



Coeliac Disease Symptom Tracker

Research Document

Student: Niamh Coleman (C00205225)

Supervisor: Joseph Kehoe

Date: 07/11/2018

Abstract

In Ireland, coeliac disease affects an approximate one in one hundred people. However, the likelihood of being coeliac rises to one in ten for every person with a direct relation impacted by the disease [1]. This document consists of the research that took place prior to the development of the application regarding coeliac disease, similar applications and application building technologies. This application is suitable for people with any level of gluten intolerance but is specifically targeted at teenagers with coeliac disease. The application will encourage diet compliance by tracking the symptoms of an individual and the severity of those symptoms. The information will also be useful when the coeliac patient sees their doctor, as they will have an accurate repository of information on their symptoms over time.

Being a coeliac is burdensome, restrictive and challenging. This application will provide information that is crucial to their continued wellbeing by allowing the individual to keep track of the symptoms that they possess and the severity of those symptoms.

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Design Thinking Process

When deciding on a project, I followed the design thinking process. The design thinking process is a solution focused methodology that encourages an initial emotional understanding of the user before any idea development. This approach was chosen due to its user focused approach. The five-stage model was proposed by the Hasso-Plattner Institute of Design at Stanford [2].

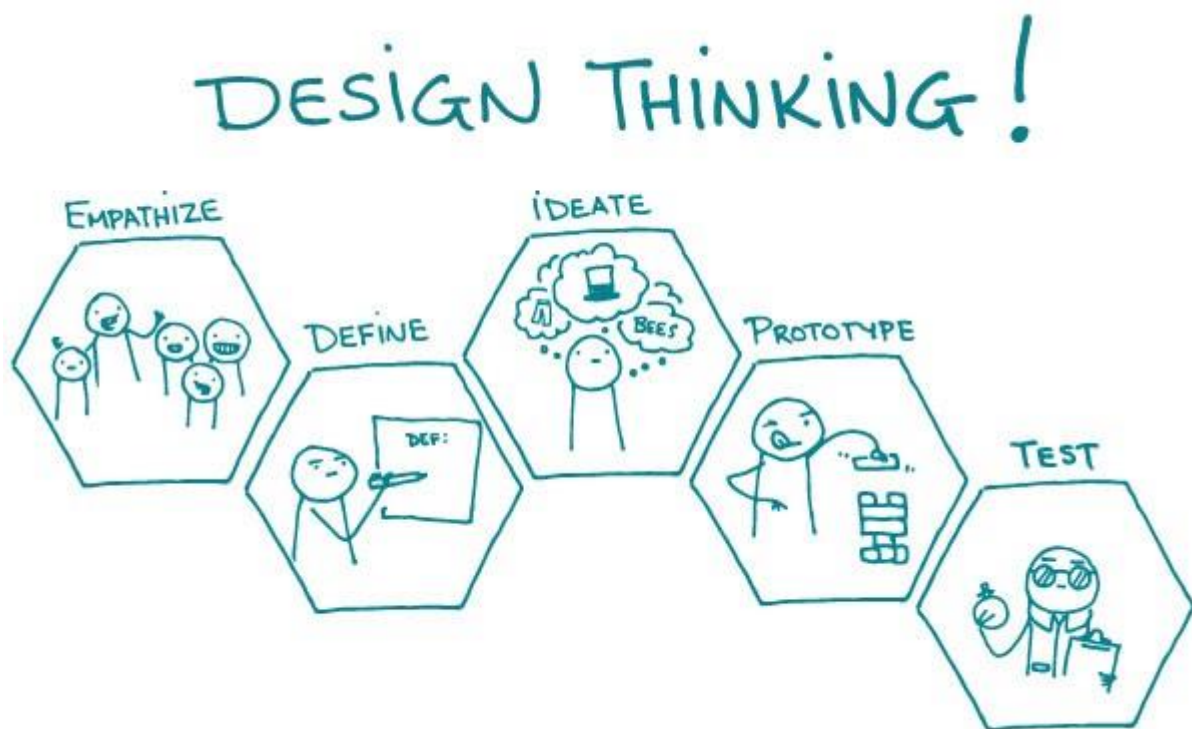


Figure 1. Design Thinking Process [3].

As mentioned above, the design thinking process is broken down into five steps consisting of empathize, define, ideate, prototype and test.

Empathize

The empathize stage allows the designer to better understand the user and attempt to gain insight into their needs and wants. An important part of this phase is to let go of any previous assumptions that the designer had about their target group(s). The information gathered in this phase is carried through the whole process.

During this process I carried out extensive research into individuals with coeliac disease. I did this by researching online and reading any educational material that I could find pertaining to

coeliac disease. I also utilised a report written by two health science students (Appendix A) where interviews were carried out with teenage coeliac patients. This research was hugely beneficial as it allowed me to better understand what it is like to be a teenager that must comply with a gluten-free diet. It also allowed me to discover whether my natural assumptions were accurate or not.

Define

In this stage, the designer takes the information previously gathered and attempts to analyse that data to better define the problem. The principal aim of the definition phase is to bring clarity and focus to the design space. In this stage, designers will frequently make use of materials such as user personas and problem statements. Having a good problem statement is integral to the success of the design process. The statement must be user focused and narrow enough to make it manageable without being too narrow as to restrict the ideation phase. The problem phase must allow the designer to ideate in a goal-oriented manner.

During this phase, I developed the following problem statement:

“How might I help a coeliac teenager comply with a gluten-free diet?”

Ideation

In this phase, designers begin to use the information gathered so far to generate logical ideas for the user. Designers use creative processes to create ideas in a judgement-free environment. I used the method of brainstorming and came up with two ideas for consideration; barcode-scanner that checks for the presence of gluten (Appendix B) and a symptom tracker. As there is no internationally maintained database of barcodes and this application is targeted globally, the idea of a barcode scanner is not a viable one for this project. Following this, I decided to carry the symptom tracker idea forward into the prototype and testing phases.

