

# Artificial intelligence in the field of nutrition: An automated diet planner mobile application

## Abstract

This study demonstrates how the design thinking methodology has been applied to explore the ways in which Artificial Intelligence can solve various problems within the field of nutrition. A number of two think-aloud sessions, in which five participants took part, were conducted in order to discover usability issues concerning the prototypes developed for the purpose of this study. Various data analysis methods were then applied to categorise user responses and analyse them accordingly. Results showed numerous positive comments and recommendations for improvement, along with a few usability issues. The outcomes of this study evidence a need to further research the scope of the problem and the conceptual potential this app holds.

## Introduction

An individual's lifestyle and diet are factors which can influence the human gut microbiome, which in turn is able to affect health and influence the likelihood of disease and mental health related issues (Matusheski *et al.*, 2021; Amati, McCann and Spector, 2022). Following the recent COVID-19 pandemic, numerous links between diet quality and COVID-19 severity have been found (Merino *et al.*, 2021; Amati, McCann and Spector, 2022), highlighting an elevated importance for the general public to be more mindful when it comes to their diet and gut microbiome, due to their vital role in aiding the immune system (Amati, McCann and Spector, 2022).

When it comes to nutrition, one size does not fit all, as dietary choices elicit distinct responses from person to person based on various factors such as age and genetics (Matusheski *et al.*, 2021; Amati, McCann and Spector, 2022). However, thanks to the continuous advancements in Artificial Intelligence (AI), machine learning (ML) has the ability to analyse complex sets of data and the potential to achieve a more in depth, precise and individualised approach to diet related factors (Matusheski *et al.*, 2021; Amati, McCann and Spector, 2022; Côté and Lamarche, 2022).

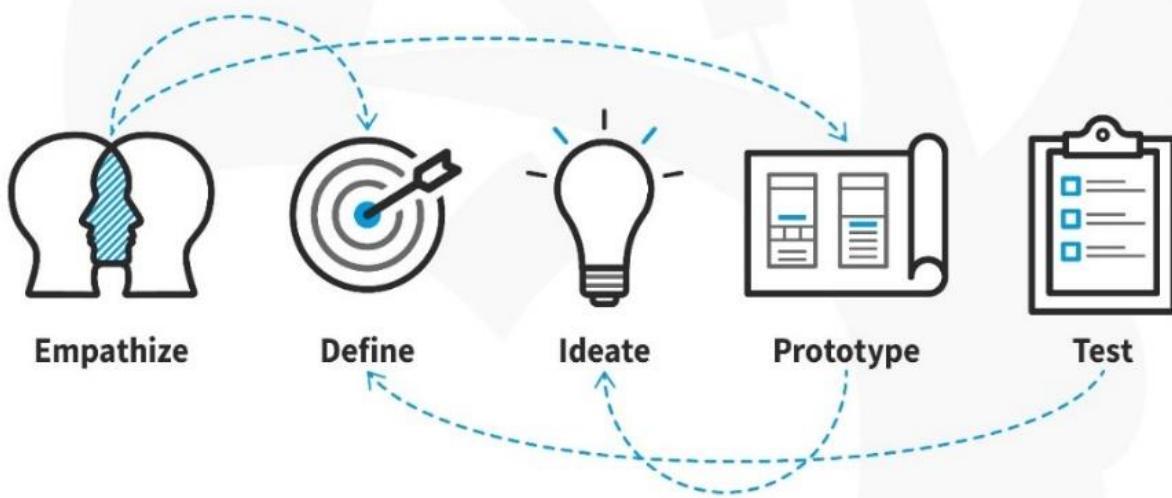
This paper will demonstrate the ways in which the design thinking methodology has been applied to encourage long-term wellbeing by making use of ML. With the use of this technology, the proposed mobile application intends to identify nutritional deficiencies, calculate nutrient intakes and accurately generate fully personalised diet plans for users.

## Design thinking methodology

The design thinking methodology (See Fig. 1) is a human-centered approach which entails profound empathy and understanding of end-users' needs, goals and pain points to fully grasp a problem. This is done in hopes of creating a more effective and thorough solution (Gibbons, 2016; Roberts *et al.*, 2016; Oppliger, 2021; Dai, 2022; Darmawan *et al.*, 2022). Although a non-linear process, the design thinking framework is commonly made up of a five step process: understanding and empathising with the target user group, stating the problem, finding innovative solutions to the problem, prototyping the solutions and finally testing the prototypes (Gibbons, 2016; Roberts *et al.*, 2016; Oppliger, 2021; Dai, 2022; Darmawan *et al.*, 2022). This paper will make use of this method to encourage innovation and explore a variety of approaches in developing the aforementioned mobile application.



# Design Thinking: A 5-Stage Process



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Figure 1 | Design thinking process diagram

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## 1. Empathise

In order to successfully empathise with the user, there is a need to get to know who the target demographic is, what their story is, along with what their goals and frustrations are. The first step taken in this process was identifying the concurrent problems within the field of nutrition while attempting to immerse into the experiences of customers and nutritionists going through the nutrition care process.

### 1.1. Background

Within the field of nutrition research, computational techniques are gaining increasing amounts of popularity, along with AI based methods of health prediction (Ülker and Ayyıldız, 2021; Côté and Lamarche, 2022). In contrast to ML, which is more inclined towards accurate classification and prediction through learning algorithms trained on vast datasets, traditional methods of statistics are mostly focused on probability and the relationship between variables. As an example, a study shows that an algorithm enhanced by data from a variety of sources such as blood samples, outperformed conventional glucose monitoring methods in predicting postprandial glycemic responses to meals (Zeevi *et al.*, 2015). Furthermore, compared to traditional statistical methods, ML has the ability to efficiently analyse large and complex datasets (Côté and Lamarche, 2022). This means that implementing such technologies within the field can greatly help the nutrition industry, since ML is capable of automating tasks that would normally be time-consuming.

By conducting secondary research, it was found that the current, most common process of a visit to the nutritionist involves a five-step procedure. Firstly, a specialist will run a comprehensive nutrition assessment (Koh, 2019; Hungate, 2022), which will be used to decide upon a diagnosis (Hungate, 2022). Following the first two steps, the specialist will work on a healing-process plan with the patient by providing different resources such as healthy recipes, grocery shopping lists, and a few sample meal plans (*What to Expect from your Appointment*, no date). According to the NHS Foundation Trust, the most common way of communicating treatment plans is by post (*Nutrition and dietetics - Appointments*, no date). Finally, the last stage of this process is the reassessment stage, where another visit is scheduled to assess health progress (The British Dietetic Association, 2021; Hungate, 2022). This process can be thought to be daunting, creating various challenges for both patients and dietitians. For example, an internet source (Bender, 2022) explains that clients have often found it difficult to stick to long-term changes, which can result in a high loss of motivation and willingness to report dietary intakes (Ülker and Ayyıldız, 2021). In connection with the aforementioned finding, some patients are often not prepared to change their eating habits, believing it is not that important to switch certain aspects of their diets (Bender, 2022), ultimately hindering their progress, increasing skepticism toward dietitians and losing faith in their health journey. Current methods of measuring dietary intakes such as food diaries, questionnaires and other self-reported methods are highly time-consuming and challenging, as well as error prone and subjective, leading to nutritionists having difficulties when deciding which method is most suitable (Ülker and Ayyıldız, 2021; Côté and Lamarche, 2022).

However, with the use of AI, the current knowledge of the complexities of the microbiome and its relations to health results can be highly increased, with particular focus on reducing errors and bias. (Amati, McCann and Spector, 2022; Côté and Lamarche, 2022). Furthermore, tracking dietary intakes is an important factor in assessing the nutritional status of patients, therefore, with the use of technologies such as ML, dietitians, along with customers can greatly benefit from an easier time following diet plans and controlling their diet adaptations (Ülker and Ayyıldız, 2021). At the moment, various AI-based dietary apps are emerging (Ülker and Ayyıldız, 2021; Amati, McCann and Spector, 2022; Côté and Lamarche, 2022). For example, companies such as "ZOE" make use of AI to bring out advanced blood sugar monitors and microbiome testing, creating a fully personalised plan to improve customers' health (Amati, McCann and Spector, 2022). Another example of this is "Keenoa", which is an image-based mobile application that can be used to recognise and identify different foods with the use of AI, allowing users to edit food diaries in real time (Ülker and Ayyıldız, 2021). This shaped the foundation for the RQ1: "How can AI contribute to creating a better user experience for users seeking nutritional guidance?"

## 1.2. Target audience research

In terms of who the users are, research shows there are three main categories of nutrition content consumers: athletes, regular people who are health-conscious (e.g.: people who want to build muscle, people who suffer from nutritional related issues, people who want to lose weight, etc.) and people who would attempt to live healthily if given motivation (Justesen, 2018; Bats, 2022). A paper also shows that the general demographic that visits the dietitian is older patients, typically more females than males, along with people who have dietetic problems, want to lose weight or have other health issues (Hendrie, Coveney and Cox, 2008; Tol *et al.*, 2012). Research further shows that people have very basic nutritional knowledge and there was confusion when subject matters became more detailed, highlighting a need for people to have this type information easily accessible (Hendrie, Coveney and Cox, 2008). Another paper also shows that men have less knowledge than women when it comes to nutrition, evidencing a higher female audience. Relative to socio-economic status, the lower the status, the poorer the knowledge (Parmenter, Waller and Wardle, 2000). Furthermore, according to a 2019 report (Mitchell, 2019), it was found that people who have little to no experience regarding dieticians tend to trust them significantly less and people younger than 50 years-old tend to have negative beliefs when it comes to dieticians.

## 1.3. Competitor analysis

A comprehensive competitor analysis was conducted in order to assess this project's competitors' strengths and weaknesses and identify a gap in the current market. Using a competitor analysis comparison table, contenders have been analysed in terms of product quality, reputation, pricing, position on globe and user reviews (see Table 1).

Afterwards, in order to easily view and compare their strengths and weaknesses, two additional tables have been created in this sense (see Table 2 & 3).

|                 | Zoe | CareClinic | Omada | DayTwo | Enbiosis |
|-----------------|-----|------------|-------|--------|----------|
| Product Quality | 8   | 4          | 7     | 7      | 8        |
| Reputation      | 8   | 3          | 8     | 8      | 8        |
| Pricing         | 5   | 10         | 4     | 6      | 3        |
| Place           | 7   | 10         | 2     | 2      | 7        |
| People          | 5   | 6          | 2     | 2      | 1        |

Table 1 | Competitor analysis comparison table

| STRENGTHS            |                       |                  |                        |  | WEAKNESSES                         |  |                           |                                 |                           |  |
|----------------------|-----------------------|------------------|------------------------|--|------------------------------------|--|---------------------------|---------------------------------|---------------------------|--|
| Zoe                  | CareClinic            | Omada            | DayTwo                 | Enbiosis                                   | Zoe                                | CareClinic                               | Omada                     | DayTwo                          | Enbiosis                  |  |
| Dish recommendations | Multitude of features | Daily tasks      | Daily tracker          | Test results charts                        | Long wait time                     | Complicated to set up                    | No syncing                | Not enough meals to choose from | No additional information |  |
| Personalised plan    | Dietary tracker       | Dietitian chat   | Test results status    | Food recommendations                       | Pricy                              | Difficult to navigate                    | Difficult to understand   | Difficult to use                | Clunky app                |  |
| Journal              | Medication tracker    | Dietary advice   | Additional information | Detailed meal instructions and information | Unclear personalised food plan     | Buggy and laggy                          | Too many notifications    | Very laggy                      | iOS only                  |  |
| Product Scanner      | Sympton checker       | Food tracker     | Food scanner           | Related health issues                      | No test results charts             | Doesn't work properly                    | Not advanced enough       | No test results charts          |                           |  |
| Displays calories    | Custom health plan    | Progress tracker | Progress tracker       | Shoping list                               | Unstructured dish browsing options | Important features locked behind premium | No calorie tracking       | Pricy                           |                           |  |
|                      |                       |                  |                        |  | No additional information          | No professional instructions             | No test results charts    | No food prioritisation          |                           |  |
|                      |                       |                  |                        |  | No additional information          | No additional information                | No additional information | Overall poor UX                 |                           |  |
|                      |                       |                  |                        |  | Pricy                              |  |                           |                                 |                           |  |

Table 2 | Competitors' strengths

Table 3 | Competitors' weaknesses

Following the competitor analysis and considering user feedback, it can be concluded that the apps associated with these businesses have various gaps. These apps do not offer enough information, content or features, and have an overall poor reported user experience.

