July 25, 2022
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RE: ENSC 405W/440 Design Specification for e-minder

This document has been prepared by the purple mango team to clearly list the design specifications for the product "e-minder" for our ENSC 405W and ENSC 440 capstone design project. Each section will list the specific design specifications for e-minder and reference the requirements that were created in the Requirements Specification Document.

We believe that e-minder will be a helpful aid for forgetful individuals who have trouble remembering to bring items with them as they leave their homes. In this design specifications document, the team will provide a detailed description of the system design along with appropriate justification for the design approach selected, including any design decisions taken. This document will focus on the following design aspects:

- System Design
- Mechanical Design
- Hardware Design
- Software Design

At the end of this document there you will find three appendices which discuss the test plans, user interface design, and supporting design choices. Reading these documents will provide an even clearer picture on why we chose to design e-minder in the way that we did.

By the end of the document the reader should have a firm grasp on how e-minder will be designed and implemented for the alpha phase of development (i.e., the proof of concept) and should have sufficient detail regarding later versions of the product (i.e., the prototype & production models).

This document has been written by six engineering science students from Simon Fraser University: Ramanpreet Kaur, Riku Makita, Harely McLachlan, Anika Sheikh, Adham Sorour, and Dylan Rowsell. Each student has a different background and skill set that they bring to the purple mango team.

Thank-you for taking the time to read this document reviewing the design specifications for e-minder.

Sincerely,

Team purple mango

Design Specification: purple mango

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1.0	Purple Mango	07/25/2022	Dylan Rowsell	07/25/2022	Initial Design

Abstract

This document provides detailed information on the design choices for the item reminder device e-minder. e-minder will use RFID detecting technology to ensure that users do not leave their home without user-specified items with a purple mango branded RFID tag attached on them. The goal for e-minder is to create a system which helps forgetful users to always leave with their items while not being intrusive to their everyday life. The device should not look out of place in an entryway, yet alert the user if necessary. The system consists of 3 subsystems which together make up the product:

1. A physical device for scanning tags attached to items.
2. A remote database which stores all the information required for operation.
3. A smartphone application which the user directly interfaces with to add, remove, and modify items that are not to be forgotten.

All of the components, and any design decisions taken regarding them, will be discussed in depth. We will start by presenting an encompassing overview of the project as a whole; this will include challenges faced, the scope of the different phases of the project, changes made after the feedback, mechanical design, hardware design and software design requirements of the e-minder. In these sections, we will present a detailed technical discussion of the system design of the various components of the product.

Test plan appendix A details the tests required to deem each of the mentioned phases as sufficient. User interface appendix B breaks down the user and technical analysis. It also provides an in-depth graphical representation of the e-minder device. Appendix C highlights the primary design choices discussed throughout the document.

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Glossary

Table I: Glossary

Term	Definition
ADHD	Adult attention-deficit/hyperactivity disorder
DSR	Design Specifications Requirements
EM	Electromagnetic
IoT	Internet of Things
PLA	Polylactic acid
POC	Proof of Concept
RFID	Radio-Frequency Identification
SoC	System-on-Chip
UHF	Ultra High Frequency
UI	User Interface

1.0 Introduction

Forgetfulness is part of human nature. A lot of times we walk out of our house and after getting to our vehicle and realize we have forgotten our phone, wallet, keys or another important item. This forgetfulness is particularly high in the elderly and ADHD patients. The reminders on phones and sticky notes fail to work when one is in a rush or become complacent with such tools. e-minder by purple mango will remind users of forgotten items as they leave their homes since it is placed near the exit of the house. e-minder incorporates item scanning technology with an app to help those in need. RFID tags will be placed on critical everyday items and will be searched for upon exit of the house. Major challenges will be getting the tags to communicate with the reader through various barriers, like backpacks, from an acceptable distance and designing a user experience that is helpful without being an annoyance.

1.1 Background

RFID is a technology used in object tracking and tracing which allows users to capture digital information in smart tags and radio waves to transmit the information to nearby RFID scanners. E-minder will integrate RFID tags, antennas and a RFID reader to allow users to track tagged objects and customize the list of items they would like to be reminded of through the mobile app. The secondary function of the app is to register newly tagged items and reassign tags to specific users within the household. These tasks can be done remotely in the app on the user's smartphone. The design is kept simple to make the device more affordable, efficient and streamlined for the user. The device will be an excellent addition to a smart home or nursing home. Caregivers for nursing homes and hospitals will be required to set up the system once for each patient and take a hands off approach afterwards allowing them to take care of other important tasks.

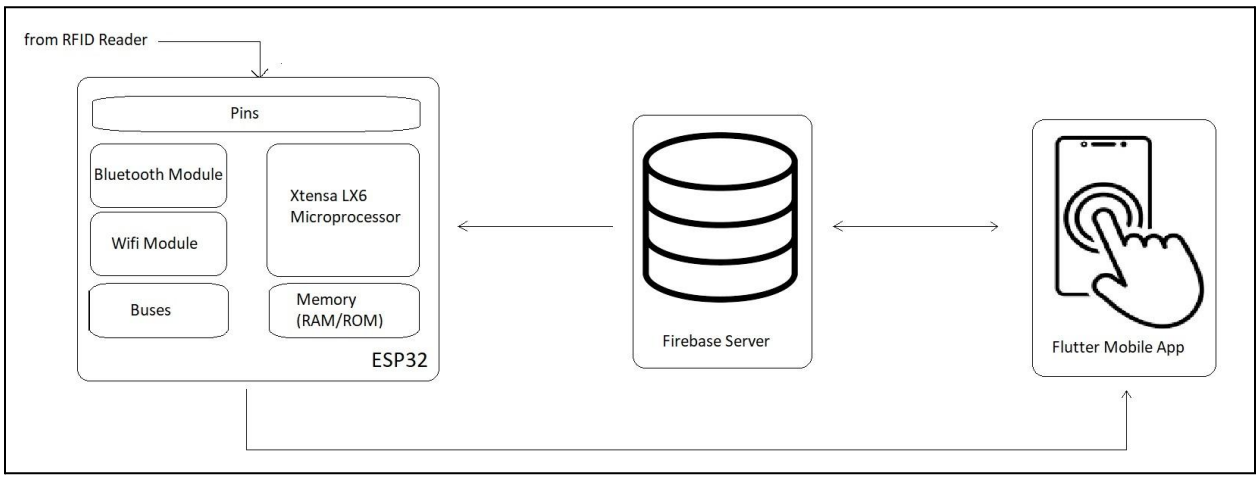

Fig. 1: Block diagram of system's flow of information

1.2 Target Audience

The sale of e-minder is targeted toward three main demographics; the Elderly, People with ADHD, and Parents. At the current time and state of the company, the product is targeted toward people living in British Columbia, Canada. Specifically, the initial sales will be catered toward people living in Burnaby, and the Tri-Cities.

About 40% of people aged 65 or older have age-associated memory impairment [1]. This can lead to them requiring frequent assistance in remembering to carry their medications and other important things with them outside their residents or rooms in Elderly care homes. Upon surveying multiple Elderly care homes, it was gathered that they are willing to pay between $100 - $200 as one e-minder system can be used for an entire department consisting of 5 - 6 patients. Purple mango is looking to expand its business in 2 - 3 Elderly care homes per year for them to generate about 30% of sales from this target market.

According to the National Institute of Mental Health, the overall prevalence of current adult ADHD is 4.4% [2]. People with ADHD can appear to be inattentive at times which can lead to frequent forgetfulness. This is where we introduce e-minder to help take the stress off of people living with ADHD. For our target market, as our SOM, Serviceable Obtainable Market, we consider 20% out of the 4.4% adults with ADHD which gives us around 2500 adults in British Columbia [1].

After talking to several parents, a common day-to-day mishap is their children forgetting school materials with them when exiting their home in the morning. E-minder is a simple solution to this problem as parents can set up an account for their children in the mobile application so they don’t have to worry about remembering important school materials for their children.

1.3 Changes After Feedback

Since the submission of the Requirements Specifications document, there have been several changes to the project to simplify the design. Many of these suggestions were given in our Progress Review Meeting #2.

1.3.1 Removing Touch Screen

Previously e-minder was planned to incorporate a touch screen component that would display missing items similar to the smartphone application. This feature was redundant as the user can see this information on their smartphone through the e-minder application. In addition, the touchscreen significantly increased the cost of the project.

In future versions of e-minder, the team would consider adding a touchscreen if there was significant consumer demand. At the moment text-to-speech is planned to act as a notification system and users may access their notifications via their smartphone. This leaves e-minder with the option in the future to create more premium versions of the product if there is a market for it.

1.3.2 Embedded Device

The team decided to switch to a low-cost microcontroller directly instead of using a Raspberry Pi for development. The team made this change after considering the portability concerns that would have been faced going into ENSC440 with a Raspberry Pi as the main component of e-minder. Since the project no longer needs to run Flutter for the touchscreen on the physical device, the change to a microcontroller made financial sense. After some research the team has decided that an ESP32 SoC microcontroller will fit the needs of the device since it is widely used, cheap, small in size, and powerful. More information about the ESP32 microcontroller can be found in the ESP32 Microcontroller section.

1.3.3 Online Database

By moving from the Raspberry Pi to a ESP32 microcontroller, the embedded device will lose most of its local storage capacity. Rather than storing user data on the e-minder, we decided that the product will connect to an online database over the internet. This means that the device will now require internet access. However, this seems to be a common requirement of IoT devices. Even though we can still store some data on-board, the software team decided that having a real-time online database connected to the device is a more practical and scalable solution. This also has the benefit of allowing the user to access the database and update their item list from inside or outside the house.

1.4 Project Challenges

There were a number of challenges faced by both the Hardware and the Software teams. Some of the challenges require intensive testing of components before they're finalized for the prototype. This is important since the performance of some components such as the RFID reader form the working principle of e-minder.

1.4.1 RFID Testing

The RFID testing was done extensively using PuTTY to connect to the serial port of the RFID scanner. PuTTY is a free and open-source serial console. The testing was done on the Ultra High Frequency RFID reader of UHF tags. The tags were advertised to be detectable from a 3 meter range but weren't detected at the advertised distance. They also didn't penetrate through the barriers very effectively, such as pockets and bags, and hence more types of tags were ordered for testing as discussed in RFID Tags.

1.4.2 Switching From Raspberry Pi to ESP32

Since the team is switching development boards from the Raspberry Pi to the ESP32 it means that a lot of the work to get Flutter running on the Raspberry Pi was wasted. Flutter will still be used for the mobile application as it was found to be the ideal framework for developing the app, the advantages of flutter over other frameworks are discussed in Smartphone Application | Flutter & in Appendix C.