The following features for the symptom tracker were developed using brainstorming:

- Tracking negative physical symptoms and emotions.
- Tracking positive physical symptoms and emotions.
- Tracking whether it was a ‘compliant day’ i.e. did the user consume gluten or not.
- Tracking the severity of symptoms and assigning them as low, moderate or severe.
- Provide the user with a graph giving information on the improvement of symptoms that occurs when a gluten free diet is followed.

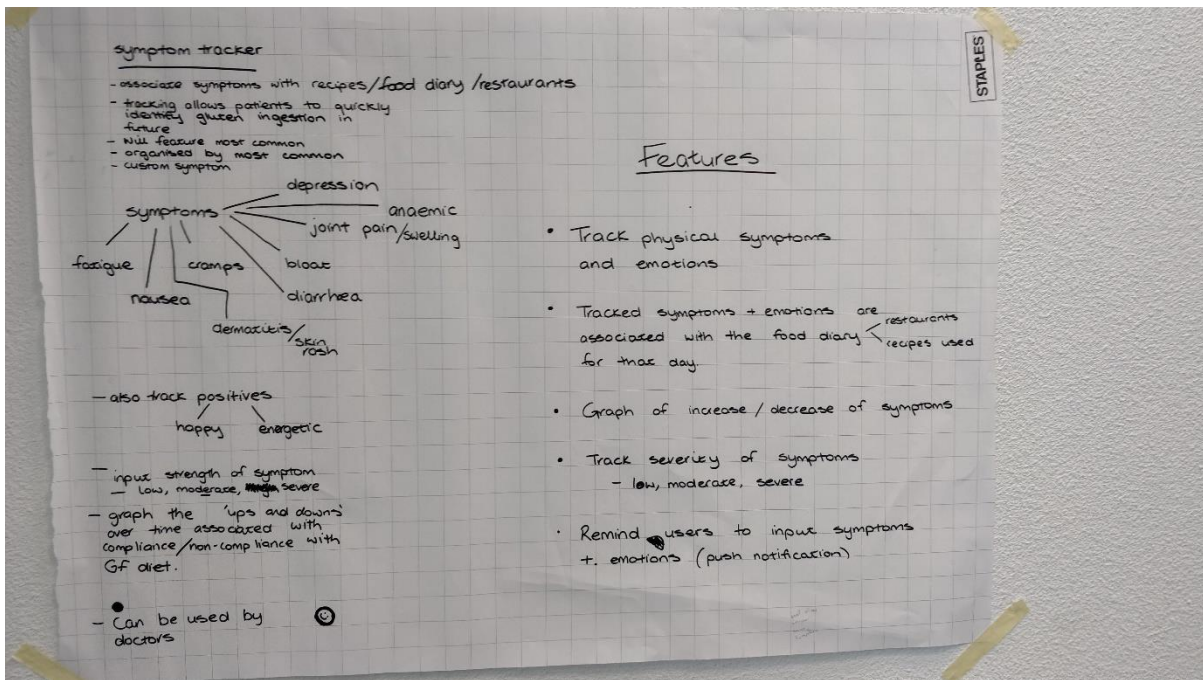


Figure 3. Symptom Tracker Brainstorm [4].

Prototyping

Prototypes are built so that designers can think about their solutions as tangible products rather than abstract ideas. They are an expression of design intent and are crucial when trying to create a good user experience. Prototypes can allow projects to fail quickly and with less investment if the idea turns out to be a bad one. Tom Brown, CEO of the international design and innovation firm IDEO said the following [5] regarding prototyping:

“They slow us down to speed us up. By taking the time to prototype our ideas, we avoid costly mistakes such as becoming too complex too early and sticking with a weak idea for too long.”

Prototyping is divided into two sections; low-fidelity and high-fidelity [6]. High-fidelity prototypes refer to those that are closer to the finished product. High-fidelity prototyping allows for designers to have high confidence in user testing, as the prototype is a very close representation of the finished product. However, these prototypes take longer to produce and therefore result in much more time wasted if the project is brought no further than prototyping. Low-fidelity prototypes are a fast and inexpensive method that helps clarify expectations of the product for developers and stakeholders. However, low-fidelity prototyping has less interactivity available and as such can make it difficult to convey any complex animations to a tester.

With this information in mind, I created low-fidelity paper-based wireframes of what the symptom tracker might look like. This helped me to think practically about which features would be the most important to the user and to see the opportunity for new features.



Figure 4. Low-fidelity Wireframes

To prepare for the testing part of the design thinking process, I also created a high-fidelity prototype using Adobe XD. Adobe XD allowed me to create a clickable prototype that could be given to test users and result in useful feedback.