## 2. Define

### 2.1. Problem statement

In the define stage of this process, the insights and observations gained during the previous stage have been synthesized into the core problems which are to be explored throughout this project. Therefore, it can be concluded that nutrition is an important aspect to take into consideration when it comes to leading a healthy life. Improving the ways in which people, especially those who have unbalanced diets, belong to risk groups, and/or have dietary restrictions, control their diets is relevant in order to maintain a healthy lifestyle. Many nutrition centres have not yet upgraded to digital ways of offering services, thus, when consulting a specialist, people are likely to be overloaded with paper-based guidelines or generalised information which they do not fully understand and can easily be lost. Moreover, patients, more often than not, are given very few diet plans and meal options, due to the fact that nutritionists do not have the time to give patients extensive, personalised diet plans, nor to share all the information they would have liked to share. Given all the drawbacks, the general public may be discouraged to check in with nutritionists, and patients are going to be less likely to stick to long-term changes and/or fully understand why it is important to switch eating habits. Lastly, a lack of knowledge regarding nutrition has been observed, which can have a negative effect on our population's health.

### 2.2. Stakeholders

Having defined the problem, the solutions and benefits, the next step was identifying who the stakeholders are. Identifying and categorising the hierarchy on the user groups which this project will focus on is a crucial step in this

process (Lyon, 2020). In this sense, the primary stakeholders for this project are the regular users, nutritionists and athletes. Secondary stakeholders include clinic staff and family/carers, while the tertiary stakeholders include the general public, competitors, the pharma, and supermarkets.

### 2.3. Personas and user stories

By means of the insights gained so far in the project, personas, along with their stories have been created to help further empathise (Miaskiewicz, Sumner and Kozar, 2008; Siika-aho, 2016) and focus on the four main user groups, along with their needs goals and problems (Miaskiewicz, Sumner and Kozar, 2008; Nielsen and Storgaard Hansen, 2014; Siika-aho, 2016). This step guided the project and created a better understanding of the user's goals (Miaskiewicz, Sumner and Kozar, 2008; Siika-aho, 2016). The personas represent a middle-aged woman with a few health issues who is struggling to organise, the ways nutrition clinics operate, and limitations in meal options, along with a young lady who is struggling with weight loss and sugar cravings, has little faith in nutritionists, little to no motivation and is picky with food (See Fig. 2 & 3). Additionally, a boy with issues related to muscle gain, exhaustion and little knowledge regarding nutrition, along with a young nutritionist who is overloaded with work and struggles to know her patients' progress and whether or not they are sticking to their diet plans (See Fig. 4 & 5).

**Gwen Fernsby**

**ABOUT**

Gwen has always been preoccupied with staying healthy in all the ways possible. She suffers from an autoimmune disease, which she keeps under control with the help of medication and maintaining a strict diet. After running multiple tests, she found out she suffers from various food intolerances, forcing her to stop eating multiple aliments. She has a personal dietitian which she frequently goes to seek advice. Upon her visits, she feels she doesn't get enough information or enough meals plans, making her feel limited in her food options. She also found it hard to make sense of the examples her specialist provided, and found it inconvenient the way her results and guidelines were displayed on paper.

**GOALS**

- A strict and personalised diet plan
- Have an easier way of managing her test results

**NEEDS**

- Have more meal plans available
- Detailed and structured test results

**AGE** 48  
**JOB TITLE** Teacher  
**STATUS** Married  
**LOCATION** London, UK  
**PERSONALITY** Extrovert  
**VALUES** MODERN, OPEN-MINDED, OPTIMISTIC, CULTURED

Figure 2 | Gwen persona

**Alexandra Loughtry**

**ABOUT**

Alexandra is a passionate artist who enjoys every day things. Besides art, she loves parties and hanging out with her friends. Due to her nature, she has always been conscious of her appearance and looking her best when hanging out with her friends. Recently, she has dealing with a great deal of stress, failing to maintain her weight. She always craves sugar right after having a meal and especially when stressed. She has been determined to deal with these issues, but found it difficult to get to motivation as she feels nothing works. Alexandra has little faith in nutritionists and feels she is not likely to get the help she is looking for.

**GOALS**

- Lose the weight gained
- Fix her sugar cravings

**NEEDS**

- Straightforward, easily accessible instructions
- Looking for motivation

**AGE** 32  
**JOB TITLE** Painter  
**STATUS** In a relationship  
**LOCATION** Glasgow, UK  
**PERSONALITY** Extrovert  
**VALUES** IMPATIENT, PASSIONATE, PERFECTIONIST, SKEPTICAL

Figure 3 | Alexandra persona

**Elias Dankworth**

**ABOUT**

Elias has always been a skinny person and throughout his life, he has had people comment on it, making him uncomfortable. Recently, he has started his undergraduate degree in London and quickly became friends with someone who frequently goes to the gym. He started joining his friend and becoming more active. Despite the time and effort he's been investing, he feels more exhausted than ever and is not seeing results. Elias has no experience when it comes to nutrition and wants to understand what is holding him back from building muscle.

**GOALS**

- Build muscle
- Stop feeling so exhausted

**NEEDS**

- Clear information and guidelines
- Looking to maintain a fixed schedule

**AGE** 20  
**JOB TITLE** Student  
**STATUS** In a relationship  
**LOCATION** London, UK  
**PERSONALITY** Extrovert  
**VALUES** DETERMINED, ACTIVE, BRAVE, PERSISTENT

Figure 4 | Elias persona

**Robyn Hawking**

**ABOUT**

Robyn has recently become a registered nutritionist at a local clinic. Growing up as a child, her mother always insisted on having a balanced diet and controlling her nutrients. As time passed, her friend fell seriously ill due to their chaotic diet and lifestyle. That is when she realised the real importance of healthy eating habits and how few people take this into consideration. She pursued a career studying nutrition in the hope to prevent others from falling ill and leading happier lives.

**GOALS**

- Help her patients change their diet habits and lead healthy lives
- Successfully give patients all the information and care they need

**NEEDS**

- Looking for ways to reduce workload and find some time for herself
- An easier way to address questions from her patients

**AGE** 27  
**JOB TITLE** Nutritionist  
**STATUS** Married  
**LOCATION** Manchester, UK  
**PERSONALITY** Extrovert  
**VALUES** DETERMINED, EMPATHETIC, CURIOUS, ADVENTUROUS

Figure 5 | Robyn persona

## 2.4. Empathy mapping

Empathy maps were then created to form a basis for who the personas were, and clearly define their thoughts, feelings, goals and pain points (Gibbons, 2018a). This stage helped ensure the quality of the personas and strengthen their overall feelings (See Fig. 6, 7 & 8).



**GWEN**

Figure 6 | Gwen's empathy map

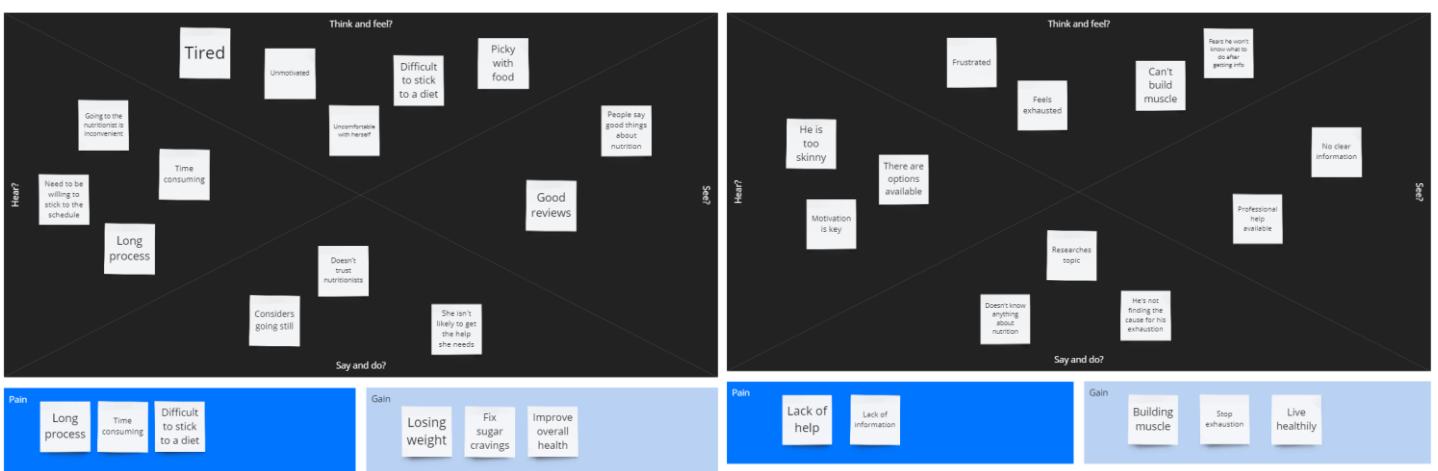


Figure 7 | Alexandra's empathy map



Figure 8 | Elias's empathy map

## 2.5. User POVs and HMW questions

Following this stage, user POVs (points of view) were framed, and used to focus and narrow down the personas' needs and goals, guiding the first steps of coming up with solutions to their problems (Dam, 2020a; Zhmikhov, 2022) (See Fig. 9). Creating the user POVs helped come up with HMW (How might we?) questions which in turn, helped brainstorm innovative solutions based on the personas' needs (Zhmikhov, 2022) (See Fig. 10, 11, 12 & 13). For example, a narrative such as "Alexandra needs to know roughly how long the process will be so that she can get more motivated to keep pushing." enabled brainstorming pioneering ideas for the application such as a way to track progress and healing time estimates.

**Gwen needs** an easier way to talk to her dietitian **so that** she can decrease travel distance.

**Gwen needs** more information from her dietitian **so that** she can increase her meal options.

**Gwen needs** to find a more organised way of viewing her test results and dietitian advice **so that** she manage her health more easily.

**Elias needs** to keep track of his calorie intake **so that** he can gain weight and build muscle.

**Elias needs** a way to understand how nutrition influences his progress **so that he** can improve his workouts and physical energy.

**Alexandra needs** a straightforward and accessible list of instruction **so that** she can be more motivated to maintain a schedule.

**Alexandra needs** to know roughly how long the process will be **so that** she can get more motivated to keep pushing.

**Alexandra needs** various meal options **so that** he can eat things he enjoys.

**Robyn needs** to reduce workload while also giving patients all the information they need **so that** she can have more time for herself.