Another challenge was addressed in the Online Database section relating to the database. When the Raspberry Pi was being used, we were able to use SQLite to easily store the database

on the device locally. The ESP32 has much less memory, so an online database makes more sense.

1.5 Design Specification Requirements Classification

Design Specification Requirements (DSR) will be discussed in the following sections of this document. Each sub-section of this document will have a table which will summarize each DSR that has been addressed in that section and may reference specifications from the requirements document. The DSR will be of the following format:

DSR {Section}.{Subsection}.{Requirement Number}.{Stage of Development}

Clarification for the meaning of "Stage of Development" can be found in Table II below.

Table II

Stage of Development	Symbol
Proof of Concept	POC
Prototype	PRO
Finished Product	FIN

1.6 Scope

This document mainly refers to the alpha phase POC for e-minder. Our goal for the alpha phase is to satisfy some of the most fundamental requirements. The details of the fundamental requirements for hardware, software, and embedded systems will be covered in the sections below. The purpose of this document is to bridge the requirements specification document with a justification for the design. The prototype or the beta phase of the project will be discussed briefly outlining the more intricate requirements by adding secondary features and handling any edge cases or issues that are discovered in the POC. This document also includes the Test Plan, User Interface Requirements, and Other Supporting Design Options.

1.6.1 Hardware Scope

The nature of e-minder will require lots of testing with hardware to determine the best products and their orientation to meet specifications, rather than the development of separate components themselves. During these tests, we will determine the sensing range of our chosen components and the overall feasibility of the e-minder.

With the POC, the main goal is to meet our requirements specifications of sensing objects at 2 meters and objects inside thin bags/purses (REQ.HW.9, REQ.HW.10, REQ.HW.11). Other specifications such as size, price, and power consumption will not be our main focus, but will be kept in mind.

An acceptable prototype may consume twice the power and be twice the size and price of our production product. The prototype will also be an entirely self-contained unit (REQ.HW.3). Not connected to any external equipment besides a power supply. It will be enclosed in a plastic case designed in SolidWorks and 3D printed using the resources available from SFU. We plan for the enclosure design to assist the function by using the shape of the enclosure to enhance the scanning capabilities. This could be done with angling the RFID antenna in an optimal way or using radio-reflective material to aim the signal in a specific area.

1.6.2 Software Scope

The e-minder's software components comprise a mobile application and an online database. The POC must allow users to use the app to manage the database (REQ.SW.1, REQ.SW.19). This includes basic operations such as creating a user profile (REQ.SW.5a), accessing a stored item list (REQ.SW.5b), adding items to the list and removing items from the list (REQ.SW.6, REQ.SW.7). Additionally, the POC must allow the user to store the RFID tag numbers associated with each item (REQ.SW.17) - this is necessary for the embedded system to identify the user and their items.

The software components for the e-minder prototype will remain the same as the POC but will include more features. The prototype will capture several other secondary requirements not captured by the POC. App notifications will have the highest priority; this will require knowing when the user is at the door (REQ.SW.4) and what items they are missing (REQ.SW.16). This will potentially be done via Bluetooth/wifi communication with the embedded system. As a secondary priority, the system will allow users to control the classification and reminding setting for each item. Items will be classified as tagged or untagged - untagged items will have no RFID tag associated with them and will be reminded of on every exit via push notifications (REQ.SW.12, REQ.SW.14, REQ.SW.15). Item reminding settings will allow the user to select if, for a given item, they would like to be reminded on every exit, just a select number of times, or throughout a given interval of time (REQ.SW.9, REQ.SW.11).

Additional features such as tag reassignment, Google profile authentication, etc... will be subject to our schedule. Further, any considerations of security or efficiency will be deferred to the beta development phase.

1.6.3 Embedded Scope

e-minder's embedded system revolves around the microcontroller and its interactions with the RFID reader, the database, and the mobile app. The microcontroller will have real-time access to the online database and will be able to access all item lists for all users. For the POC, the system must be able to detect items within the specified range (mentioned above in Hardware Scope) and use that information to identify the user at the door (REQ.SW.3). Upon identification, the system must retrieve the user's item list from the database and check if there are any missing items based on their RFID tags not being detected (REQ.SW.10). If there are missing items, the system must notify the user (REQ.SW.13). For the POC, a simple beep (using the speaker) will be sufficient for notification. For the prototype, however, we would need more descriptive notification capabilities. Aside from the app notification, the system will produce a

text-to-speech output notifying the user of what exactly is missing. This can perhaps be a feature that can be toggled on/off.

As mentioned in Software Scope, in the prototype (beta) phase we will consider ways of communicating directly between the embedded system and the mobile app.

2.0 System Design

System design consists of hardware design, software application design, and embedded designs to integrate the two. The block diagram explaining the communication and the flow of information between the different hardware & software components is shown in Fig. 2:

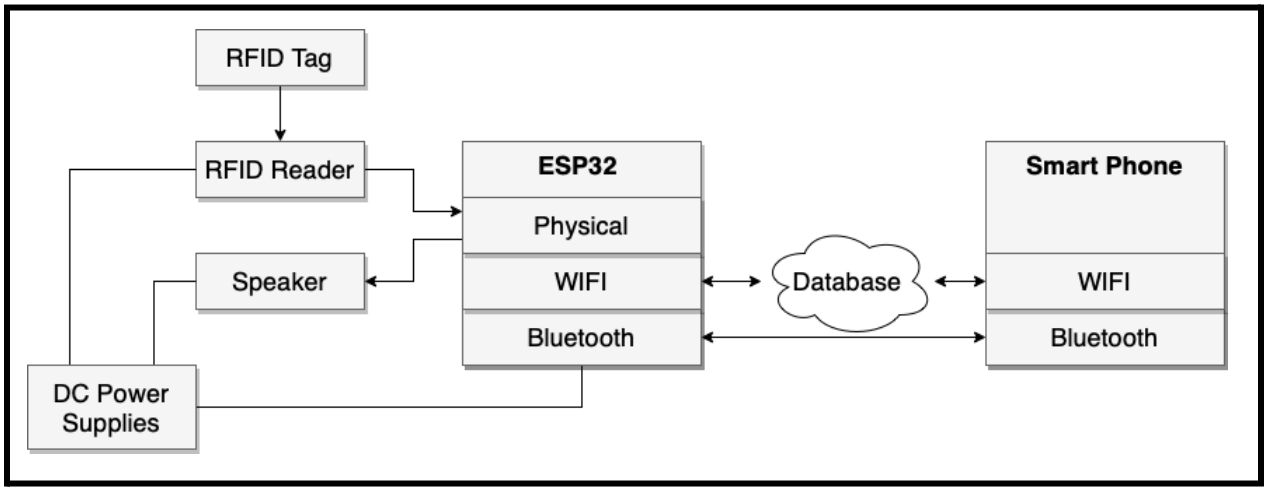

Fig. 2: e-minder Block Diagram

e-minder's physical system will incorporate RFID tags, a RFID reader and a ESP32 SoC microcontroller. The system also includes an online database and a mobile application that can be installed on the user's smartphone. The microcontroller will have real-time access to the database as long as it is connected to the internet via its on-board wifi module. Users will register tagged items on the database using the mobile app, and once an item is registered, the user will be notified if they ever exit their home without that item. Every user will have a list of registered items stored on the database, each item having its RFID tag stored with it.

The RFID tags transmit electromagnetic waves that are received by the RFID reader. From here, the RFID reader passes the detected tag IDs to the microcontroller. Upon detecting a tag at the door, the microcontroller will use the tag ID to identify the user and retrieve the item list corresponding to that user. The microcontroller will then determine if they are missing any items as they leave the house by comparing the database item list with the list of detected tags. If a mismatch is detected, the microcontroller will send a signal to the speaker to notify the user of a missing item. This implementation will support multiple users within the same household, which allows each user to personalize which items they would like to be reminded of. This will require the system to correctly and quickly identify users at the door.

The team also researched using bluetooth to detect the user through the user's phone. As this requires further research and inspection, it will be considered for the product prototype if we deem it beneficial and if the POC requires some improvement in item detection and speed.

Table III: System DSR

Design ID	Design Specification Requirements
DSR.2.0.1.POC	The system must remind the user at the door of any missing registered items [REQ.G.1, REQ.G.2, REQ.G.6, REQ.G.8, REQ.G.9]
DSR.2.0.2.PRO	User profiles and items must be customizable [REQ.G.3, REQ.G.10]
DSR.2.0.3.FIN	Application Interface must be scalable and easily navigable for seniors [REQ.G.4, REQ.G.5]

3.0 Mechanical design

A draft of the POC enclosure is shown below [Fig. 3]. It is designed to have an adjustable RFID mount specially made for testing. It allows us to angle the RFID module in two axes. It can be angled left, right, up and down to find the best scanning position [DSR.3.0.1.POC].

These rough dimensions are designed to be just large enough to hold all the internal components, this includes the controller, speaker, power solution and the RFID module itself [DSR.3.0.2.PRO, DSR.3.0.3.FIN].

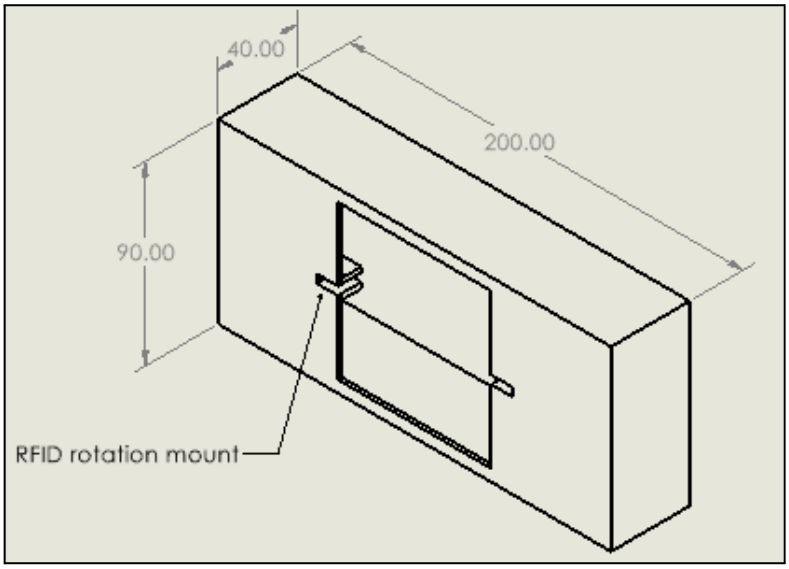

Fig. 3. Main enclosure with rotation mount, POC dimensions

The back plate screws on to secure the internal components and has a bracket to attach to the wall [Fig. 4]. The specific mounting locations are discussed in detail in the UI appendix.

