is hypothesized that the modality in which cues are delivered will affect the participants' recall scores a week later.

It is assumed that the participants will score significantly higher on the quiz on the same day as reading the text compared to after a week. This result would not undermine RQ2, as forgetting over time is to be expected. If the daily and weekly results were to converge, there could be evidence that the system have a significant impact not only on memory recall, but also on the field of learning.

In addition to testing the different modalities, a set of independent variables will be recorded to model how applications for the devices can be designed in the future. Time, duration, and presentation are examples of the variables.

1.4 Objectives

To answer the research questions, the study consists of four research objectives:

Obj. 1 *Designing three applications.* They should be suited for delivering memory cues and providing interaction with them. They need to be able to log the user's activity. A set of requirements created in the prestudy will guide the process. The design objective consists of creating mock-ups and designing system architecture.

Obj. 2 *Developing the applications.* The development objective consists of developing the three different applications over an agile two-month process. The research team will do four sprints while keeping a backlog of user stories to guide the process. Regular testing needs to be done after each sprint.

Obj. 3 *Perform empirical study.* The empirical study objective consists of designing a multiweek in-the-wild study for 20 participants, creating the necessary content, and executing the study. The participants will use the applications as a tool for increasing memory recall of the content they are provided. Data will be generated from questionnaires, multiple-choice tests, and in-app activity logging.

Obj. 4 *Analysis of the gathered data.* The analysis objective consists of analyzing the quantitative data gathered in the empirical study. The results need to be put in the context of related theory and will be the basis for answering the research questions of the study.

1.5 Prestudy

Creating a wearable memory augmentation system is a process that demands extensive research, exploration, creativity, and lots of time. The literature review provided some pointers to start thinking about narrowing down which direction a solution might take. A couple of weeks of reading and categorizing previous research in memory theory and wearable computing created the basis for finding the appropriate novelty to explore. Specifically, the plan at this point was to create applications for a smartphone, smartwatch, and a pair of smart-glasses, to find the favorable device for wearable memory augmentation. A further plan was to identify the most effective design solutions in order to create applications that would be successful in achieving the objective.

The design phase started with a pilot study to map how it felt to receive and react to simple memory cues. The research team sent scheduled emails with text-based memory cues containing semantic information to each other for a whole week. There were five different cues each day, and a small test in the evening. The memory cues had different lengths and thematic content on each of the days. The key takeaways were that receiving a few memory cues a day did not annoy the user, and it seemed to make the research team remember better. Another important takeaway was that email was not the appropriate medium, since the user is likely to ignore them in the midst of all the other noise in the email inbox. Next, the cues should not be too long apart time-wise to make sure that the process feels continuous. The team experienced that two-three hours of waiting time before the next cue was received felt like beginning a new task. This was tedious. An important realization from the experiment was that the memory cues should be concise to avoid adding too much cognitive strain during augmentation on the user. The longer cues were borderline annoying and the shorter ones seemed to help the team remember more. For example, the memory cue ”1814” seemed more successful than ”Norway’s independence day (May 17, 1814, Eidsvoll Treaty)”. Another takeaway was that something was missing when receiving the cues. The team did not know what, but there clearly had to be some interaction with the cue. Lastly, the experiment guided which direction the team wanted to go regarding the theme of the memory cues. Language learning seemed like the way to go initially, but after seeing how close it was to other existing solutions it was scrapped. More content-based themes were the direction to move forward with.

After doing the literature review, conducting the experiment, and carrying out several brainstorming sessions between the team and the supervisors, it was time to create the first mockups in Figma. It was a pretty quick process, as the foundation for the ideas and most of the requirements were already solidified. The design went through three rounds of feedback and adaption before the development phase of the study began. During development, the design also saw several improvements due to the process being agile.

Chapter 2

Literature Review

Wearable Memory Augmentation lies at the intersection of Memory Theory from Cognitive Psychology, and Wearable Computing from Computer Science. These fields are well-documented in literature. The combination of them still has much ground to cover. To develop and design wearable memory augmentation applications, the preparatory work consisted of diving into the fields mentioned. The related work in this chapter is divided into theory and how to apply it.

2.1 Memory Theory

The definition of memory used in this thesis refers to memory as the mental processes used to acquire (learn), store, and retrieve (remember) information (Spear and Riccio (1994), as cited in Radvansky (2017)). There are no simple ways to inspect memory and measure it, and therefore it is common to refer to metaphors when talking about memory. The most dominant metaphor for memory is the literacy metaphor where memories are treated as discrete units such as books or pages. This formed the conception that memory involves encoding, storage, and retrieval, like writing in a book and storing it on a shelf (Radvansky, 2017).

Memory recall is remembering the information or events that were previously encoded and stored in the brain (retrieval) (The Human Memory, 2022). It requires revisiting the nerve pathways formed during the encoding and storage of the memory. The strength of these nerve pathways determines how quickly a memory is retrieved. Memory recall can be divided into three types: free recall, cued recall, and serial recall. Free recall consists of recalling a list of items in any order. Cued recall refers to recalling a list of items with the help of cues or guides. Cues help recall items that are thought to be lost and result in people remembering things they did not in free recall. Serial recall refers to remembering items in the order of their occurrence. Recalling previous items cues the recall of the next item in the list.

Long-term memories are a result of the combination of experiences and general knowledge about the world. This split of memory into two major components in memory theory is called episodic memory and semantic memory respectively (Radvansky, 2017). They differ in the type of information they store. Episodic memory addresses the who, what, when, where, why, and how of an experience, creating a mental model of the event. Semantic memory holds information regarding events, facts, and concepts, allowing us to take advantage of regularities in the world. An example of the distinction is the difference between remembering what happened at a birthday party as opposed to remembering what a birthday party is.

Memory cues are simply something that helps us remember. It is a sensory stimulus of some information that helps us to access a memory (Dingler et al., 2016). There are almost no boundaries for what a memory cue can be: an old song might remind you about your first crush; a plane in the sky could remind you of your vacation on Côte d'Azur last summer; the smell of freshly cut grass might remind you of a satisfied dad. A song, a picture, or a smell could thus be the sensory stimuli for recalling an episodic memory (Niforatos et al., 2018).

Semantic memory is based on regularities in your episodic memory. This means that you may need to remember where you were and what you were doing to retrieve a recently learned fact from memory (Radvansky, 2017). For example, when remembering the name of a new colleague you would think back to when, what, and where you first met. Eventually, you will forget the context and just remember the fact, making the transition from episodic to semantic memory complete. In this way, memory cues can be designed to trigger the recall of episodes that contain desired semantic memory. Another suggested way to target semantic memory is to associate newly acquired semantic information with keywords as memory cues, creating an attachment for retrieving the memory (Xia and Maes, 2013). For example, the cue "1814" could help trigger semantic information about Norway's Independence Day.

Memories have a tendency to attenuate over time. Ebbinghaus' forgetting curve is a representation of the process of forgetting (Figure 2.1). It shows the declining rate at which information is lost if there is no effort made to remember it. The curve illustrates that the rate of forgetting is exponential, and after a day or two, a person typically forgets 75% of what has been learned. Some factors that can influence the rate of forgetting are prior knowledge of a subject, the way the information is delivered, and physiological factors such as lack of sleep and hunger. According to Ebbinghaus, rehearsing the information helps strengthen the memory, and ideally, the repetition should occur within the first day of learning something (Theodore Thudium, 2022).

One of the most durable memory effects is the serial position curve (Radvansky, 2017). It states that memory is better for information at the start and end of a set, whereas the information in the middle of the set is less remembered. The curve is found for various information types and set sizes. The primacy effect is the idea that the first items in a set will have more opportunity to be rehearsed and are more likely to be consolidated in long-term memory. It is increased when people are given more time to rehearse the information. At the other end of the serial position curve, the recency effect makes it easier to remember information stored at the end of a set. These items have not been displaced by other pieces of information, and thus are less likely to be forgotten.

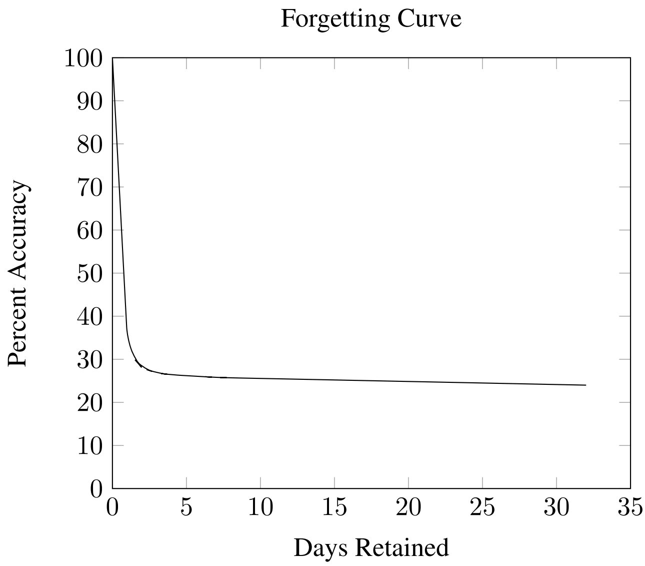


Figure 2.1: Ebbinghaus' Forgetting Curve shows how new memories attenuate over time.

2.2 Related Work

Regarding the presentation of memory cues, the literature includes a range of different solutions based on what type of memories are targeted. Systems targeting the episodic part of memory usually make use of multimedia cues (photos, sound, video) to trigger memories about previous experiences (Hodges et al. (2006), Dingler et al. (2016), Ikei and Ishigaki (2008), Lee and Dey (2007)). Several findings indicate that pictures of memories are effective in episodic recall as they are similar to how our memories exist in the consciousness. Solutions that are trying to trigger or encode semantic memories are often limited to text-based cues as there is no mental model involved. There are some examples of the use of multimedia for retrieving semantic information, but the results are mixed. The system combining text and pictures in Niforatos et al. (2018) performed convincingly overall, but participants expressed that the pictures did not help them. However, their view is that the combination is the power of the system. Pearson and Wilbiks (2021) measured the effects of audiovisual cues on memory recall. They did not find any advantages in using the combination as opposed to audio and visual cues by themselves.

Pearson and Wilbiks (2021) found advantages in presenting three memory cues compared to presenting only one. It yielded a higher recall among the participants. Similar results are seen in Mäantylä (1986) and Jiang et al. (2010) which also supports the finding that presenting several memory cues has advantages in memory.

There has been a few research studies trying to measure and create baselines for how to design and make use of memory cues to augment human memory. One of these studies is Schneegass et al. (2021), where the researchers make use of an online questionnaire and a focus group to address how Personal Knowledge Management Applications (PKMA) with memory augmentation features can counteract long-term forgetting. The feature is periodically reminders to revisit stored content. They theorize that these reminders may also in some cases be treated as memory cues. One key result is that the participants expressed that a balance between user control and system control in timing, frequency and amount of content presented would be desired. This entails automatic default mechanisms based on user behavior, and the possibility for customization. They also expressed that text or pictures would serve as reminders to trigger memory without needing to read the content. One participant stressed the importance of actively engaging with the content. This could for example be memory cues in the shape of questions.

Literature on memory in HCI (Human-Computer Interaction) suggests that content interactivity leads to greater cognitive absorption (Oh and Sundar (2015), Sicilia et al. (2005)). Agarwal and Karahanna (2000) describes cognitive absorption as a deep state of involvement with software. It involves a state where all of an individual's attention resources are consumed by the object of attention. Xu and Sundar (2016) also supports these findings. They conducted a study to understand how levels of interactivity affect information processing among users of an e-commerce website. The user interaction consisted of clicking buttons to see more information, images, or more interactive features. The relevant finding is that higher interactivity enhanced recognition and memory recall, and diminished recognition and memory recall of non-interactive content.

Selecting successful content as memory cues to trigger memory recall seems to be based on several qualities or processes. Lee and Dey (2007) researched how memory cues should be designed for people with episodic memory impairment. They found that recognizability, distinctiveness and personal significance were the utmost important qualities for cues to trigger memories about previous experiences. This may help to design memory cues outside the scope of memory impairment.

In Niforatos et al. (2018) the content of the memory cues were based on memory attachment, as proposed by Xia and Maes (2013). The research team were trying to augment memory recall in work meetings by providing a slide with keywords about the last meeting's topics. The keywords were automatically generated with the help of language processing. They also used pictures from the last meeting as content to trigger episodic memories associated with the semantic information. The participants were able to recall 15% more details when using the research team's memory intervention.

Chapter 3

System

This chapter describes the requirements and technologies used in the wearable memory augmentation system. Next, it contains a detailed description of how the system architecture is planned and implemented to amplify students' memory recall. Following, it presents and explains the design and user experience of the applications, before showing how the final implementation was.

3.1 Requirements

The requirements for the system design are based on the literature review, the prestudy-experiment, and discussions between the researchers and the supervisors. It is the most important characteristics that need to be included for the system to perform most favorable in augmenting students' memory, as well as the requirements needed to measure the study in the best way possible. Other choices of design and software are taken along the way. The requirements are:

- Three applications for Android (One smartphone app, one smartwatch app, and one smart-glasses app).
- Ensure data privacy of users.
- Backend and database for storing memory cues and users.
- Analytics on user behavior.
- The applications must present textual memory cues and associated info.
- Every cue needs to be repeated three times.
- Cues must be presented in a randomized order.
- The memory cue needs interaction: ”See more info about the cue”.

- Notifications for new cues.
- Memory cues need to be delivered automatically within some time limit (less than an hour).
- The applications must support several lists of cues.
- The applications need to be customizable.
- Appealing, user friendly, and no-effort design.

3.2 Technologies

The system and its associated testing phase creates a need for several COTS (Commercial off-the-shelf software). The following will provide an overview and justification for the different technologies that are used in development and the experimental study.

Android Android is a software package and Linux-based operating system for mobile devices such as smartphones, smartwatches, and even smart-glasses. Java language is mainly used to write the android code even though other languages can be used. It is chosen as the operating system to develop for because of its easy development process and its flexibility in terms of device compatibility. This makes it easy to develop and launch the applications on three different devices. (Android, 2022a).

Android Studio Android Studio is Android's official IDE. It is purpose-built for Android to accelerate your development and help you build the highest-quality apps for every Android device. It is the obvious choice when developing for android. (Android, 2022b).

Firebase Firebase is a Backend-as-a-Service (Baas). It provides developers with a variety of tools and services to help them develop quality apps, grow their user base, and earn profit. Firebase Realtime Database and Firebase Authentication are used for the applications for their easy setup and maintenance. (Firebase, 2022).

Google Analytics Google Analytics is a website traffic analysis application that provides real-time statistics and analysis of user interaction with the website. The service can also be used for applications to track users' behavior. It is chosen because of its easy setup, wide range of features, and integration with Firebase. (Google Analytics, 2022).

BigQuery BigQuery is a serverless, highly scalable, and cost-effective multicloud data warehouse designed for business agility. It is used in integration with Google Analytics to be able to access all data in the user behavior tracking. (Google, 2022a).

IBM SPSS IBM SPSS Statistics is a powerful statistical software platform. It offers a user-friendly interface and a robust set of features. It is chosen as the data statistics tool for the analysis of the results in the experimental study because it is easy to learn and provides all the features needed to extract relevant results from the dataset. (IBM, 2022).

Google Forms Easily create and share online forms and surveys and analyze responses in real-time. It is chosen as the tool to use to gather participant information as well as doing multiple-choice quizzes with. As it provides great functionality, Google authentication, and direct interaction with Google Sheets, it is the natural choice to work with in this case. (Google, 2022b).

Figma Figma is a web-based graphics editing and user interface design app. It is used in the design and creation of mock-ups for the applications. It is chosen as the design tool because it is free and the researchers have great experience in using it. (Figma, 2022)

3.3 System Architecture

3.3.1 System Task

The architecture models that are presented are targeting three different applications: one for smartphones, one for smartwatches, and one for smart-glasses. These are thought to work together, with the smartphone application as a hub. The smartphone app is independent, while the other two were planned to depend on it. In the end, the watch was chosen to be independent as well. The goal is to deliver memory cues in three different ways, at the same time as the three ways feel seamless. By focusing a great deal on making it easy to use, the study will provide more accurate results and contribute to amplifying memory recall with little effort from the users.

3.3.2 Models

The activity diagram in figure 3.1 depicts the flow of receiving memory cues in all the applications. All three begin on the home screen when starting the app. This is the screen used throughout the whole activity. The first choice happens only in the phone application, where the user needs to decide which device they will use for receiving cues. After this, the cue-receiving begins. For each cue, it is possible to see more information. This information is the actual memory the cue tries to trigger. If the user wants to receive more cues, they return to the starting point. If the user wants to quit the process, they have to turn off the application. Leaving it on will make the application continue giving cues, even if the user suspends it for doing something else.

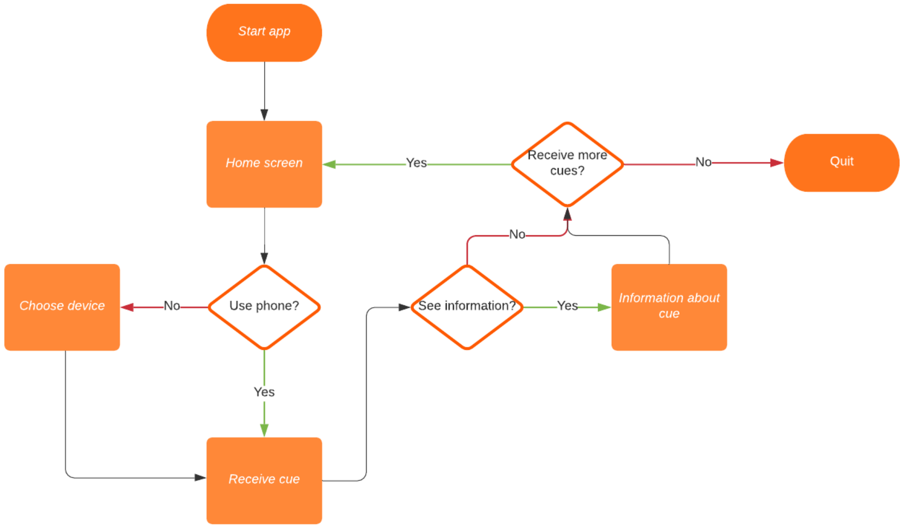


Figure 3.1: Activity diagram for receiving cues in the system.

The logical view of the phone and smart-glasses applications is presented in figure 3.2. This class diagram represents important packages, classes, resources, services, and their general interaction in the implementation. The architecture of the phone application follows the MVVM (Model-View-ViewModel) architectural pattern. It is the industry-recognized pattern that overcomes the drawbacks of MVP (Model-View-Presenter) and MVC (Model-View-Controller) design patterns (Rishu Mishra, 2021). MVVM separates data presentation logic from the core business logic and has three code layers:

- **Model:** Abstraction of data sources.
- **View:** Defining the structure, layout and appearance.
- **ViewModel:** Exposes those data streams which are relevant to the View. Moreover, it serves as a link between the Model and the View.

The phone part of the view shows how the three layers of MVVM communicate. The Model package contains Apprepository and Cue which represent and communicate with the backend and database of the application. The View package contains the MainActivity class, which serves as the main access point to the view. The package also contains four fragments that represent the different views of the application, including home, settings, login, and the cue card. The ViewModel package contains view models for the four different fragments in the View. This is the layer that connects the data in the Model with the user-interactive View. The res/layout package represents the xml-code for the appearance of the layout UI.

The phone also includes the CueWorker class which is an instance of Worker from the WorkManager library. This library is recommended for applications that need to schedule persistent tasks (Android, 2022c). The applications needs to schedule consistent memory cues to the user, which the CueWorker handles. The class is static and the library works in the background processes of the device. This makes it so that the CueWorker communicates directly with the backend and database to retrieve cues. When started, the CueWorker retrieves a new cue every 15 minutes. Depending on which mode the application is in (phone or smart-glasses), the CueWorker will create a notification for the new cue and update the view in the phone application, or it will send the new cue to the smart-glasses application over Bluetooth.