**Robyn needs** an easier way to answer simple patient questions **so that** focus on other relevant work tasks.

Figure 9 | User POV's

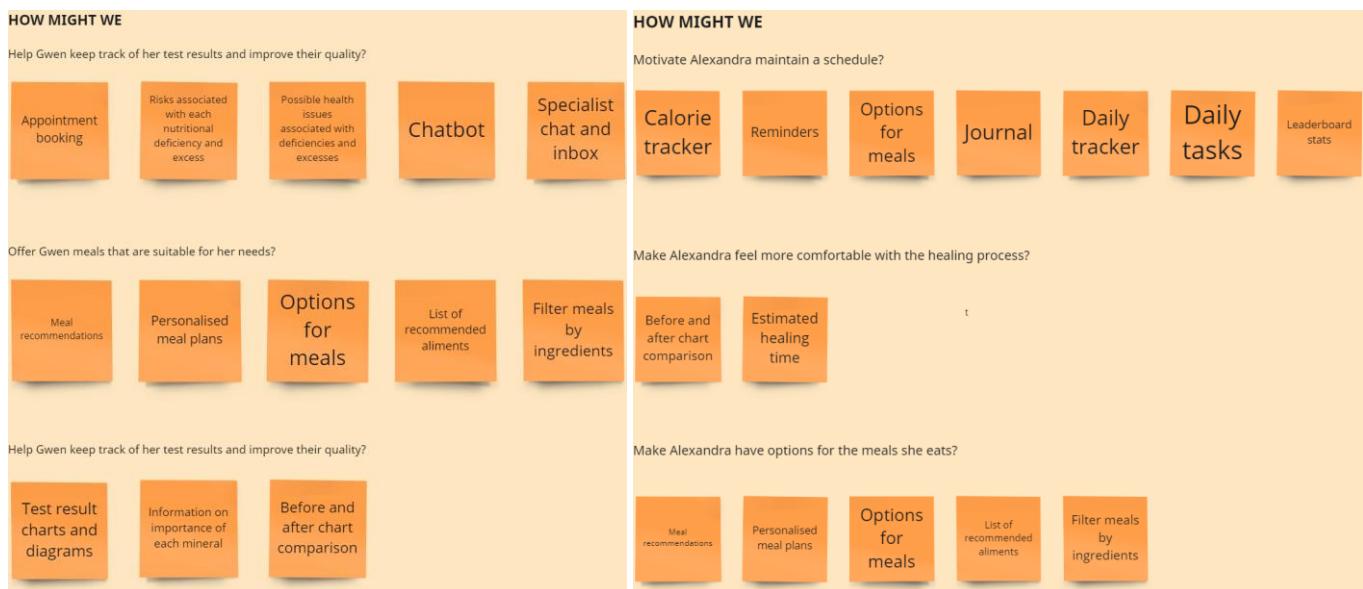


Figure 10 | Gwen's HMW questions

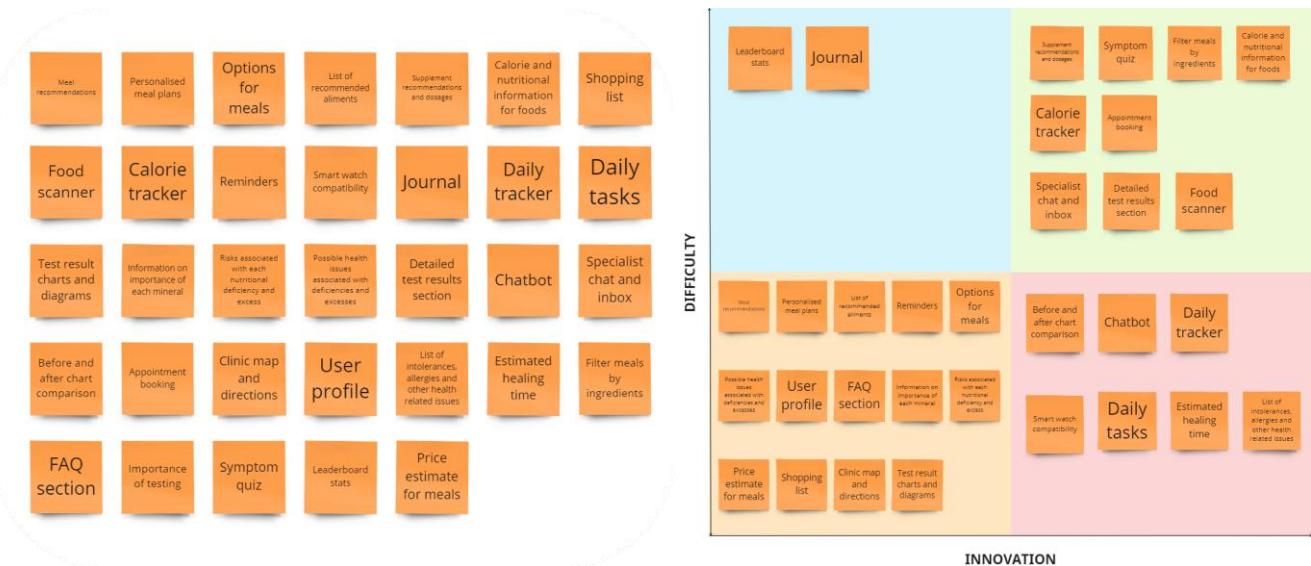
Figure 11 | Alexandra's HMW questions



2.6. Brainstorming and decision matrix

Given the iterative trait of the design thinking methodology, various design tools were repeated throughout the project. An example of this is the brainstorming process which was done twice, through two different techniques in the define phase, using the HMW questions and brainwriting (See Fig. 14) to envisage possible features which could help users achieve their goals and solve their problems.

Lastly, a decision matrix has been created during this design stage to structure the further stages of the project, and evaluate and prioritise the features which were previously brainstormed (Gibbons, 2018b) (See Fig. 15).



### 3. Ideate

Having a solid and structured background plan prior to the define stage, the ideation phase was conducted to refine current ideas and generate new ideas using various tools, envision how users would interact with the product and create a flow of their actions and thoughts while navigating the product.

#### 3.1. Crazy 8's

The Crazy 8's is a design method which was used during this project to quickly generate ideas and attempt to find the best ways of displaying important features. The first crazy 8s session focused on coming up with ideas for the main aspects of the app (See Fig. 16). Once the session was over, three UX design students from the University of Central Lancashire, along with two regular students with no design background were explained the idea behind each

frame and asked to rate them using voting dots. Following the voting stage, it was assessed that the “diet plan” frame (4 votes) was the most important aspect of the app to focus on, followed by the “test results” frame (3 votes) and the “daily tasks” frame (3 votes). The second and third Crazy 8’s session focused on the aforementioned most popular screens and attempted to ideate different designs and features (See Fig. 17 & 18). Three students with a non-design background were explained the purpose of each screen and asked to rate their favourite frame using the same dot system. The use of this method allowed to set apart the ideas that would not work and instead focus on the ideas that had potential.

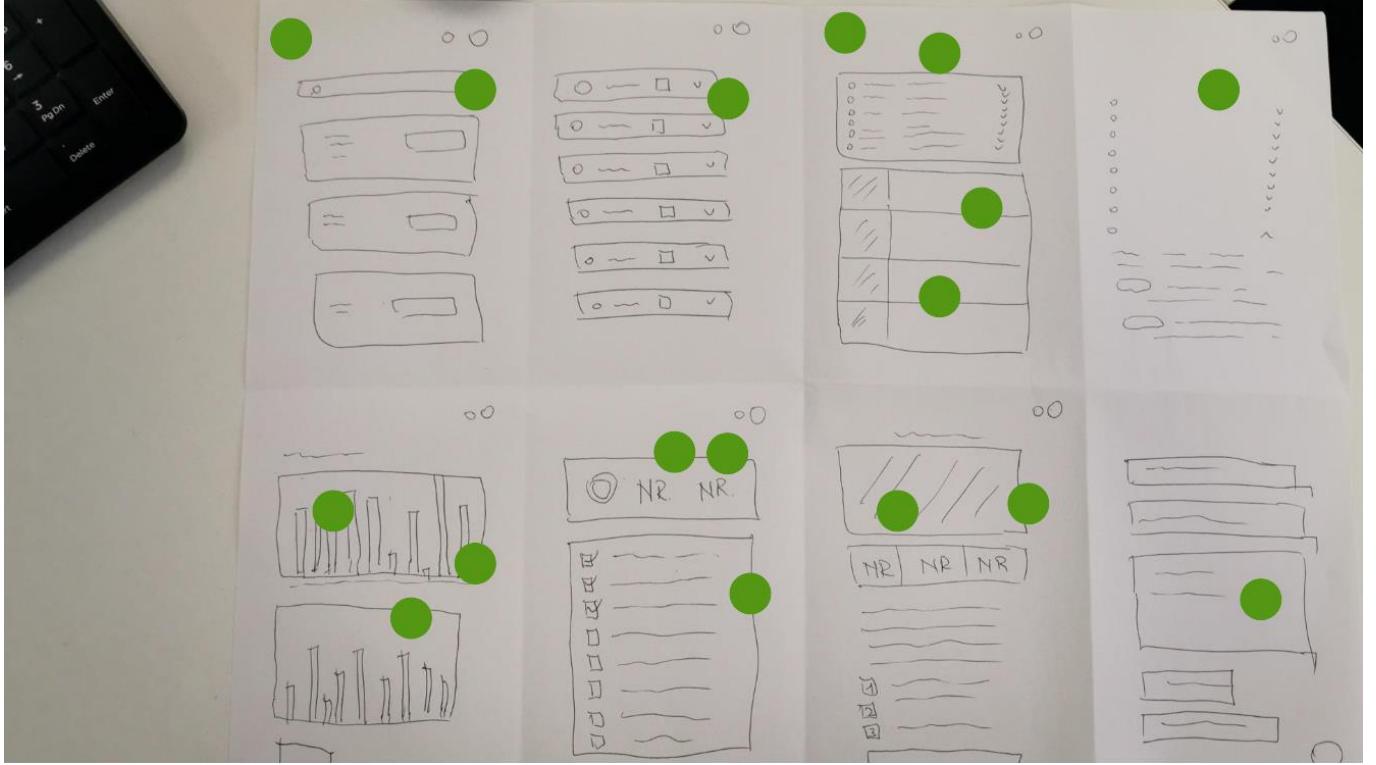


Figure 16 | First session of Crazy 8's

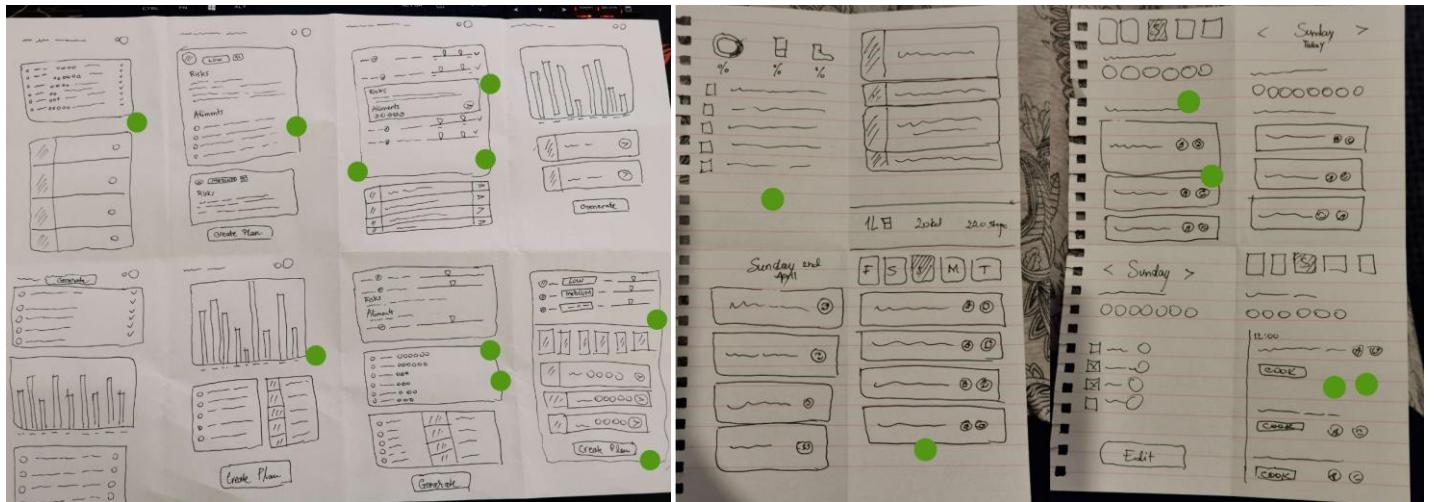


Figure 17 | Second session of Crazy 8's

Figure 18 | Third session of Crazy 8's

### 3.2. SCAMPER

Due to the fact the previous stage did not offer enough clarity regarding the “daily tasks” and the “test results” design screens, the SCAMPER method has been applied in order to understand how the current ideas generated