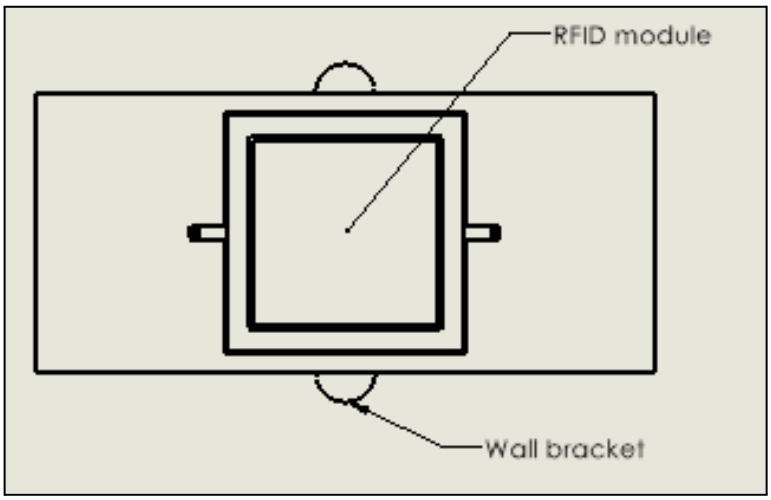

Fig. 4: Fully assembled e-minder POC

The prototype may look very similar. The specifics will be developed during further POC testing. For example, if the testing proves that the angling feature is not necessary, it will be removed in favor of a cleaner, robust enclosure.

The enclosure will be 3D printed in white or black PLA using the resources available at SFU. This allows rapid-prototyping and is the least labor intensive process, compared to wood working, or molded plastic for example.

Table IV: Mechanical DSR

Design ID	**Design Specification Requirements**
DSR.3.0.1.POC	The scanner must have adjustable height and angle [REQ.HW.4, REQ.HW.12]
DSR.3.0.2.PRO	The device must be smaller than 225 square cm [REQ.HW.3]
DSR.3.0.3.FIN	The device must have compact power and component management [REQ.HW.1,REQ.HW.2]

4.0 Hardware design

4.1 ESP32 Microcontroller

The ESP32-WROOM is a low-cost, low-power system on-chip microcontroller with integrated 802.11b/g/n Wi-Fi, Bluetooth V4.2, BR/EDR, and Bluetooth LE [3]. This built-in Bluetooth and Wifi on the chip was a major reason the ESP32 device was selected [DSR.4.1.1.POC]. The device has a low cost of $2 to $5 depending on the quantity of microcontrollers ordered [DSR.4.1.4.FIN]. The ESP32-WROOM is also a low power device that operates on a 3.0-3.6V power supply [DSR.4.1.3.FIN] [4].

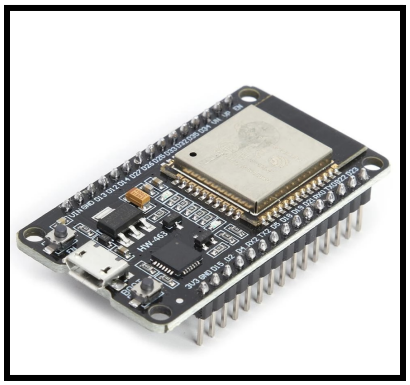

Fig 5: ESP32-Wroom Development Board [3]

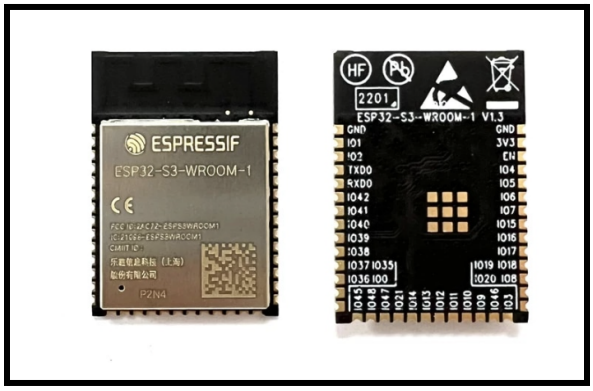

Fig 6. ESP32-Wroom Module Board [3]

An attractive design advantage of the ESP32 series is that it has multiple forms. The two of interest to the project are the developer board seen in Fig. 5 and the module board seen in Fig. 6. The development board makes it easy to test the device for the POC for ENSC 405W, while the module board has a smaller form factor and is able to be soldered onto a custom printed PCB [DSR.4.1.5.FIN].

The ESP32 will be used to communicate to the UHF RFID Module, speaker, and to the online database as seen in Fig. 2.

4.1.1 ESP32 Schematic

The ESP32-WROOM has 38 pins available to the user which can be seen in Fig. 7. All pin descriptions can be found in the ESP32-WROOM-32 Datasheet in section 2.2. This datasheet can be found in the References section of this document [5].

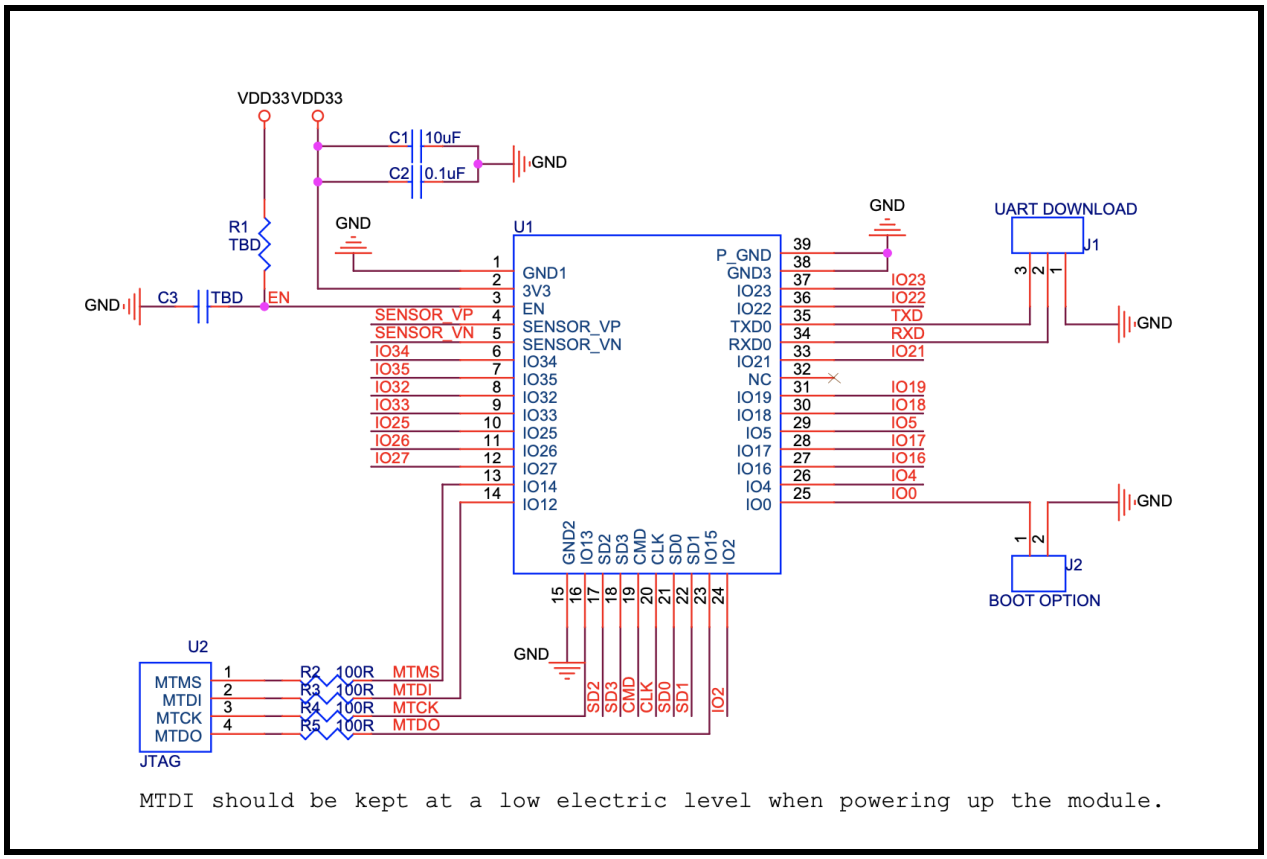

Fig. 7: ESP32-Wroom Peripheral Schematics [5]

4.1.2 ESP32 Maximum Voltage, Current, and Temperature

When designing the e-minder product, the maximum values from Table V should be followed in accordance with the ESP32 datasheet [DSR.4.1.3.FIN] [5]. It is important to note that the ESP32 can operate under normal household temperatures [DSR.4.1.2.PRO].

Table V : ESP32 Maximum Values

Symbol	Parameter	Min	Max	Unit
VDD33	Power Supply Voltage	-0.3	3.6	V
I_{Output}	Cumulative IO Output Current	-	1,100	mA
T_{Store}	Storage Temperature	-40	105	°C

Table VI: Microcontroller DSR

Design ID	Design Specification Requirements
DSR.4.1.1.POC	The device must be able to connect to a smartphone via bluetooth and the internet. [REQ.SW.1, REQ.G.6]
DSR.4.1.2.PRO	The device should be able to operate under normal household temperatures. [REQ.HW.7]
DSR.4.1.3.FIN	The device should be able to run on a standard power outlet. [REQ.EL.1, REQ.EL.2, REQ.EL.3, REQ.HW.1]
DSR.4.1.4.FIN	The device should contain affordable, easy to source electronic components. [REQ.HW.5, REQ.HW.6]
DSR.4.1.5.FIN	The device should contain electronic components which can be made smaller in the final product. [REQ.HW.3]

4.2 UHF RFID

4.2.1 RFID Reader

The core function of the e-minder is scanning for tags using RFID. This will be done by the Fonkan UHF RFID Integrated Module 4dBi version. This reader was chosen for the POC because of its modularity, ease of use, frequency and range characteristics. Other readers were either a consumer product itself and expensive, or cheaper but required extra circuitry to function. In the final version of e-minder, a circuit would be developed to use the cheaper reader and bring the cost down.