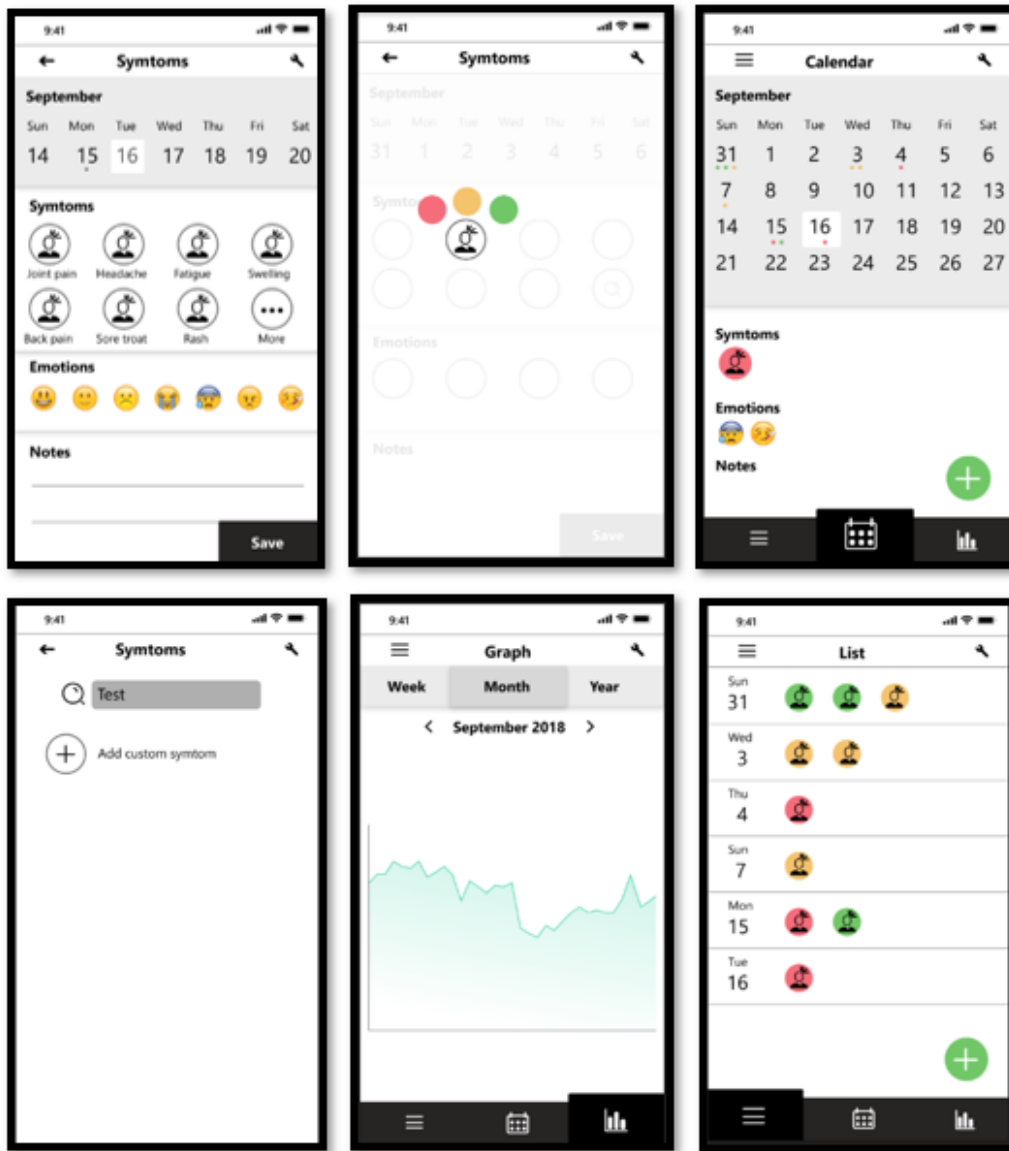


Figure 5. High-fidelity Clickable Prototype.

Testing

During the testing phase, designers can solicit feedback on the prototypes they have created. This also provides another opportunity to revisit the first phase and gain more empathy for the target user group(s). Testing provides the chance to refine solutions and improve them. When testing, it is imperative that the tester let the user instinctively interpret the prototype, thereby taking a ‘show don’t tell’ approach. This prevents the tester from inadvertently influencing the user. When a user is present and willing to test an application, it is crucial that as much useful information as possible is gleaned from that person. User feedback can also be gained by observing a user interacting with the prototype and taking note of their body language and facial expressions. This information can provide huge insight into how easy or difficult an application is to use.

Before testing with any users, I meticulously planned how the test would be carried out. Questions were separated into ‘general’ and ‘prototype testing’.

General questions included:

- What applications do you use every day?
- Do you talk about your symptoms with any of the people around you?
 - If so, who?
 - If not, why?
- Would you be comfortable to share information about your symptoms with an application?
 - If not, why is that?

Prototype testing questions included:

- Can you please describe what you see on this screen and how you think it would work?
- Do you think this information is valuable?
- Would you change this page in any way?

After every question, I must ask the tester why/why not. This allows the test to produce the best results possible. After sufficiently preparing, I carried out testing with four users. As these users did not have coeliac disease, the testing was flawed and only gave feedback on the application from a user experience perspective. The following observations were obtained from testing:

- Users would only want to input symptoms once a day.
- Users thought the screens were generally descriptive and self-explanatory.
- Users thought the input field on the search page was not large enough.

Coeliac Disease

Coeliac disease is a condition that occurs when the ingestion of gluten causes damage to the small intestine. Gluten intolerance is an autoimmune disorder, which is where the immune system attacks healthy cells mistakenly [7]. Coeliac disease occurs in genetically predisposed individuals in all age groups. Gluten intolerance is caused by an abnormal reaction to gliadin. Gliadin is a gluten protein found in wheat. Upon exposure to gliadin, the immune system reacts with the enzyme tissue transglutaminase. This causes an inflammatory reaction, called villous atrophy [8]. Villous atrophy occurs when the intestinal villi – the tiny, microscopic tentacles that line the wall of the small intestine – are worn away. As the intestinal villi are responsible for nutrient absorption, losing them to villous atrophy can result in serious nutritional deficiencies. In coeliac patients, an individual's immune system attacks its own villi [9]. The treatment for coeliac disease is to adhere to a gluten free diet for life. Coeliac patients are regularly incorrectly diagnosed with conditions such as irritable bowel syndrome. In some cases, people receive no symptoms at all externally, while there is still damage being done internally [10].

Risk Factors

Everyone is at risk for coeliac disease. However, certain groups have a higher chance of developing the condition. This includes:

- People biologically related to an individual with coeliac disease - coeliac disease occurs in up to 5 – 10% of family members diagnosed with coeliac disease [11].
- Individuals with type 1 diabetes – up to 10% of people with coeliac disease also have type 1 diabetes [12].
- Individuals with Down syndrome – up to 16% of people with Down syndrome also have coeliac disease [13].

Long Term Effects

Even very small amounts of gluten can cause internal damage to gluten intolerant individuals [14]. It is exceedingly difficult for a person to have a complete absence of gluten in their diet. This can be due to cross contamination. Cross contamination occurs when coeliac friendly food is exposed to gluten-containing food, making it unfit for consumption by a coeliac. In Ireland, standards dictate that a gluten free label product must contain less than twenty milligrams of gluten per kilogram (<20mg gluten/kg) [15]. Ingesting gluten increases the effect of developing conditions such as osteoporosis, malnutrition, lactose intolerance and even cancer.