could be improved (Dam, 2020b) (See Fig. 19 & 20). Following the use of this method, ideas such as combining “Generate” and “Modify buttons” were brainstormed, helping in forming a better start at designing the product.

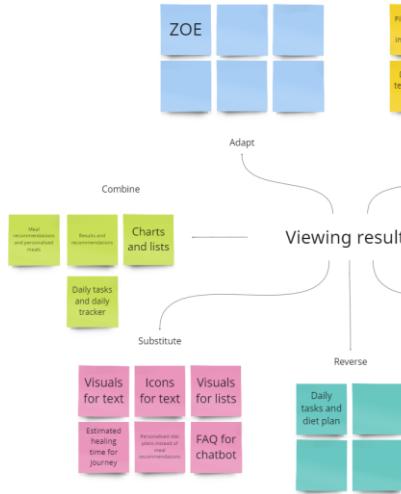


Figure 19 | "Viewing results" feature SCAMPER

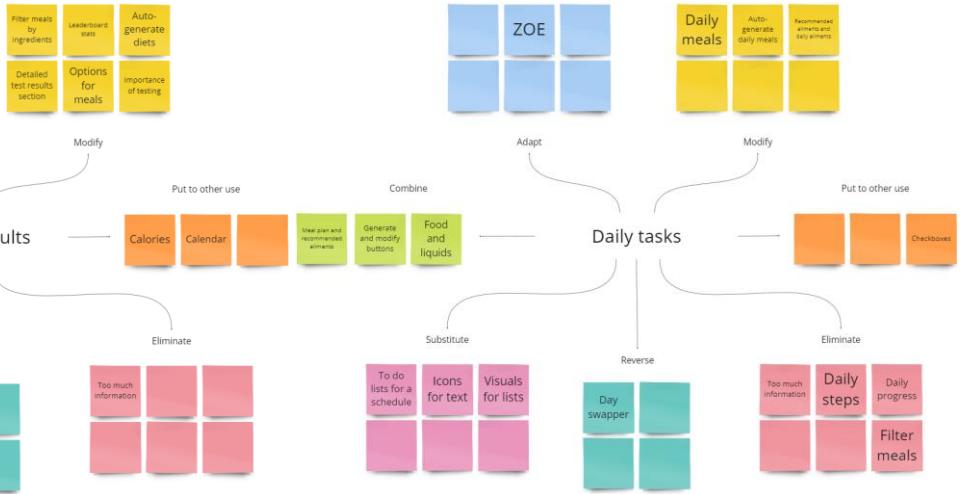


Figure 20 | "Daily tasks" feature SCAMPER

### 3.3. User journey mapping

The next step taken within the ideation phase was creating user journey maps, which were used to clearly visualise the steps each persona would take when using the intended product, along with the areas which needed improvement (See Fig. 21, 22 & 23). In this sense, clearly defining their sequence of action, needs and/or pains, the parts of the system they interact with, along with their feelings, helped identify how users' experiences meet expectations and what the outcomes of using the products are.

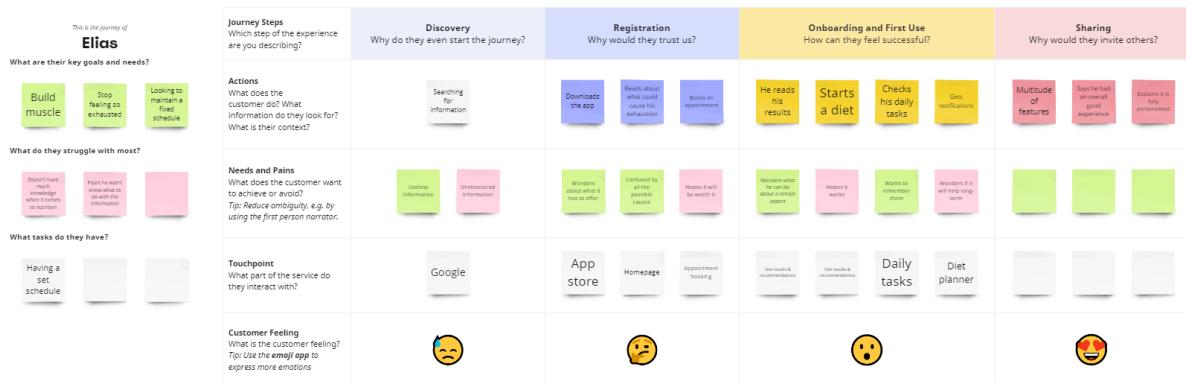


Figure 21 | Gwen's journey map

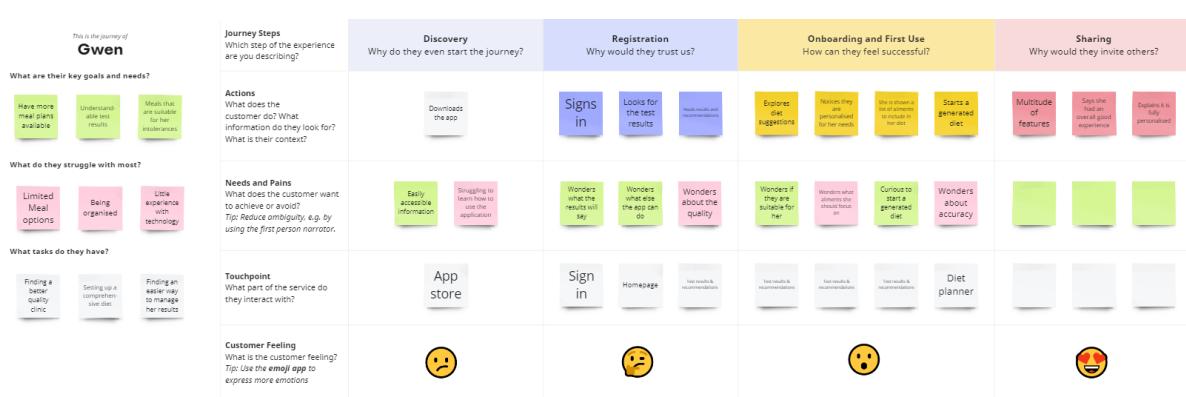
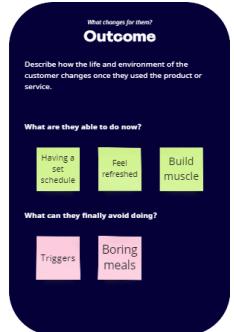
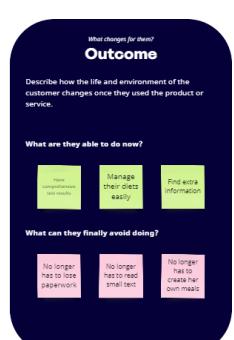


Figure 22 | Elias's journey map



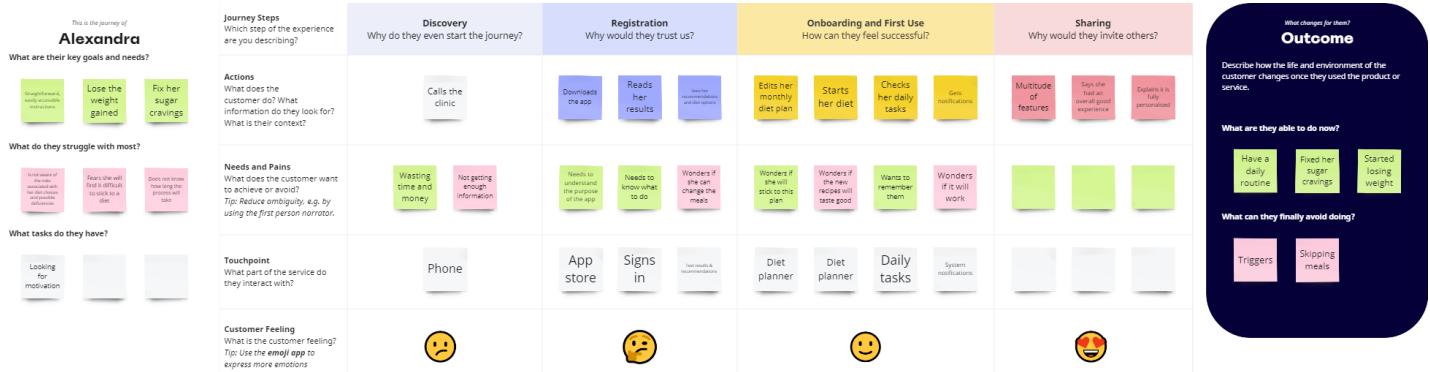


Figure 23 | Alexandra's journey map

### 3.4. User flow

Following the user journey mapping, a user flow was created due to its various benefits in the UX process (See Fig. 24). In this regard, producing a user flow helped clearly visualise the flow of actions users will take when using the product. This way, helping find any issues related to the user journey maps, unnecessary steps and possible confusions users might have while using the product (Meyer, 2021).