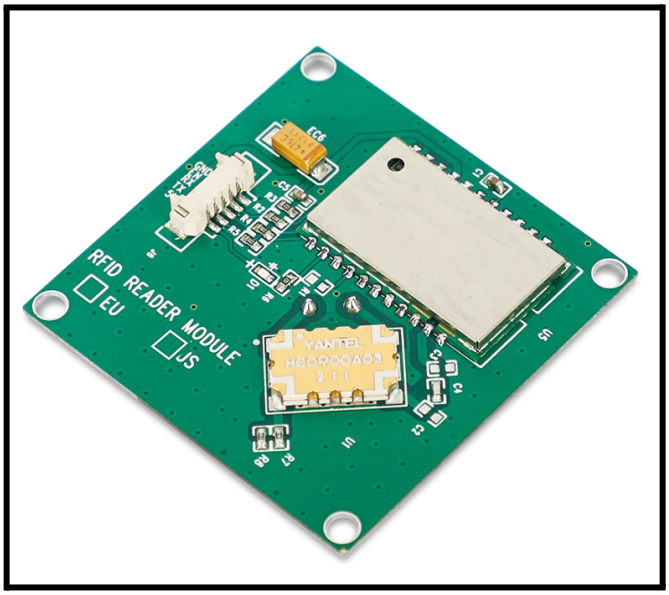

Fig. 8: Fonkan UHF RFID module

Communication with the module is done through 3.3V TTL, a universal UART protocol, therefore most microcontrollers are compatible. This will connect to the RX TX pins (34 and 35) of the ESP32.

The 4dBi version is advertised to achieve 3m readings in optimal conditions [Fig 9]. Our requirements of 2m should be achievable with this module [DSR.4.2.1.POC]. With a peak current draw of 180mA at 5V, it meets our wattage requirements [Tab. III]. It has a standby and sleeping mode with low current draw. It can operate in a wide temperature range [DSR.4.2.2.FIN].

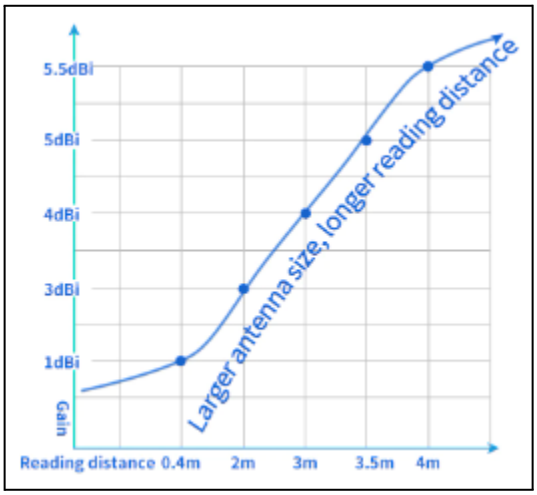

Fig. 9: Antenna gain vs read distance

Table VII : Fonkan RFID Reader Electrical Values

Parameter	Value
Standby current	80mA
Sleeping current	100uA
Operation current (25dBm output, 25℃)	180mA

It operates in the North American UHF frequency range of 902-928MHz. We chose the UHF range because it has the largest read distance. The read distance is determined by the antenna gain and power output, as well as the size, type, and quality of the RFID tags being read [6].

4.2.2 RFID Tags

The RFID tags are equally as important as the scanner. A short range tag cannot be detected by a long-range reader and vice-versa. The tags must match the reader frequency. Tags may come with features such as kill-switches, editable IDs and passwords. For our system, none

of these extra features are necessary, because no data is stored on the tags. They only must have unique IDs, which are set from the factory.

There are 3 technologies of tags on the market and below in Table VIII is a comparison [7]:

Table VIII

	Passive	**Battery-Assisted/Semi Passive**	**Battery Powered**
Practical Range	<10m	<100m	<1km
Cost (Per Tag)	$0.10-$1.00	$10-$30	$20-$60
Longevity	Infinite	3-5 years	1 year
Form	Flexible	Stiff	Stiff

Purple Mango decided to use passive RFID tags as they advertised to meet DSR.4.2.1.POC and DSR.4.2.2.FIN, as well as being the cheapest, can be used indefinitely, and has a moldable form allowing users to stick onto more items.

4.2.2.1 Passive RFID tags 73x20mm 915 UHF tags

The first tags tested were these adhesive tags distributed by KARUISI. The advertised range was up to 5m, however initial testing showed about half this. Testing is ongoing and more tags have been ordered to determine the best.

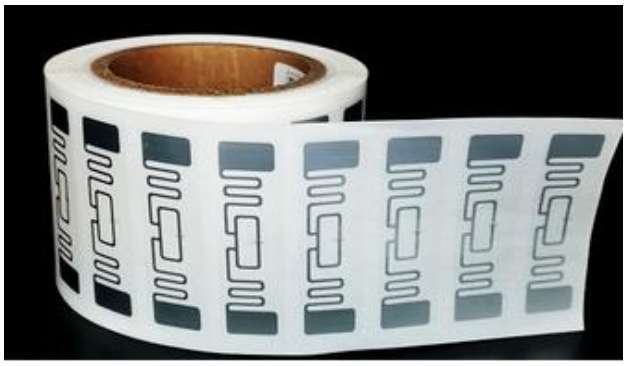

Fig. 10: Passive RFID tags 73x20mm 915 UHF tags

4.2.2.2 Passive RFID TAG R/W 860-960MHZ INLAY

These tags are distributed by Avery Denison and have 96 bit writable memory. The advertised range for these UHF RFID tags are upto 5-6 meters.

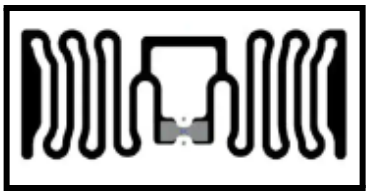

Figure 11: Passive RFID TAG R/W 860-960MHZ INLAY

4.2.2.3 RFID LABEL AD-456U8 (FCC)

These passive tags are also distributed by Avery Denison but have 128 bit writable memory and operate on the NXP Ucode 8 chip. The advertised reading distance for these RFID tags is upto 6 meters as well.

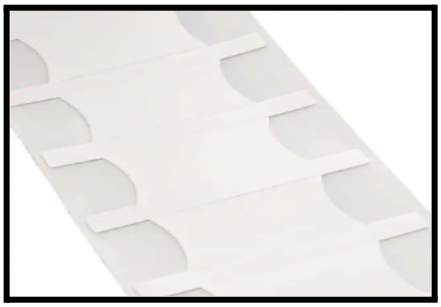

Fig. 12: RFID LABEL AD-456U8 (FCC)

Table IX: RFID DSR

Design ID	**Design Specification Requirements**
DSR.4.2.1.POC	The device must be capable of identifying tags in common conditions [REQ.HW.9, REQ.HW.10, REQ.HW.11, REQ.HW.12]
DSR.4.2.2.FIN	The device must operate in rough climates [REQ.HW.7]

4.3 Speaker

The speaker will be an important component for the successful functioning of e-minder. The frequency response must cover the voice range in the case of text-to-speech being used to notify users of specific items. A mini 8 Ohm 3 watt speaker from MakerHawk was chosen because of its full band response and compact size, while outputting an audible voice in a noisy environment. The speakers will be placed with ESP32 behind the RFID reader in the enclosure, however, they will be placed in a manner such that the cone and the surrounding are not blocked by the enclosure. If text-to-speech is not used, a cheaper and smaller speaker may be used to make a beeping noise to notify the user instead.

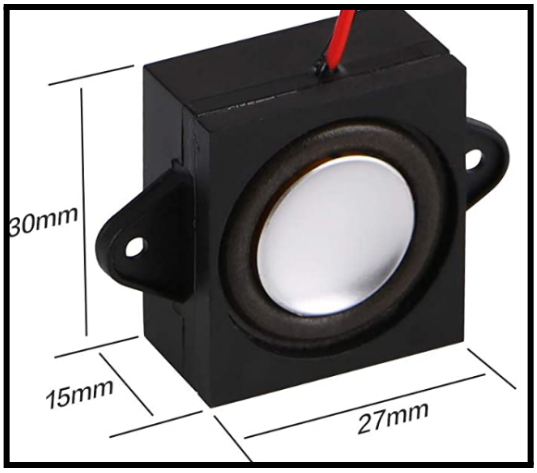

Fig. 13: Mini full band MakerHawk speaker

Table X: Speaker DSR

Design ID	Design Specification Requirements
DSR.4.3.1.POC	The speakers must make a beep noise in case the user forgets to carry any tagged items outside their homes. [REQ. G.1, REQ. SW.4]
DSR.4.3.2.PRO	The device creates a text-to-speech output describing the missing item when leaving without that item [REQ.SW.4]

5.0 Software design

5.1 Database | Firebase

The Firebase Realtime Database is a cloud-hosted NoSQL database that allows us to store and sync data between users in real-time. Real-time syncing makes it easy for users to access their data from any device: web or mobile, and it helps users collaborate with one another [8]. NoSQL databases are non-relational databases - the data objects do not relate to each other in any inherit way. In the case of Firebase the data is structured in a JSON Tree format. SQL databases, on the other hand, are relational databases where the data is structured in tabular form; for such databases we can design an entity relation diagram that describes the structure of our data and its relation to each other. e-minder's data can be structured to fit either style. The reason behind using Firebase is due to the ease of use of the platform and the services available through it. Firebase allows us to build serverless apps, is very quick to set up, and works well with the flutter framework since they are both developed by Google. It also has a very helpful authentication feature that allows us to authenticate users and maintain their profiles on the cloud without needing to implement any authentication logic within our app. It supports authentication using passwords, phone numbers, and other identity providers like Google, Facebook, and more.

5.1.1 JSON Tree Data Structure

Fig. 14 shows an example of the JSON tree structure and the names and attributes of the objects stored within it. This is how the data will be stored in the database. There will be one parent list: users. The users list will contain all the user objects. User objects will be indexed via a unique identifier assigned to the user by the Firebase authentication service upon registration. Each user object will contain a name and an item list that contains all the user's registered items. Each item will be indexed by its RFID and will contain a name attribute (an item description) and an owner attribute. For the prototype and production versions of the product, items may also include a type (RFID or non_RFID), a notification setting (Always, Once, etc.), as well as any other features that may come up.