Osteoporosis

Osteoporosis is a condition that results in weakened bones, making the affected individual more susceptible to broken/fractured bones [16]. Approximately two million fractures occur each year due to osteoporosis [17]. Due to the reduced ability of those with coeliac disease to absorb nutrients, there is an increased chance of those with the condition to have decreased bone mineral density. This leads to a larger chance of osteoporosis. As many as 50% of individuals with coeliac disease will develop osteoporosis in their lifetime [18]. If a coeliac diagnosis is made during childhood and the child follows a gluten-free diet, long term bone health will likely be unaffected. However, if an individual is diagnosed with coeliac disease later in life then it can be very difficult to improve their bone mineral density. Women diagnosed after menopause are a perfect example of this as after menopause there is less of the hormone oestrogen, which contributes to bone strength [19].

Malnutrition

Poor compliance to a gluten free diet can result in ongoing nutritional deficiencies in coeliac patients. Malnutrition occurs in an individual when their diet is lacking in one or more nutrients that are necessary for their body to function successfully. Malnutrition may refer to undernutrition or overnutrition. In the case of gluten intolerance, individuals may have a reduced ability to absorb nutrients and this can cause undernutrition. This stunted absorption can result in further problems arising such as anaemia. Malnutrition can negatively impact the body in many ways, both mentally and physically [20]. The symptoms of a malnourished individual differ from person to person depending on their specific nutritional deficiency. However, these symptoms may include:

- Dizziness
- Stunted or slowed growth
- Bloat
- Fatigue and low energy
- Weak bones
- Slow reaction times
- Poor immune function

Lactose Intolerance

Lactose intolerance occurs when an individual cannot break down lactose and absorb it into their blood. Lactose intolerance is typically associated with undiagnosed coeliac disease or coeliac patients who are not complying with a gluten free diet. This is due to the damage caused to the gut by gluten ingestion preventing lactase development in the body [21]. The condition is typically temporary and disappears when a gluten free diet is being followed for some time. Lactose is a sugar found in milk from cows, sheep, goats and humans. Lactose is broken down by an enzyme called lactase. Lactase is found in the lining of the gut [22]. Lactose intolerance puts individuals at a greater risk of developing osteoporosis and malnutrition. An intolerance to lactose can cause symptoms [23] such as:

- Abdominal bloating, pain or cramps
- Diarrhoea
- Flatulence
- Nausea
- Vomiting

Cancer

People with coeliac disease have a higher risk for specific kinds of cancer. This risk is at its highest when the individual isn't adhering to a gluten free diet and decreasing as the gut lining heals with diet adherence [24]. Lymphoma is cancer that begins in the infection-fighting cells of the immune system and affects the lymphatic system. The lymphatic system is made up of the lymph glands, lymphatic vessels and the spleen. The lymphatic system helps the body to fight infection and filter bodily fluids. Lymphoma affects a type of white blood cells known as lymphocytes. Coeliac disease also means a higher risk for colon cancer, which is cancer of the large intestine [25]. The colon works as part of the digestive system, alongside organs such as the stomach and small intestine. The function of the colon is to remove stool and maintain the fluid and electrolyte balance in the body. Lymphoma and colon cancer are both rare forms of cancer. Interestingly, there appears to be a lower risk of developing breast cancer or lung cancer in individuals with coeliac disease [26].

Infertility

Undiagnosed or non-adherence to a coeliac diet can lead to infertility in both women and men. Infertility is defined as the inability to get pregnant after one year of unprotected sex. It's not clear why infertility rates are higher in individuals with coeliac disease. It's possible that it may be the result of malnutrition or iron deficiency caused anaemia [27]. As with many conditions caused by coeliac disease, adherence to a gluten free diet usually restores fertility.

Short Term Effects

Coeliac disease has a huge range of signs and symptoms, this factor is likely why so many cases go undiagnosed or misdiagnosed. Individuals may suffer from few or many symptoms, which can last from hours to days. Symptoms also differ in severity from person to person.

Short-term symptoms may include:

- Fatigue and low energy
- Nausea and vomiting
- Diarrhoea
- Mouth ulcers
- Stomach pain, cramps and bloating
- Flatulence
- Loss of appetite
- Swelling of limbs

Gluten

Gluten is a name given to the family of proteins that are found in wheat, rye, barely and spelt. Gluten is found in the endosperm of cereal grains and nourishes plant embryos during germination. Gluten is a mixture of hundreds of distinct proteins, although it consists primarily of gliadin and glutenin. Gliadin gives bread the ability to rise and glutenin is responsible for the elasticity of a dough [28].

Wheat is commonly found in:

- Breads
- Baked goods
- Pasta
- Cereals
- Sauces
- Dressings

Barely is commonly found in:

- Malt
- Food Colouring
- Soups
- Beer
- Yeast

Rye is commonly found in:

- Rye bread
- Cereals

Types of Coeliac Disease

Coeliac disease may be further classified into three categories; based on the symptoms (or lack thereof) experienced by the patient. These categories are silent, minor and major. If an individual has coeliac disease without any noticeable symptoms, that condition is called silent or asymptomatic coeliac disease. Although there are no outward symptoms for the individual, villous atrophy (damage of the lining of the intestines) may still occur. This can mean serious long-term effects and can foreshadow the development of serious conditions in the future such as osteoporosis, depression and infertility. Individuals with silent coeliac disease usually only receive a diagnosis if they are referred for screening due to a related condition, such as anaemia. If a person receives no symptoms from ingesting gluten, then the temptation to eat gluten free food is very difficult to resist. Individuals with minor coeliac disease usually experience intermittent symptoms of a less severe nature. These symptoms might include indigestion, bloating or loss of appetite [29]. Major coeliac disease patients may experience all symptoms previously described, including those that are more severe such as diarrhoea, swollen limbs, muscle spasms or stomach cramps.