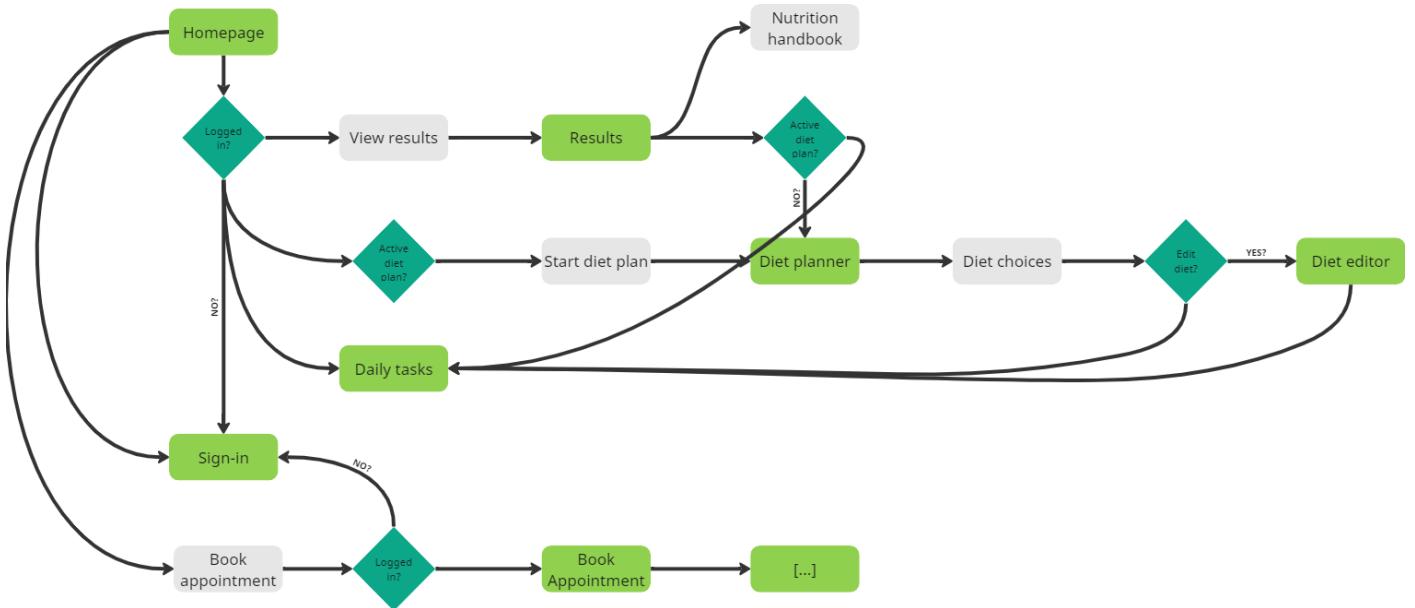


Figure 24 | User flow example

### 3.5. Storyboarding

Along with the user flow, one of final steps of the ideation process was making use of storyboards to create and communicate detailed narratives of users' journey from start to finish, allowing to observe gaps in the process formed so far (See Fig. 25, 26 & 27).

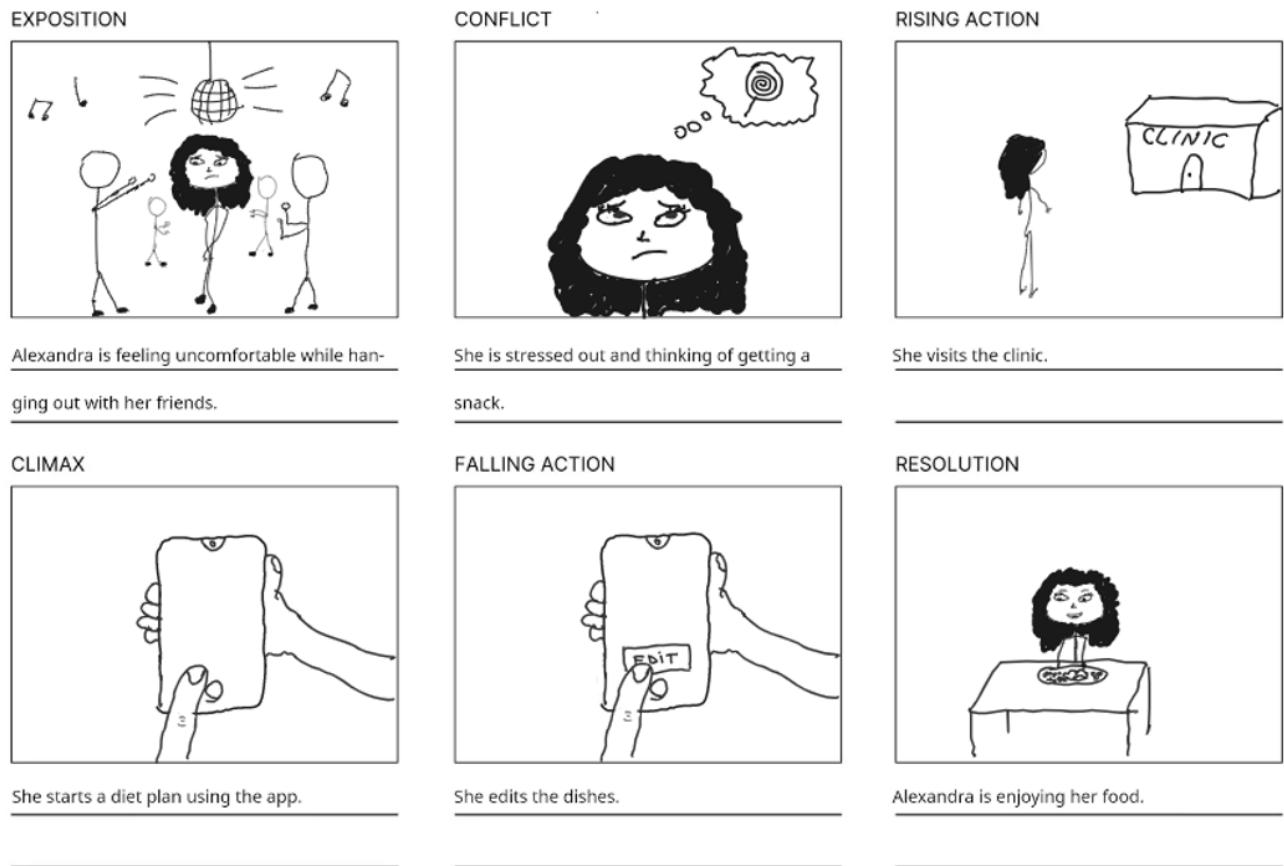


Figure 25 | Alexandra's storyboard

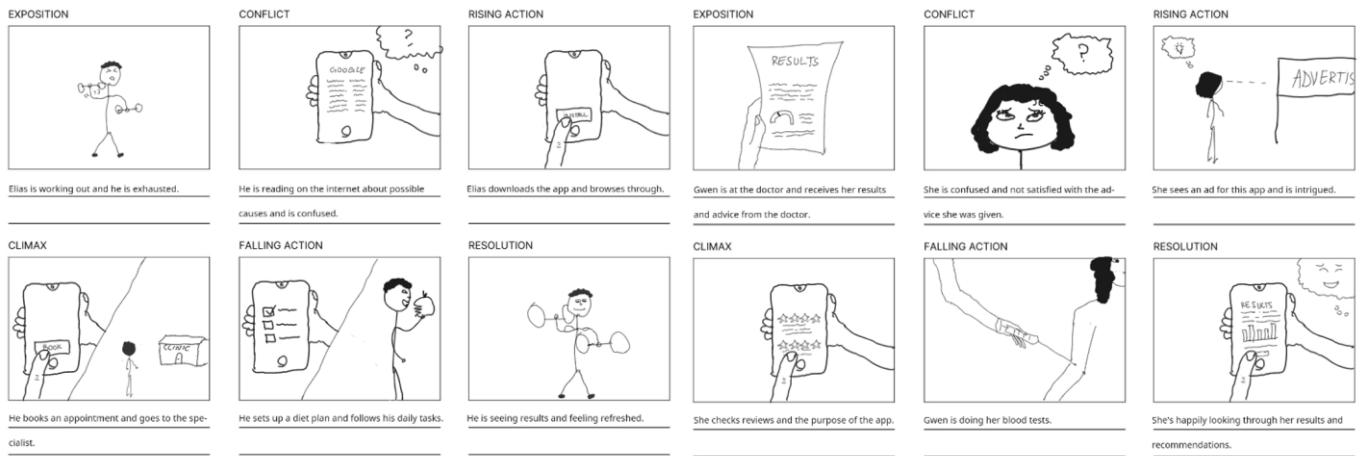


Figure 26 | Elias's storyboard

Figure 27 | Gwen's storyboard

### 3.6. Iteration

With the use of user flows and storyboards, a few gaps within the current design process have been noticed, such as having separate screens for “daily tasks” and “diet plan”, along with a general lack of features. Due to this, a new decision matrix was created (See Fig. 28), together with iterated journey maps and user flows (See Fig. 29, 30, 31 & 32) in order to rethink decisions, reflect the changes made and guide the following stages of the design process.

WHAT CHANGED

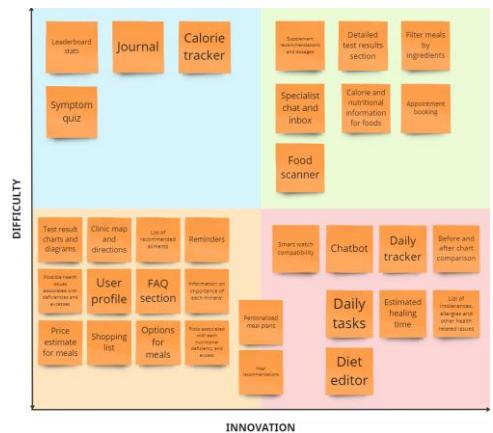


Figure 28 | Iterated decision matrix

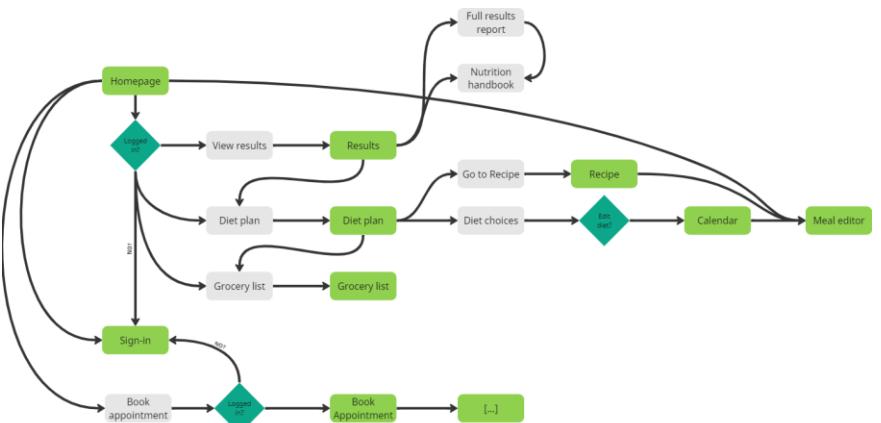


Figure 29 | Iterated user flow

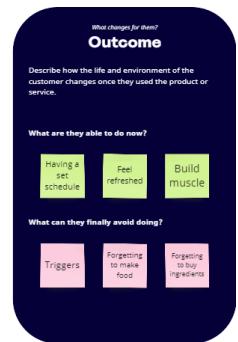


Figure 30 | Gwen's iterated journey map

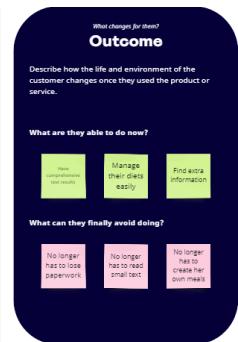


Figure 31 | Elias's iterated journey map

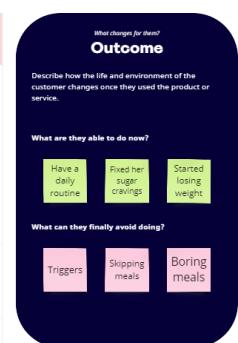


Figure 32 | Alexandra's iterated journey map

## 4. Prototype & Test

### 4.1. Study 1

The first study focused on implementing the insights gained throughout the course of this project into low-fidelity digital prototypes and testing them in order to gain new insights and solve further problems (Roberts *et al.*, 2016).