Fig. 14: Firebase JSON Data Tree Structure

This structure was developed to allow for fast identification at the door [DSR.5.1.1.POC]. The owner attribute may seem redundant but is actually crucial for this purpose. Given an RFID, the microcontroller will quickly request all items in the system (this can be done quickly in firebase because all item lists have the same identifier and are all on the second level of the tree structure). And since the items are indexed by their RFID we don't need to go down the JSON Tree. Once the item is found, the owner will be instantly identified by the owner attribute within each item. The microcontroller would then request the corresponding item list of that owner from the database and confirm that all the other items are detected at the door.

Table XI: Database DSR

Design ID	Design Specification Requirements
DSR.5.1.1.POC	System must be able to correctly & quickly identify users at the door, retrieve their registered item lists, and detect any missing items [REQ.SW.1, REQ.SW.3, REQ.SW.5a, REQ.SW.5b, REQ.SW.7, REQ.SW.10, REQ.SW.13, REQ.SW.17]
DSR.5.1.2.PRO	Users must get notified of the nature of the alert (what items are missing) via the app. [REQ.SW.4]
DSR.5.1.3.PRO	Users may customize their items, their item types, and their alert settings [REQ.SW.6, REQ.SW.9, REQ.SW.11, REQ.SW.12, REQ.SW.14, REQ.SW.15, REQ.SW.16, REQ.SW.18]
DSR.5.1.4.FIN	User data must be protected and secure [REQ.SW.19]

5.2 Mobile Application | Flutter

Flutter is an open-source UI software development kit. The software team has chosen Flutter to develop the mobile application for e-minder as it allows development of cross platform applications for both Android and IOS. Flutter is written in C, C++, and Dart. However, Dart is mostly used to develop within Flutter. The team has also done research on possible use of Flutter embedders for future e-minder products. Flutter offers a simple user interface for custom embedders that can run Flutter apps on new hardware and operating systems.

5.2.1 Figma

The software team has decided to use Figma to design the UI prototype for the mobile application. Figma is a primarily web-based vector graphics editor and prototyping tool. While the UI prototype for certain features is currently under construction, Fig. 15 shows the initial prototype being built. The figure shows two pages, where the page on the right is displayed once the user taps on either the ‘View Added Items’ or ‘Add New Items’[DSR.5.2.1.POC]. This is further demonstrated by the arrow.

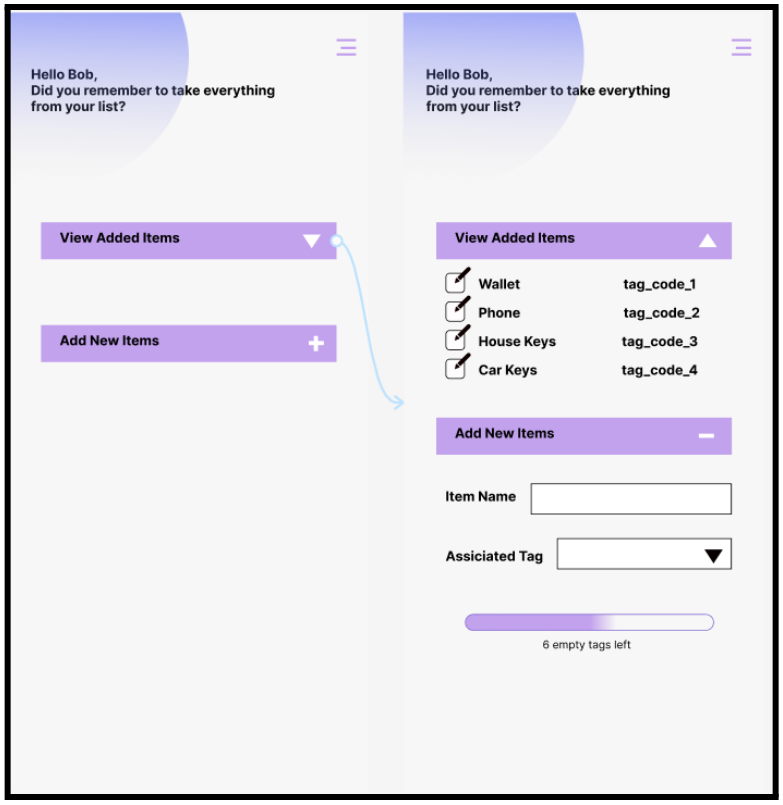

Fig. 15: Rough Figma UI Prototype for Mobile App

Table XII: Smartphone Application DSR

Design ID	Design Specification Requirements
DSR.5.2.1.POC	Item lists must be accessible, customizable, able to be added, removed, and modified via the App [REQ.SW.5, REQ.SW.6, REQ.SW.7]
DSR.5.2.2.PRO	Regular items must be checked on every exit. [REQ.SW.10]
DSR.5.2.3.FIN	Items can be marked as having an RFID tag or not. [REQ.SW.12]
DSR.5.2.4.FIN	Special items must be checked only on the next exit and then removed from the list [REQ.SW.11]

5.3 Microcontroller | C++

The programming on the ESP32 microcontroller will involve communication between the RFID reader, speaker, and remote database. The ESP32 is able to be used via a modified C++ language, which features extra libraries for Arduino. There are additional languages and methods to program on the ESP32, but the Arduino IDE works for our needs.

The microcontroller will store any scanned RFID data in a queue, and will use the RFID at the start of the queue to query the database to identify the user. If a user is identified, it will go through the queued RFIDs one by one and verify that all user items are present [DSR.5.3.1.POC].

Table XIII: Microcontroller Software DSR

Design ID	**Design Specification Requirements**
DSR.5.3.1.POC	User's objects should be detected and updated when standing in front of the device. [REQ.SW.10, REQ.G.1]

6.0 Conclusion

This document provides a detailed discussion of the design process and design decisions for the e-minder product. All updated Design Specification Requirements (DSRs) are addressed in their relevant sections and are tied back to the corresponding Requirement Specifications. e-minder is designed to act as a helpful reminding agent to forgetful individuals without getting in the way of their daily lives. The document discusses in detail the purpose of the product and how that purpose is to be fulfilled.

The following recaps the overarching system design:

- The physical component
  - ESP32: A microcontroller SoC board with on-board wifi and bluetooth modules that will be required to connect to the internet. This is the central component and will facilitate the communication between all the other components. A discussion behind the choice of ESP32 is provided in ESP32 Microcontroller.
  - RFID Reader: This will read the RFID tags and pass the information to the microcontroller. This is the most challenging part of the implementation. The challenges along with our approach and plan to solve them is discussed in RFID Testing.
  - Speaker: This is used for notification purposes. A beep will be sufficient for the POC while the prototype will explore more descriptive alerts such as text-to-speech. The distinctions between the POC and the prototype roadmap have been discussed in detail in Scope.

- The software component
  - Firebase: An online database platform that will be used to store all user data including items lists, their tags, and all user credentials. The database's features and the justification behind its choice has been discussed in Database | Firebase and the Firebase section under Appendix C, respectively.
  - Flutter: A cross-platform UI software development framework that will be used to develop and deploy an Android and an IOS mobile application. The mobile app will be used by the user to manage their information in the database. A discussion regarding the choice of framework and an initial conception of the app is presented in Mobile Application | Flutter.

The user will be instructed to register all their important tagged items via the app, which will store them as part of the user's profile in the database. Upon exiting the home, the product will detect all present RFID tags via the RFID Reader; sending the IDs to the microcontroller for identification. The wifi-connected microcontroller will then access the online database via the internet and use the detected IDs to identify the user and retrieve the corresponding item list. Finally, The microcontroller will then do a simple check to verify that all items in the user's item list are detected by the RFID reader. If not, the system will alert the user, otherwise the user will exit their home worry-free.

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7.0 Appendix A: Test Plan

The following test plans are to be carried out to determine how successful the POC and prototype builds are. Tests will be related to requirements laid out in the requirement specifications document. Tests will be done during two different development phases, namely the POC and prototype. POC tests can be done on individual components, while prototype tests will be done with all modules in their designed places, interacting with each other.

7.1 Test Plan Requirements Classification

Test Plan Requirements will be discussed in 9.2 Individual Tests. The Test Plan Requirements will be of the following format:

TPR {Section}.{Subsection}.{Requirement Number}.{Stage of Development}

Clarification for the meaning of "Stage of Development" can be found in Table XIV below.

Table XIV

Stage of Development	Symbol
Proof of Concept	POC
Prototype	PRO
Finished Product	FIN

7.2 Individual Tests

TABLE XV: Test Plan for POC and Prototype

Test ID	Requirement Referenced	Test case	Expected results	Pass? (Y/N)
TPR.7.2.01.POC	REQ.HW.8	Tag is placed on a piece of paper and person holding it walks past sensor at 1m at walking pace	Item ID is outputted within 0.5 seconds	
TPR.7.2.02.POC	REQ.HW.9	Tagged item is in person's pocket and person walks past sensor at 1m at walking pace	Item ID is outputted	

TPR.7.2.03.POC	REQ.HW.10	Tag is in wallet and person walks past sensor at 1m at walking pace	Item ID is outputted	
TPR.7.2.04.POC	REQ.HW.10	Tag is in empty backpack and person walks past sensor at 1m at walking pace	Item ID is outputted	
TPR.7.2.05.POC	REQ.HW.11	Tag is on outside of leather wallet and moved from 5m to 2m	Item ID is outputted before passing the 2m mark	
TPR.7.2.06.PRO	REQ.HW.3	All components are enclosed in a plastic enclosure	No components are hanging out or wired to external computer	
TPR.7.2.07.POC	REQ.G.1	User profile contains at least two items. User walks past sensor with one of the two items	User is notified of this without needing to look at app. IE: beep	
TPR.7.2.08.PRO	REQ.G.3	User can add/remove items with instruction	User agrees it was easy	
TPR.7.2.09.POC	REQ.G.8	Two registered users walk by separately, each missing an item.	Their missing items are separately reminded	
TPR.7.2.10.POC	REQ.SW.1	User opens app	App prompts two options: login & profile creation	
TPR.7.2.11.POC	REQ.SW.4	User causes a notification (ex: walks to door without a registered item)	A beep is clearly heard from the device	
TPR.7.2.12.PRO	REQ.SW.4	User causes a notification (ex: walks to door without a registered item)	A text-to-speech output is clearly heard from the device describing the issue (ex: stating the missing item’s name)	
TPR.7.2.13.POC	REQ.SW.5	User creates a new profile via the app	The user can login using their credentials	