The architecture for the smart-glasses application is relatively uncomplicated to facilitate simpler wearable hardware and battery life. The main features are located in the MainActivity class, with one screen for the cues and one for a tutorial. The Receiver class is an instance of BroadcastReceiver which handles the incoming cues sent from the phone application. As a result, the smart-glasses application needs to be connected to the phone to work.

To handle the data associated with memory cues, learning content, and user history, the applications use Firebase as Backend-as-a-Service. The Firebase Realtime Database is a cloud-hosted database where data is stored as JSON and synchronized in real-time to every connected client. It is used to hold the memory cue data in the applications. Firebase also provides the authentication needed. Google Analytics for Firebase is utilized to gather data on how the apps are used and will provide the data needed to model how cue delivery applications should be designed.

Figure 3.3 shows the logical view of the watch application. It displays the general interaction between the different packages, classes, resources, and services. The application for the watch is similar to the phone application, containing the same main structure. The watch application follows the MVVM structure, where the model is the same as in the phone. The ViewModel is similar, but the Settings-ViewModel is removed due to not being necessary for the application to work as intended. In the View, the HomeFragment is not present as the application only uses the CardFragment when the cues are being delivered. The CueWorker works in the same way by retrieving a new cue every 15th minute as well as displaying a notification on the watch. It is connected to the same Firebase project as the other devices.

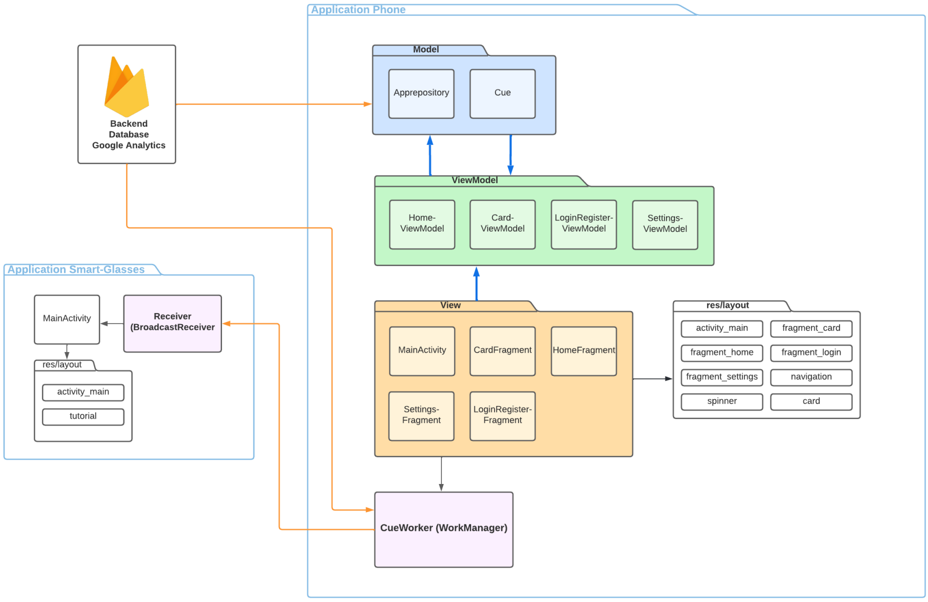


Figure 3.2: Class diagram: Logical view of architecture for the phone and smart-glasses applications.

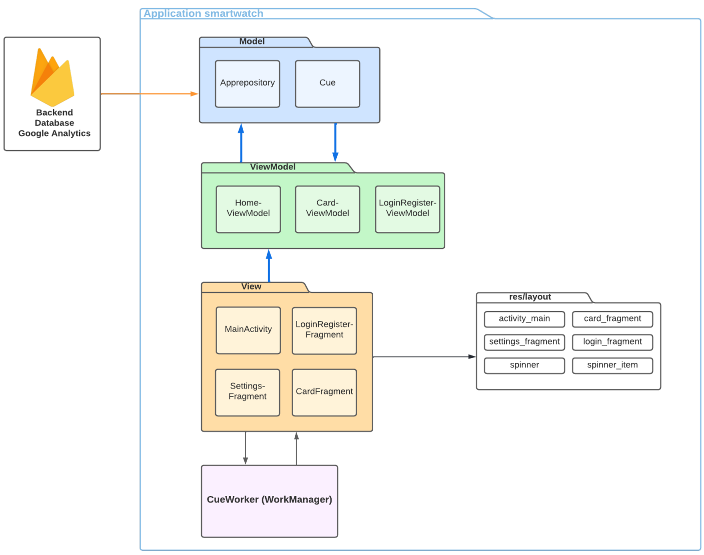


Figure 3.3: Class diagram: Logical view of architecture for the smartwatch application.

3.4 Design and User Experience

The design and user experience of the system are based on best practices and design theory like the Gestalt principles (Interaction Design Foundation, 2021) and Don Norman's fundamental design principles (Batterbee, 2020). They are also grounded in the requirements developed in the prestudy. This section gives insight into how the design and flow of the applications were to be implemented. After the design and user experience, a short section will explain the differences in design and implementation. The system is named "Amplified" in reference to its role as an amplifier, rather than a substitute for memory.

3.4.1 Visual Profile

Figure 3.4 shows the color scheme used in the design of the applications. It is a lively color palette created to be be easy to look at and catch the eye of the user. The scheme consists of ten colors and is described as both tetradic and analogous in color theory. Tetradic for its division in four main colors that are pairwise complementary, and analogous for the range of colors that are neighbours on the color wheel (David Peterson, 2022). The complementary colors assist with high contrast, making important content pop, while the analogous colors assist in creating a comfortable space.

Figure 3.5 is the logo designed for the applications. It is a simple round logo created to be recognizable and targeted. It utilizes light, but recognizable colors of the color scheme to stand out among other apps on the devices' home screens. The purpose of the logo lies in the focus on amplifying humans. The user is the main attraction, hence the highlighted person in the focal point.

Figure 3.4: Color scheme used in the applications.

Figure 3.5: Logo for the applications.

3.4.2 Phone

The application for the smartphone is a cue delivery platform as well as the hub for the smart-glasses. This means that the smartphone application contains several features that are not required in the application for the smart-glasses. These and all the basic design interaction are explained in the following.

Figure 3.6 provides a small tutorial that explains the main features of the home screen. This is the screen the user enters when opening the app. It is also the main screen as it contains the memory cues and principal functionality. The current memory cue is displayed on a card in the middle of the screen. From this screen it is possible to turn the cue mode on or off, access the menu, access previous or next cue, and get more information of the current cue.

The process of cue-delivering is shown in figure 3.7. The application delivers a memory cue, trying to get the user to remember a previously read fact. In this case, the memory cue is ”Sarajevo 1914” and the memory it should trigger is the assassination of Archduke Franz Ferdinand, which lead to the outbreak of the first world war. If the user does not remember or wants to verify the memory, they can click the arrow on the card in figure 3.7a. This will turn it over and provide the memory the user is trying to remember (figure 3.7b). When the user is ready, pressing the green ”Finish”-text will flip the card back.

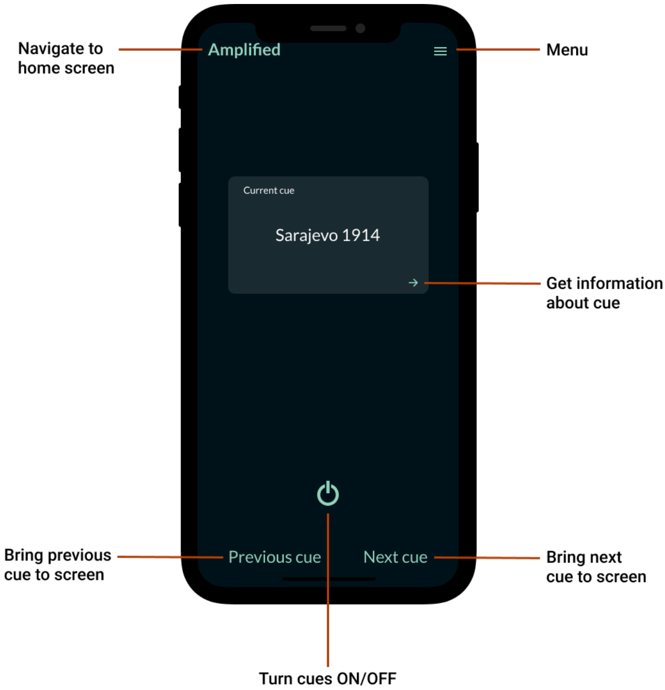
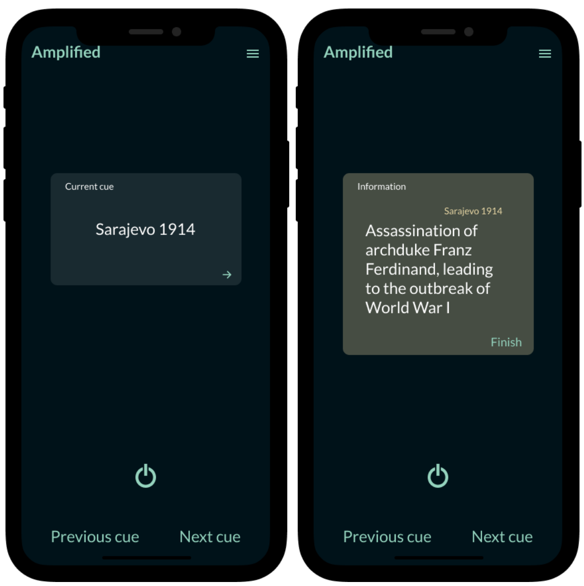


Figure 3.6: Home screen/Cue screen on phone with instructions.



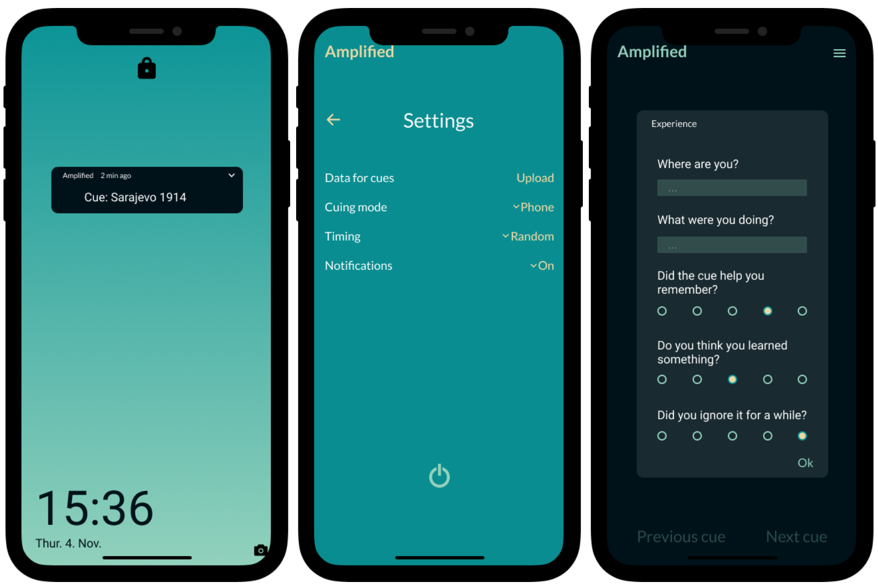
(a) Home screen/Cue screen **(b)** Cue information screen

Figure 3.7: Design and flow of current cue on a phone. Figure (a) presents the current cue. Pressing the card takes the user to the information in (b). Pressing the card again takes the user back to (a).

When the user is finished with a cue, there is no need to stay in the application. If the user has turned notifications on, leaving the app will activate the notification mode. This state will make the app go into idle mode till a new cue is retrieved. The new cue will show up as a notification on the lock screen, as shown in figure 3.8a. Pressing the notification opens the app. If the cue triggers the memory correctly, there is no need to open the app. In this case, the user can dismiss the notification or do nothing. The next cue in line will show up either way.

The notifications can be switched on or off in the settings of the app, shown in figure 3.8b. To get to settings the user can go through the menu. In the settings, the user can also potentially upload their own data in a structured xml-file for learning a theme of their choice. Here they can also choose between devices to use and how the timing of the cues should be structured. The settings page on the phone also handles how the cues will be delivered in the cuing mode for the smart-glasses.

To be able to capture the experience of the user, there also need to exist some kind of feedback mechanism. The form in figure 3.8c satisfies the needs of doing some type of sampling on the users. The questions in this figure are only examples on how it may look like. The user gets a notification in the end of the day or the period of testing, asking the user to answer some questions on the experience of retrieving memory cues through the app. The form is for the phone. This means that during testing on the watch or the glasses, the participants would use a phone for doing the sampling. The reason for doing it this way is that the space and interaction on the other devices would not suit a form like this. The other two devices are also designed to be as simple as possible to minimize the amount of distraction from other tasks in the users life.



(a) Notification on lock screen **(b)** Settings **(c)** How to retrieve feedback

Figure 3.8: Lock screen, settings and experience sampling on phone.

3.4.3 Watch

To make the design and interaction on the smartwatch as simple as possible, the only features of the application are cue-retrieving, flipping the card for more information, and a small settings section. However, the watch app is a standalone version and receives memory cues directly from the database. The simple interface is depicted in figure 3.9a. Pressing the ”flip” button flips the entire interface like a card and reveals the memory associated with the cue (figure 3.9b). Flipping it back will mark the cue as finished. Notifications when leaving the app works in the same way as on the phone. Seeing the previous or next cue is possible by swiping left or right respectively.

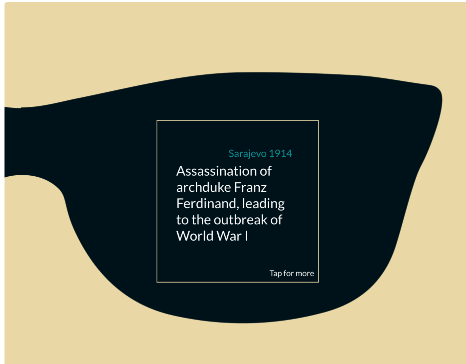
(a) Cue screen for watch **(b)** Cue information screen for watches

Figure 3.9: Design and flow of current cue on a watch. Figure (a) presents the current cue. Pressing the ”flip” button takes the user to the information in (b). Pressing the ”flip” button again takes the user back in (a). The settings button takes the user to a setting screen.

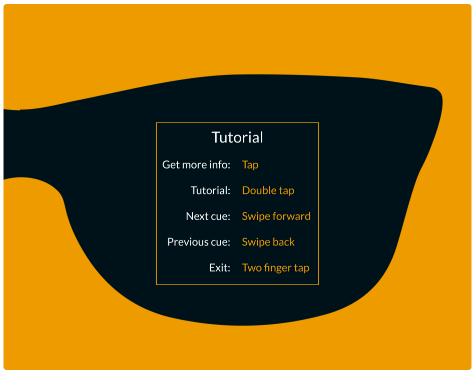
3.4.4 Glasses

The smart-glasses application depicted in figure 3.10 contains the same functionality as the watch application, except a setting screen. The design and interaction in the figures is designed for Vuzix Blade smart-glasses (Vuzix, 2021). When the glasses is connected to the phone application and the application is open, the glasses receives memory cues. The interface is see-through, making it possible to see everything behind the content and not be disturbed. The screen is turned off when no cue is present. When a cue is retrieved, the content will show up in the middle of the interface as in figure 3.10a. Tapping the side of the glasses flips the interface and reveals the associated memory (figure 3.10b). Tapping again flips back. After some appropriate time, the screen shuts off again. A tutorial shows up on startup to make the user familiar with interaction in Vuzix Blade (figure 3.10c). Settings for the application is handled in the phone application.

(a) Cue screen for glasses



(b) Cue information screen for glasses



(c) Tutorial screen for glasses

Figure 3.10: Design and flow of current cue on a pair of glasses. Figure (a) presents the current cue. Tapping at the glasses takes the user to the information in (b). The tutorial in (c) displays on startup. The tutorial is based on interaction with Vuzix Blade.

3.5 Final Implementation

This section provides details regarding the final implementations of the applications. This includes the differences and why these differences were chosen in the final product. The main reason for the design or flow changes lies in making sure the testing of the applications gives most accurate results.

3.5.1 Phone

The implementation of the phone application mostly follows the design and flow as intended in section 3.4. To make sure the app gives the best fit for testing, there are some small changes. These changes and the reasoning behind them follows:

- **Next/previous buttons** in figure 3.11a are removed because the participants should not be allowed to go back and forth to practice the different cues. The buttons are however implemented and can be included, should the application see publication.

- **Data for cues in settings** (figure 3.11b) is removed as the participants is provided with finished cue sets from the database. This feature would however be important in publication of the app.

- **Cue set in settings** (figure 3.11b) is added for the participants to choose between the themes of the cues. This makes it easy to perform testing with different groups.

- **Participant number** (figure 3.11b) is added in the corner of the settings screen to make sure the participants remember and input the correct information when logging in.

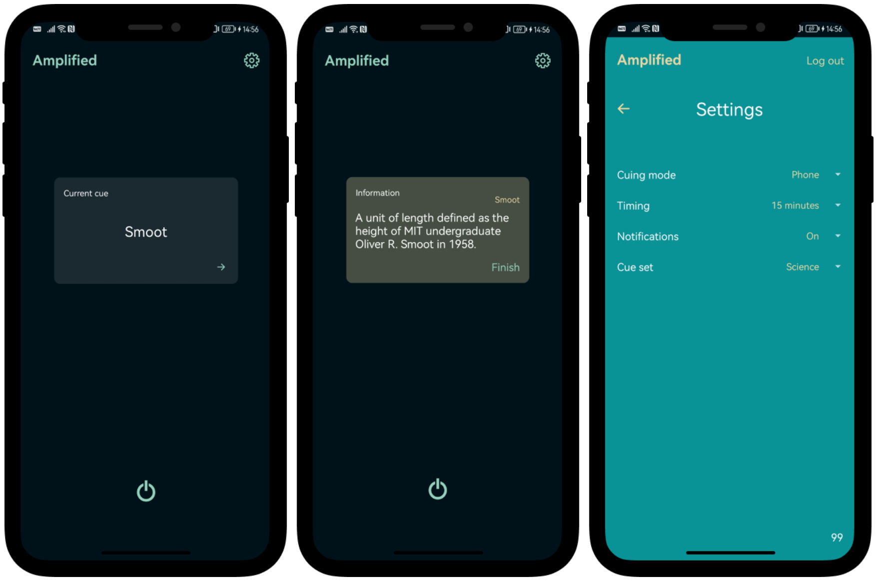
- **The login screen** in figure 3.12a is added to the application to make sure the participant data is handled correctly. This screen also provides a reset settings feature to prepare the app for the next user.

- **Long-click on on/off-button** opens up an overlay where the user can choose device to use (3.12b). This makes it easier to connect and interact with the smart-glasses.

- **The feedback form** in figure 3.8c was down-prioritized because Google Forms provides sufficient features for no cost.

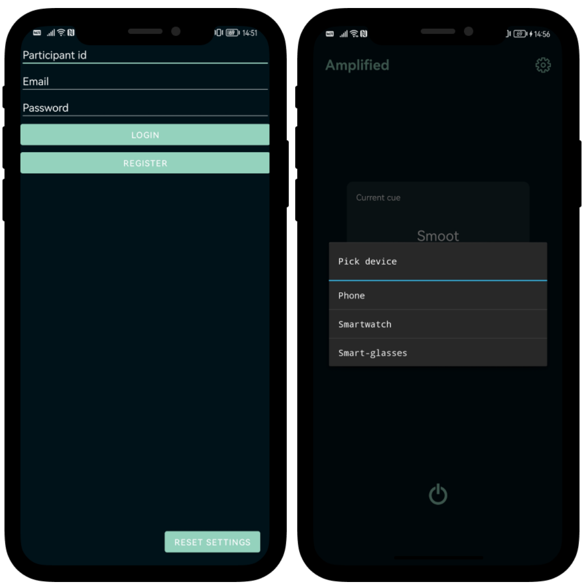
- **The menu** in the design was removed and replaced with a settings button. The menu was redundant.

The notifications on the phone are created through the device's notification center. That means that the notifications are sound and tactile, depending on the user's current settings. During the user study, the devices were setup with sound and vibration.