#### 4.1.1. Method

##### Participants

Using the convenience sampling method, a number of five participants, four males and one female, from Denmark, Finland, Poland and Romania, with ages ranging from 23 to 65 years of age and no design background were selected to voluntarily take part in testing the first version of the prototype.

##### Stimulus materials

The first prototype was created as stimulus material, and attempted to implement the best possible solution to the problems identified in the prior stages of the process (See Fig. 33). Due to convenience, the first low-fidelity prototype was created using Figma (Dam, 2022). The prototype featured the main pages of the intended product, such as “diet plan”, “test results”, “recipe”, “grocery list” and “meal editor”. Furthermore, all pages were interconnected and various links between artifacts were created to convey interaction design.

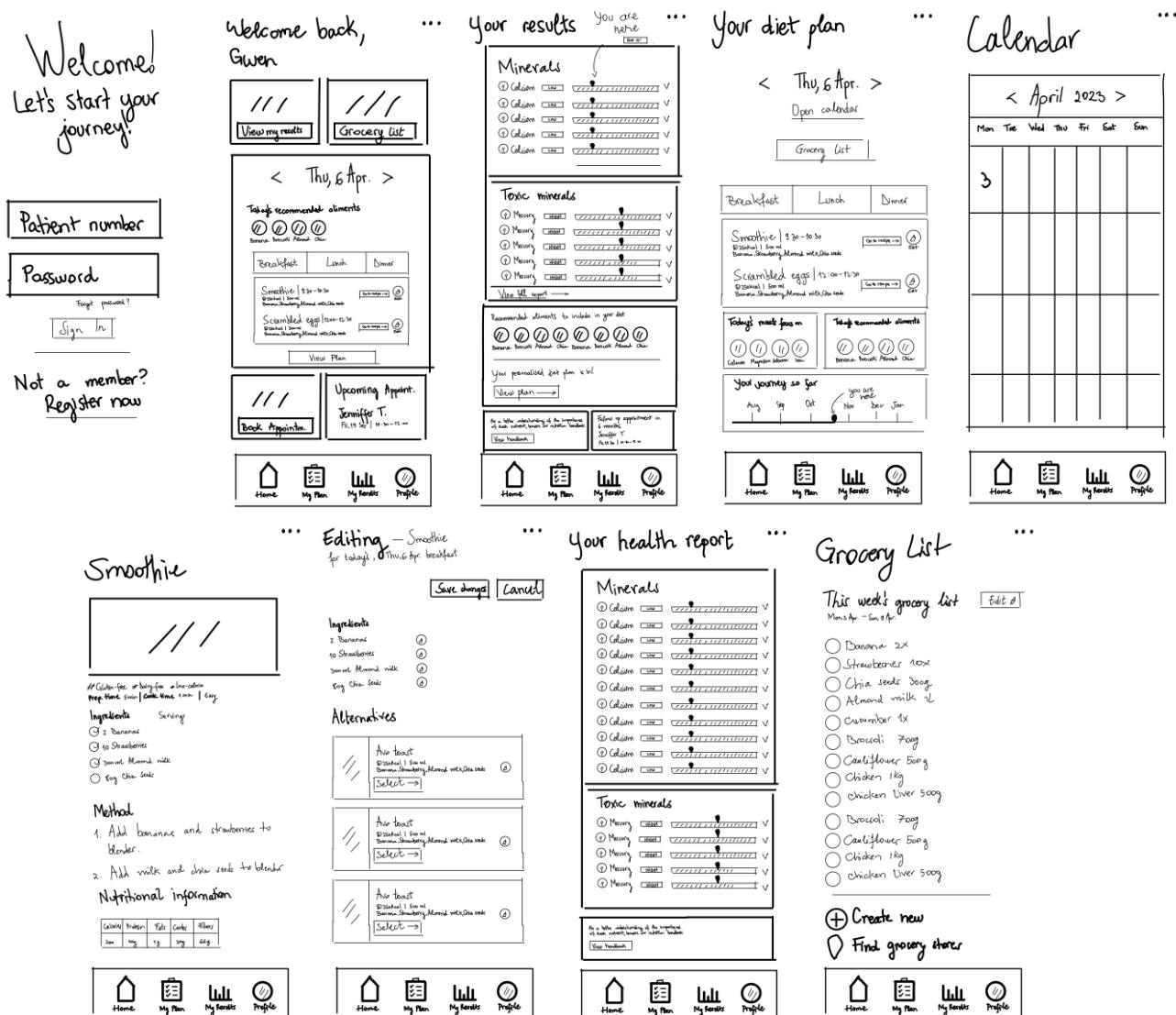


Figure 33 | Low-fidelity prototype example

## Procedure

Participants were provided with a link to the prototype and asked to join an online meeting anonymously through Microsoft Teams, where they were instructed to share their screens. Prior to starting the study, participants were explained the purpose of it and the prototype. They were then asked to navigate through the prototype while thinking out loud. Participants were additionally ensured that there is no right or wrong answers and that they should attempt to be critical (*Think aloud study: qualitative studies*, 2021). Finally, during the study, participants were observed while they navigated through the prototype and notes of their actions and comments were taken (*Think aloud study: qualitative studies*, 2021; ‘Think aloud protocol’, 2023).

## Data Analysis

The generated insights were then colour coded into the following codes: “positive observations”, “negative issues”, “understanding of the system”, “lack of understand of the system” and finally “improvement recommendations” associated with each screen. The notes were then contracted and an affinity map was created to display and analyse the data.

### 4.1.2. Results

In terms of positive observations, a multitude of comments were made. For example, four participants liked having additional information on the “results” screen and two participants liked the “your journey so far” feature. Participants found it easy to navigate the prototype, appreciated the complexity of features and liked the overall idea of the app, making comments such as “professional” and “consistent”. However, in terms of negative observations, two participants found the arrow down located on the results screen to look like a checkmark and did not understand its purpose, while two other participants noted it would display additional information. Similarly, three participants understood the purpose of the calendar feature, while one participant did not, suggesting an icon could make this feature more obvious. Moreover, two participants found the editing page intuitive, while one participant found it confusing. Other usability issues were found such as the “view full report” and “you are viewing breakfast” indicator links not being obvious. Lastly, various recommendations for improvement were mentioned such as adding an “edit button on the recipe page”, “tools needed for recipe”, and adding the “calendar” function on “homepage” (See Appendix A, Table 4).

### 4.1.3. Implementations and rationale for changes

Based on the insights gained, various changes were made to the prototype in order to implement recommendations and solve the current conflicts and usability issues discovered. Many usability issues found were possibly due to a lack of detail, such as the “arrow down” and the “calendar” link, for which a high-fidelity wireframe prototype was created. Other features, such as the low visibility “full report” link and indicators for which meals are being viewed, were transformed into buttons to increase visibility. Additionally, recommendations were considered and a large amount were implemented into the iterated version of the prototype, such as adding a “tools” section and “edit” buttons on the “recipe” page, a section mentioning what the recipe is rich in, “back” buttons, adding “calendar” on the homepage, etc. Finally, an improved version of the “recipe editing” screen was created to solve any remaining confusions.

## 4.2. Study 2

Due to the iterative trait of the design thinking process, a second study was conducted, where the initial prototype was transformed based on the prior insights gained from users and used to find new usability issues, ultimately attempting to discover and fix all the usability issues associated with the product (Roberts *et al.*, 2016).

### 4.2.1. Method

#### Participants

A number of five participants, four males and one female, from India, Denmark, Finland, and Romania, ranging from 23 to 65 years of age were selected using convenience sampling to voluntarily take part in testing the second version of the prototype. One participant had a design background, while the rest did not.

#### Stimulus material

The second prototype of the product was created using Figma as a high-fidelity wireframe version of the original prototype in order to provide a higher level of detail (See Fig. 34). It attempted to adapt the initial version based on the

observations made in the first study. The second prototype featured the same screens (e.g.: “diet plan”, “test results”, “recipe”, “grocery list” and “meal editor”) and level of interaction.

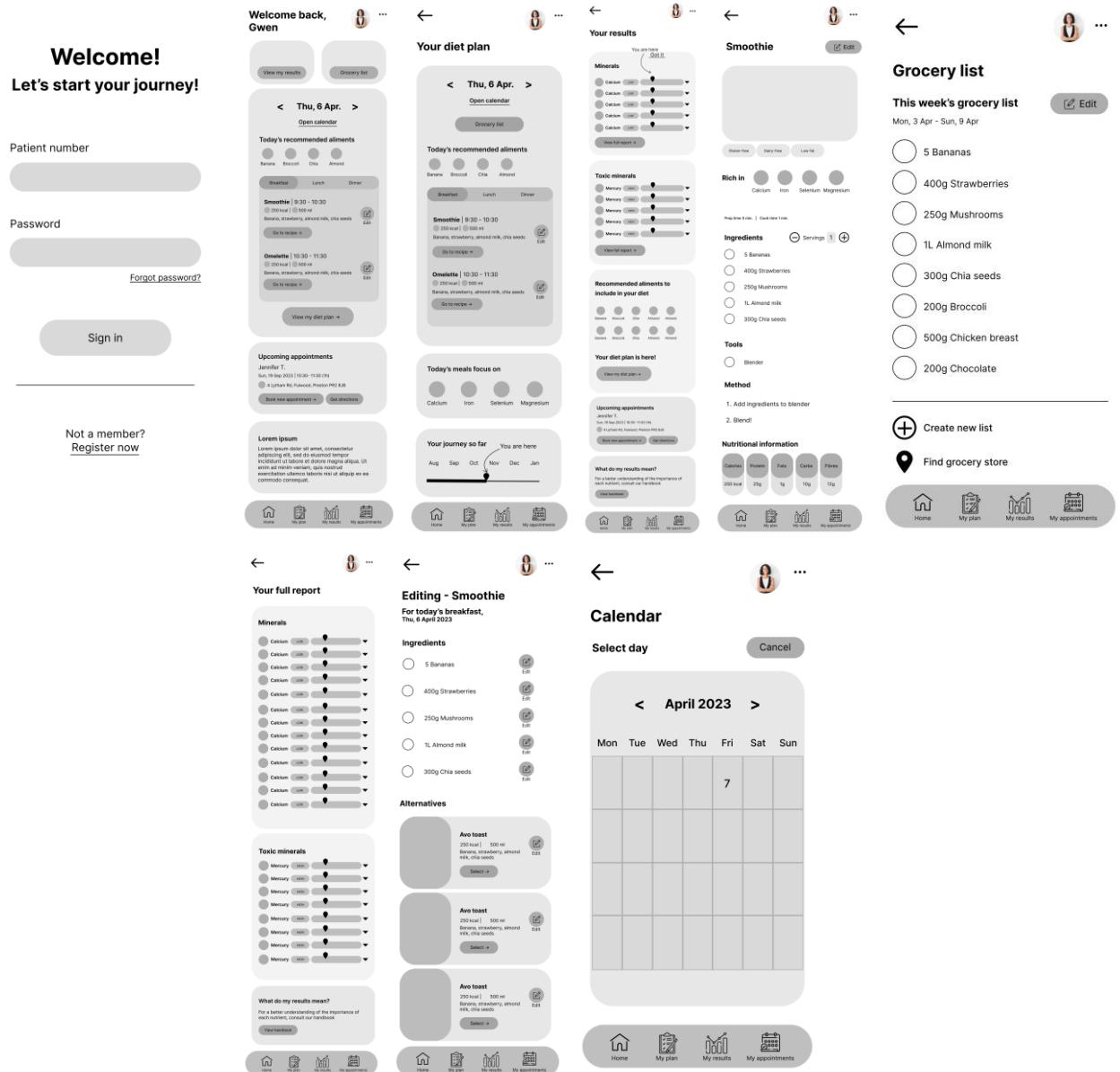


Figure 34 | Hi-Fidelity wireframe prototype example

## Procedure

Related to the first study, participants were provided with a link to the prototype and asked to join an online meeting anonymously through Microsoft Teams, where they shared their screen. Once again, participants were explained the purpose of the study and the prototype. Additionally, they were asked to give their thoughts while navigating through the prototype. Participants were also ensured there is no right or wrong answers and that they should try to be critical (*Think aloud study: qualitative studies*, 2021). Think-aloud session were conducted while participants navigated through the prototype.