TPR.7.2.14.POC	REQ.SW.5	User logs into app and navigates to the item list	The user can see their item list displayed	
TPR.7.2.15.POC	REQ.SW.6	User logs into app and navigates to the item list	The user can see Delete Item & Add Item buttons	
TPR.7.2.16.POC	REQ.SW.7	User adds a new item to the list, logs off, then logs back on & navigates to item list	The new item is displayed in the item list	
TPR.7.2.17.POC	REQ.SW.7	User adds a new item to the list then walks to the door without the new item (all other items present)	The user is notified of missing item	
TPR.7.2.18.POC	REQ.SW.7	User removes an existing item from the list, logs off, then logs back on & navigates to item list	The existing item is no longer displayed in the item list	
TPR.7.2.19.POC	REQ.SW.7	User removes an existing item from the list then walks to the door without the existing item (all other items present)	The user is not notified	
TPR.7.2.20.PRO	REQ.SW.9	User navigates to the Add Item page	User is prompted to select a notification setting for the item from the following options: - Always - Once - Date	
TPR.7.2.21.POC	REQ.SW.10	User walks to door without a registered item multiple times	User is notified every time	
TPR.7.2.22.PRO	REQ.SW.10	User adds an item with notification setting set to	User is notified every time	

		"Always", then walks to the door multiple times without the item (all other items present)		
TPR.7.2.23.PRO	REQ.SW.11	User adds an item with notification setting set to "Once", then walks to the door twice without the item (all other items present)	User is notified only once. The item no longer exists in the item list	
TPR.7.2.24.PRO	REQ.SW.11	User adds an item with notification setting set to "Date", then walks to the door once before the date, and once after the date without the item (all other items present)	User is notified only before the date. The item no longer exists in the item list.	
TPR.7.2.25.PRO	REQ.SW.12	User navigates to the Add Item page	User is prompted to specify if the item has an RFID tag attached or not	
TPR.7.2.26.POC	REQ.SW.13	User walks to door with all registered items on person	The user is not notified	
TPR.7.2.27.PRO	REQ.SW.14	User adds untagged item to item list, then walks to door with item not on person	The user is notified	
TPR.7.2.28.PRO	REQ.SW.14	User adds untagged item to item list, then walks to door with item on person	The user is notified	
TPR.7.2.29.PRO	REQ.SW.15	User navigates to item list	Each item has an "Edit" button (or any equivalent function)	

TPR.7.2.30.PRO	REQ.SW.15	User navigates to item list and edits an item	User can change the notification setting to be Always, Once, or Date	
TPR.7.2.31.PRO	REQ.SW.15	User navigates to item list and edits an item	User can change the item classification to be tagged or untagged	
TPR.7.2.32.PRO	REQ.SW.4, REQ.SW.16	User causes a notification (ex: walks to door without a registered item)	A push notification is sent to the user via the mobile app describing the issue (ex: the name of the missing item)	
TPR.7.2.33.POC	REQ.SW.17	User navigates to the Add Item page	User is prompted to enter the RFID tag attached to the item	

8.0 Appendix B : User Interface

8.1 Introduction

e-minder is an embedded device designed to be placed on the wall directly beside the front door of the user's home. The device scans the user for items they don't want to forget. The product features a smartphone application that allows users to add or remove the items they wish to be reminded about. e-minder will be geared towards customers living in residential homes, long term care homes, people with ADHD or otherwise forgetful people who struggle with remembering everyday items. The physical device strives to look clean and not out of place in a family home, while the smartphone application is meant to be simple enough for an elderly user to use.

8.1.1 Purpose

The purpose of this appendix is to list the user analysis and technical analysis of the device and the engineering standards that it conforms to. The document will illustrate the specific design choices made for the proof of concept and prototype design.

8.1.2 Scope

This document will be discussing five main topics:

1. User Analysis
2. Graphical presentation
3. Technical Analysis
4. Engineering standards
5. Usability test

8.2 User Analysis

e-minder is designed to act as an aid for people who have trouble remembering to bring important objects with them as they leave their home. The target market for this product is people with ADHD and the elderly population. e-minder is designed for intuitive use and the scanning device can be installed near the entrance of a home on the wall. Installation will require the user to mount the device to the wall in a similar manner to a picture frame.

Once installation is complete, the embedded device will not require interaction from the user as all user input is done through the smartphone application. The user must be able to operate a smartphone application to add or remove items that they wish to remember. A smartphone application will need to be downloaded in order to use e-minder. All registration will

be done online to initialize the product and configure all required information into a user profile. For this reason, Wifi connection is required for users.

Users will be verbally reminded through text-to-speech software as they leave the residence if they are missing items. There will also be an LED indicator for users that have trouble with hearing. The verbal and visual indicators will prompt users to check their smartphone application and check for missing items. The app will display the missing item in a user readable list format.

A future feature that would allow e-minder to have a better commercial use would be to allow administrator users who could add items for other users. For example, an administrator could be a mother wishing to remind their children to bring their lunch or a nurse wishing to remind a patient to not leave without their medication. e-minder can lessen some of the workload for healthcare assistants especially in non-cognitive wards as e-minder can help them with patient's day to day activities. Healthcare professionals could use e-minder to register all patients to one device and track their things such as exercise kits assigned by specialists, pill organizers, and many other items that should be with patients.

e-minder utilizes both physical and virtual reminders for users. Virtual reminders are when a user wishes to be reminded of something at a specific time or date when they leave the home.This type of reminder would be added directly to the list on the smartphone app by the user. Physical reminders require the user to attach an e-minder branded RFID tag to an object. The scanner at the door will require the item to be detected before checking off the item on the smartphone application's reminder list. This means that the user or an aid to the user must be able to physically attach the tags to their belongings for physical reminders.

8.3 Graphical Presentation

8.3.1 Hardware Presentation

The prototype dimensions are estimated in the figure [Fig. 16] below. It will be an appropriate size to house all the components. The main component being the RFID sensor in the middle, with only a white square surface visible to the user. Internally, there will be the controller board, speaker, and associated wires. The prototype housing will be black or white PLA plastic. Slight adjustments will be made to the housing based on the results of future tests. This is discussed in detail in the following paragraph.

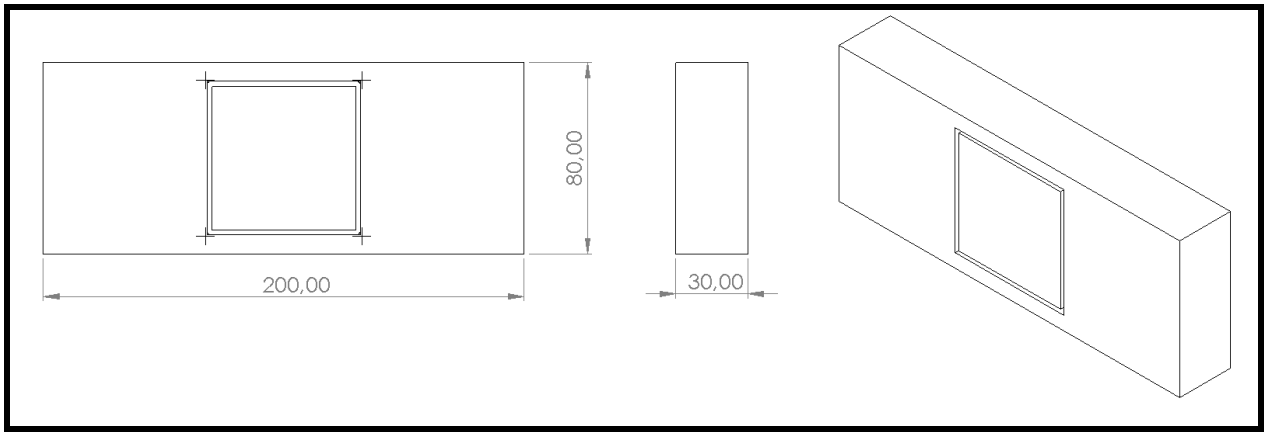

Fig. 16: Estimated prototype dimensions

The e-minder device is designed to be out of the way and unobtrusive to the user. Depending on future testing of RFID scanning capabilities, there will be different possible layouts. In the scenario of a doorway [Fig. 17], the sensor can be placed at different heights such as chest height or close to the floor. The optimal angle will be found to have a balance between scanning capability while being out of the way.

The first placement of the e-minder could be at chest height and scanning perpendicular to the wall. This will be best suited for whole body scanning, however it will be in line of sight of the user and will need a wire to the nearest outlet.

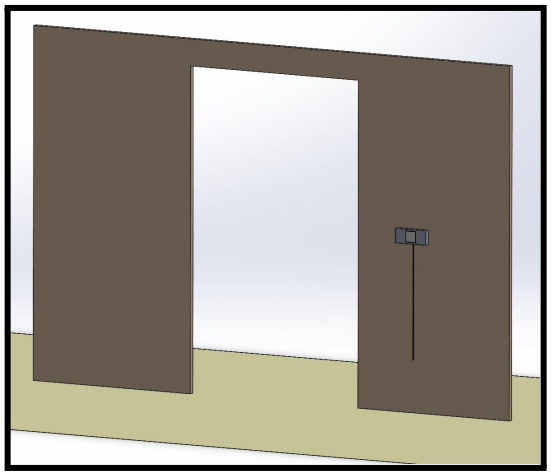

Fig. 17: Doorway with e-minder chest height configuration

The second placement which would be near the floor would be the most aesthetically pleasing as the device is out of the way and the power cable can be routed lower out of sight [Fig. 18]. The enclosure is designed to point the scanner upwards in this case. If the scanner is still able to detect all items, this placement would be the best.

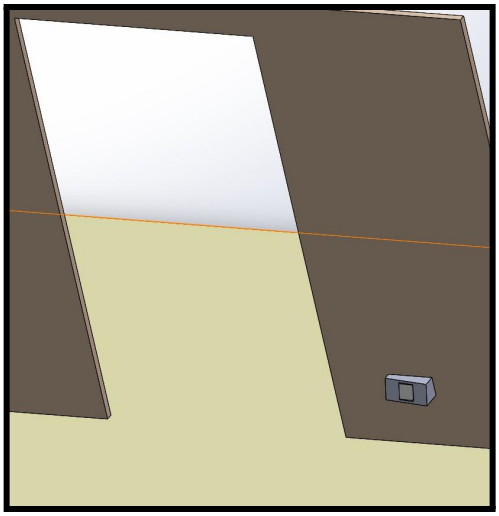

Fig. 18: Near floor configuration

The last possible placement is the least desirable but could provide the best scanning opportunity. The e-minder is again placed in eyesight at chest height, however it is also angled to one side [Fig. 19]. This allows the user to stay in the scanning zone longer while at the door. Because of the angle, the device would sit farther away from the wall, which is the least aesthetically pleasing.