(a) Cue screen implementation **(b)** Cue info implementation **(c)** Settings implementation

Figure 3.11: Implementation of the cue screen, the flipped cue and settings in the app on the phone.



(a) Login implementation **(b)** Choose device

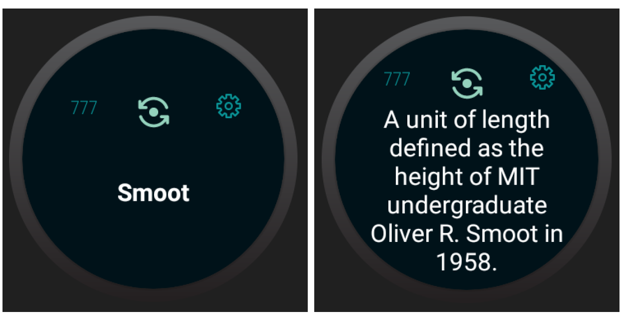
Figure 3.12: Implementation of the login screen and choose device on the cue screen on the phone.

3.5.2 Watch

The implementation for the smartwatch ended up being very similar to the planned design. The differences in the planned design were as follows:

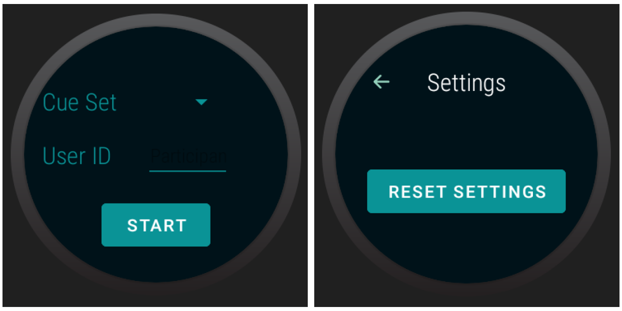
- **Login-screen** (figure 3.14a) is added to select the cue set and participant ID as well as provide a screen to start the process of getting cues.
- **Participant number** (figure 3.13a and figure 3.13b) is added to display the current logged in participant ID in the upper left corner of the user interface.
- **Flip button** is moved above the cue text in figure 3.13a. This is to follow the same design on both the cue screen and the cue information screen.
- **Settings screen** (figure 3.14b) is added to be able to reset the application. Here it is possible to log out and stop the background workers from fetching cues.
- **Scrollable view** is used for displaying the cue text. When the cue text is longer than the available space in the view, it is possible to scroll to make the rest of the text appear in the view.

The notifications on the watch are created through the device's notification center. That means that the notifications are sound and tactile, depending on the user's current settings. During the user study, the devices were set up with sound and vibration.



(a) Cue screen **(b)** Cue information screen

Figure 3.13: Implementation of cue and cue information interfaces on the watch.



(a) Login screen **(b)** Settings screen

Figure 3.14: Implementation of login and settings interfaces on the watch.

3.5.3 Glasses

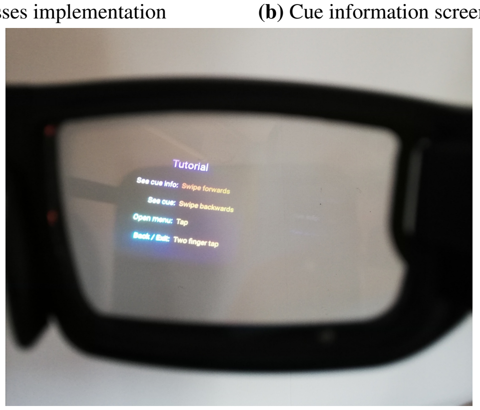
The implementation of the smart-glasses application turned out to go almost exactly as the architecture and design indicated. The app works as a "shell" that receives data from the phone application. This means that the smart-glasses do not need an internet connection, only a Bluetooth connection to the phone that hosts the sister app. When the glasses are connected to the phone, the application is open on the glasses, and the phone application is in "glasses"-mode, cues will appear. The differences in implementation compared to the planned design follows:

- **The "Tap for more"** text is removed from the cue screens (figure 3.15a and 3.15b). This was redundant information for the user.
- **A menu is added** when tapping the side of the glasses. This is to make sure the users understand the UI.
- **Sliding back or forth** reveals either the cue screen or the cue information screen. This was tapping in the design, but sliding provided a "flip"-feel, like seen on the other devices.
- **Tutorial** is no longer at startup, but rather has its own menu item (figure 3.15c). This is because the participants will use already "used" apps, and the tutorial would not appear in this case.

The glasses-application did not feature any notifications in the normal sense. It was designed to be worn during the entire memory augmentation. When a new cue is received, the screen turns on and presents it. There is no sound or tactile feedback.

(a) Cue screen glasses implementation

(b) Cue information screen glasses implementation



(c) Tutorial screen glasses implementation

Figure 3.15: The implementation of the cue screen, the flipped cue and tutorial in the app on the glasses.

Chapter 4

Methodology

The methodology presents and justifies the methods and procedures of the user study. It is divided into five main parts consisting of study design, procedure, study contents, and data collection.

4.1 Study Design

Experimental Design

The experimental design of the study was a true experimental within-subjects design. A true experimental research design is also known as randomized experimental design, and as such refers to the participants being randomly assigned to the experimental and control groups (Gliner et al., 2016). This should eliminate potential biases such as interpersonal differences before the independent variable is introduced. As a result, it should be the better design to provide information whether the independent variables caused changes in the dependent variable.

The within-subjects design is also known as repeated measures design where all participants are exposed to every condition (Gliner et al., 2016). This choice reduces the number of participants necessary for the experiment because the research only requires the amount needed for each condition. It does however increase the work for each participant compared to a between-subjects experimental design. Within-subjects also reduce random noise in the experiment by having the same participants respond to every condition. This means that there is a reduction in error variance as each participant is their own control. Within-subjects introduces the possibility of carryover effects, but they can be controlled by randomizing and counterbalancing participants.

Population

The target group of the study was university students. The choice was based on the way the group is in a constant learning situation and was easily accessible for the study. It makes sense to try amplifying the memory of individuals that is highly likely to have use of such a system daily.

A power analysis was conducted prior to recruitment to find a suitable sample size in order to produce accurate, statistically significant results. The initial power analysis was a one-sample mean t-test with a power of .80, an effect size of .5, and an alpha of .05. Since there was no previous research to base these standard deviation estimates on, the effect size was chosen as a standardized medium. The test revealed that a sample size of approximately 30 participants was suiting. With a limit on devices, time, and overall complexity in the research design, the choice was to lower the power of the study to .60. The analysis then showed a sample size of approximately 20 participants, which is the amount chosen for the study.

The participants were recruited from the personal network of the research team. Also, some participants were interested and reached out to the team after hearing about the research through word of mouth. As the load on the participants was high, it was necessary to recruit highly motivated participants. By recruiting from the personal network, it was easy to know the effort the participants were willing to put in. The participants reaching out were also clearly motivated to put in the work. As compensation for participating in the study, each participant received a cinema ticket which was given by the Department of Computer Science at the Norwegian University of Science and Technology. There is a span of different studies and study years in the participant group, which should represent a satisfying amount of different study techniques.

Conditions

The study was split into four groups of conditions:

- **Smartphone:** Memory cues were delivered to the participants on a smartphone.
- **Smartwatch:** Memory cues were delivered to the participants on a smartwatch.
- **Smart-glasses:** Memory cues were delivered to the participants through the display of a pair of smart-glasses
- **No Device:** Control group where participants do not receive any cues.

Validity Strategies

To assure the validity of the experimental design and its data, some measures needed to be taken. The following describes the methods used in this within-subjects design:

- **Randomized and consistent cues:** The memory cues were delivered in a randomized order for each participant. Each participant received on the other hand the exact same amount and repetitions of cues.
- **Counterbalancing conditions between participants:** To minimize the influence of extraneous factors, the conditions (no cue, phone, watch, glasses) were used in a particular order, spread between participants. This way, the order in which the conditions were used should not influence the analysis.

- **Counterbalancing texts across conditions:** The priming texts were also counterbalanced across the conditions.

- **Controlling for pre-existing knowledge:** To prevent tainted results by participants' previous knowledge, they answered with sliding scales how knowledgeable they were in the selected themes. This happened before the augmentation phase of the study began.

- **Preventing memorizing questions and answers:** The participants took all the quizzes two times. To prevent them from learning the first quiz and tainting the results, they were not able to see the correct options after taking it.

- **Strategies to avoid recognition**: The multiple-choice quizzes were constructed with distractors and paraphrasing to avoid memory recognition of the answers.

Randomization of cues helped combat the serial position curve by making the participants receive different cues as the first and last in the sequence. This prevented one of the memory cues getting increased recall from the primacy effect or the recency effect since each participant had different cues as their first and last in the sequence.

Counterbalancing was achieved by utilizing a balanced Latin square as shown in the plan in figure 4.2. It was designed to balance the strengths of counterbalancing with practical reality (Martyn Shuttleworth, 2022). The study design could as a result be done with a reasonable size and with minimal risk of carryover effects.

Multiple-choice quizzes may be associated with recognition memory research as they can resemble a forced-choice recognition test. It is, however, possible to create multiple-choice tests that measure comprehension rather than recognition and as a result target memory recall. The strategy is to construct distracters that also trigger recognition responses (Dewey, 2018). Paraphrasing the content may also help. These strategies are used in the quizzes to avoid answers based on recognition alone.

Hardware

The experimental design and implementation choices sat a minimum limit of devices to make sure every participant got what they needed during the evaluation phase. Ten smartphones, five smart-glasses, and five smartwatches were needed. The devices used for the study were:

- 8 Huawei P20 lite smartphones.

- 2 Oneplus Nord N100 smartphones.

- 5 Samsung Galaxy Watch 4.

- 5 Vuzix Blade Smart Glasses.

The four different types of devices are shown in figure 4.1.

Figure 4.1: The four types of devices used in the study. From left: Vuzix Blade Smart Glasses, Samsung Galaxy Watch 4, Oneplus Nord N100, and Huwawei P20 lite.

4.2 Procedure

The study was scheduled over two weeks. Four of these days were the main participation with approximately three hours a day. Four days in the following week were additional test days, but these only took a couple of minutes of their day. The procedure in the eyes of the participants consisted of the three main activities priming, memory augmentation, and evaluation:

1 **Priming**

At the beginning of each study day, the participants were given a text of approximately one page, containing arcane information about a theme. There were four unique texts, one for each of the four thematic categories. The text was to be read in the morning before the Memory Augmentation phase began. The participants received the text in a form and they needed to confirm that they had read it by clicking “read”. The form was not accessible after clicking to make sure there was no cheating in the evaluation phase at the end of the day.

2 **Memory Augmentation**

In the memory augmentation phase, the participants received memory cues related to the priming text on the device they were provided for the day. The priming text holds sufficient information to generate eight facts to be remembered. The participants were given four memory cues to help them remember the facts. The remaining four facts were used as control.

The cues were delivered every 15 minutes in a randomized order. Every cue was repeated three times. In total, the participants received 4x3=12 memory cues each day.

The memory augmentation phase lasted three full hours each day. The participants were free to begin the phase at any time after the priming phase but before 3 pm. They were also free to do whatever activity they wanted, as long as they could interact with the applications when needed.

3 **Evaluation**

At the end of each study day, the participants received a multiple-choice questionnaire that corresponded to the unique primer text they received in the morning. It was sent out at 6 pm and had to be answered as soon as possible. There were eight questions: four corresponding to the memory cues, four were control.

One week after each participation day, the participants received the same quiz they took at the end of that day. This quiz was meant to test how their memory of the content developed over time.

There were four participant groups, one for each of the conditions. The within-subjects design makes it so that every group participated in every condition. Figure 4.2 shows how the groups were distributed throughout the four days of memory augmentation. Every group and every condition were tested on each of the days. Monday, Wednesday, Friday, and the next Monday were the days of memory augmentation. The days in-between were off days, such that the research team could collect the devices, reset them, and redistribute them for the next day. As an example, group 1 used a phone on Monday, no device on Wednesday, smart-glasses on Friday, and a smartwatch on the next Monday. The quizzes after one week followed the same plan, only one week later.

Figure 4.3 is a visualization of how the participants could structure their day. There were three activities they needed to schedule in their plan: reading the morning text, using the device for three hours, and answering the quiz at the end of their day. As the figure visualizes, they could start reading the text between 08:00 and 14:00, start using the device between 09:00 and 15:00, and answer the quiz between 18:00 and 22:00. The green color indicates the optimal time for starting the activities, and the red indicates the latest time. The point of providing this plan was to give the participants enough freedom to schedule their day as it suited them, at the same time as their start times should be similar. By giving them freedom, the ”in-the-wild” part of the study was maintained. This way of learning is meant to be incorporated into an otherwise busy day. Their start times should be similar to decrease the amount of independent variables and different circumstances in the data analysis.

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon
Day	1	2	3	4	5	6	7	8
Phone	Group 1		Group 2		Group 4			Group 3
Glasses	Group 2		Group 3		Group 1			Group 4
Watch	Group 3		Group 4		Group 2			Group 1
No device	Group 4		Group 1		Group 3			Group 2

Figure 4.2: Plan for the participants' involvement in the study.

Time:	Read morning text	Start using device	Answer quiz
08:00			
09:00	Optimal time		
10:00		Optimal time	
11:00			
12:00			
13:00			
14:00	Latest		
15:00		Latest	
16:00			
17:00			
18:00			Optimal time
19:00			
20:00			
21:00			
22:00			Latest

Figure 4.3: Time plan for how the participants could structure their memory augmentation day.

4.3 Study Contents

Themes

The process of choosing contents for the study was a long one, where several arrangements and themes were discussed. The only thing that was set in stone from the beginning was that the contents should be associated with learning. Early ideas ranged from language learning to mathematics. In the end, the choice fell on choosing a theme that contains sufficient information to create several memory cues, at the same time as it can be read through in a relatively short time window. This moved the choice to typical themes students encounter in schools (social studies, physics, biology, etc.).

With a background in the four conditions and the experimental design, there had to be generated four different texts. To make sure the texts and cues did not cross each other content-wise, there needed to be four themes as well. The chosen themes were:

- Astronomy
- Biology
- Psychology
- Science

History, arts, and social studies were also considered, but the chosen themes provided the best structure and are similar in how they are taught.

Texts

There are several criteria for the texts that the participants read on the morning of each augmentation day. The first one is that it had to be short enough to only take a couple of minutes from their day. This is to make sure the motivation and concentration of the participants did not decrease. The second criterion is that the text needed to contain sufficient information that eight memory cues could be extracted from it. Roughly 400 words for each text were estimated to satisfy these two criteria. The third criterion is that content of the text could not be well-known facts and information. It had to be content that most people did not have general knowledge about. If they did, it would influence the results of the testing.

The texts were chosen by doing a quick literature search on exciting and less-known areas of each theme. As the participants were students and their studies were known to the researchers, their general knowledge was roughly mapped. This way, their specialized knowledge could be avoided. For the astronomy theme, the research area of quasars was chosen. Epigenetics was chosen for biology, memory theory was chosen for psychology, and unknown interesting units was chosen for science. Several other areas could be picked, as long as they satisfy the criteria.

Memory Cues

The memory cues created from the texts are designed to be the most important keywords associated with the newly acquired semantic information. The purpose is to give the participants the best possible base to learn what they have read. To manifest this, the cues are the keywords that provide the most recognizability and distinctiveness. To be consistent, every cue only holds one word or concept. This concept corresponds to one of the concepts in the text.

Associated with every cue, there was one sentence that explained it. This sentence was used as the extra information the participant could access when flipping the cue card in the application. They are between 15 and 20 words long. The cue information sentence was used as a helper for the participants if they did not remember what a concept was. To only remember the name of it would not conclude any learning for the participant.

Corresponding to the memory cue and the memory cue information is a multiple-choice question which the participants answered at the end of each day. If the participants had access to the memory cue information at the time of the quiz, they would most likely be able to answer the questions. This is because the questions are created directly from the cue and information, albeit with some reformulations.

Table 4.1 is an example of how every cue is processed to several different content variations. As there are four texts with eight associated memory cues, there are 32 tables like this one in the study contents.

Cue	Cue Info	Question	Choices
Morgen	Morgen arises from the Germanic word for morning and refers to the amount of land that could be ploughed in one morning.	What does the unit Morgen refer to?	To the amount of land that could be ploughed in one morning.
			To the amount of trees that could be chopped in one morning
			To the amount of ploughed land needed to pay off the mortgage on a medium sized house.
			To the amount trees needed to pay off the mortgage on a medium sized house.

Table 4.1: The content associated to one memory cue.

4.4 Data Collection

Norwegian Centre for Research Data

The data collection for the study included name, age, gender, study, year of study, and email. These demographics were used to provide context for the study. The collection entailed applying for a notification form with the NSD (Norwegian Centre for Research Data) (NSD, 2022). The significant details of the notification form are:

- Name, age, gender, study, year of study and email will be gathered.
- In-app analytics will record the choices the participants make.
- Personal data will be processed confidentially and in accordance with the data protection legislation (The General Data Protection Regulation and Personal Data Act).

- Identifiable data will be anonymized when processed.
- Anonymized data is stored as verification and archived for future research.
- The project is scheduled to end 20.06.22. All identifiable data will be deleted by this date.

Questionnaire and Testing

The first step the participants went through was the demographics questionnaire. It was sent to them the first morning with the first priming text. It was made up of three parts. The first part gathered the participants' names, ages, genders, studies, and study levels. The second part mapped the participants' experience in the relevant technology use. This information provided context if they encountered any problems during testing. Part three consisted of a mapping of the participants' knowledge about the selected themes. They got to rate their knowledge about the themes on a scale from one to five. By doing this it was possible to see why some participants would perform very well even without memory augmentation.

After every augmentation day, a questionnaire in the form of a quiz was sent to the participants. Here they got multiple-choice questions related to the topic of the day. Four questions related to the memory cues, and four questions related only to the text. These last four were used as control, in addition to the control group. In total there were four quizzes reflecting the four topics and the four conditions. The questionnaires generated quantitative data for the analysis.

Analytics

To map the participants' behavior during the augmentation phase, several interesting data points got recorded. It was done through in-app analytics. By doing analytics, it was possible to make correlations between how the participants handled the applications to how well they performed during testing. It is insightful data that did not apply any burden on the participants. The analytics recorded were:

- Condition (smartphone, smartwatch, smart-glasses).
- Receiving a new cue.
- Cue interaction (flipping of cue card).
- Cue design (cue, length of cue, and cue hint).
- In-app settings (timing, notifications, cue set, userId).

All analytics were provided with a timestamp and are countable. It was handled and stored in Google Analytics for Firebase. The Firebase dashboard provides basic analytics functionality which is suited for user trends and behavior. Since the analysis required a more detailed view, BigQuery was integrated with Google Analytics. Detailed user tracking was therefore achieved through SQL-queries on the complete data set in BigQuery. The analytics generated quantitative data for the analysis.

Chapter 5

Results

Data were collected from a total of 19 participants throughout the study. Each of these participated in the four different conditions in the span of two weeks. For each condition, the participants received a score between 0 and 8 based on their performance on the multiple-choice quiz they took. They answered the multiple-choice quiz two times, one time the same day as they received the cues, and one time after a week had elapsed.

One of the smartwatches malfunctioned and caused three data points to be worthless. Due to this, the sample size of the watch was lowered to 16. This resulted in running the analysis twice, first with all devices and second without the watch. This was done to see whether the increase in data points from 16 to 19 resulted in more significant results, which it did.

5.1 Participants

Demographics

The data from the demographics questionnaire provides the study with context and gives an overview over how generalizable the results are. It gives a measure of how useful the effects are for a broader group of people or situations. The target population in this case was students at university level. It is both a large population, at the same time as it targets a rather specific situation. The results should be generalizable for all students at university level. As the study targets basic memory features that are not unique in students, one can also argue that it should be applicable for all people in the same age group. The fact that basic memory features are common among people is the reasoning behind not hunting rigorously after an even more generalizable population.