Application Building Technologies

A mobile application development platform is a software that allows rapid building of mobile applications for smartphones or tablets. A native mobile application is a smartphone application that is coded in a specific programming language, such as Objective C for iOS or Java for Android OS. Native mobile apps provide a high degree of reliability and fast performance. A hybrid application is one that combines elements of native and web applications and provide a cross platform user interface. They enable a single code base for multiple mobile platforms. The following technologies are suitable for the project as they all have ease-of-use, speed, good documentation and community.

Front-end Technologies

Cordova

Formerly known as Phone Gap, Cordova is an open-source mobile development framework. Cordova uses web technologies such as HTML5, CSS3 and JavaScript for cross-platform development, avoiding the native development language of each platform. Applications execute within wrappers targeted to each platform, relying on core API bindings to access various device capabilities i.e. device sensors, network status, geolocation etc. Additional APIs are available via third-party plugins. Cordova enables developers to target multiple platforms with one code base as well as being free and open-source.

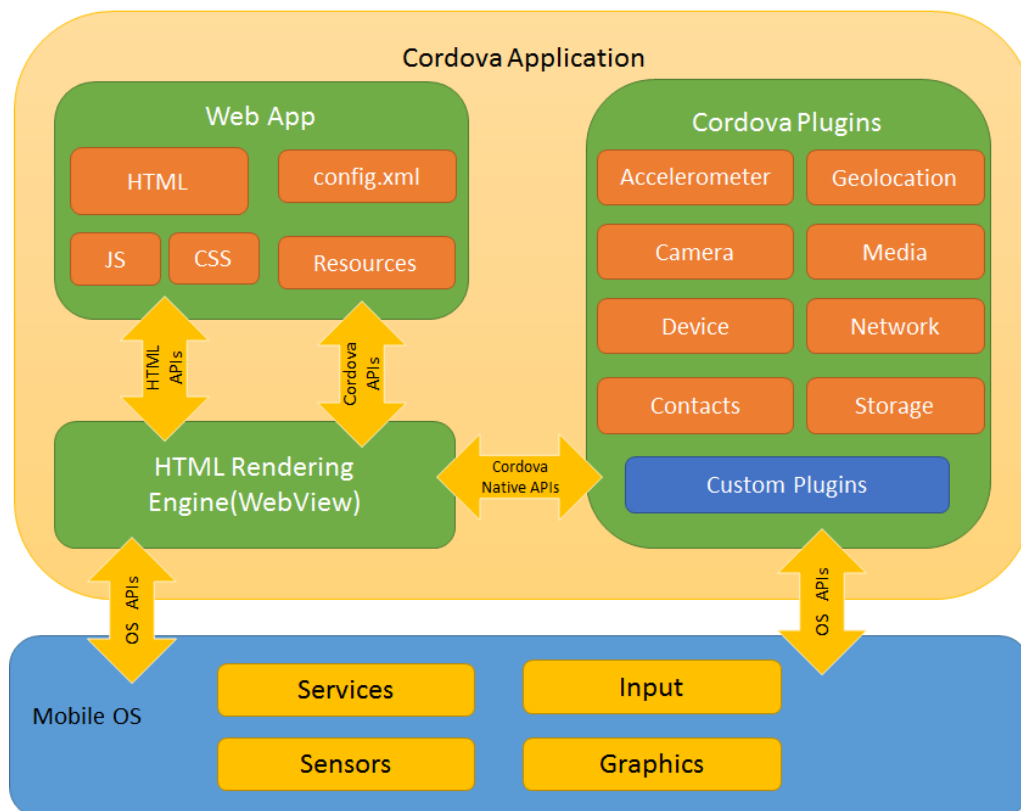


Figure 6. Cordova Application High-Level Architecture Diagram [30]

Plugins are an essential part of Cordova, providing an interface for Cordova and native components to communicate. Apache Cordova maintains a set of plugins called the ‘core plugins’. These plugins provide access to device capabilities such as batter, camera, contacts etc. There are also third-party plugins available which provide additional bindings to features not available on all platforms. Developers can also create their own plugins e.g. to communicate between Cordova and custom native components. When creating a mobile application, developers can use one of two workflows; cross-platform (CLI) workflow or platform-centred workflow. Cross-platform workflow is suitable for developers who want their application to run on as many different mobile operating systems as possible. Platform-centred workflow is used if the developer wants to run their app for a single platform.

Xamarin

Xamarin is a software company owned by Microsoft that allows developers to create applications for iOS and Android. Using a C#-shared codebase, developers use Xamarin tools to write native Android, iOS and Windows applications with native user interfaces. Xamarin development can be done in Visual Studio using either a Mac or Windows machine. The key benefit of using Xamarin is that the application user interface uses native controls on each platform, creating applications with the feel of a native application. At a root level, Xamarin converts the entire existing Android and iOS SDK to C# so that you can code in a more familiar language. However, the user interfaces must be built separately and must then be connected to the codebase. The Xamarin component store lets you add more functionality to your applications by downloading simple plugins. You can easily integrate your application with many popular backends such as Microsoft Azure. Azure is a cloud platform for building, deploying and managing services and applications.