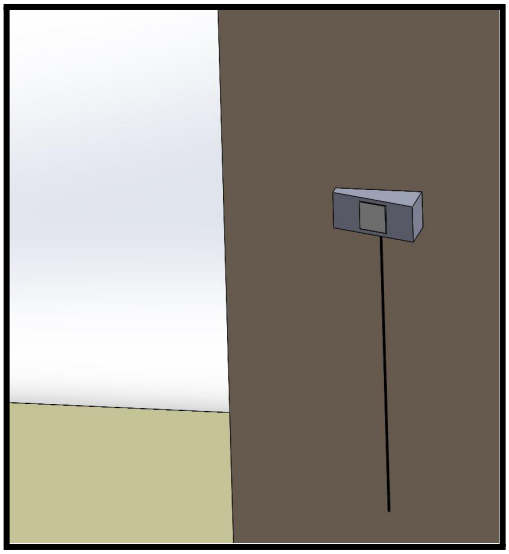

Fig. 19: Chest height angled configuration

8.3.2 Software Presentation

e-minder also comes with a mobile application for users to specify items they want to be reminded of. The app will be available for installation at the app store for Apple and Android smartphones. Upon opening the app, the user is greeted with the options shown in Fig. 20 and 21

below. The user can view their added items by tapping on the down arrow beside ‘View Added Items’. Fig. 20 below shows the drop down list for the added items. In this section users are also able to edit the names of the item, change associated tags with the item, and delete the item and free up the associated tag. Users can also add new items by tapping the plus button beside ‘Add new items’. Upon adding a new item, the app will display the number of non-associated tags left as displayed on Figure 21. By default, the app will stay on the user that signed in last, however, users are able to change/switch user profiles by tapping on the three bar option menu on the top right corner of Figure 20.

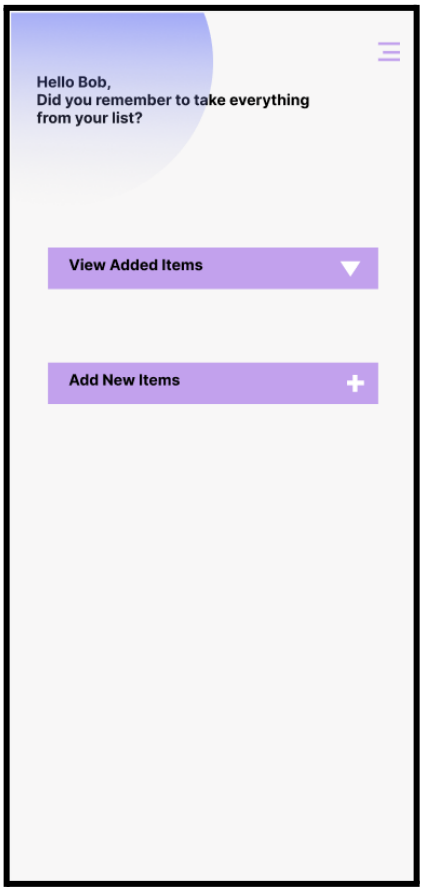

Fig. 20: Initial App Screen

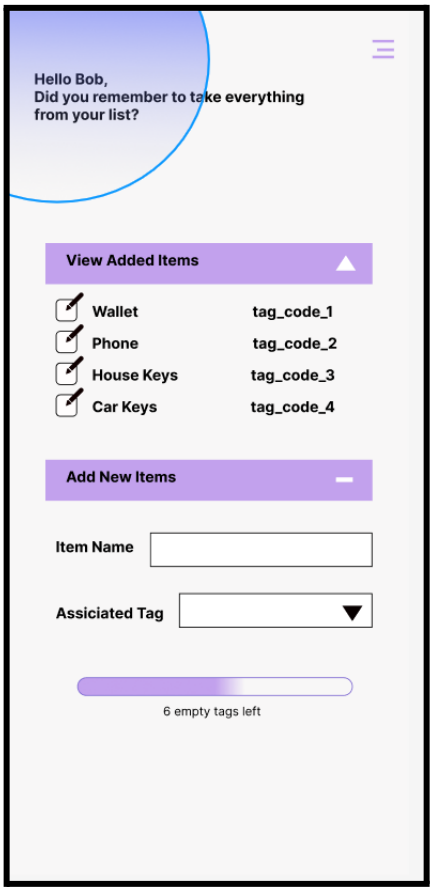

Fig. 21: Options Menu

8.4 Technical Analysis

From Don Norman’s Book “The Design of Everyday Things” it discusses 7 main criteria for everyday designs: Discoverability, Feedback, Conceptual Models, Affordance, Signifiers, Mapping, and Constraints [9]. Here we will discuss how we have taken these topics into account for our device.

8.4.1 Discoverability

A good product aims to be intuitive for its users. e-minder utilizes discovery through the use of text-to-speech. The voice reminder will directly tell the user that they are missing items and that they will need to check their smartphone application. Once at the application, the user will be presented with the items that are missing. The process walks the user through the process of remembering to leave with their items.

8.4.2 Monitoring

In order to deliver a high standard product continuously, Purple-Mango takes monitoring their product very seriously. For the mobile application as well as the physical system, e-minder keeps a log of any unexpected behavior or crashes at the backend of the system. The logs are collected in a manner to provide efficient problem solving. Every log entry consists of the following [10]:

- An actor (who: username, IP address)
- An action (what: read/write on which resource)
- A time (when: timestamp)
- A location(where: geolocation, browser)

8.4.3 Feedback

Feedback is used to inform the user of any changes or issues with the system. There will be two forms of feedback during everyday usage. The primary method is the audible notifications from the speaker when an item is forgotten. An LED will serve as secondary feedback. It will flash rapidly when an item is forgotten and steady when it has sensed a tag. It will flash slowly when the device is in an idle state.

8.4.4 Conceptual Models

The user's only interaction method with the e-minder system is using the mobile app. We are using Flutter to develop an intuitive modernized mobile app that will seem familiar to most users. The main and most frequent operation in our app will be the viewing and modifying of the item list. This will be similar to many experiences users had with ordering any items from e-commerce platforms and the like; where they have lists of items and can add, remove, and edit those items.

8.4.5 Affordance

Affordance is defined as the relation between an object and its user. The device we have designed is easy to set up and has multiple interfaces. For set up, the only prerequisite is battery power that will need to be plugged into a nearby outlet by the entrance for optimal use. The RFID tags are easily placed as they come in the form of a sticker or label. The app is intuitive and easy to use.

8.4.6 Signifiers

Communication for e-minder will be done both through the app and through the hardware system installed on the door. Hardware signifiers will be through the speaker system alerting the user that they have forgotten to bring a user-identified item. Software signifiers will take place through the mobile app that will alert the user via notification on their mobile device of the certain user-identified item that was forgotten. Labels will also be put into place in the form of an instruction manual for installation and warnings such as not blocking the signal from the RFID reader will be specified there.

8.4.7 Mapping

Mapping is an essential part of any system to allow users to understand and efficiently make use of the system itself. Therefore, the mobile application of e-minder takes great importance in mapping in its UI prototype. If a user was previously signed in when opening the app, the user is faced with a small introduction following the form: ‘Hello *user_name*, did you remember to take everything from your list?’ This lets the user know who is currently signed in in the event that multiple users share one device. Furthermore, within the list of items the user is able to see the associated tag to the item. The code on these tags are also visible at the back of the physical tags so users are able to easily locate their items and the tags by referring to the list on the app.

Additionally, the system will be equipped with an LED for clarification on when the system is active. The LED will turn on when the sensors are active and scanning the user, and it will be off when the sensors are inactive. Aside from a visual representation of scanning the users, this lets the user and developers confirm if the system is working as expected. The system will also have a speaker to let the user know when they leave an item from their list behind. If no item is left behind the speaker will be inactive, however since the addition of LED the user will be able to differentiate between the system not working or the user simply has everything with them from their list.

8.5 Engineering Standards

Table XVI shows the Engineering standards chosen for the e-minder. e-minder will conform to proper Canadian and International standards to create a sustainable, marketable and safe product. It will follow the standards outlined by ISO, IEC , IEEE and UL.

Table XVI:

Standard ID	Description
UL 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use — Part 1: General Requirements [11]
IEC 60950-1	Information technology equipment - Safety - Part 1: General requirements [12]
IEC 60335-1:2020	Household and similar electrical appliances - Safety - Part 1: General requirements [13]
ISO 10377:2013	Standard for assessing and managing the safety of consumer products[14]
CSA 22.1-18	Safety standard for electrical installations , Canadian Electrical Code, Part I[15]
IEEE 21451-7:2011	Standard to define data formats to facilitate communications between radio frequency identification and smart RFID tags- Part 7[16]

8.6 Usability Testing

8.6.1 Analytical Usability Testing

Analytical usability testing will be performed by the Purple Mango team engineering students. The purpose of these tests is to find issues that have been overlooked when designing the product. When testing the e-minder device, it is important that after each test the tester confirms that the device is intuitive to use for a user.

Testing will cover 3 components:

- Installation
- Physical Device
- Smartphone Application

Each of these tests should work towards the following three e-minder core functions:

1. Detects all RFID Tagged items when walking through the door.
2. Notifies user if RFID tagged items are missing
3. Sends a notification through the app to alert the user

8.6.1.1 Installation

Installation of the device should be safe and straightforward. The test plan for installation is as follows:

1. The holes where screw holes for the device are not damaged during proper installation.
2. The device when mounted to the wall is physically secure when leaned on by a user.
3. The power cable is undamaged and not pinched during proper installation.

8.6.1.2 Physical Device

The physical e-minder device's main function is to detect tags that the user has with them and to audibly alert them. The following tests should be done to ensure the device is properly working.

1. The device LED lights up when the device is powered on.
2. The device can be clearly heard when using text-to speech.
3. The device reliably connects to the user's WIFI.
4. The RFID reader detects tagged items under normal circumstances.

8.6.1.2 Smartphone Application

The user should be able to quickly check if their items are with them when they check the application. The following tests should be conducted to ensure the application is fulfilling its purpose:

1. The user is immediately able to see missing items when entering the app
2. The user is able to navigate to a tab to add and remove items from their list.
3. The user should have to log in to add or remove items.
4. The user should be able to adjust the text size to help with visibility.

8.6.2 Empirical Usability Testing

Testing will be conducted within the purple mando team to get feedback and will focus on empirical testing from Table XVII. Testing will be sectioned into core functionality, safe and reliable use, and end user testing.