There was a total of 19 participants in the study. Originally there were 20, but one participant had to leave the study for reasons unknown. The sample consisted of 79% male and 21% female participants. The age distribution is depicted in figure 5.1. The range was between 20 and 26 years old, which is to be expected for university students. The average age was 24 years. Figure 5.2 shows the distribution of study levels in the sample. The range was between two and five years of study at university, and the average was four years. The participants can accordingly be characterized as an experienced student sample.

There were seven different directions of studies in the sample. The highest represented study was Master in Informatics. Subsequently, there was Mechanical Engineering, Bachelor in Informatics, Energy and Environmental Engineering, Civil and Environmental Engineering, Industrial Economics and Technology Management, and Teacher Education. All were part of NTNU.

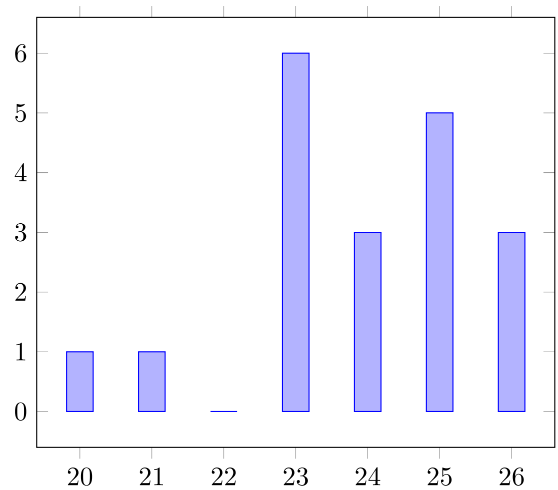


Figure 5.1: Age distribution of participants.

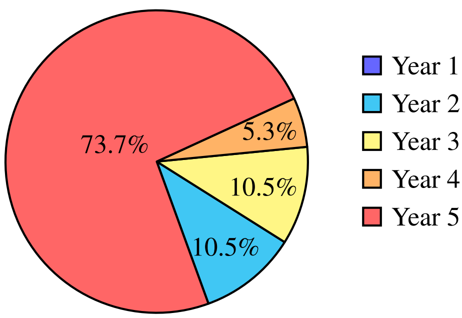


Figure 5.2: Study level distribution of participants.

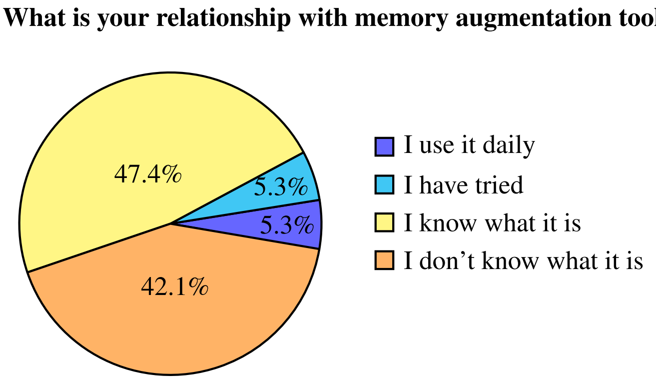
Previous Knowledge

The second part of the questionnaire provided insight into how familiar the participants were with the technology they were going to use. The results were as expected, as the technology is in the innovation phase of the technology adoption lifecycle (Gainsight, 2022). Figure 5.3a shows how their relationship with memory augmentation tools were. 42% did not know what it was, while 47% had heard of it. One person had tried it, and one person used it sometimes. It is safe to say that the field is new to most of them.

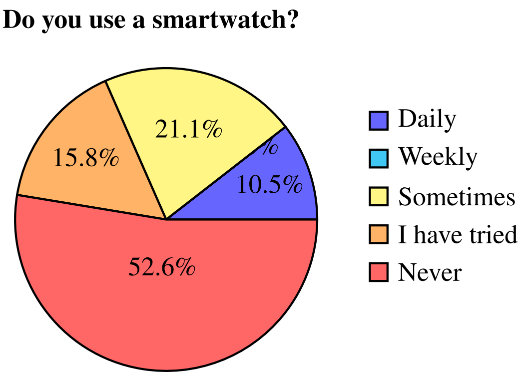
Figure 5.3b shows the relationship with smartwatches. The participants were more familiar with smartwatches than the other technology. Smartwatches can be placed somewhere between early adopters and early majority on the adoption lifecycle, and it makes sense on that account. 11% used smartwatches daily, 21% had used it sometimes, 16% had tried, while 53% had never tried.

Figure 5.3c shows how the relationship was with smart-glasses. Almost every participant had never tried using a pair (95%). Only one person had tried to use a pair earlier.

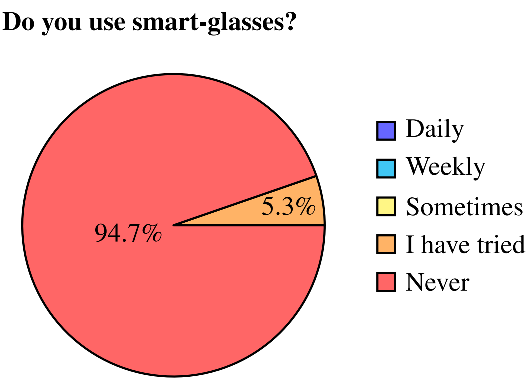
The third part of the questionnaire provided context for how knowledgeable the participants were in the themes they encountered in the study. Figure 5.4 shows the results. They were asked to rate their knowledge of the themes from one (no knowledge about the theme) to five (expert in the theme). The average scores for the themes were: astronomy = 2.4, biology = 2.3, science = 3.6, psychology = 2.3.



(a) Participant experience with memory augmentation tools.

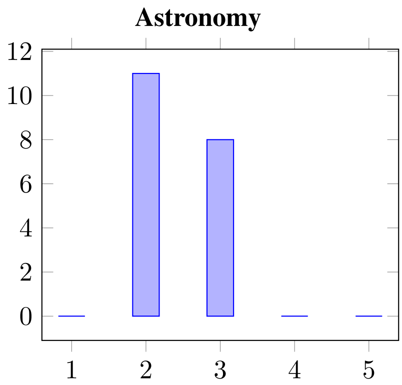


(b) Participant experience with smartwatches.

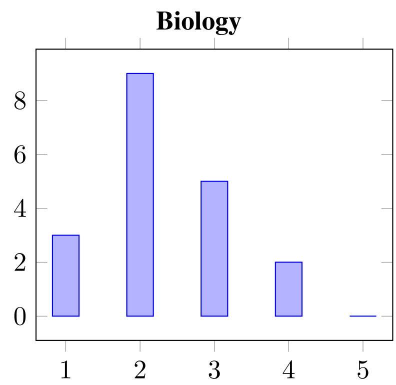


(c) Participant experience with smart-glasses.

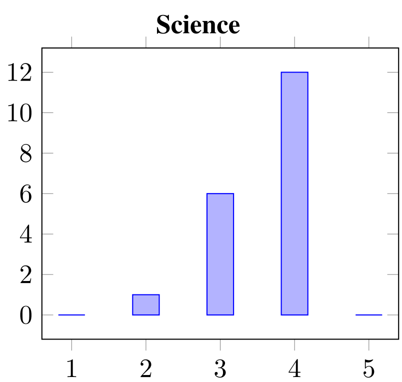
Figure 5.3: Participant experience with technology in the study.



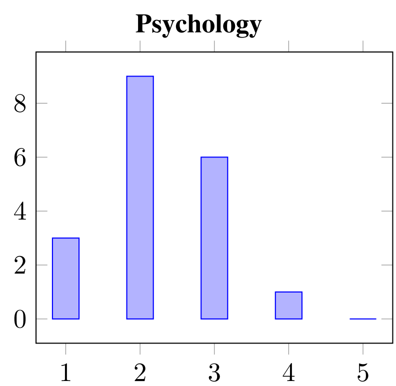
(a) Participant experience with astronomy.



(b) Participant experience with biology.



(c) Participant experience with science.



(d) Participant experience with psychology.

Figure 5.4: Participant experience with the themes in the study.

Participant Behavior

The participants mostly followed the plan that was given to them in figure 4.3. They were given an interval where they could choose to start each activity. The interval for reading the morning text, and start using the device were six hours, while they had four hours to answer the quiz. Starting with the first activity (reading morning text), there were only four incidents of participants starting outside the time slot given to them. The majority read the morning text around the optimal time. For the second activity (start using the device), there were only three incidents of participants starting later than the intended interval. However, the starting times were scattered more within the interval (less optimal times).

The third activity (answering the quiz) was also scattered, but the majority answered within the time slot. For each of the augmentation days, there were always a couple of participants that forgot the quizzes and needed reminders. Some of these answered outside the interval the same day, and some answered the day after. Specifically, there were eight incidents outside the time interval for the quiz after memory augmentation. The quiz one week later had a scattering between two days for every quiz.

5.2 At First Glance

Before executing the several different analyzing techniques on the data gathered from the study, let us present the initial glance at the trends in the data set. After the participants partook in reading and memory augmentation, the quizzes modeled their learning of the different themes. The first look at the results shows some promising results for the use of memory cues in general. Table 5.1 shows the average results of the quizzes after the first week, as well as the average results of participants with cues vs. without cues. The average of all the themes for participants with cues is 5/8, compared to those without cues which is 3/8.

The same promising results go for the average correct on cued questions vs. uncued questions in table 5.2. We see a higher rate of correct answers on the questions that the participants received cues on, with 75% correct on average vs. only 56% correct on average on the uncued questions. The average score of all participants on the first day was 4.96, and after a week had elapsed this score was 4.86. Table 5.3 shows the average scores for each device as well as the total average for all conditions. The figure also shows how each device scored on the first day and after a week had elapsed and their differences.

Table 5.4 shows the average scores for each category both the same day and after a week. It shows that science was the category with the highest average day-score, followed by memory theory, astronomy, and finally biology at last. There was a slight increase in scores after a week for astronomy and memory theory and a decrease in scores for biology and science.

These results provide the basis for comparing and doing analysis further on the four different conditions. To prove or disprove the assumptions and research questions, the next step is statistical analysis.

ALL SETS TOTAL	**Science**	**Biology**	**Psychology**	**Astronomy**	**AVG**
Avg. results	5/8	5/8	5/8	5/8	5/8
Avg. participants with cues	6/8	5/8	5/8	5/8	5/8
Avg. participants without cues	5/8	4/8	6/8	3/8	3/8

Table 5.1: The average results for all participants on the quizzes - with the average results for participants who received cues vs. those who did not.

ALL SETS TOTAL CUED	Science	Biology	Psychology	Astronomy	AVG
Avg. correct on cued questions	85.71%	57.69%	76.79%	78.85%	74.76%
Avg. correct on uncued questions	53.57%	59.62%	53.57%	55.77%	55.63%

Table 5.2: The average correct on cued questions in the quizzes vs. uncued questions. Only on cued participants (the control group is excluded).

Device	Day	Week	Difference
Phone	5.16	4.84	-0.32
Watch	5.00	5.00	0
Glasses	5.47	5.00	-0.47
No Device	4.21	4.68	0.47
All	**4.96**	**4.86**	**-0.10**

Table 5.3: Participant mean recall score among the different devices.

Category	Score Day	Score Week	Difference
Astronomy	4.61	4.72	0.11
Biology	4.50	4.11	-0.39
Memory Theory	5.28	5.67	0.39
Science	5.42	4.95	-0.47

Table 5.4: Participant mean recall score among the different categories.

5.3 Statistical Analysis

5.3.1 Statistical Methods

All the statistical analysis was performed using SPSS Statistics (IBM, 2022). The tutorials for each of the testing methods guided the way the tests were performed in SPSS Statistics.

To compare the means of the different conditions, a repeated-measures ANOVA was used. The independent variables for this test were the different conditions, and the dependent variables were the score the participants received either at the end of the day or after a week had elapsed. It was used to see if there were statistically significant differences in the participants' scores among the different conditions. The repeated measures ANOVA assumes the data set is approximately normally distributed but can handle small deviations (Laerd Statistics, 2018a). It also assumes the participants are the same in each group, making it a well-suited analysis for the data set. In the data sets where a significant difference in means was concluded, a Bonferroni post hoc test was used to discover which specific means differed.

To test if the data set is normally distributed, a Shapiro-Wilk test was used. It was used since it is preferred for data sets with less than 50 participants (Laerd Statistics, 2018c). The approach to Shapiro-Wilk can be divided into two themes: statistical analysis and visual inspection. Statistical analysis makes a more objective judgment of normality, but is sometimes not sensitive enough at low sample sizes. Visual inspection of data plots and graphs is more subjective, and requires more experience than numerical tests. The approach was to weight the numerical test most, but also inspect the data visually in the form of histograms and QQ plots due to the small sample size.

To see if cue interaction played a part in the effectiveness of cues, the cue flip data was tested with a Pearson Correlation Test. The Pearson correlation test is a measure of the strength of a linear association between two variables (Laerd Statistics, 2018b). The correlation coefficient has a range from -1 to +1, where a positive value indicates a positive association and a negative value indicates a negative association. A value of 0 indicates that there is no association between the two variables. The first variable in the test was the amount of cue flips performed by the participants, and the second were either the day score or the week score.

5.3.2 Statistical Results

In this section there are references to mean participant scores from the multiple choice tests either the same day as they received the cues (day score) or a week after they received the cues (week score).

Day Score

A Shapiro-Wilk test of normality was conducted to check the data set for normal distribution. The results show that the conditions of phone, glasses, and no device do not show evidence of non-normality. The watch condition showed evidence of non-normality. From the results of the normality test, a repeated-measures ANOVA test was conducted to compare the day score between the conditions of phone, glasses, watch, and no device. The results depict that there were no significant difference between the participants using phone (M=5.06, SD=1.611), glasses (M=5.50, SD=1.506), watch (M=5.00, SD=1.414), and no device (M=4.50, SD=1.751); $F(3,45) = 1.309$, $p = 0.283$.

Week Score

A Shapiro-Wilk test of normality shows that the conditions of phone, glasses, and no device did not show evidence of non-normality. The watch condition showed evidence of non-normality. A repeated-measures ANOVA was conducted to compare the week score of the participants using phone (M=5.06, SD=1.692), glasses (M=4.81, SD=1.167), watch (M=5.00, SD=1.751), and no device (M=5.00, SD=1.592); $F(3,45) = 1.118$, $p = 0.949$. The results show that there was no significant difference between the different conditions.

Day Score without watch condition

The data set has already been tested for normal distribution, and a repeated-measures ANOVA was conducted to compare the day score between participants using phone (M=5.16, SD=1.708), glasses (M=5.47, SD=1.389), and no device (M=4.21, SD=1.873); F(2,36) = 4.129, p = 0.024. The result is shown in table 5.5. Table 5.6 visualise a post hoc analysis with a Bonferroni adjustment that was conducted and it revealed a statistically significant difference between using the glasses and no device; 1.26(95% CI, 0.22 to 2.31, p = 0.015). It did not show significant difference between phone and glasses (-0.316(95% CI, -1.58 to 0.95, p = 1) or between phone and no device (0.95(95% CI, -0.35 to 2.25, p = 0.21).

	df	Mean Square	F	Sig.	Partial Eta Squared
Sphericity Assumed	2	8.211	4.129	0.024	0.187

Table 5.5: Repeated measures ANOVA test on Day Score without the watch condition.

Device	Condition	Mean Difference	Std.Error	Sig.	Lower Bound	Upper Bound
Phone	Glasses	-0.316	0.478	1	-1.577	0.945
	No Device	0.947	0.492	0.211	-0.352	2.247
Glasses	Phone	0.316	0.478	1	-0.495	1.577
	No Device	1.263	0.396	0.015	0.218	2.309
No Device	Phone	-0.947	0.492	0.211	-2.247	0.352
	Glasses	-1.263	0.396	0.015	-2.309	-0.218

Table 5.6: Bonferroni post hoc test on Day Score without the watch condition.

Week Score without watch condition

The data set has already been tested for normal distribution, and a repeated-measures ANOVA was conducted to compare the week score between participants using phone (M=4.84, SD=1.708), glasses (M=5.00, SD=1.202), and no device (M=4.68, 1.668); F(2,36) = 0.286, p = 0.753. The results did not show a significant difference between the different conditions.

Pearson Correlation Test of Day Score and Cue Flips

Table 5.7 shows a Pearson correlation test run to determine the relationship between day score received by participants and cue flips done by the participants. There was not found a strong correlation between Day Score and the number of cue flips (r=-0.160, n=49, p=0.271).

		Day Score	Cue Flips
Day Score	Pearson Correlation	1	-0.160
	Sig. (2-tailed)		0.271
	N	73	49
Cue Flips	Pearson Correlation	-0.160	1
	Sig. (2-tailed)	0.271	
	N	49	49

Table 5.7: Pearson Correlation Test on Day Score and Cue Flips.

Pearson Correlation Test on Week Score and Cue Flips

Table 5.8 shows a Pearson correlation test run to determine the relationship between the participant week score and the number of cue flips performed by the participant. There was no strong correlation between the Week Score and the number of cue flips (r=-0.029, n=49, p=0.841).

		Week Score	Cue Flips
Week Score	Pearson Correlation	1	-0.029
	Sig. (2-tailed)		0.841
	N	73	49
Cue Flips	Pearson Correlation	-0.029	1
	Sig. (2-tailed)	0.841	
	N	49	49

Table 5.8: Pearson Correlation Test of Score Week and Cue Flips.

Chapter 6

Discussion

This chapter begins by restating the purpose of doing the study. Next, it provides interpretations and implications from the results of the statistical analysis and trends in the data set. In the end, it recommends actions for future research and provides an overview of the limitations of the study.

6.1 Purpose of the Study

To begin to cover the considerable novelty gap in wearable memory augmentation, three wearable devices were compared in how successful they are in amplifying memory recall. The motivators for creating and evaluating a wearable memory-augmenting system for memory recall were to amplify memory recall with a marginal increase in effort, the complete novelty of the research, and to move cued recall out of the lab. These motivators were included in the design of the research questions, which were:

RQ1 How does cue delivery modality (no cue vs. smartphone vs. smartwatch vs. smart-glasses) affect participants' recall scores at the end of the day?

RQ2 How does cue delivery modality (no cue vs. smartphone vs. smartwatch vs. smart-glasses) affect participants' recall scores when a week has elapsed?

To answer how the modalities relatively performed in amplifying memory recall, the research was divided into two directions. RQ1 covered if the cue delivery modality had an effect on participants' recall scores at the end of the day. RQ2 covered if the modalities had an effect after a week had elapsed. In addition, a set of independent variables got recorded for trying to model how the applications can be designed in the future.

The first assumption regarding the outcome of the study was that the more immersive the cue delivery modality is, the more likely participants were to remember the study contents. The second assumption was that the participants would score significantly higher on the quiz after each day compared to the same quiz one week later. If the results were to converge, the assumption was that the research could have a significant impact on the field of learning.

The statistical analysis of the gathered data shows that the smart-glasses had a significant effect on participants' recall after each day of memory augmentation compared to the no-cue condition. This satisfies the assumption made. The trends in the data set also suggest that when participants undergo memory augmentation, they perform better on the quizzes overall. This is even suggested in the recall scores after a week had elapsed. To summarize, the research question can be answered with that the heads-up modality is the most promising to be used as a memory augmentation tool.

6.2 Interpreting the Results

The demographics of the participant sample were considered to be sufficient for doing an initial analysis on the wearable memory augmentation system. The age distribution represented a normal range for students, the study levels had an adequate distribution, and there were several different direction of studies. Their previous knowledge did not affect how the results were interpreted, as they did not show any surprising averages. There were neither any statistical results that needed to be grounded in their background. One takeaway is that the participants rated their knowledge in science best, which was confirmed in the results of the quizzes.

Looking at the participants' behavior during the user study in relation with the results of the quizzes: there were not observed any correlations between the individuals who started the activities outside of the intended time intervals and their success on the quizzes. The point of providing the desired time slot was to minimize the effects from independent variables in the wild. The investigation of the time the participants performed activities in relation to their success was outside the scope of the research. However, it would be valuable for future research to provide such insights.