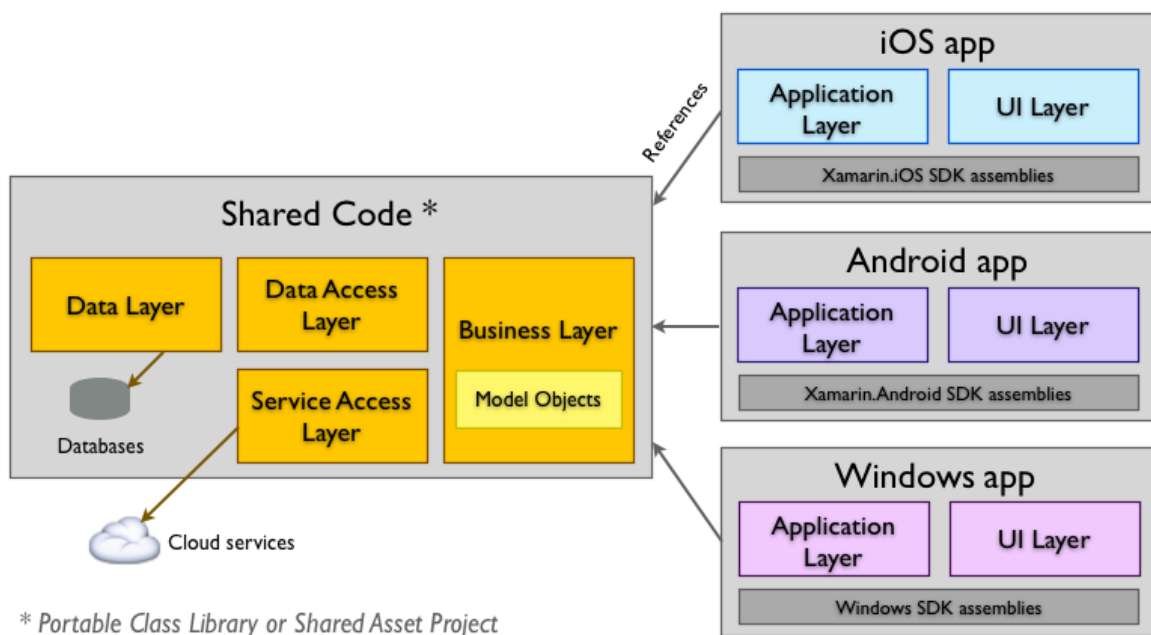


Figure 7. Xamarin Code Sharing between Platforms [31]

ReactJS

ReactJS was initially created by Jordan Walke, a software developer who was working on Facebook Ads [32]. ReactJS is an open-source JavaScript library used for building dynamic user interfaces. React allows the user to create reusable user interface components. The main purpose of ReactJS is to be fast, scalable and simple. ReactJS can be used with a combination of other JavaScript libraries or frameworks, such as Angular JS. At the heart of ReactJS are components. A component is a self-contained module that serves to render output. Components are composable and might include one or more other components in its output.

Virtual Document Object Model

The DOM (Document Object Model) is an application programming interface for HTML (HyperText Markup Language) and XML (Extensible Markup Language) documents. Manipulating the DOM is a very slow process and using a virtual DOM is much faster as nothing gets drawn onscreen. Code Academy describes the process as follows.

“Think of manipulating the virtual DOM as editing a blueprint, as opposed to moving rooms in an actual house.” [33]

React creates an in-memory data structure cache. The changes are then computed, and the browser is updated.

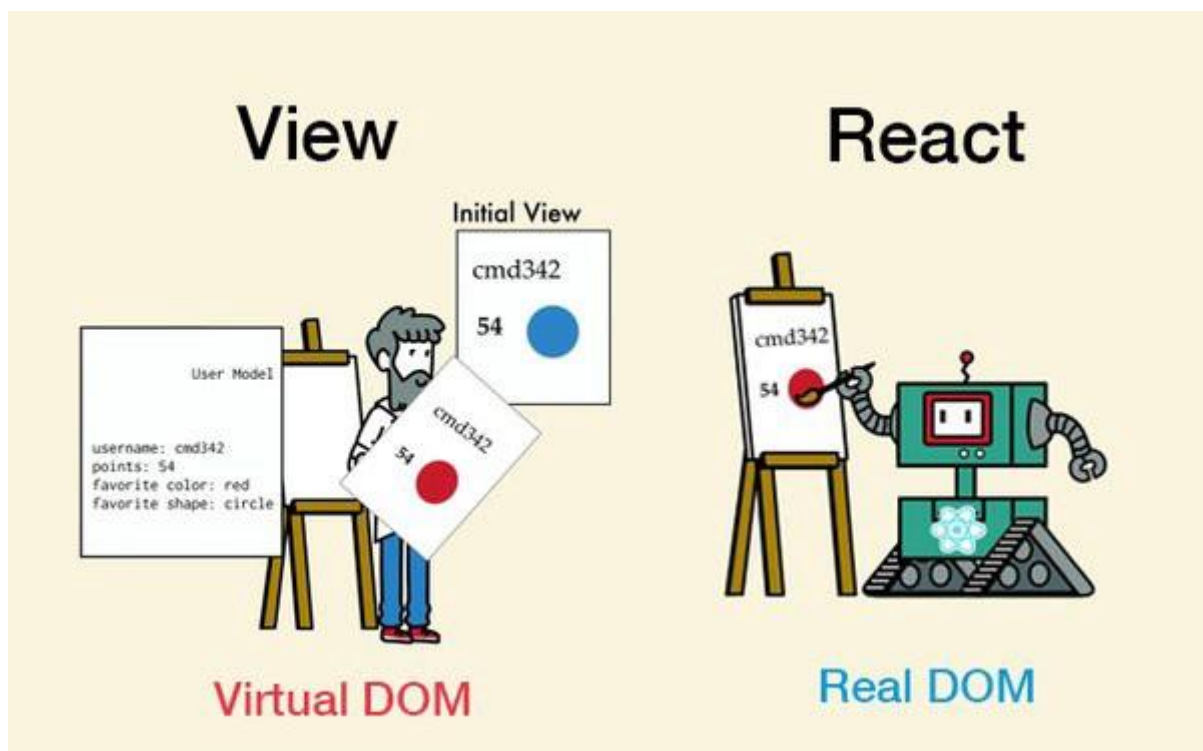


Figure 7. ReactJS uses a Virtual DOM [34]

JavaScript eXtension

JSX is a syntax extension to JavaScript that allows writing JavaScript in a similar way to HTML. Instead of using regular JavaScript for templating, ReactJS uses simple JavaScript, which allows for HTML quoting. It also allows writing in pure JavaScript. JSX is a pre-processor step that adds XML syntax to JavaScript. JSX enhances the experience of ReactJS, making it much more elegant. Like XML (eXtensible Markup Language), JSX tags have a tag name, attributes and children. After compilation, JSX expressions become regular JavaScript function calls and evaluate to JavaScript objects.

Database

A database is an ordered collection of data, organised by logic and association. The hold information in a structured way that allows the developer to easily manage, access and update data. The primary and base function of a database is information storage. Databases underpin nearly all software.