Table XVII: Empirical Tests

Empirical Test	Process
RFID Range	Range should be appropriate for an entryway in a home.
RFID Angle	The angle should provide the best object detection.
RFID Penetration	The device should reasonably detect items in bags.

Wall Mount	The device should not fall off the wall when under stress.
Electrical	The device should not cause electrical harm to the user.
Setup	The device should be easy to install and register.
Affordance	The device should be affordable to the target market.

8.6.2.1 Core Functionality Testing

The core functionality of the e-minder product revolves around RFID Tag detection. The RFID tag and reader setup determines the performance, so testing different ranges and sensitivity will be the most important aspects to get correct. The device will be placed in different kinds of settings, such as apartments, basement suites, and nursing homes where the placement options will be reported.

The RFID readers' readability depends significantly on SOAP (Size, Orientation, Angle and Placement) [17]. Finding the optimum angle at which the device is placed is crucial to the performance.

8.6.2.2 Safe and Reliable Usage of Device Testing

Once the e-minder device is installed, there are very few safety risks. The majority of the risk comes when the device is being installed. The device must be able to be mounted securely so as to not fall off the wall. If the device were to fall off the wall this could damage the user's wall, floor, device, and also cause a potential tripping hazard. The device is designed to be light, so a fall is unlikely if properly mounted.

In addition, it is important to ensure the safety of the user when installing the plug of the device. There should be no risk of electrical shock when installing the device.

8.6.2.3 End User Testing

Product usability will be tested for the following 3 tasks:

1) Set up of e-minder, including installation and user registration
2) Performance
3) Affordance of e-minder

Tables XVIII to XX featured below represent example user feedback forms based on our top three targeted markets. Users are meant to check one box from each row with #1 representing the response "Strongly Agree", #3 representing the response "Neutral", and #5 representing the response "Strongly Disagree". The survey can be easily filled on any cellular device. The following statements will be presented to the users:

Table XVIII: Nursing Home Feedback Form

Question for User	1	2	3	4	5
The device was easy to set up and place on the wall.	▢	▢	▢	▢	▢
I required assistance when setting up the device.	▢	▢	▢	▢	▢
User registration was intuitive and straightforward.	▢	▢	▢	▢	▢
I had no problems accessing the app from a smartphone.	▢	▢	▢	▢	▢
The device is not intrusive in everyday life.	▢	▢	▢	▢	▢
The e-minder device volume was adequate.	▢	▢	▢	▢	▢
The e-minder app font was easily readable.	▢	▢	▢	▢	▢
The device performed as expected.	▢	▢	▢	▢	▢
The device aided me in day to day activities.	▢	▢	▢	▢	▢
Nursing homes could benefit from this device.	▢	▢	▢	▢	▢
Would you purchase this device for $100?	▢	▢	▢	▢	▢
I would purchase additional e-minder tags for $2.00 each.	▢	▢	▢	▢	▢

Table XIX: ADHD Feedback Form

Question for User	1	2	3	4	5
The device was easy to set up and place on the wall.	▢	▢	▢	▢	▢
User registration was intuitive and straightforward.	▢	▢	▢	▢	▢
The Device is not intrusive in everyday life.	▢	▢	▢	▢	▢
The device performed as expected.	▢	▢	▢	▢	▢
The device aided me in day to day activities.	▢	▢	▢	▢	▢
The device successfully caught my attention with reminders.	▢	▢	▢	▢	▢
I found it easy to keep track of my e-minder tags.	▢	▢	▢	▢	▢
Would you purchase this device for $100?	▢	▢	▢	▢	▢
I would purchase additional e-minder tags for $2.00 each.	▢	▢	▢	▢	▢

Table XX: Parents Feedback Form

Question for User	1	2	3	4	5
The device was easy to set up and place on the wall.	▢	▢	▢	▢	▢
User registration was intuitive and straightforward.	▢	▢	▢	▢	▢
The Device is not intrusive in everyday life.	▢	▢	▢	▢	▢
The device performed as expected.	▢	▢	▢	▢	▢
The device aided me in day to day activities.	▢	▢	▢	▢	▢
The device improved my experience when leaving home.	▢	▢	▢	▢	▢
My children were able to use the e-minder app.	▢	▢	▢	▢	▢
Would you purchase this device for $100?	▢	▢	▢	▢	▢
I would purchase additional e-minder tags for $2.00 each.	▢	▢	▢	▢	▢

8.7 Conclusion

e-minder is a device that is installed beside the front door that scans for specific user-identified items. e-minder will feature a smartphone application that allows users to customize items they wish to be reminded about. Users will be notified via the speakers on the hardware device alongside a push notification on their smartphones. The target demographic for e-minder is the elderly, parents of children attending school, and individuals with ADHD. The physical device will be clean and sleek, and the connected smartphone application will be simple and streamlined. The hardware enclosure will be built off PLA plastic which will be offered in white and black to match the user's preferences. The 7 criteria for everyday designs: Discoverability, Feedback, Conceptual Models, Affordance, Signifiers, Mapping, and Constraints were used to guide the direction Purple Mango should take. These include an intuitive interface, simple ways to communicate, security, and a feedback system.

Analytical usability testing was done through personal research on RFID technology, software implications such as flutter, and the best hardware components to match the needs of e-minder. Empirical usability test cases were created to receive feedback from the public and the target market. These include core functionality test cases, safety and reliability test cases, and a survey for nursing homes, parents, and the general public. The feedback received from these forms will help address target points to fix and features to add in the future. Further testing will need to be done to determine the best location for the hardware device. Chest height, bottom-up,

and different angles will all be considered and the most accurate signal alongside appearance will be chosen.

At Purple Mango, we look forward to the development of e-minder, a creative concept having the potential to improve the lives of elderly, parents, and individuals with ADHD. The team at Purple Mango will present an original concept that is designed to be commercially successful as a consumer product.

9.0 Appendix C: Supporting Design Options

This appendix will briefly discuss the hardware and software specific design choices the purple mango team made for e-minder and what were the alternatives we chose not to pursue. This appendix will be in reference to the Requirement Specification document to provide justification for each design choice taken. This section will be broken down into hardware, software, and embedded with subsections for each component used and option considered.

9.1 Hardware Options

9.1.1 Scanning method

Two scanning methods were considered: Bluetooth or RFID. Bluetooth technology would allow for much bigger data storage, location accuracy, and realtime tracking. However Bluetooth tags are much more expensive, require memory, bigger in size, and only compatible for use in two Bluetooth devices. In comparison, RFID tags are static and low maintenance and complete the basic functionality of asset tracking and identification. RFID tags were selected over Bluetooth as RFID tags last longer without the need for batteries and are significantly cheaper.

9.1.2 Notification method

A few options for the notifications were discussed in initial planning, however, speakers were decided to be the most viable and cost effective option. Options including touch screen and face recognition were discussed but these interfaces were not compatible with our application as our users were still required to register on the app. In addition, the usage of the interface is just to remind the user of a missing item via app so the most effective way to implement this function while maintaining costs was sound. Touch screen and face recognition would also add complexity for users and contradict the target audience.

9.1.3 Enclosure

The enclosure for e-minder will assist in its function as a signal reader rather than be strictly a container. It helps angle and position the sensor. Therefore we needed to pick a method for the POC that allows easy adjustments. The chosen design allows rapid tests in different orientations rather than building multiple enclosures with different angles. Other discussed methods included 3 different angled designs and wooden enclosures. Thin printed plastic is chosen because it absorbs the least amount of RF signal.

9.2 Software Options

9.2.1 Flutter

Flutter is a cross-platform UI framework. It was clearly a superior choice over all other single-platform mobile app development frameworks since we would only need to develop one application and it would run on both IOS and Android[20]. This would cut development costs significantly and will give us more time to work on the core functionalities of the product. Other

cross-platform frameworks that were considered include: React Native, Ionic, and Xamarin. However, flutter, among all the other cross-platform frameworks, is by far the simplest and quickest framework to learn and develop mobile apps. Further, Flutter has the same look and feel across all platforms since it uses unique UI rendering tools. This is beneficial for our brand.

9.2.2 Firebase

As mentioned in Database | Firebase, the use of Firebase - a NoSQL non-relational online database - was determined based on the ease of use and the ease of setup. The main benefit of Firebase is that it allows us to develop serveless mobile applications while other databases, including relational SQL databases such as MySQL, require hosting the database on a server. Further, Firebase and Flutter are both developed by Google so integrating them is simple and there is a wide range of documentation about it online.

9.3 Embedded Options

9.3.1 ESP32 Microcontroller

Originally the team was not planning to use an ESP32 microcontroller for e-minder and was instead planning to use a Raspberry Pi 3B. The plan was to use the Raspberry Pi 3B for the PoC then to replace the board with a Raspberry Pi 3+ Lite Compute for the prototype. There were several issues with this initial choice:

1. The cost of a Raspberry Pi is significantly higher than a ESP32 microcontroller. The Raspberry Pi 3B Compute would cost around $30 per unit, while an ESP32 can cost between $2-4 [1] [18] .
2. The Raspberry Pi is very difficult to purchase currently due to supplier shortages. This makes the Pi an unreliable choice for mass production. An ESP32 is easily acquired in bulk.
3. The Raspberry Pi was too powerful. For our project, we were not using 90% of the Raspberry Pi's capabilities.

When choosing the ESP32-WROOM we also had to consider its sister models:

- ESP8266
- ESP32
- ESP32-S2
- ESP32-S3
- ESP32-C3
- ESP32-C6

As seen in Table XXI, most of the sister ESP32s would have worked for our needs besides the ESP8266 and ESP32-S2 as they did not have Bluetooth [19]. The deciding factor was shipping time and cost as we needed to get the microcontroller quickly and there was no benefit in overpaying since the regular ESP-32 could fit our products needs. In the future if we decide to upgrade we would most likely switch to the ESP32-S3 or ESP-C3.

Table XXI: ESP32 Board Comparisons [19]

	ESP8266	ESP32	ESP32-S2	ESP32-S3	ESP32-C3	ESP32-C6
WiFi	Wi-Fi 4 (only up to 72.2Mbps)	Wi-Fi 4	Wi-Fi 4	Wi-Fi 4	Wi-Fi 4	Wi-Fi 6
Bluetooth	X	BLE 4.2 (upgrade to 5.0, with limitations)	X	BLE 5.0	BLE 5.0	BLE 5.0
Ethernet	X	✓	X	?	X	?
UART	2 (one TX only)	3	2	?	2	?
GPIO	17	34	43	44	22	22