The results showed that participants that received cues on average performed better than the participants that did not, with 5/8 correct compared to 3/8. The percentage of correct answers on cued questions was also higher than those questions that were not cued with 74.76% compared to 55.63%. This is inline with the expectations, and assures that the applications were successful in delivering memory cues. It is the first sign that the literature-based and experimental choices taken in the design phase yielded three effective memory augmentation systems. This satisfying product lays the grounds for the rest of the discussion.

The analysis of the different conditions showed a statistically significant difference between using the glasses compared to not using any device. Specifically, the differences in means is 16%. It is therefore possible to draw the conclusion that the glasses had a positive effect on the participants in comparison to the group without any device. In relation to the research question, this confirms that cue delivery modality has an effect on participant's recall score at the end of the day. Due to not getting a statistically significant result for the week scores, it is not possible to say with certainty that cue delivery modality has an effect on participants' recall scores when a week has elapsed. The trends did however show that glasses still outperform no device after a week.

Although there were no statistically significant differences between the phone, glasses and watch, by looking at the mean values of the devices it is possible to see differences. The average score for the participants using the glasses were 5.47, making it the device that scored the highest on average. In second and third were phone and watch with score of 5.16 and 5.00. The condition without device had an average score of 4.21, making it the lowest scorer on average by a solid margin. The results imply that the glasses was the most effective device. This could be due to the fact that the screen that displays the cue in the glasses is immersive, and forces the participant to see the cue as soon as it is delivered. With the phone or watch, it is possible to notice a notification and not interact with the cue by simply not looking at the device. These results supports the assumption that the more immersive the cue delivery modality is, the more likely participants are to remember the content. The exception is that the phone scored better than the watch.

The results showed that the average score of all participants taking the quiz the same day is 4.96 out of 8. This is slightly higher than the average after a week at 4.86. It is in line with the expectations ahead of the study. However, the expectation was a more significant change than 0.1 on average (*Ebbinghaus forgetting curve*, section 2.1).

Looking at the different devices, the phone and glasses follow the expectations with a decrease of -0.32 and -0.47 in average after a week compared to the first day. However, the watch returned the exact same average on both occasions, and the no device condition showed an increase of 0.47 in score after a week compared to the same day score. This is contrary to the expectation that the participants would forget information over time. Parts of this result could be explained by the structure of the quizzes. Since the questions are in multiple choice format with four options, the participants had a 25% chance of getting a correct answer by guessing the answer that sounds most likely to be correct.

Seeing how the results on the quizzes either decreased marginally or not at all after a week had elapsed, the argument about how the system might have a significant impact on learning theory may be valid. The participants did not only retrieve semantic facts from memory the same day as they were cued, they also managed to perform almost as good after a week. This hints towards that the use of the applications can be a means of learning where newly learned information are linked to previously stored information in memory. The reason may be that most of the participants actively used the cue interaction option, which can have acted as a cognitive task where knowledge change (*Definition of learning*, section 1.1). There is also a possibility that the repetition of memory cues is the reason behind the converging results. Looking past these theories, the research fields of memory and learning are undoubtedly closely connected. The matter of moving the research into the learning domain seems as the obvious next move.

The option of cue interaction in the systems was considered the most interesting independent variable to investigate in relation to the results of the quizzes. Its prominence in literature and its importance to the research team in the prestudy prompted this analysis. Why the investigation of cue flips did not uncover any correlations to the results, may be due to the fact that mostly all the participants used them for every cue. The positive outcome of seeing the feature utilized is that the intended application behavior was followed. If it is due to the participants' need for something to interact with when receiving a cue, or their will to do the 'correct' action during testing is unknown. In any event, the researchers believe that the possibility of interaction played a decisive part in amplifying memory recall among the participants.

Other independent variables were not examined in the analysis. Some may have influenced the results of the study as a whole: time looking at cues, time before reacting to notifications, which activities the participants partook in during augmentation, and what mental state they were in. The dataset provides data to perform analyses on some of these relations, but they are not prioritized in the context of the research questions. There are also some variables that may have influenced results between modalities. For example the differences in screen real estate and notification modalities. The watch had the smallest screen (scrolling may happen), and sound and tactile notifications. The smart-glasses had a slightly bigger screen with no sound or tactile feedback. The phone had a big screen and both types of feedback. These qualities may introduce bias and should be investigated further. Having said that, the differences in qualities with each device are a part of why they need to be compared in the first place.

So why do these results matter? Starting with RQ2, cue delivery had an effect on participants' recall scores at the end of the day. In fact, smart-glasses or similar prominent devices may be the most promising technologies for amplifying memory recall. That is what the analysis reveals and should merit further use of the device in memory research. The analysis of RQ3 did not prove that cue delivery modality affected participants' recall scores when a week had elapsed. However, the trends indicate that this is the case which should give sufficient motivation for further investigations into the long-term effects of wearable memory augmentation.

Where do we put the implications in the context of Memory Theory and Wearable Computing? Using wearable technology for amplifying memory recall was a novel task to set in motion. As a result, it is the intersection between the two fields that the novelty of the applications moves into. Firstly, the most effective modality has been identified (smart-glasses: heads-up modality). Secondly, the success of the applications' design can serve as an initial model upon which wearable memory augmentation can be improved.

6.3 Design Implications

The literature provided proven design strategies to follow, as well as ideas that were tested in the study. To create the best memory augmentation system possible, the research team based the design of the system and memory cue delivery on promising research. The implications are manifested in a list of recommended design guidelines:

- **Textual memory cues targeting semantic memory:** The content of memory cues in the study were semantic information. As literature could not prove that multimedia memory cues are favorable in semantic retrieval there was no need to add it to the system. To make sure the research is not overcomplicated and the system is not overengineered, the cues should be text-based. The investigation of other sensory stimuli as memory cues should nevertheless be investigated.

- **Three repetitions of memory cues:** The literature revealed that repetition of memory cues are effective for increasing memory recall. Systems should accordingly repeat every cue three times to improve the chances of successfully triggering memories among the participants. The promising results in this study add to say that this is the case, but other variations were not tested.

- **Randomization of cue order:** The serial position curve stated that people tend to remember information better at the start and end of a set, as opposed to in the middle (Section 2.1). The order in which cues are delivered should therefore be randomized. This way, bias is avoided.

- **Balance between user control and system control:** The system should be designed with user experience in mind. This includes the balance between user control and system control in the timing and frequency of cues. Memory cues should on that account be displayed in a timely manner, with an option of customization. The system in the study was designed in this way, but the participants were limited to a 15-minute time interval to avoid more independent variables.

- **Cue interaction:** Both literature and the prestudy-experiment manifest that there is a need for some kind of interaction when the participants receive a new cue. The study did not manage to prove its effectiveness, but it is the view of the researchers that it is decisive. Nearly all participants used the option of cue interaction for every received cue. Having the alternative to see more information about the cue will most likely lead to greater cognitive absorption and in turn increase memory recall.

- **Memory attachment:** The promising results of memory attachment in literature substantiate that the memory cues should be designed to be the most important keywords associated with newly acquired semantic information. The memory cues should as a result be based on memory attachment to the content in the texts. Niforatos et al. (2018) achieved a 15% increase in recall using this strategy (Section 2.2). An increase of 16% is reported in this study to support the finding.

- **Recognizability and distinctiveness:** The memory cues should be chosen from the texts based on the qualities of recognizability and distinctiveness as stated in Lee and Dey (2007)(Section 2.2). The qualities were taken into consideration during the design of memory cues in this study. Creating cues this way helps in encoding them to memory.

6.4 Recommendations for Future Research

The research in this study is centered around the three research questions, as well as trying to model how a memory augmentation should be designed. The research questions have been answered by some significant results and the trends seen in the data set. The design of the system has shown to be a success, with some more investigation needed. The way forward on the topic should be to do a bigger study with investigations into more independent variables and multimedia memory cues. The most interesting turn should be to move the study into the research field of learning. These recommendations are further explained in the following:

1 **Further investigations into the long-term effects of wearable memory augmentation**

Further research on the topic should conduct a closer investigation into the long-term effects wearable memory augmentation has on memory. It would be interesting to see if the devices have any individual benefits for memory in the long run. The recommendation is to increase the sample size and generalizability to increase the power in drawing conclusions and further prove the trends that are seen in this study. Doing a similar study with longer waiting periods between memory augmentation and tests could also provide additional insights.

2 Further investigation into the influence of independent variables

To establish why the participants perform differently with each device, a further investigation into the influence of independent variables is recommended. The analysis of the time looking at cues, time before reacting to notifications, which activities the participants partake during memory augmentation, the mental state of the participants, or the differences in screen real estate, to make some suggestions. Comparing cue delivery modalities in the context of these independent variables may add to why they perform differently. It would also be interesting to validate the design choices that are taken. For example, a further investigation into cue flips in a longer study may prove that cue interaction is crucial for the effectiveness of cues.

3 Multimedia memory cues

Multimedia memory cues could add another dimension to the study by leveraging the episodic part of long-term memories. It was intentionally left out of the design to avoid overcomplicating the research and focus on the research objectives at hand. As seen in literature, multimedia cues could combine images, audio, and even video to create a more complex retrieval of memories among the participants. There are two possible ways of doing this. The first is to create memorable cues through the use of distinct related images, audio, or video to force a mental model of the cue through to the participant. The second is to make use of the contextual information around the participants when they first read the priming text. The context could be where they were, who where there, time, and other specific details. It could be used as a sensory stimulus together with the textual cue to trigger the retrieval of knowledge in the text. Eventually making the transition from episodic to semantic memory complete.

4 Move into the learning domain

The affinity of memory recall and learning warrants that the study may have a significant impact on the research field of learning. The recommendation is subsequently to move the use of the system into the learning domain to reliably make contributions to the field. For example doing the study in the context of a course, workshop, seminar, or tutorial. One idea is to perform the study on students in a course over a period of multiple weeks or months as a tool for studying for the exam. The results of the exam could serve as the evaluation of the cue delivery modalities. The long-term effects on memory by wearable memory augmentation would be closely related to such a study.

6.5 Limitations

The sample size affected the likelihood that the study would find significant differences if differences existed. With a sample size of 20, the power was .60, which preferably should have been .80. One participant also had to leave the study before it began, making it a total of 19. However, the power was accepted with the reasoning of decreasing complexity in the experiment and that the novelty would still be maintained.

A malfunctioning watch made three data points worthless and effected the sample size in the analysis. The result was that their data was seen as not valid compared to the other data points. The sample size for the watch was effectively lowered to 16. The solution was to do another analysis with the three other conditions, and leaving out the watch. This raised the number of data points back to 19 for each of the conditions, and proved to be sufficient for seeing significant results. Due to the lack of data points on the watch, its analysis did not show significant differences. With 19 or more data points, it is plausible that it could have shown the expected difference.

The generalizability of the study may have been affected by a couple of factors. The first being that recruitment was performed through the research team's personal network. Preferably should there have been more new students and a wider age distribution. The second factor is that the participants only represent students at NTNU. It is not expected to be cultural or other demographic differences on a trait such as memory, but diversity should be accounted for in the future. The recommendation is to measure results of students from different universities or even from different countries.

Data loss in the in-app analytics may have influenced some of the results to not show significant differences. The results in question are how many cue flips the participants performed during memory augmentation. The goal of this analytic was to see if the action had any impact on scores in the quizzes. Internet instability and duplicate logging are the reasons for the data loss. It did not impact the analysis related to the research questions.

It is important to mention the limitations of doing a study in the wild. While it had a range of advantages for evaluating realistic behavior and outcomes, it also warranted less control in the investigation. It entailed the introduction of a range of independent variables that were not possible to measure. The sum of all these independent variables can have affected the results. The study is however designed to see the system in realistic environments with unknowns at the practical minimum.

Chapter 7

Conclusion

The contribution of this thesis is in two parts: Identifying the favorable modalities and their performances, and establishing a preliminary model for the design of wearable memory augmentation systems. The multi-week study with 19 participants gave rise to a quantification of the memory enhancement the wearable system is capable of: 16% on average with smart-glasses. It shows that the heads-up modality is the most promising wearable technology in amplifying memory recall. The trends also suggest that the system has considerable potential on handheld and wrist-worn devices. A similar trend can also be observed in the long-term effects of memory augmentation. The second part of the contribution is based on the systems' success and manifested in seven implications for future wearable memory augmentation design. Most importantly, the researchers believe cue interaction plays a decisive role in the enhancement process.

Future research can take several avenues to confirm or expand upon these findings. It includes looking further into the long-term effects, closer investigations into the influence of independent variables, and the complex lane of multimedia memory cues. Above all, the take-home message is to move the research of wearable memory augmentation into the learning domain.

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Appendix

Appendix A

Code

The code repository is available at:

https:// github.com/ adrianflatner/ Wearable-Memory-Augmentation.

Appendix B

Analysis

B.1 Score Day ANOVA

Tests of Within-Subjects Effects

Measure: DayScore

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Device	Sphericity Assumed	8,047	3	2,682	1,309	,283	,080
	Greenhouse-Geisser	8,047	2,621	3,070	1,309	,285	,080
	Huynh-Feldt	8,047	3,000	2,682	1,309	,283	,080
	Lower-bound	8,047	1,000	8,047	1,309	,270	,080
Error(Device)	Sphericity Assumed	92,203	45	2,049			
	Greenhouse-Geisser	92,203	39,313	2,345			
	Huynh-Feldt	92,203	45,000	2,049			
	Lower-bound	92,203	15,000	6,147			

B.2 Score Week ANOVA

Tests of Within-Subjects Effects

Measure: WeekScore

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Device	Sphericity Assumed	,563	3	,188	,118	,949	,008
	Greenhouse-Geisser	,563	2,337	,241	,118	,915	,008
	Huynh-Feldt	,563	2,795	,201	,118	,940	,008
	Lower-bound	,563	1,000	,563	,118	,736	,008
Error(Device)	Sphericity Assumed	71,438	45	1,588			
	Greenhouse-Geisser	71,438	35,057	2,038			
	Huynh-Feldt	71,438	41,927	1,704			
	Lower-bound	71,438	15,000	4,763			

B.3 Score Day Normality Test

Tests of Normality

	Condition	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Score Same Day	0	,168	19	,161	,904	19	,058
	1	,265	19	,001	,913	19	,083
	2	,260	16	,005	,871	16	,028
	3	,162	19	,200*	,934	19	,203

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

B.4 Score Week Normality Test

Tests of Normality

	Condition	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
ScoreAfterWeek	Phone	,160	19	,200*	,948	19	,369
	Glasses	,166	19	,180	,927	19	,154
	Watch	,221	16	,035	,823	16	,006
	No Device	,159	19	,200*	,966	19	,687

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

B.5 Power Analysis with 0.8 Effect Size

Power Analysis Table

	N	Actual Power[b]	Test Assumptions: Power	Effect Size	Sig.
Test for Mean[a]	34	,808	,8	,5	,05

a. Two-sided test.

b. Based on noncentral t-distribution.

B.6 Power Analysis with 0.6 Effect Size

Power Analysis Table

	N	Actual Power[b]	Test Assumptions		
			Power	Effect Size	Sig.
Test for Mean[a]	22	,609	,6	,5	,05

a. Two-sided test.

b. Based on noncentral t-distribution.

B.7 Bonferroni Post Hoc Test for Phone (1), Glasses (2) and No Device (3)

Pairwise Comparisons

Measure: ScoreDayWithoutWatch

(I) Device	(J) Device	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-,316	,478	1,000	-1,577	,945
	3	,947	,492	,211	-,352	2,247
2	1	,316	,478	1,000	-,945	1,577
	3	1,263*	,396	,015	,218	2,309
3	1	-,947	,492	,211	-2,247	,352
	2	-1,263*	,396	,015	-2,309	-,218

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

B.8 Pearson Day Score

Correlations

		ScoreDay	CueFlips
ScoreDay	Pearson Correlation	1	-,160
	Sig. (2-tailed)		,271
	N	73	49
CueFlips	Pearson Correlation	-,160	1
	Sig. (2-tailed)	,271	
	N	49	49

B.9 Pearson Week Score

Correlations

		ScoreAfterWee k	CueFlips
ScoreAfterWeek	Pearson Correlation	1	-,029
	Sig. (2-tailed)		,841
	N	73	49
CueFlips	Pearson Correlation	-,029	1
	Sig. (2-tailed)	,841	
	N	49	49

Appendix C

Instructions

C.1 Instructions for Phone and Glasses (in Norwegian)

Memory cues

Memory cues er små gjenkjennbare "huskelapper" som skal få oss til å tenke tilbake på noe vi har sett, lest eller opplevd. På denne måten skal man lære bedre og raskere, samtidig som læringen skal være mindre til bry for brukeren. I dette studiet vil du bli servert memory cues gjennom tre applikasjoner på tre forskjellige smartenheter.

Noen viktige detaljer om memory cues på applikasjonene:

- De vil bli gjentatt opptil flere ganger per dag.
- Rekkefølgen er randomisert, hvilket betyr at det samme cuet kan komme to-tre ganger på rad. Det er ikke en bug.
- Når du mottar et nytt memory cue vil det forrige forsvinne. Gikk du glipp av et cue går det helt fint.
- Alle applikasjonene har en flipp-funksjon på hvert memory cue. Flippes kortet vil du kunne se mer informasjon om det aktuelle cuet. Det er ikke meningen at det skal pugges, men har du glemt hva cuet handler om så kan du ta en titt for å friske opp minnet ditt.

Instruksjoner for bruk av Amplified på mobil

Instruksjoner

1. Åpne Amplified.
2. Trykk på reset settings.
3. Registrer deg ved å skrive inn ditt deltakernummer, email og passord og trykk på register.
4. Trykk på settingsikonet oppe til høyre.
5. Valg av settings:
    a. Cuing mode: **Phone**
    b. Timing: **15 minutes**
    c. Notifications: **On**
    d. Cue set: **Settet du er tildelt for dagen**
6. Sjekk at det er ditt deltakernummer som står nederst i høyre hjørne (er det ikke det, kan du logge ut og logge inn med samme bruker med nytt deltakernummer).
7. Trykk på tilbakepilen oppe til venstre.
8. Du vil nå bli servert memory cues hvert 15. minutt i tre timer. Happy learning :)

Info

- Dersom du har logget inn, men ikke vil begynne enda kan du trykke på av/på-knappen for å starte senere. Skjer det noe i løpet av dagen, kan dette også fungere som en pauseknapp. Det skal helst unngås, ettersom studiet skal representere et normalt liv med avbrytelser osv. :))

- Applikasjonen krever tilkobling til Wi-Fi. Er du på reisefot mens du får memory cues må du derfor sette på pause.
- Treat: Av/på-knappen fungerer også som valg av smartenhet ved et longclick.

Instruksjoner for bruk av Amplified på smartbriller

Instruksjoner Vuzix smartbriller

- På-knapp på innsiden av venstre brillearm.
- Høyre brillearm fungerer som en touchskjerm for å navigere vuzix.
    - Swipe frem og bakover for å navigere.
    - Swipe opp og ned for å navigere i noen menyer.
    - Tap for å velge.
    - Tap samtidig med to fingre for å gå tilbake.

Instruksjoner Amplified

1. Utfør "Instruksjoner for bruk av Amplified på mobil".
2. <u>På mobil:</u> Gå inn på Vuzix Companion appen og se at brillene er tilkoblet.
3. Gå inn på Amplified-appen på briller og mobil.
4. <u>På mobil:</u> Gjør et longclick på av/på-knappen og velg "Smart-glasses".
5. Dersom et memory cue har dukket opp på brillene vil du nå bli servert memory cues hvert 15. minutt i tre timer på brillene.
6. Touchskjerm i Amplified:
    a. Åpne meny: **Tap**
    b. Tilbake/exit: **Tap samtidig med to fingre**
    c. Se cue info: **Swipe fremover**
    d. Se cue: **Swipe bakover**

Info

- Applikasjonen på smartbrillene jobber gjennom mobilversjonen av appen. Det vil si at disse skal kobles sammen. Wi-Fi på brillene er derfor ikke nødvendig.
- Memory cues vil dukke opp automatisk på brillene, så du behøver ikke å ha lyd på telefonen.
- Brillene må være inne på appen for at memory cues skal dukke opp.
- Batterikapasiteten på brillene er begrenset, så skal du spille eller gjøre andre ting på dem må du gjøre det utenom memory cue fasen.