MySQL

MySQL is an open-source database management system that uses structured query language (SQL). MySQL is the most popular freely available database, with SQL being the standardized language used to access databases. MySQL was chosen for its reliability, suitability for the project and ease of use. It was also chosen because it is free. MySQL also has a large online community of resources for using it.

Server

Communication and interaction with the database will be done using Python MySQL. Python MySQL with Flask allows you to define all the operations that you wish to carry out against the database (input/data retrieval/data deletion) in definitions associated with a specific URL. This API is then called by the application and acts as a 'go-between' for the user interface and the database.

Chosen Technologies

The research in this report was compiled and used to help decide which technologies would be used in this project. The technologies were chosen by leaders of the *Erasmus+* project to maintain synchronicity across all the individual projects being carried out and make it easier to integrate those projects at some stage in the future. After my initial research, I wanted to use Xamarin for user interface and design. This was because I was interested in how one code base can be used to develop a cross-platform native mobile application. However, the *Erasmus+*

project spec included a web application, not a native mobile application. Due to this, ReactJS was chosen for application interface design as it offers an easy to use component-based architecture which will be easy to integrate with other applications in future stages of the project. The database and API technology were also chosen by *Erasmus+* project leaders. The database will consist of a MySQL database that is shared by all developers involved in the project. The application API will be written in Python MySQL and deployed on a Flask server. The API will also be shared by all the developers working on the project.

Similar Applications

While researching symptom tracking applications, I downloaded and used several. This helped me to understand what features would help provide the best user interface and make the application more intuitive to use. The following two applications were among those installed and used by me over a span of about two weeks.

mySymptoms Food Diary & Symptom Tracker

Cost - €3.36

Stars - 4.5

Installs - 10,000+ (Free version has 100k+ downloads)

“Record, track, and analyse your food, mood and symptoms to gain insights into your digestive health.” [35]

The symptom tracker allows the user to record food, drink, medication, stress, exercise and notes. It also allows the user to keep track of any symptoms that they experience. Users may view and alter their entries as well as create their own symptoms. The information gathered can be exported as a PDF, CSV or web report. The application aims to help the user discover patterns between diet and symptoms and provides a trend chart to help with this.

Positives:

- Ability to export information in various formats.
- Ability to edit previous entries.
- Ability to add new symptoms.
- Core features easy to use.
- Users can set reminders for logging meals.
- Is available on both Android and iOS.

Negatives:

- Data entry is time consuming.
- Action of adding new food items is not intuitive.
- Interface can initially be challenging to navigate.
- Is relatively expensive considering there are multiple free applications that allow symptom tracking.



Figure 8. mySymptoms Food Diary & Symptom Tracker [36]

Correlate – Symptoms and Habits Diary

Cost - €3.09

Stars - 5

Installs – 100,000+

“Correlate is a smart health journal app that allows you to track symptoms, to log activities, and to discover correlations between bad or good habits and illnesses / intolerances / allergies / moods.” [37]

Correlate allows users to journal their symptoms, log activities and to discover correlations between habits and symptoms. Correlate is targeted at people suffering from chronic pains, intolerances, mood disorders and undiagnosed sickness. Correlate helps analyse symptom frequency and attempts to provide suggestions on possible connections. The application also supports the exportation of the information to a CSV file.

Positives:

- Sleek user interface.
- Easy to use.
- Allows for quick input of logging information.
- Ability to easily edit past days information.
- Users can set reminders for logging information.

Negatives:

- Can be sluggish on launch.
- Does not allow users to enter the severity of symptoms.
- The application is only available on Android devices.



Figure 9. Correlate -Symptoms and Habits Diary [38]

Similar Application Research Summary

The first application (mySymptoms) appeared very promising initially, especially as it was available on both Android and iOS devices. However, upon trying to use the application, it lacked an intuitive user interface. Some features were difficult to navigate and figure out upon first uses. The application proposed for this project needs to have a simple user interface that can be used intuitively from the initial use. The second application discussed (Correlate) had a much more attractive user interface and was much easier to use. When I used the application initially, there was a free version. This version has since been removed and replaced with the paid application version described above. However, unlike mySymptoms, it is not available on iOS devices. It also does not allow the user to input severity of symptoms. Including the option to add symptom severity is an important aspect of the application being researched herein, as well as providing cross-platform availability.

Conclusion

Coeliac disease is an auto-immune disorder that occurs in one in one hundred people, to which everyone is susceptible. Coeliac disease can result in multiple long-term illnesses, such as lactose-intolerance, osteoporosis and cancer. There are also several short-term effects. These include fatigue, diarrhoea, vomiting and insomnia. These symptoms are worsened when the individual does not comply to a gluten free lifestyle. By following the design thinking process stages of empathize, define, ideate, prototype and test, I gained various insights to assist me in developing an application that would be helpful to the user. The steps included carrying out tasks such as brainstorming, creating problem statements and user testing with prototypes.

The following observations were obtained from testing:

- Users would only want to input symptoms once a day.
- Users thought the screens were generally descriptive and self-explanatory.
- Users thought the input field on the search page was not large enough.

As part of researching for this application, I explored applications that had similar features to those defined in brainstorming sessions. These included the applications *mySymptoms* and *Correlate*. While both applications performed the same core function i.e. to track symptoms, they lacked in other areas such as usability and available platforms. Despite this, each application also had numerous positive characteristics from which I could learn such as the sleek user interface employed by *Correlate*.

The application building technologies researched for this application included Xamarin, Cordova and ReactJS. ReactJS was the chosen medium for development of the application. Although extensive research was carried out, ReactJS was chosen by the *Erasmus+* project leaders. As I had not worked with ReactJS before, this was an opportunity for me to master a new tool. ReactJS was chosen for its component-based architecture, as this would make it easier for integration of the individual projects.

The application will be a cross-platform symptom tracker that is targeted specifically at teenage coeliac patients. The target audience was also chosen by *Erasmus+* leaders, however it was important to me that the application be suitable for as wide an audience as possible. As such, the application can be useful to any individual with a level of gluten intolerance. The purpose of the application will be to allow the user to track all emotional and physical symptoms, as well as the severity of those symptoms. The purpose of allowing the user to log symptom severity is so that the user may see regression/progression over time.