## Data analysis

Similarly to two clinical think-aloud studies (Forsberg *et al.*, 2014; Lee *et al.*, 2016), transcripts were analysed and content analysis was conducted according to the steps mentioned in an earlier research paper (Graneheim and Lundman, 2004). Firstly, transcripts were read repeatedly in order to understand the data gained and notes with the sentences describing the app, along with interactions and comments made during the interviews were taken (Forsberg *et al.*, 2014; Lee *et al.*, 2016). The notes were then condensed and coded (e.g.: “positive observations”, “negative

issues", "understanding of the system", "lack of understanding of the system" and "improvement recommendations". Finally, an affinity diagram was used to group the codes based on the associated prototype screens.

#### 4.2.2. Results

Various positive affirmations were made during the interviews. Regarding the homepage, no negative statements were made, and participants appreciated the layout and content of the page. However, two contradicting observations were made. One participant mentioned the "grocery list" button should be on top, while another mentioned it should be further down the page, along with the "test results" button. Regarding the "test results" page, the "arrow down" feature to view more information was noticed and understood by three interviewees, while one did not know what to expect when clicking on it. Similarly, three participants understood the use of the "marker and scale" on the "test results" screen, while one did not. In regards to the "calendar" function, four participants encountered difficulties understanding its purpose and noticing it in the first place, while one understood it and another noticed the link to open the "calendar". Similarly, about the "edit recipe" screen, four participants understood its functionality, while one participant did not. A multitude of recommendations were made for the second version of the prototype, such as adding more information in the "your journey so far" feature, adding a "grocery list" link in the navigation bar and adding "snacks". Other recommendations regarding the visuals such as "simpler icons", making arrows more obvious and text bolder were mentioned. Overall, a surplus of positive affirmations was made for each screen, in this sense, participants appreciated the functions associated with each page, had an overall easy time navigating the screens and made comments regarding the overall app such as "useful", "logical", "professional", "friendly design", and "obvious and intuitive" (See Appendix A, Table 5).

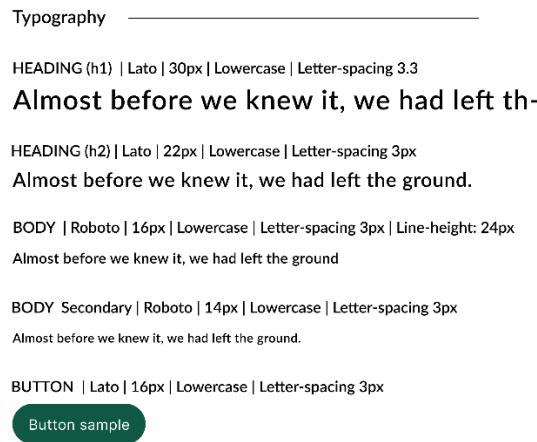
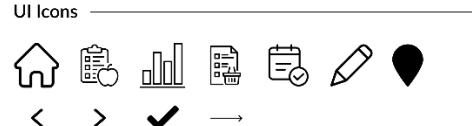
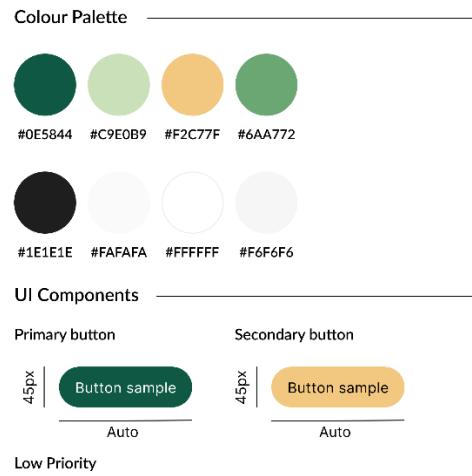
#### 4.2.3. Implementation and rationale for changes

Prior to the second round of interviews, mock-ups were created to reflect the insights gained (See Fig. 37). Although it would have been more feasible to create low-fidelity prototypes to reflect on these insights due to this project's short time-frame. However, based on the highlighted need for detail, mock-up prototypes were chosen as they allowed for greater detail which played a pivotal role in showcasing the look of the final product along with the changes made. For example, some participants mentioned some aspects of the wireframes looked "clickable", while other participants recommended more simplified visuals such as icons and arrows. In terms of the contradicting observations made regarding the "grocery list" button, the position of this item remained the same, as it would allow for quicker navigation when users would be shopping for items in the store. The "calendar" link was transformed into a button to elevate visibility and the wording was changed to "change date" to make the purpose of the feature more obvious. Moreover, the "your journey so far" section was enhanced in order to offer additional information to users and encourage their progress and motivation. A myriad of recommendations was added into the interface design, such as a "snack of the day" tab, simpler, more modern icons and an improved order of displaying items.

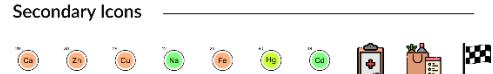
#### Style guide

A style guide was used to define, lead and reference the design of the product (See Fig. 35). In terms of the choice of typography, decisions were made in accordance with various usability guidelines. For example, various studies show that preference in font size varies on age (Darroch *et al.*, 2005; Zhou, Rau and Salvendy, 2014; Kiat and Chen, 2015), however, since this project caters to a large range of age groups, the main body font-size was selected based on the most recommended and commonly found mobile font size of 16px (Darroch *et al.*, 2005; Wallace *et al.*, 2022; Sigei *et al.*, no date; *Typography - Foundations - Human Interface Guidelines - Design - Apple Developer*, no date). Other secondary fonts range between 12px for low-priority information and 18px for secondary headings (Darroch *et al.*, 2005). Furthermore, in terms of the typeface chosen, an earlier paper (Bernard *et al.*, 2002) evidences Arial, Verdana, Courier, and Georgia are the most readable fonts, however, these fonts may be outdated, meaning a choice of a more modern font might inspire higher levels of trust (Li and Yeh, 2010) while also retaining legibility. In this sense, a research study demonstrated that while younger user groups read faster across most of the fonts tested (e.g.: Lato, Montserrat, Garamond, etc.), older adults performed better when reading in Montserrat (Wallace *et al.*, 2022), statements further supported by various online sources (Morris, 2020; Marfice, 2022). Additionally, line height and letter spacing were also considered and, in this context, a line height of 24 (1.5 times higher than the body font size) was selected, along with a 3% letter spacing (Olsson, 2014).

In regards to the choice of colour, research shows colour preference is tightly related to culture (Sakamoto, 2014; Bonnardel *et al.*, 2018; Cheng, Wu and Leiner, 2019) and the first impressions users make when viewing an interface (Cheng, Wu and Leiner, 2019). In this sense, the colour green was found to be one of the most accepted colours across cultures (Sakamoto, 2014; Bonnardel *et al.*, 2018), eliciting feelings of peace, restfulness and positivity (Lichtenfeld *et al.*, 2012; Swasty and Adriyanto, 2017), along with tight associations with environmental factors such as nature, forests and trees (Hemphill, 1996). A shade of golden yellow was also selected as the secondary button colour, as it is associated with the warmth of the sun (Hemphill, 1996) and prestige. Both the positivity and the associations to the environment synergise well with the health and food related aspect of this app. These colours were further tested against the WCAG (Web Content Accessibility Guidelines) (See Fig. 36). Lastly, the choice of text/background colour combination was grounded by two research studies which found that the most readable text/background colour combination is black on white (Hall and Hanna, 2004; Kamollimsakul, Petrie and Power, 2014).



Low importance | Roboto | 12px | Uppercase | Letter-spacing 3px  
**Almost before we knew it, we had left the ground.**



**Contrast Checker**

Home > Resources > Contrast Checker

|                                |                             |
|--------------------------------|-----------------------------|
| Foreground Color<br>#FFFFFF    | Background Color<br>#0E5844 |
| Lightness                      | Lightness                   |
| Contrast Ratio<br><b>8.4:1</b> |                             |
| permalink                      |                             |

**Normal Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Large Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Graphical Objects and User Interface Components**

WCAG AA: **Pass** ✓ Text Input

**Contrast Checker**

Home > Resources > Contrast Checker

|                                  |                             |
|----------------------------------|-----------------------------|
| Foreground Color<br>#000000      | Background Color<br>#F2C77F |
| Lightness                        | Lightness                   |
| Contrast Ratio<br><b>13.25:1</b> |                             |
| permalink                        |                             |

**Normal Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Large Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Graphical Objects and User Interface Components**

WCAG AA: **Pass** ✓ Text Input

**Contrast Checker**

Home > Resources > Contrast Checker

|                                  |                             |
|----------------------------------|-----------------------------|
| Foreground Color<br>#000000      | Background Color<br>#C9E0B9 |
| Lightness                        | Lightness                   |
| Contrast Ratio<br><b>14.84:1</b> |                             |
| permalink                        |                             |

**Normal Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Large Text**

WCAG AA: **Pass**  
WCAG AAA: **Pass** The five boxing wizards jump quickly.

**Graphical Objects and User Interface Components**

WCAG AA: **Pass** ✓ Text Input

Figure 35 | Style guide example

Figure 36 | Colour contrast test example

**Welcome!**  
Let's start your journey!

Patient number

Password

[Forgot password?](#)

**Sign in**

**Not a member?**  
[Register now](#)

**Welcome back, Gwen**

**Your diet plan**

**Your results**

**Smoothie**

**Grocery list**

**Upcoming appointments**

**Your journey so far**

**Nutritional information**

**Your full health report**

**Editing - Smoothie**

**Calendar**

**Select day**

Figure 37 | Mock-up prototype example

## Discussion

This project has the potential to transform the nutrition sector by solving various problems regarding dieting, not only for customers, but also for nutritionists. With the use of MIL, the proposed application is able to identify nutritional deficiencies, calculate nutrient intakes and generate automated diets based on blood sample data (Zeevi *et al.*, 2015). This, in turn, would bring a large set of benefits for both the managements of nutritional clinics and the clients.