C.2 Instructions for Watch (in Norwegian)

Memory cues

Memory cues er små gjenkjennbare "huskelapper" som skal få oss til å huske tilbake på noe vi har sett, lest eller opplevd. På denne måten skal man lære bedre og raskere, samtidig som læringen skal være mindre til bry for brukeren. I dette studiet vil du bli servert memory cues gjennom tre applikasjoner på tre forskjellige smartenheter.

Noen viktige detaljer om memory cues på applikasjonene:

- De vil bli gjentatt opptil flere ganger per dag.
- Rekkefølgen er randomisert, hvilket betyr at det samme cuet kan komme to-tre ganger på rad. Det er ikke en bug.
- Når du mottar et nytt memory cue vil det forrige forsvinne. Gikk du glipp av et cue går det helt fint.
- Alle applikasjonene har en flipp-funksjon på hvert memory cue. Flippes kortet vil du kunne se mer informasjon om det aktuelle cuet. Det er ikke meningen at det skal pugges, men har du glemt hva cuet handler om så kan du ta en titt for å friske opp minnet ditt.

Instruksjoner for bruk av Amplified med smartklokke

1. Koble smartklokken til et wifi-nettverk. Smartklokken må ha stabil tilkobling til wifi gjennom hele den 3-timersperioden man får memory cues.
2. Når man har koblet seg til wifi, kan man starte Amplified-appen. Den finner man ved å scrolle nedover til man finner appen med dette ikonet:
3. Når man har åpnet appen må man skrive inn sitt deltakernummer i ID-feltet. Deretter velger man dagens kategori fra dropdown-menyen, også kan man trykke på START.
4. Du vil da se ditt første memory cue for perioden. Du kan bytte mellom cue og info ved å trykke på teksten.
5. Når man har sett på cuet, vil skjermen bli svart etter noen sekunder, og man trenger ikke tenke på klokka før man får nye notifikasjoner.
6. Når du har fått notifikasjon, trykk på varslingen og "open in app" for å se det nye cuet.
7. Når du har fått siste cue, vil du få et varsel der det står "finished with all cues".

Info:

- Det er dessverre ikke mulig å koble smartklokka til Eduroam, men dersom man ønsker å sitte på NTNU, kan man sette opp en wifi-bridge dersom man har en Android mobil. (Ikke hotspot siden det bruker mobildata!)
- Hvis det har gått over 3 timer siden start, og du fremdeles ikke har fått melding om at cuene er ferdig, kan du trykke på settings-knappen opp til høyre i appen, og trykke på "reset settings". Da vil du slutte å få notifikasjoner.
- Ta kontakt dersom det er noen spørsmål!

Appendix D

NSD

D.1 NSD Information Letter

Are you interested in taking part in the research project

”Wearable Memory Augmentation”?

This is an inquiry about participation in a research project where the main purpose is to explore and evaluate how smartphones, smartwatches and smart-glasses can deliver memory cues in the wild to increase students’ memory recall in learning. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
Exploring and evaluating how smartphones, smartwatches and smart-glasses can deliver memory cues in the wild to increase students’ memory recall in learning. This entails the development of three apps that can provide memory cues to amplify the learning of some theme or curriculum. There is one app for each device, namely smartphone-, smartwatch- and smart-glasses applications.

The objectives are to design and develop three applications, perform an empirical study and analyse the data that is gathered. These objectives will help us answer the research questions:

- How do smartphones, smartwatches and smart-glasses relatively perform in amplifying memory recall using a memory augmentation app for learning?
- How should cue interaction methods be designed to amplify memory recall in learning?

The project is a research project and master’s thesis.

Who is responsible for the research project?
- Norges teknisk-naturvitenskapelige universitet
- Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk

Why are you being asked to participate?
The sample has been selected through the researchers’ own network and/or through email lists provided by NTNU. The sample is 20-30 years of age and study at NTNU Gløshaugen. There are 15-25 participants.

What does participation involve for you?

If you choose to take part in the project, this will involve that you use each of the three applications over two days, for a couple of hours per day. In total 3x2 days which sum up to approximately 12 hours. The participant may choose the time of day freely. Google Analytics will record the choices you make in the app, and you will participate in experience sampling (in-app survey) for measuring the results of using the applications. Name, email, age, gender, field of study and year of study will be collected.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

The people that will have access to the personal data are Adrian Flatner and Ola Holde who are students at NTNU. We will replace the name and contact details with a code, and this will be stored separately from the rest of the collected data. Collection of data will be through the use of Google Analytics and Google Forms. Participants will not be recognizable, but age, gender, study and year of study of participants can occur in the publication.

What will happen to your personal data at the end of the research project?
The project is scheduled to end 10.06.22. The personal data will be anonymised when the data is processed. This means that name, email address and other possible identifying data are removed from results. The data is stored as verification and archived for future research.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with Norges teknisk-naturvitenskapelige universitet, Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:
- Adrian Flatner, adrianrflatner@gmail.com
- Ola Holde, ola.holde@hotmail.com
- Norges teknisk-naturvitenskapelige universitet, Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk via Michail Giannakos. *For*
- Our Data Protection Officer: Thomas Helgesen
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Michail Giannakos

Adrian Flatner
Student

(Researcher/supervisor)

Consent form

I have received and understood information about the project *Wearable Memory Augmentation* and have been given the opportunity to ask questions. I give consent:

- □ to participate in *in-app survey*
- □ to participate in field experiment (use of apps)
- □ for my personal data to be stored after the end of the project for verification and archiving for future research (not identifiable data).

I give consent for my personal data to be processed until the end date of the project, approx. *10.06.2022.*

(Signed by participant, date)

Appendix E

Background

E.1 Background Questionnaire

Wearable Memory Augmentation: Background

Background of the participant taking part in the field study "Wearable Memory Augmentation"

*Må fylles ut

1. E-postadresse *

2. Name *

3. Age *

4. Gender *

   Markér bare én oval.

   - Male
   - Female
   - Prefer not to say
   - Other

5. Study *

6. Study level *

Markér bare én oval.

- 1
- 2
- 3
- 4
- 5

Participant technology use

Mapping of participants knowledge relevant to the results of the study

7. What is your relationship with memory augmentation tools? *

Markér bare én oval.

- I use it daily
- I use it weekly
- I use it sometimes
- I have tried
- I know what it is
- I don't know what it is

8. Do you use a smartwatch? *

Markér bare én oval.

- Daily
- Weekly
- Sometimes
- I have tried
- Never

9. Do you use smart-glasses? *

Markér bare én oval.

- Daily
- Weekly
- Sometimes
- I have tried
- Never

How well do you consider your knowledge in the following themes?

1 - 5 (1 = No knowledge, 5 = Expert)

10. Astronomy *

Markér bare én oval.

1	2	3	4	5

11. Biology *

Markér bare én oval.

1	2	3	4	5

12. Science *

Markér bare én oval.

1	2	3	4	5

13. Psychology *

Markér bare én oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Appendix F

Texts

F.1 Astronomy

A quasar is a supermassive black hole feeding on gas at the center of a distant galaxy.

Quasar is short for quasi-stellar radio source, because astronomers first discovered quasars in 1963 as objects that looked like stars but emitted radio waves. Now, the term is a catch-all for all feeding, and therefore luminous supermassive black holes, also often called active galactic nuclei.

It's a bit of a contradiction to call a black hole luminous; black holes themselves are, of course, black. In fact, almost every large galaxy hosts a black hole with the mass of millions to billions of Suns, and many of these black holes lurk in the dark. Our Milky Way's behemoth weighs in at 4.3 million solar masses, but its starvation diet mutes all but faint flashes and flickers. We know it's there, though, from the orbits of stars around it. Other dormant black holes occasionally shred an infalling star, making their presence known by the flare of radiation that ensues.

But quasars are a different breed of black hole. They reside in galaxies with plentiful gas supplies, perhaps supplied by a recent galaxy-galaxy collision, and they gorge on the inflowing material. The gas spirals around as it falls in, heating up in the process and emitting radiation across the electromagnetic spectrum.

Supermassive black holes in nearby galaxies typically do not have that much gas available to them, so quasars are typically found in distant galaxies. The nearest quasar is Markarian 231, which lies about 600 million light-years from Earth.

A quasar is not only the feeding black hole itself, but the light-producing structures that surround it. Visible and ultraviolet light come from the glowing disk of infalling material, while even hotter gas above the disk shines at X-ray energies. Jets shooting out along the black hole's poles emit everything from radio waves to X-rays. Farther out from the black hole, the prolific dust and gas glow at infrared wavelengths.

The inward spiral of matter in a supermassive black hole's accretion disk – that is, at the center of a quasar – is the result of particles colliding and bouncing against each other and losing momentum. That material came from the enormous clouds of gas, mainly consisting of molecular hydrogen, which filled the universe in the era shortly after the Big Bang.

The size of a quasar accretion disk, which scales with the mass of its black hole, is typically a few light-days across. That dwarfs in comparison to its host galaxy; the Milky Way for comparison is roughly 100,000 light-years across. Yet quasars often outshine their hosts.

F.2 Biology

Epigenetics is the study of how cells control gene activity without changing the DNA sequence. "Epi-" means on or above in Greek, and "epigenetic" describes factors beyond the genetic code. Epigenetic changes are modifications to DNA that regulate whether genes are turned on or off. These modifications are attached to DNA and do not change the sequence of DNA building blocks. Within the complete set of DNA in a cell (genome), all of the modifications that regulate the activity (expression) of the genes is known as the epigenome.

Because epigenetic changes help determine whether genes are turned on or off, they influence the production of proteins in cells. This regulation helps ensure that each cell produces only proteins that are necessary for its function. For example, proteins that promote bone growth are not produced in muscle cells. Patterns of epigenetic modification vary among individuals, in different tissues within an individual, and even in different cells within a tissue. Environmental influences, such as a person's diet and exposure to pollutants, can impact the epigenome. Epigenetic modifications can be maintained from cell to cell as cells divide and, in some cases, can be inherited through the generations.

A common type of epigenetic modification is called DNA methylation. DNA methylation involves the attachment of small chemical groups called methyl groups (each consisting of one carbon atom and three hydrogen atoms) to DNA building blocks. When methyl groups are present on a gene, that gene is turned off or silenced, and no protein is produced from that gene.

Another common epigenetic change is histone modification. Histones are structural proteins in the cell nucleus. DNA wraps around histones, giving chromosomes their shape. Histones can be modified by the addition or removal of chemical groups, such as methyl groups or acetyl groups (each consisting of two carbon, three hydrogen, and one oxygen atoms). The chemical groups influence how tightly the DNA is wrapped around histones, which affects whether a gene can be turned on or off.

Errors in the epigenetic process, such as modification of the wrong gene or failure to add a chemical group to a particular gene or histone, can lead to abnormal gene activity or inactivity. Altered gene activity, including that caused by epigenetic errors, is a common cause of genetic disorders. Conditions such as cancers, metabolic disorders, and degenerative disorders have been found to be related to epigenetic errors.

Scientists continue to explore the relationship between the genome and the chemical compounds that modify it. In particular, they are studying the effects that epigenetic modifications and errors have on gene function, protein production, and human health.

F.3 Psychology

Human long-term memory is comprised of two major components: episodic and semantic memory. The two types of memory differ primarily in the type of information they store. While semantic memory holds information regarding events, facts, and concepts (thus it is also known as factual memory), episodic memory holds contextual information regarding who, what, where, and when of past experiences – a summary of records of our life, thus often characterized as autobiographical memory. Episodic memories are typically dominated by visual imagery that can have either a field (first-person) or an observer (third-person) perspective, and are usually recalled in a temporal order. Once an episodic memory is formed, its information is said to be differentially accessible, i.e., different sensory stimuli can trigger recalling this event (though with various rates of success). Any episodic memory thus has its own specific pattern of activation (episodic activation) that determines how its details are accessed. The sensory stimuli needed for successfully recalling an episodic memory is known in Psychology as a memory cue: contextual information that, when replayed, helps one remember a past experience – a practice known as cued recall.

Memory cues can come in many different forms and are per definition never complete – they do not comprise the entire experience but merely a related context, e.g., a visual capture (picture), a sound (a song), or a smell. A memory cue can also be textual, thus facilitating semantic recall, or an abstract visual that hints at one's activity, location, or social interaction at a certain time (e.g., device and application usage, GPS logs, Facebook posts) – a personal context of an episodic memory.

A discussion of memory recall is incomplete without acknowledging cognitive load theory. This theory explains that working memory has a limited capacity, and thus, instructional design can be adjusted to reduce cognitive load. Consequently, there has been a surge of research manipulating instructional design to minimize cognitive load and, in turn, improve memory recall. For example, Jiang and colleagues conducted a study where stimuli were presented in three different conditions: four different sets of four identical faces (four-same condition), four different faces (four-different) shown sequentially, or four different faces presented one at a time (single). In each of these conditions, four different stimuli were encoded; however, the four-same conditions yielded the best performance. This suggests that presenting more copies of the same stimulus has a positive effect on cognitive load. These behavioral results are supported by neural responses in ventral visual areas. These studies demonstrate that the manner in which stimuli are presented (i.e., modality, sequence and quantity) each affects the encoding and in turn retrieval of information.

F.4 Science

Barn A unit used to measure the cross-sectional area of atomic nuclei. It was devised in 1942 by MG Holloway and CP Baker and arises from the expression 'as big as a barn door' implying that, to a subatomic particle, the nucleus of an atom is an unmissable target. A barn represents an area of 10-28 m2 and the terms microbarn, nanobarn and femtobarn are used by particle physicists.

Crab The Crab Nebula contains a pulsar which is one of the brightest objects in the sky at X-ray and gamma-ray wavelengths. The nebula has become a standard for the measurement of the X-ray intensity of astronomical bodies. For example, an object with an intensity one thousandth of the nebula may be reported to measure 1 millicrab.

Garn A unit of space sickness jokingly used by NASA. Astronaut Senator Jack Garn was reported to have suffered one of the most extreme cases of space sickness on the Space Shuttle in 1985. The Garn represents the maximum level of sickness that it is possible to reach – most astronauts reach a level of a tenth of a Garn.

Jar An obsolete unit of capacitance. The unit is believed to be one of the oldest electrical units, introduced in 1834 by Sir William Harris. A jar represents the capacitance of an early Leiden jar, with 9 × 108 jars being equivalent to 1 farad. The unit was used by the Royal Navy in the Admiralty Handbook of Wireless Telegraphy as late as 1938.

Kan A story, which may be apocryphal, is that a rival of American physicist Robert Millikan suggested that the unit of conceit should be the kan. The kan was defined as a large amount of conceit so for everyday measurements the millikan would be more appropriate.

Morgen A measure of area somewhere in the range of 2,168 m2 to 6,643 m2. It arises from the Germanic word for morning and refers to the amount of land that could be ploughed in one morning. When the Dutchman Peter Minuit bought the island of Manhattan, its area was given as 11,000 morgens.

Shake In nuclear and astrophysics contexts, the shake is equal to 10 ns and is thought to originate from the phrase 'two shakes of a lamb's tail.' The unit refers to the period between one nucleus ejecting a neutron and the consequent fission of a second nucleus.

Smoot A unit of length defined as the height of MIT undergraduate Oliver R. Smoot in 1958. New entrants to a fraternity at MIT were set the task of measuring the length of Harvard Bridge. Smoot laid down on the deck of the bridge, his fellow initiates chalked his height (170 cm) on the surface and he repeated the process to measure the length of the bridge as just over 360 Smoots. A plaque on the bridge commemorates the measurement. Smoot went on to became the Chairman of the American National Standards Institute.

Appendix G

Quizzes

G.1 Astronomy

Multiple choice: Quasars (Astronomy)

Answer to the best of your knowledge the multiple choice questions below. The results will not be published connected to you or anything that can identify you. Do not use any aids to help you with the questions. One answer is correct for each question. This test is connected to the astronomy cue set.

*Må fylles ut

1. E-postadresse *

2. What are luminous supermassive black holes also called? *

   Markér bare én oval.

   - Galactic Nebulae
   - Galactic Cluster
   - Galactic Nuclei
   - Galactic Bolide

3. What is the size of a quasar accretion disk? *

   Markér bare én oval.

   - A quasar accretion disk scales with its black hole, and is typically a few light-days across.
   - A quasar accretion disk is between 10-100 light-days across
   - A quasar accretion disk is approximately 10 000 light-days across
   - A quasar accretion disk is of constant size, and is typically a few light-days across

4. What does a quasar consist of? *

Markér bare én oval.

- The feeding black hole itself and the light produced in its core.
- The black hole itself and light-producing structures containing everything from radio waves to x-rays.
- The feeding black hole itself and lights between radio waves and x-rays that is produced by nearby stars.
- The feeding black hole itself.

5. What is the nearest quasar from earth? *

Markér bare én oval.

- 3C 274
- 3C 273
- Markarian 231
- Markarian 322

6. What is quasar short for? *

Markér bare én oval.

- Quasi-stellar radio source
- Quasi-matter radio waves
- Quasi-nuclear wavelengths
- Quasi-radio luminous source

7. Why is there an inward spiral of matter at the center of a quasar? *

Markér bare én oval.

- The center is dense and creates a gravitational pull inwards
- The center is sparse and creates a gravitational pull inwards
- Particles collide and bounce against eachother and gain inwards momentum
- Particles collide and bounce against each other and lose momentum

8. What does the enourmous clouds of gas which filled the universe in the era shortly after the big bang mainly contain? *

Markér bare én oval.

- Molecular hydrogen
- Molecular helium
- Molecular nitrogen
- Molecular carbon

9. What kinds of light are emited from the glowing disk of infalling material in a quasar? *

Markér bare én oval.

- Visible and ultraviolet light
- Visible and infrared light
- Invisible light
- No light

G.2 Biology

Multiple choice: Epigenetics (Biology)

Answer to the best of your knowledge the multiple choice questions below. The results will not be published connected to you or anything that can identify you. Do not use any aids to help you with the questions. One answer is correct for each question. This test are connected to the biology cue set.

*Må fylles ut

1. E-postadresse *

____

2. What regulates that proteins for bone growth are not produced in muscle cells? *

Markér bare én oval.

- ◯ Macromolecules that are joined together to form chains called polymers fire warnings to the cell.
- ◯ Macromolecules that are joined together to form chains called monomers fire warnings to the cell.
- ◯ The regulation from epigenetic changes that ensures that each muscle cell contains a sufficient amount of fibers.
- ◯ The regulation from epigenetic changes that ensures that each cell produces only proteins that are necessary for its function.

3. Where are histones the structural proteins? What do they do? *

Markér bare én oval.

- ◯ In the cell membrane, they give chromosomes their shape.
- ◯ In the cell cytoplasm, they give cells their shape.
- ◯ In the cell nucleus, they give chromosomes their shape.
- ◯ In the cell organelles, they give cells their shape.

4. What is epigenetics? *

Markér bare én oval.

- The study of how cells control gene activity by changing the DNA sequence.
- The study of how genes control cell activity by changing the DNA sequence.
- The study of how genes control cell activity without changing the DNA sequence.
- The study of how cells control gene activity without changing the DNA sequence.

5. Histones can be modified by the addition or removal of what chemical groups? *

Markér bare én oval.

- deoxyribose sugars or phosphate groups
- methyl groups or acetyl groups
- methyl groups or hydrogen groups
- methyl groups or phosphate groups

6. What is DNA methylation? *

Markér bare én oval.

- Involves the attachment of small chemical groups called phosphate groups to DNA building blocks.
- Involves the attachement of small chemical groups called methyl groups to DNA building blocks.
- Involves the alkylation of the epigenome in DNA.
- Involves the alkylation of histones in DNA.

7. What does "Epi" mean in Greek? *

Markér bare én oval.

- A drop in the bucket
- A drop in the ocean
- Above and beyond
- Over and above

8. What can errors in the epigenetic process lead to? *

Markér bare én oval.

- Abnormal gene activity or inactivity and are a common cause of infectious disorders.
- Abnormal gene activity or inactivity and are a common cause of genetic disorders.
- Abnormal DNA splitting that can lead to serious illnesses.
- Abnormal protein generation that can lead to serious illnesses.

9. What does a genome represent? *

Markér bare én oval.

- The complete set of DNA in a cell
- The phosphate group from DNA in a cell
- The complete set of epigenetic changes in a cell
- An error of DNA in a cell

G.3 Psychology

Multiple choice: Memory theory (Psychology)

Answer to the best of your knowledge the multiple choice questions below. The results will not be published connected to you or anything that can identify you. Do not use any aids to help you with the questions. One answer is correct for each question. This test are connected to the psychology cue set.

*Må fylles ut

1. E-postadresse *

2. What characterizes episodic memory? *

Markér bare én oval.

- The linguistic information regarding widely known knowledge
- Holds contextual information regarding widely known knowledge
- The linguistic information regarding who, what, where, and when of past experiences
- Holds contextual information regarding who, what, where, and when of past experiences

3. What characterizes semantic memory? *

Markér bare én oval.

- Holds information regarding events, appointments, and concerts
- Holds information regarding events, facts, and concepts
- The information regarding how our brain does not keep unimportant memories
- The information regarding how the memory filters memories

4. In Psychology, what is considered as a memory cue? *

Markér bare én oval.

- The sensory stimuli needed for successfully recalling an episodic memory.
- The sensory stimuli needed for successfully recalling unimportant memories.
- The centripetal stimuli needed for successfully recalling an episodic memory.
- The centripetal stimuli needed for successfully recalling unimportant memories.

5. What is the cognitive load theory? *

Markér bare én oval.

- Working memory has a limited capacity, and thus, instructional design can be adjusted to create more space.
- Working memory has a limited capacity, and thus, instructional design can be adjusted to reduce cognitive load.
- Sensory memory has unlimited capacity, and thus, instructional design can be adjusted to create more space.
- Sensory memory has unlimited capacity, and thus, instructional design can be adjusted to reduce cognitive load.

6. What is true about stimuli? *

Markér bare én oval.

- The manner in which stimuli are presented (physically or psychologically) effects the retrieval of information.
- The manner in which stimuli are presented (modality, sequence and quantity) effects the glutamate in the brain.
- The manner in which stimuli are presented (physically or psychologically) effects the glutamate in the brain.
- The manner in which stimuli are presented (modality, sequence and quantity) effects the retrieval of information.

7. What is a personal context of an episodic memory? *

Markér bare én oval.

- An abstract visual that hints at one's learning theme, course or assignment at a certain time
- A precise visual that describes one's activity, location, or social interaction at a certain time
- An abstract visual that hints at one's activity, location, or social interaction at a certain time
- A precise visual that describes one's learning theme, course or assignment at a certain time

8. Memory cues are per definition what? *

Markér bare én oval.

- never retrieved
- never complete
- always complete
- always retrieved

9. What is episodic memory also called? *

Markér bare én oval.

- Autobiographical memory
- Long-term memory
- Short-term memory
- Sensory memory

G.4 Science

Multiple choice: Unusual units

Answer to the best of your knowledge the multiple choice questions below. The results will not be published connected to you or anything that can identify you. Do not use any aids to help you with the questions. One answer is correct for each question. This test is connected to the science cue set.

*Må fylles ut

1. E-postadresse *

2. What phrase does the unit Barn arise from? *

   Markér bare én oval.

   - Can't hit the side of a barn
   - Bit by a barn mouse
   - As big as a barn door
   - Born in a barn

3. What has the Crab nebula become the standard for? *

   Markér bare én oval.

   - For the measurement of ultraviolet intensity of astronomical bodies
   - For the measurement of ultraviolet intensity in subastral space travel
   - For the measurement of X-ray intensity of astronomical bodies
   - For the measurement of X-ray intensity in subastral space travel

4. What is Garn the unit for? *

Markér bare én oval.

- A unit of boat sickness jokingly used by the US Navy.
- The width of the beds in the International Space Station jokingly used by NASA.
- A unit of space sickness jokingly used by NASA.
- The width of the beds in the US Navy Cruisers jokingly used by the US Navy.

5. What does a Jar represent? *

Markér bare én oval.

- The capacitance of an early Leiden jar
- The conductance of an early Leiden jar
- The amount of pressure needed to break a Roetell jar
- The amount of currents needed to break a Roetell jar

6. Who suggested that the unit of conceit should be derived from his name? *

Markér bare én oval.

- Marshall Holloway
- William Harris
- Robert Millikan
- CP Baker

7. What does the unit Morgen refer to? *

Markér bare én oval.

- To the amount of land that could be ploughed in one morning.
- To the amount of trees that could be chopped in one morning.
- To the amount of ploughed land needed to pay off the mortgage on a medium sized house.
- To the amount trees needed to pay off the mortgage on a medium sized house.

8. Which phrase does the unit Shake originate from? *

Markér bare én oval.

- More than you can shake a stick at
- In two shakes of a dead lamb’s tail
- In two shakes of a lamb’s tail
- Shake the pagoda tree

9. What is the unit Smoot? *

Markér bare én oval.

- A unit of mass defined by MIT undergraduate Oliver R. Smoot in 1958 as 170 kg.
- A unit of mass defined as the weight of MIT undergraduate Oliver R. Smoot in 1958.
- A unit of length defined by MIT undergraduate Oliver R. Smoot in 1958 as 170 meters.
- A unit of length defined as the height of MIT undergraduate Oliver R. Smoot in 1958.

Appendix H

Data Set

ID	Condition	ConditionOrder	Category	Age	Gender	StudyYear	PrevKnowledge	ScoreDay	ScoreAfterWeek	CuesReceived	CueFlips	ReadTextTime	StartCuesTime	QuizTime	QuizTime2	CuedAnswerScore	UncuedAnswerScore
1	A	ADBC	Science	24	M	5	4	8	2	7	11	02.05.2022 kl. 14.06.41	Mon May 02 2022 14:00:02	02.05.2022 kl. 18.05.57	11.05.2022 kl. 14.41.39	4	4
1	D	ADBC	Biology	24	M	5	3	5	4			04.05.2022 kl. 11.28.22		04.05.2022 kl. 20.29.35	20.05.2022 kl. 12.19.46	2	3
1	B	ADBC	Memory Theory	24	M	5	3	5	7	12	33	06.05.2022 kl. 14.52.45	Fri May 06 2022 17:50:09	06.05.2022 kl. 19.22.30	20.05.2022 kl. 11.41.47	2	3
1		ADBC	Astronomy	24	M	5	3										
2	A	ADBC	Science	25	F	5	4	7	4	12	14	02.05.2022 kl. 08.48.39	Mon May 02 2022 09:55:08	02.05.2022 kl. 18.06.26	10.05.2022 kl. 19.36.22	4	3
2	D	ADBC	Biology	25	F	5	1	3	4			04.05.2022 kl. 08.38.41		04.05.2022 kl. 18.05.54	12.05.2022 kl. 18.05.47	2	1
2	B	ADBC	Memory Theory	25	F	5	1	5	4	12	6	06.05.2022 kl. 10.13.05	Fri May 06 2022 11:44:23	06.05.2022 kl. 19.54.34	16.05.2022 kl. 12.23.44	3	2
2	C	ADBC	Astronomy	25	F	5	2	4	5	12	21	09.05.2022 kl. 08.21.13	Mon May 09 2022 10:15:00	09.05.2022 kl. 19.08.00	18.05.2022 kl. 21.56.32	3	1
3	A	ADBC	Science	26	M	5	4	5	6	12	13	02.05.2022 kl. 09.10.10	Mon May 02 2022 10:12:59	02.05.2022 kl. 18.36.17	10.05.2022 kl. 20.23.07	3	2
3	D	ADBC	Biology	26	M	5	4	6	5			04.05.2022 kl. 08.55.42		04.05.2022 kl. 20.20.17	12.05.2022 kl. 19.13.06	4	2
3	B	ADBC	Memory Theory	26	M	5	4	7	7	12	4	06.05.2022 kl. 10.31.13	Fri May 06 2022 14:59:04	06.05.2022 kl. 18.57.04	16.05.2022 kl. 12.20.16	4	3
3	C	ADBC	Astronomy	26	M	5	2	4	5	12	39	09.05.2022 kl. 08.53.06	Mon May 09 2022 12:58:58	09.05.2022 kl. 19.16.22	18.05.2022 kl. 17.23.44	3	1
4	A	ADBC	Science	25	M	5	3	5	5	12	20	02.05.2022 kl. 08.35.52	Mon May 02 2022 10:55:29	02.05.2022 kl. 22.51.52	11.05.2022 kl. 08.16.25	3	2
4	D	ADBC	Biology	25	M	5	2	3	6			04.05.2022 kl. 12.11.21		04.05.2022 kl. 22.24.22	12.05.2022 kl. 20.16.22	2	1
4	B	ADBC	Memory Theory	25	M	5	3	4	4	12	17	06.05.2022 kl. 11.40.52	Fri May 06 2022 12:39:54	06.05.2022 kl. 19.40.12	20.05.2022 kl. 13.11.18	4	0
4	C	ADBC	Astronomy	25	M	5	3	6	6	12	18	09.05.2022 kl. 09.54.53	Mon May 09 2022 10:13:38	09.05.2022 kl. 18.48.57	18.05.2022 kl. 21.58.18	4	2
5	A	ADBC	Science	26	M	5	4	5	5	12	27	02.05.2022 kl. 08.19.18	Mon May 02 2022 09:45:32	02.05.2022 kl. 21.34.50	10.05.2022 kl. 19.43.22	3	2
5	D	ADBC	Biology	26	M	5	2	3	3			11.05.2022 kl. 10.08.45		12.05.2022 kl. 12.06.38	12.05.2022 kl. 18.09.47	2	1
5	B	ADBC	Memory Theory	26	M	5	2	4	4			06.05.2022 kl. 11.33.54		07.05.2022 kl. 12.05.16	16.05.2022 kl. 23.21.57	3	1
5	C	ADBC	Astronomy	26	M	5	2	6	5	12	14	09.05.2022 kl. 09.02.05	Mon May 09 2022 10:19:09	10.05.2022 kl. 00.23.25	18.05.2022 kl. 17.59.17	4	2
6	B	BACD	Science	20	M	2	2	5	5	10	10	02.05.2022 kl. 09.14.59	Mon May 02 2022 15:23:46	02.05.2022 kl. 20.08.39	10.05.2022 kl. 19.32.35	4	1
6	A	BACD	Biology	20	M	2	1	4	4	12	10	04.05.2022 kl. 14.51.59	Wed May 04 2022 14:51:21	04.05.2022 kl. 20.38.08	13.05.2022 kl. 09.05.58	3	1
6	C	BACD	Memory Theory	20	M	2	2	6	5	12	8	06.05.2022 kl. 10.38.42	Fri May 06 2022 11:02:05	07.05.2022 kl. 02.25.35	16.05.2022 kl. 13.09.10	4	2
6	D	BACD	Astronomy	20	M	2	2	3	4			09.05.2022 kl. 12.22.51		10.05.2022 kl. 10.39.56	18.05.2022 kl. 19.29.06	2	1
7	B	BACD	Science	25	M	5	4	7	6	12	19	02.05.2022 kl. 08.34.49	Mon May 02 2022 09:55:38	02.05.2022 kl. 19.06.27	10.05.2022 kl. 22.12.07	3	4
7	A	BACD	Biology	25	M	5	2	5	5	12	11	04.05.2022 kl. 09.19.10	Wed May 04 2022 10:00:01	04.05.2022 kl. 19.41.24	12.05.2022 kl. 23.54.58	3	2
7	C	BACD	Memory Theory	25	M	5	3	7	7	12	29	06.05.2022 kl. 08.40.28	Fri May 06 2022 11:39:49	06.05.2022 kl. 21.39.21	16.05.2022 kl. 12.49.26	3	4
7	D	BACD	Astronomy	25	M	5	2	4	4			09.05.2022 kl. 08.46.39		09.05.2022 kl. 20.28.59	18.05.2022 kl. 15.52.17	2	2
8	B	BACD	Science	23	M	4	4	6	6	11	13	02.05.2022 kl. 13.59.01	Mon May 02 2022 14:58:22	02.05.2022 kl. 19.31.55	10.05.2022 kl. 23.12.59	4	2
8	A	BACD	Biology	23	M	4	2	6	4	12	21	04.05.2022 kl. 09.43.36	Wed May 04 2022 12:26:58	04.05.2022 kl. 20.47.39	13.05.2022 kl. 10.08.33	2	4
8		BACD	Memory Theory	23	M	4	2					06.05.2022 kl. 09.23.55					
8	D	BACD	Astronomy	23	M	4	3	2	1			09.05.2022 kl. 08.43.52		09.05.2022 kl. 20.51.57	21.05.2022 kl. 15.17.36	0	2
9	B	BACD	Science	26	M	5	4	5	3	12	13	02.05.2022 kl. 08.41.59	Mon May 02 2022 10:46:51	02.05.2022 kl. 18.05.33	11.05.2022 kl. 07.25.07	3	2
9	A	BACD	Biology	26	M	5	3	3	3	12	16	04.05.2022 kl. 08.09.32	Wed May 04 2022 10:42:33	04.05.2022 kl. 18.11.32	12.05.2022 kl. 18.07.51	1	2
9	C	BACD	Memory Theory	26	M	5	3	4	4	9	12	06.05.2022 kl. 08.12.46	Fri May 06 2022 10:44:07	06.05.2022 kl. 20.27.36	16.05.2022 kl. 12.05.06	2	2
9	D	BACD	Astronomy	26	M	5	3	1	2			09.05.2022 kl. 08.20.40		09.05.2022 kl. 22.03.10	18.05.2022 kl. 15.30.42	1	0
10	B	BACD	Science	21	M	2	3	4	5	12	51	02.05.2022 kl. 09.11.32	Mon May 02 2022 12:44:50	02.05.2022 kl. 19.47.14	10.05.2022 kl. 19.41.50	3	1
10	A	BACD	Biology	21	M	2	2	4	2	12	19	04.05.2022 kl. 09.12.22	Wed May 04 2022 14:50:00	04.05.2022 kl. 20.47.44	12.05.2022 kl. 23.30.37	1	3
10	C	BACD	Memory Theory	21	M	2	2	4	4	10	66	06.05.2022 kl. 09.11.27	Fri May 06 2022 12:09:06	06.05.2022 kl. 18.55.21	16.05.2022 kl. 12.09.22	3	1
10	D	BACD	Astronomy	21	M	2	2	3	4			09.05.2022 kl. 11.08.37		09.05.2022 kl. 20.13.43	18.05.2022 kl. 17.36.36	1	2
11	C	CBDA	Science	23	F	5	4	4	4	12	19	02.05.2022 kl. 09.59.09	Mon May 02 2022 11:15:11	02.05.2022 kl. 18.17.24	11.05.2022 kl. 15.09.11	3	1
11	B	CBDA	Biology	23	F	5	3	3	3	11	8		Wed May 04 2022 12:44:55	05.05.2022 kl. 09.32.57	12.05.2022 kl. 19.35.19	2	1
11	D	CBDA	Memory Theory	23	F	5	2	5	5			06.05.2022 kl. 11.25.25		06.05.2022 kl. 21.41.24	16.05.2022 kl. 16.52.41	3	2
11	A	CBDA	Astronomy	23	F	5	2	3	3	12	10	09.05.2022 kl. 09.12.43	Mon May 09 2022 10:10:15	09.05.2022 kl. 18.35.40	20.05.2022 kl. 11.40.06	3	0
12	C	CBDA	Science	23	F	5	3	7	7	12	20	02.05.2022 kl. 10.01.09	Mon May 02 2022 11:13:42	02.05.2022 kl. 18.17.20	11.05.2022 kl. 10.29.38	4	3
12	B	CBDA	Biology	23	F	5	2	5	4	12	40	04.05.2022 kl. 09.52.55	Wed May 04 2022 11:16:20	04.05.2022 kl. 20.38.23	16.05.2022 kl. 16.10.28	3	2
12	D	CBDA	Memory Theory	23	F	5	2	5	7			06.05.2022 kl. 10.18.13		06.05.2022 kl. 21.56.38	16.05.2022 kl. 16.50.46	3	2
12	A	CBDA	Astronomy	23	F	5	2	6	6	12	12	09.05.2022 kl. 09.15.34	Mon May 09 2022 10:40:15	09.05.2022 kl. 18.37.41	19.05.2022 kl. 10.55.39	3	3
14	C	CBDA	Science	23	M	5	4	4	4	12	24	02.05.2022 kl. 08.43.52	Mon May 02 2022 10:27:59	02.05.2022 kl. 19.39.45	10.05.2022 kl. 19.34.09	3	1
14	B	CBDA	Biology	23	M	5	1	5	5	12	6	04.05.2022 kl. 08.38.51	Wed May 04 2022 09:34:12	04.05.2022 kl. 18.04.58	12.05.2022 kl. 18.04.40	2	3
14	D	CBDA	Memory Theory	23	M	5	1	6	6			06.05.2022 kl. 09.45.03		06.05.2022 kl. 19.50.57	16.05.2022 kl. 14.56.00	3	3
14	A	CBDA	Astronomy	23	M	5	2	4	5	11	14	09.05.2022 kl. 08.18.21	Mon May 09 2022 11:41:57	09.05.2022 kl. 19.18.21	18.05.2022 kl. 15.46.01	2	2
15	C	CBDA	Science	23	M	5	4	6	7	12	18	02.05.2022 kl. 09.51.22	Mon May 02 2022 11:35:01	02.05.2022 kl. 18.05.14	10.05.2022 kl. 19.38.14	4	2
15	B	CBDA	Biology	23	M	5	2	8	5	11	14	04.05.2022 kl. 08.22.01	Wed May 04 2022 10:24:28	04.05.2022 kl. 18.09.07	20.05.2022 kl. 12.26.43	4	4
15	D	CBDA	Memory Theory	23	M	5	1	6	8			06.05.2022 kl. 11.01.37		06.05.2022 kl. 21.13.25	20.05.2022 kl. 11.44.52	3	3
15	A	CBDA	Astronomy	23	M	5	2	6	8	12	17	09.05.2022 kl. 10.35.32	Mon May 09 2022 10:49:51	09.05.2022 kl. 18.29.58	20.05.2022 kl. 12.02.18	4	2
16	D	DCAB	Science	25	M	5	4	6	5			02.05.2022 kl. 12.49.01		02.05.2022 kl. 21.34.09	15.05.2022 kl. 11.49.06	3	3
16	C	DCAB	Biology	25	M	5	2	7	7	12		04.05.2022 kl. 09.52.40	Wed May 04 2022 12:43:00	04.05.2022 kl. 18.23.07	15.05.2022 kl. 11.46.45	3	4
16	A	DCAB	Memory Theory	25	M	5	2	3	5	9	11	06.05.2022 kl. 12.47.32	Fri May 06 2022 13:52:23	07.05.2022 kl. 00.20.56	19.05.2022 kl. 12.17.26	3	0
16	B	DCAB	Astronomy	25	M	5	3	8	6	12	13	09.05.2022 kl. 11.00.01	Mon May 09 2022 09:29:36	10.05.2022 kl. 08.32.33	19.05.2022 kl. 12.24.28	4	4
17	D	DCAB	Science	25	M	3	4	7	6			02.05.2022 kl. 12.30.51		02.05.2022 kl. 21.04.38	10.05.2022 kl. 20.23.49	4	3
17	C	DCAB	Biology	25	M	3	3	3	5	12	19	04.05.2022 kl. 11.09.24	Wed May 04 2022 11:34:00	04.05.2022 kl. 20.53.19	12.05.2022 kl. 20.45.53	1	2
17	A	DCAB	Memory Theory	25	M	3	2	5	5	12	15	06.05.2022 kl. 11.33.02	Fri May 06 2022 15:51:52	06.05.2022 kl. 20.43.23	16.05.2022 kl. 13.39.14	3	2
17	B	DCAB	Astronomy	25	M	3	3	7	6	11	10	09.05.2022 kl. 10.49.22	Mon May 09 2022 12:23:36	09.05.2022 kl. 19.02.48	18.05.2022 kl. 16.54.31	4	3
18	D	DCAB	Science	23	M	3	3	7	7			02.05.2022 kl. 09.55.54		02.05.2022 kl. 18.23.47	11.05.2022 kl. 02.03.35	4	3
18	C	DCAB	Biology	23	M	3	2	5	5	12	38	04.05.2022 kl. 09.08.05	Wed May 04 2022 11:19:13	04.05.2022 kl. 18.42.10	12.05.2022 kl. 20.17.36	3	2
18	A	DCAB	Memory Theory	23	M	3	2	8	8			06.05.2022 kl. 10.41.57		06.05.2022 kl. 19.35.58	16.05.2022 kl. 15.10.04	4	4