From a customer point of view, the idea of this app would increase the potential of health improvement and provide convenience in comparison with current ways of communicating assessment results (*What to Expect from your*

*Appointment*, no date), (*Nutrition and dietetics - Appointments*, no date), as users would have all the information needed into an accessible and mobile way. Another benefit to customers is the option of progress tracking, which has potential to provide motivation and make it easier to maintain a health schedule, problems which both nutritionists and customers were found to struggle with (Bender, 2022). Another important factor which was considered was the basic nutritional knowledge from the common individual regarding nutrition (Hendrie, Coveney and Cox, 2008). With the use of the proposed app, users would be able to receive accurate and easily accessible information, serving not only for health improvement, but also for educational purposes. Lastly, the importance of nutrition has been highlighted throughout literature, evidencing that diets must be personalised (Matusheski *et al.*, 2021; Amati, McCann and Spector, 2022), along with the fact that a balanced diet greatly contributes to solid health (Matusheski *et al.*, 2021; Amati, McCann and Spector, 2022). This app has potential to reach significantly more people than through current means, meaning more people will be motivated to get nutritional help and advice to improve their health.

Concerning the health sector, research shows current methods of measuring dietary intakes are highly time-consuming, error prone, subjective and overall challenging (Ülker and Ayyıldız, 2021; Côté and Lamarche, 2022). This product would create an easier, more efficient way for nutritionists to aid their patients, greatly reducing the amount of paperwork needed for each patient and therefore improving time management efficiency, while also maintaining and improving accuracy of treatment. Last of all, this app would increase the popularity of nutritional clinics and other brands, supplement providers, diet writers, and nutrition content all-together.

## Limitations

In regards to the research insights gathered in the beginning of the project; a few drawbacks have been identified. For example, while secondary research can provide valuable information, there is a possibility some of the data was outdated, unreliable or irrelevant. Furthermore, secondary data may have not provided enough depth of understanding towards the scope of the problem. In contrast, conducting primary research may have revealed new and original ideas regarding the problem.

In terms of the two studies conducted, several other limitations can be highlighted. To begin with, the first study was not recorded, and instead, notes of participants' thoughts and interactions were taken and analysed, leading to the potential of data being missed and/or misinterpreted. Furthermore, only five participants were recruited to partake in the interviews. However, in a study conducted by Nielsen (Nielsen, 1994), it was concluded that in the context of conducting think-aloud sessions, by the time five test subjects were used, approximatively 77-85% of the usability problems had been identified. On the other hand, participants were close friends and relatives, thus, there is a possibility they were more likely to make positive affirmations and the usability problems discovered to be affected by bias. Additionally, only one participant had elevated nutritional knowledge, possibly affecting the quality and quantity of the results, as a more experienced sample of test users may have given more comprehensive insights (Margolis, 2015; Serafinelli, 2022). However, these limitations did not affect their ability to test the usability of the product (Margolis, 2015). Finally, while conducting the think-aloud sessions, participants were testing the prototype on their desktop computers instead of their phones, which may have influenced the interaction design and overall experience of navigating the prototype.

## Future work

Given the iterative trait of the design thinking process, the future of this project intends to go back to the first stages and conduct primary research, gathering further, clearer insights into the needs, wants and pains of real users, in hopes to discover new insights to be solved by this mobile application. Given the proof of concept, it is deemed justifiable to carry out the first stages of research again at a larger scale, with real nutrition consumers in order to gain key insights into real users' thoughts and experiences. Future plans will also include a stronger focus on accessibility, nutritionists and older users. Lastly, the rest of the proposed features brainstormed in the ideation phase (e.g.: "grocery list", "appointment booking", "handbook", etc.) will be developed and iteratively tested along with the present features until the most feasible and optimal user experience is achieved.

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## Appendix A

Legend:

- Positive observations
- Understanding and visibility of the system
- Improvement recommendation
- Lack of understanding and visibility of the system
- Negative issues

|  | Homepage   | Test results  |  |   | Diet plan   |   | Grocery list   |  | Recipe   |  | Diet editor  |  | General   |  |   |
|--|--|---|--|---|---|---|--|--|--|--|--|--|---|--|---|
| Positive observations                              | Having diet plan on homepage<br>Transparency about upcoming appointments   | <span style="background-color: green; color: white; padding: 2px;">Useful</span>                          | <span style="background-color: green; color: white; padding: 2px;">Additional information</span>             | <span style="background-color: green; color: white; padding: 2px;">Additional information</span>            | <span style="background-color: green; color: white; padding: 2px;">My journey so far</span>                     | <span style="background-color: green; color: white; padding: 2px;">My journey so far</span> | <span style="background-color: green; color: white; padding: 2px;">Recommendation</span>         | <span style="background-color: green; color: white; padding: 2px;">Milestone series for weekly generation</span> | <span style="background-color: green; color: white; padding: 2px;">Good to have</span>                                 |  | <span style="background-color: green; color: white; padding: 2px;">Nutritional information of various ingredients</span> | <span style="background-color: cyan; color: black; padding: 2px;">Editing page</span>                                      | <span style="background-color: cyan; color: black; padding: 2px;">Practical</span>  | <span style="background-color: cyan; color: black; padding: 2px;">More visual elements for practicality and consistency</span> |   |
| Negative issues                                    | <span style="background-color: orange; color: black; padding: 2px;">Confusing as there are many different things</span>  | <span style="background-color: orange; color: black; padding: 2px;">"You are here"</span>                 | <span style="background-color: orange; color: black; padding: 2px;">Arrow down looks like a checkmark</span> |   |   |   |  |  |  | <span style="background-color: orange; color: black; padding: 2px;">Confused about the page</span>   |  | <span style="background-color: orange; color: black; padding: 2px;">Everything is a bit small</span>                       |   |  |   |
| Recommendations                                    | "Ingredient analysis instead of alarms"<br>"Suggested minerals instead of grocery list"<br><span style="background-color: cyan; color: black; padding: 2px;">Add calendar on homepage</span> | <span style="background-color: cyan; color: black; padding: 2px;">Clicking on mineral to read more</span> | <span style="background-color: cyan; color: black; padding: 2px;">Adding milligrams</span>                   | <span style="background-color: cyan; color: black; padding: 2px;">Indicator you're missing breakfast</span> | <span style="background-color: cyan; color: black; padding: 2px;">Add an icon for the open calendar link</span> |   |  |  | <span style="background-color: cyan; color: black; padding: 2px;">Add edit button on recipe page</span>                | <span style="background-color: cyan; color: black; padding: 2px;">Add tools needed for recipe</span> | <span style="background-color: cyan; color: black; padding: 2px;">Mention what recipe has nutrition</span>               | <span style="background-color: cyan; color: black; padding: 2px;">Some buttons are missing after changing something</span> | <span style="background-color: cyan; color: black; padding: 2px;">Add snacks</span> | <span style="background-color: cyan; color: black; padding: 2px;">Add back buttons</span>                                      | <span style="background-color: cyan; color: black; padding: 2px;">Provide set of recommendations and prioritize them again</span> |
| Understanding and visibility of the system         |  | <span style="background-color: cyan; color: black; padding: 2px;">Arrow-down</span>                       | <span style="background-color: cyan; color: black; padding: 2px;">Arrow-down</span>                          | <span style="background-color: cyan; color: black; padding: 2px;">Calendar to change date</span>            | <span style="background-color: cyan; color: black; padding: 2px;">Calendar to change date</span>                | <span style="background-color: cyan; color: black; padding: 2px;">Edit buttons</span>       | <span style="background-color: cyan; color: black; padding: 2px;">Calendar to change date</span> |  |  |  |  | <span style="background-color: cyan; color: black; padding: 2px;">Intuitive</span>   | <span style="background-color: cyan; color: black; padding: 2px;">Intuitive</span>  |  |   |
| Lack of understanding and visibility of the system |  | <span style="background-color: yellow; color: black; padding: 2px;">Arrow down</span>                     | <span style="background-color: yellow; color: black; padding: 2px;">Full report link next to previous</span> | <span style="background-color: yellow; color: black; padding: 2px;">Calendar to change date</span>          | <span style="background-color: yellow; color: black; padding: 2px;">Indicator you're missing breakfast</span>   |   |  |  | <span style="background-color: yellow; color: black; padding: 2px;">Display relevant categories for each recipe</span> | <span style="background-color: yellow; color: black; padding: 2px;">Editing each ingredient</span>   |  |  |   |  |   |

Table 4 | Study 1 Affinity diagram



New table

|  | Homepage   |  | Test results   |   | Diet plan  |  |  | Grocery list  |   | Recipe  |  | Diet editor   |  | General                         |  |
|--|--|--|--|---|--|--|--|---|---|---|--|---|--|---------------------------------|--|
| Positive observations                              | Looks of the page<br>Layout  | Calendar in the center<br>Grocery list in homepage structure   | Useless status message<br>Tip for increased calcium                            | Marker and scale<br>Additional information (instructions and responses)   | Today's meals focus on<br>"Your journey so far"<br>Today's meals focus off           | Handy<br>Uses its own icons<br>Nice to have              | Nutrition information<br>Nutrition information | Editing system<br>Editing system  | versatile<br>Alternative  | Look of the app is good<br>Very nice overall<br>Useful and friendly design<br>All pages look similar to other pages | Logical<br>Gives me a sense of an agenda<br>Easy to handle | Professional<br>Everything is obvious and intuitive<br>Easy to navigate |  |                                 |  |
| Negative issues                                    |  |  | Journal entries are not working  |   | "Your journey so far" is redundant<br>Incomplete calendar<br>Incomplete grocery list |  |  |   |   |   |  |   |  | Journal entries are not working |  |
| Recommendations                                    | Grocery list should be further down<br>Add grocery list in nav bar<br>Results should be further down too<br>More spacing between minerals<br>"You are here" isn't needed |  |  | "Today's meals focus on" shouldn't be on the same page<br>"Your journey so far" should be on top<br>Double amount to copy and paste data<br>"Find grocery store" not needed |  |  |  |   |   | Review all the recommendations before we can implement them   |  |   | Make icons simpler<br>Edit icons without look modern<br>Add snacks |                                 |  |
| Understanding and visibility of the system         | Edit buttons   | Arrow down<br>Arrow down<br>Marker and scale<br>Marker and scale<br>Marker and scale<br>Marker and scale | Marker and scale<br>"You are here"   | Marker and scale<br>Edit recipe buttons<br>Calendar link<br>Edit recipe buttons   | Date arrows<br>Grocery list link<br>Grocery list link<br>Edit recipe buttons         | Calendar system  | Serving system                                 | Editing system<br>Editing system  | Secure alternatives<br>Alternative  |   |  |   |  |                                 |  |
| Lack of understanding and visibility of the system | Calendar link<br>Aliments look clickable   | Marker and scale (should be a list)<br>Arrow down<br>Marker and scale<br>Marker and scale                | Marker and scale (should be a list)<br>"Don't notice 'you are here'" indicator | Calendar link<br>Calendar link<br>Calendar link   | Grocery list link<br>Grocery list link<br>"Your journey so far"                      | Calendar link<br>Complete tasks<br>"Your journey so far" |  | Unintuitive when clicking on the "you are here" button<br>Today's meals focus on is redundant<br>Incomplete calendar<br>Incomplete grocery list | Use of the incorrect buttons<br>Hitting wrong buttons when trying to click<br>Unsure what the application wants for |   |  |   | Ingredient alternatives<br>Alternative                             |                                 |  |

Table 5 | Study 2 Affinity diagram

Link to Miro workspace: [https://miro.com/app/board/uXjVPjVDWpk=/?share\\_link\\_id=592862015970](https://miro.com/app/board/uXjVPjVDWpk=/?share_link_id=592862015970)

Link to Figma Prototypes: <https://www.figma.com/file/nDes6MxS1PSw2Mtz8jKF4w/Diet-planner-app-prototype?type=design&node-id=0%3A1&t=QBitFAnmhGSPieao-1>