ID	Condition	ConditionOrder	Category	Age	Gender	StudyYear	PrevKnowledge	ScoreDay	ScoreAfterWeek	CuesReceived	CueFlips	ReadTextTime	StartCuesTime	QuizTime	QuizTime2	CuedAnswerScore	UncuedAnswerScore
18	B	DCAB	Astronomy	23	M	3	3	6	6			09.05.2022 kl. 10.42.41		09.05.2022 kl. 19.30.50	20.05.2022 kl. 14.51.16	4	2
19	D	DCAB	Science	24	F	5	3	1	3			02.05.2022 kl. 10.44.21		02.05.2022 kl. 18.43.57	11.05.2022 kl. 09.35.05	1	0
19		DCAB	Biology	24	F	5	4										
19	A	DCAB	Memory Theory	24	F	5	3	3	5	7	6	06.05.2022 kl. 14.17.40	Fri May 06 2022 15:05:12	06.05.2022 kl. 18.40.14	16.05.2022 kl. 12.04.38	1	2
19	B	DCAB	Astronomy	24	F	5	3	5	5	3	1	09.05.2022 kl. 08.17.49	Mon May 09 2022 09:52:05	09.05.2022 kl. 18.03.36	19.05.2022 kl. 12.56.19	1	4
20	D	DCAB	Science	24	M	5	3	4	4					02.05.2022 kl. 20.27.35	11.05.2022 kl. 10.43.31	3	1
20	C	DCAB	Biology	24	M	5	3	3	0	9	29	04.05.2022 kl. 10.34.18	Wed May 04 2022 11:51:56	04.05.2022 kl. 20.55.05	15.05.2022 kl. 16.05.56	2	1
20	A	DCAB	Memory Theory	24	M	5	3	8	7			06.05.2022 kl. 12.17.18	Fri May 06 2022 12:34:30	06.05.2022 kl. 18.09.35	16.05.2022 kl. 15.40.32	4	4
20	B	DCAB	Astronomy	24	M	5	2	5	4	10	5	09.05.2022 kl. 11.41.07	Mon May 09 2022 12:02:19	10.05.2022 kl. 07.41.17	19.05.2022 kl. 22.06.20	2	3

ID	Condition	ConditionOrder	Category	Age	Gender	StudyYear	PrevKnowledge	ScoreDay	ScoreAfterWeek	CuesReceived	CueFlips	ReadTextTime	StartCuesTime	QuizTime	QuizTime2	CuedAnswerScore	UncuedAnswerScore
1	A	ADBC	Science	24	M	5	4	8	2	7	11	02.05.2022 kl. 14.06.41	Mon May 02 2022 14:00:02	02.05.2022 kl. 18.05.57	11.05.2022 kl. 14.41.39	4	4
1	D	ADBC	Biology	24	M	5	3	5	4			04.05.2022 kl. 11.28.22		04.05.2022 kl. 20.29.35	20.05.2022 kl. 12.19.46	2	3
1	B	ADBC	Memory Theory	24	M	5	3	5	7	12	33	06.05.2022 kl. 14.52.45	Fri May 06 2022 17:50:09	06.05.2022 kl. 19.22.30	20.05.2022 kl. 11.41.47	2	3
1		ADBC	Astronomy	24	M	5	3										
2	A	ADBC	Science	25	F	5	4	7	4	12	14	02.05.2022 kl. 08.48.39	Mon May 02 2022 09:55:08	02.05.2022 kl. 18.06.26	10.05.2022 kl. 19.36.22	4	3
2	D	ADBC	Biology	25	F	5	1	3	4			04.05.2022 kl. 08.38.41		04.05.2022 kl. 18.05.54	12.05.2022 kl. 18.05.47	2	1
2	B	ADBC	Memory Theory	25	F	5	1	5	4	12	6	06.05.2022 kl. 10.13.05	Fri May 06 2022 11:44:23	06.05.2022 kl. 19.54.34	16.05.2022 kl. 12.23.44	3	2
2	C	ADBC	Astronomy	25	F	5	2	4	5	12	21	09.05.2022 kl. 08.21.13	Mon May 09 2022 10:15:00	09.05.2022 kl. 19.08.00	18.05.2022 kl. 21.56.32	3	1
3	A	ADBC	Science	26	M	5	4	5	6	12	13	02.05.2022 kl. 09.10.10	Mon May 02 2022 10:12:59	02.05.2022 kl. 18.36.17	10.05.2022 kl. 20.23.07	3	2
3	D	ADBC	Biology	26	M	5	4	6	5			04.05.2022 kl. 08.55.42		04.05.2022 kl. 20.20.17	12.05.2022 kl. 19.13.06	4	2
3	B	ADBC	Memory Theory	26	M	5	4	7	7	12	4	06.05.2022 kl. 10.31.13	Fri May 06 2022 14:59:04	06.05.2022 kl. 18.57.04	16.05.2022 kl. 12.20.16	4	3
3	C	ADBC	Astronomy	26	M	5	2	4	5	12	39	09.05.2022 kl. 08.53.06	Mon May 09 2022 12:58:58	09.05.2022 kl. 19.16.22	18.05.2022 kl. 17.23.44	3	1
4	A	ADBC	Science	25	M	5	3	5	5	12	20	02.05.2022 kl. 08.35.52	Mon May 02 2022 10:55:29	02.05.2022 kl. 22.51.52	11.05.2022 kl. 08.16.25	3	2
4	D	ADBC	Biology	25	M	5	2	3	6			04.05.2022 kl. 12.11.21		04.05.2022 kl. 22.24.22	12.05.2022 kl. 20.16.22	2	1
4	B	ADBC	Memory Theory	25	M	5	3	4	4	12	17	06.05.2022 kl. 11.40.52	Fri May 06 2022 12:39:54	06.05.2022 kl. 19.40.12	20.05.2022 kl. 13.11.18	4	0
4	C	ADBC	Astronomy	25	M	5	3	6	6	12	18	09.05.2022 kl. 09.54.53	Mon May 09 2022 10:13:38	09.05.2022 kl. 18.48.57	18.05.2022 kl. 21.58.18	4	2
5	A	ADBC	Science	26	M	5	4	5	5	12	27	02.05.2022 kl. 08.19.18	Mon May 02 2022 09:45:32	02.05.2022 kl. 21.34.50	10.05.2022 kl. 19.43.22	3	2
5	D	ADBC	Biology	26	M	5	2	3	3			11.05.2022 kl. 10.08.45		12.05.2022 kl. 12.06.38	12.05.2022 kl. 18.09.47	2	1
5	B	ADBC	Memory Theory	26	M	5	2	4	4			06.05.2022 kl. 11.33.54		07.05.2022 kl. 12.05.16	16.05.2022 kl. 23.21.57	3	1
5	C	ADBC	Astronomy	26	M	5	2	6	5	12	14	09.05.2022 kl. 09.02.05	Mon May 09 2022 10:19:09	10.05.2022 kl. 00.23.25	18.05.2022 kl. 17.59.17	4	2
6	B	BACD	Science	20	M	2	2	5	5	10	10	02.05.2022 kl. 09.14.59	Mon May 02 2022 15:23:46	02.05.2022 kl. 20.08.39	10.05.2022 kl. 19.32.35	4	1
6	A	BACD	Biology	20	M	2	1	4	4	12	10	04.05.2022 kl. 14.51.59	Wed May 04 2022 14:51:21	04.05.2022 kl. 20.38.08	13.05.2022 kl. 09.05.58	3	1
6	C	BACD	Memory Theory	20	M	2	2	6	5	12	8	06.05.2022 kl. 10.38.42	Fri May 06 2022 11:02:05	07.05.2022 kl. 02.25.35	16.05.2022 kl. 13.09.10	4	2
6	D	BACD	Astronomy	20	M	2	2	3	4			09.05.2022 kl. 12.22.51		10.05.2022 kl. 10.39.56	18.05.2022 kl. 19.29.06	2	1
7	B	BACD	Science	25	M	5	4	7	6	12	19	02.05.2022 kl. 08.34.49	Mon May 02 2022 09:55:38	02.05.2022 kl. 19.06.27	10.05.2022 kl. 22.12.07	3	4
7	A	BACD	Biology	25	M	5	2	5	5	12	11	04.05.2022 kl. 09.19.10	Wed May 04 2022 10:00:01	04.05.2022 kl. 19.41.24	12.05.2022 kl. 23.54.58	3	2
7	C	BACD	Memory Theory	25	M	5	3	7	7	12	29	06.05.2022 kl. 08.40.28	Fri May 06 2022 11:39:49	06.05.2022 kl. 21.39.21	16.05.2022 kl. 12.49.26	3	4
7	D	BACD	Astronomy	25	M	5	2	4	4			09.05.2022 kl. 08.46.39		09.05.2022 kl. 20.28.59	18.05.2022 kl. 15.52.17	2	2
8	B	BACD	Science	23	M	4	4	6	6	11	13	02.05.2022 kl. 13.59.01	Mon May 02 2022 14:58:22	02.05.2022 kl. 19.31.55	10.05.2022 kl. 23.12.59	4	2
8	A	BACD	Biology	23	M	4	2	6	4	12	21	04.05.2022 kl. 09.43.36	Wed May 04 2022 12:26:58	04.05.2022 kl. 20.47.39	13.05.2022 kl. 10.08.33	2	4
8		BACD	Memory Theory	23	M	4	2					06.05.2022 kl. 09.23.55					
8	D	BACD	Astronomy	23	M	4	3	2	1			09.05.2022 kl. 08.43.52		09.05.2022 kl. 20.51.57	21.05.2022 kl. 15.17.36	0	2
9	B	BACD	Science	26	M	5	4	5	3	12	13	02.05.2022 kl. 08.41.59	Mon May 02 2022 10:46:51	02.05.2022 kl. 18.05.33	11.05.2022 kl. 07.25.07	3	2
9	A	BACD	Biology	26	M	5	3	3	3	12	16	04.05.2022 kl. 08.09.32	Wed May 04 2022 10:42:33	04.05.2022 kl. 18.11.32	12.05.2022 kl. 18.07.51	1	2
9	C	BACD	Memory Theory	26	M	5	3	4	4	9	12	06.05.2022 kl. 08.12.46	Fri May 06 2022 10:44:07	06.05.2022 kl. 20.27.36	16.05.2022 kl. 12.05.06	2	2
9	D	BACD	Astronomy	26	M	5	3	1	2			09.05.2022 kl. 08.20.40		09.05.2022 kl. 22.03.10	18.05.2022 kl. 15.30.42	1	0
10	B	BACD	Science	21	M	2	3	4	5	12	51	02.05.2022 kl. 09.11.32	Mon May 02 2022 12:44:50	02.05.2022 kl. 19.47.14	10.05.2022 kl. 19.41.50	3	1
10	A	BACD	Biology	21	M	2	2	4	2	12	19	04.05.2022 kl. 09.12.22	Wed May 04 2022 14:50:00	04.05.2022 kl. 20.47.44	12.05.2022 kl. 23.30.37	1	3
10	C	BACD	Memory Theory	21	M	2	2	4	4	10	66	06.05.2022 kl. 09.11.27	Fri May 06 2022 12:09:06	06.05.2022 kl. 18.55.21	16.05.2022 kl. 12.09.22	3	1
10	D	BACD	Astronomy	21	M	2	2	3	4			09.05.2022 kl. 11.08.37		09.05.2022 kl. 20.13.43	18.05.2022 kl. 17.36.36	1	2
11	C	CBDA	Science	23	F	5	4	4	4	12	19	02.05.2022 kl. 09.59.09	Mon May 02 2022 11:15:11	02.05.2022 kl. 18.17.24	11.05.2022 kl. 15.09.11	3	1
11	B	CBDA	Biology	23	F	5	3	3	3	11	8		Wed May 04 2022 12:44:55	05.05.2022 kl. 09.32.57	12.05.2022 kl. 19.35.19	2	1
11	D	CBDA	Memory Theory	23	F	5	2	5	5			06.05.2022 kl. 11.25.25		06.05.2022 kl. 21.41.24	16.05.2022 kl. 16.52.41	3	2
11	A	CBDA	Astronomy	23	F	5	2	3	3	12	10	09.05.2022 kl. 09.12.43	Mon May 09 2022 10:10:15	09.05.2022 kl. 18.35.40	20.05.2022 kl. 11.40.06	3	0
12	C	CBDA	Science	23	F	5	3	7	7	12	20	02.05.2022 kl. 10.01.09	Mon May 02 2022 11:13:42	02.05.2022 kl. 18.17.20	11.05.2022 kl. 10.29.38	4	3
12	B	CBDA	Biology	23	F	5	2	5	4	12	40	04.05.2022 kl. 09.52.55	Wed May 04 2022 11:16:20	04.05.2022 kl. 20.38.23	16.05.2022 kl. 16.10.28	3	2
12	D	CBDA	Memory Theory	23	F	5	2	5	7			06.05.2022 kl. 10.18.13		06.05.2022 kl. 21.56.38	16.05.2022 kl. 16.50.46	3	2
12	A	CBDA	Astronomy	23	F	5	2	6	6	12	12	09.05.2022 kl. 09.15.34	Mon May 09 2022 10:40:15	09.05.2022 kl. 18.37.41	19.05.2022 kl. 10.55.39	3	3
14	C	CBDA	Science	23	M	5	4	4	4	12	24	02.05.2022 kl. 08.43.52	Mon May 02 2022 10:27:59	02.05.2022 kl. 19.39.45	10.05.2022 kl. 19.34.09	3	1
14	B	CBDA	Biology	23	M	5	1	5	5	12	6	04.05.2022 kl. 08.38.51	Wed May 04 2022 09:34:12	04.05.2022 kl. 18.04.58	12.05.2022 kl. 18.04.40	2	3
14	D	CBDA	Memory Theory	23	M	5	1	6	6			06.05.2022 kl. 09.45.03		06.05.2022 kl. 19.50.57	16.05.2022 kl. 14.56.00	3	3
14	A	CBDA	Astronomy	23	M	5	2	4	5	11	14	09.05.2022 kl. 08.18.21	Mon May 09 2022 11:41:57	09.05.2022 kl. 19.18.21	18.05.2022 kl. 15.46.01	2	2
15	C	CBDA	Science	23	M	5	4	6	7	12	18	02.05.2022 kl. 09.51.22	Mon May 02 2022 11:35:01	02.05.2022 kl. 18.05.14	10.05.2022 kl. 19.38.14	4	2
15	B	CBDA	Biology	23	M	5	2	8	5	11	14	04.05.2022 kl. 08.22.01	Wed May 04 2022 10:24:28	04.05.2022 kl. 18.09.07	20.05.2022 kl. 12.26.43	4	4
15	D	CBDA	Memory Theory	23	M	5	1	6	8			06.05.2022 kl. 11.01.37		06.05.2022 kl. 21.13.25	20.05.2022 kl. 11.44.52	3	3
15	A	CBDA	Astronomy	23	M	5	2	6	8	12	17	09.05.2022 kl. 10.35.32	Mon May 09 2022 10:49:51	09.05.2022 kl. 18.29.58	20.05.2022 kl. 12.02.18	4	2
16	D	DCAB	Science	25	M	5	4	6	5			02.05.2022 kl. 12.49.01		02.05.2022 kl. 21.34.09	15.05.2022 kl. 11.49.06	3	3
16	C	DCAB	Biology	25	M	5	2	7	7	12		04.05.2022 kl. 09.52.40	Wed May 04 2022 12:43:00	04.05.2022 kl. 18.23.07	15.05.2022 kl. 11.46.45	3	4
16	A	DCAB	Memory Theory	25	M	5	2	3	5	9	11	06.05.2022 kl. 12.47.32	Fri May 06 2022 13:52:23	07.05.2022 kl. 00.20.56	19.05.2022 kl. 12.17.26	3	0
16	B	DCAB	Astronomy	25	M	5	3	8	6	12	13	09.05.2022 kl. 11.00.01	Mon May 09 2022 09:29:36	10.05.2022 kl. 08.32.33	19.05.2022 kl. 12.24.28	4	4
17	D	DCAB	Science	25	M	3	4	7	6			02.05.2022 kl. 12.30.51		02.05.2022 kl. 21.04.38	10.05.2022 kl. 20.23.49	4	3
17	C	DCAB	Biology	25	M	3	3	3	5	12	19	04.05.2022 kl. 11.09.24	Wed May 04 2022 11:34:00	04.05.2022 kl. 20.53.19	12.05.2022 kl. 20.45.53	1	2
17	A	DCAB	Memory Theory	25	M	3	2	5	5	12	15	06.05.2022 kl. 11.33.02	Fri May 06 2022 15:51:52	06.05.2022 kl. 20.43.23	16.05.2022 kl. 13.39.14	3	2
17	B	DCAB	Astronomy	25	M	3	3	7	6	11	10	09.05.2022 kl. 09.49.22	Mon May 09 2022 12:23:36	09.05.2022 kl. 19.02.48	18.05.2022 kl. 16.54.31	4	3
18	D	DCAB	Science	23	M	3	3	7	7			02.05.2022 kl. 09.55.54		02.05.2022 kl. 18.23.47	11.05.2022 kl. 02.03.35	4	3
18	C	DCAB	Biology	23	M	3	2	5	5	12	38	04.05.2022 kl. 09.08.05	Wed May 04 2022 11:19:13	04.05.2022 kl. 18.42.10	12.05.2022 kl. 20.17.36	3	2
18	A	DCAB	Memory Theory	23	M	3	2	8	8			06.05.2022 kl. 10.41.57		06.05.2022 kl. 19.35.58	16.05.2022 kl. 15.10.04	4	4
18	B	DCAB	Astronomy	23	M	3	3	6	6			09.05.2022 kl. 10.42.41		09.05.2022 kl. 19.30.50	20.05.2022 kl. 14.51.16	4	2
19	D	DCAB	Science	24	F	5	3	1	3			02.05.2022 kl. 10.44.21		02.05.2022 kl. 18.43.57	11.05.2022 kl. 09.35.05	1	0
19		DCAB	Biology	24	F	5	4										
19	A	DCAB	Memory Theory	24	F	5	3	3	5	7	6	06.05.2022 kl. 14.17.40	Fri May 06 2022 15:05:12	06.05.2022 kl. 18.40.14	16.05.2022 kl. 12.04.38	1	2
19	B	DCAB	Astronomy	24	F	5	3	5	5	3	1	09.05.2022 kl. 08.17.49	Mon May 09 2022 09:52:05	09.05.2022 kl. 18.03.36	19.05.2022 kl. 12.56.19	1	4
20	D	DCAB	Science	24	M	5	3	4	4					02.05.2022 kl. 20.27.35	11.05.2022 kl. 10.43.31	3	1
20	C	DCAB	Biology	24	M	5	3	3	0	9	29	04.05.2022 kl. 10.34.18	Wed May 04 2022 11:51:56	04.05.2022 kl. 20.55.05	15.05.2022 kl. 16.05.56	2	1
20	A	DCAB	Memory Theory	24	M	5	3	8	7			06.05.2022 kl. 12.17.18	Fri May 06 2022 12:34:30	06.05.2022 kl. 18.09.35	16.05.2022 kl. 15.40.32	4	4
20	B	DCAB	Astronomy	24	M	5	2	5	4	10	5	09.05.2022 kl. 11.41.07	Mon May 09 2022 12:02:19	10.05.2022 kl. 07.41.17	19.05.2022 kl. 22.06.20	2	3

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Wearable Memory Augmentation

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