The chosen database for this project was MySQL. MySQL was chosen as it is one of the most popular open source database management systems, with numerous resources available to aid in its use. The API language chosen for this application was Python MySQL, using a Flask framework. This choice was also made by the leaders of the *Erasmus+* project. I had no previous experience with Python MySQL and was eager to learn it as Python is only growing in popularity.

To summarize, the following technologies were chosen for this project: ReactJS(front-end), MySQL (back-end database) and a Flask server.

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Appendices

Appendix A

Results:

The section below contains the results of the interviews in a table format. The themes used in the interview, previously decided on in the brainstorming session with multiple professionals were as follows; Barriers, supports, attitudes and beliefs, compliance, past experiences and emotions. Each theme was then divided farther into subthemes. Each theme and sub theme result can be seen on the below tables. Themes and sub themes are listed on table 1.2 and 1.3 for teenagers and parents respectively.

Description of teenagers interviewed

ID	Age	Gender	Duration of diagnosis (years)
1A	17	F	14
2A	15	F	2.5
3A	16	F	8
4A	14	F	2
5A	16	F	<1

Table 1.1 Characteristics of Participants (Teenagers)

Interview themes and subthemes

<p>Barriers Sometimes irritating Health impact</p> <p>Support Friends Family Organisation GP</p> <p>Attitudes & Beliefs Knows no different Happy Better option recently difficulties Food option difficulties Cost</p>	<p>Past Experiences/ Emotions Kitchen Changes Isolation when younger Food prep Pre – made food</p> <p>Compliance Adherence Fear of cross contamination</p>
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Table 1.2 showing themes and sub themes from teenage interviews

Description of parents interviewed

ID	Age	Gender
1B	49	F
3B	52	F
4B	48	F
5B	40	F

Table 1.3 Characteristics of Participants (Parents)

Interview themes and subthemes

<p>Barriers Health impact</p> <p>Support Friends Family Social media</p> <p>Attitudes & Beliefs GF options have improved Cost Greater food preparation Feelings towards diagnosis</p>	<p>Past Experiences/ Emotions Kitchen changes Isolation when younger Didn't want child to feel different Label reading Making food for events</p> <p>Compliance Strict adherence Lack of adherence Parent food preps Fear of cross contamination</p>
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Table 1.4 showing themes and sub themes of parents after interview

After the initial brainstorming session, six (6) themes were established for the participants to be interviewed under; 1) Barriers and constraints, 2) Supports, 3) Attitudes & beliefs, 4) Past experiences & emotions, 5) Compliance, and 6) Technology. Each of these themes interviewed produced their own subthemes as illustrated in Tables 2.1 and 2.2. Subthemes varied between teenagers and parents.

Themes and subthemes from teenager interviews

Participant ID						
Code	1A	2A	3A	4A	5A	Total
Barriers						
Sometimes Irritating	X	X	X	X		4
Health Impact	X	X		X		3
Support						
Friends	X	X	X	X	X	5
Family	X	X	X	X	X	5
Organisation	X		X	X		3
GP	X	X	X	X	X	5
Attitudes & Beliefs						
Knows no different	X					1
Happy	X	X	X	X	X	5
Better recently	X					1
Food option	X	X	X	X	X	5
difficulties						
Cost	X			X		2
Past Experiences/Emotions						
Kitchen Changes	X	X	X	X	X	5
Isolation when	X	X	X	X		4
younger						
Worse when younger	X		X			2
Food prep	X			X		2
Pre – made food	X		X	X		3
Compliance						
Adherence	X	X	X	X		4
Fear of cross	X		X	X		3
contamination						

Table 2.1 showing subthemes mentioned by participants (denoted by X)

Barriers

The majority of the participants did not find coeliac disease to be extremely limiting in any way or have an extraordinary amount of barriers. 80% of the participants described having coeliac disease as “sometimes irritating”, with one participant explaining that “it takes longer to get better from colds.” Two other participants also described health concerns regarding GF foods as a barrier or limitation to having coeliac disease. A common consensus emerged amongst participants that GF foods have a lot more preservatives and sugar in them when

compared to non GF foods. A X year old girl described the diet as having “opened [her] eyes on how many products are preserved” [Participant 2A]. One of the parents (not interviewed) commented that her daughter had gained 20kg in weight since starting a GF diet.

Support

All of the participants agreed that they had great support from friends and weren't treated any different as a result of having coeliac disease. Participant 4A stated that her friends “are aware of it” and understand that side effects of consuming gluten. Within the school environment, which previous to the interviews was thought to be a major environmental issue with regards to isolation and cross – contamination, turned out to be of little concern to participants. Many of the participants bring their own lunch (one school was mentioned to have GF options available) and do not feel to be outsiders from their peers as “everyone does it”.

The family unit was also another great source of support for the teenagers. All family units have switched to GF foods when meals are being cooked i.e. everyone has a gluten free dinner rather than preparing two separate dinners. One participant discussed that she had great support from her family as “three (3) out of four (4) people in my family are coeliac” and as she was diagnosed 14 years ago at age 3, she “knows no different”. There was also a family history of coeliac disease in 40% of participants with either immediate or extended family members affected. This gave the participants an insight into what the disease was like prior to diagnosis.

Many of the teenagers and their parents were members of the Coeliac Society of Ireland and found the book provided very useful.

All of the participants visit their GP regularly and feel that they have some level of support from them.

Attitudes

&

Beliefs

Attitudes and beliefs were similar amongst coeliac participants, nonetheless it was the main area of the discussion. One hundred percent (100%) of participants said that they were “happy enough” with having the disease and that it was “manageable” and “not the worst”. The most recently diagnosed participant (diagnosis one (1) week ago) relayed that she “feels ok about the disease it's manageable [I] would rather not have it”.

Unsurprisingly difficulties in food choices was a major topic amongst participants. The main difficulties when choosing food appeared when participants wanted to eat out. Participants were distrustful of restaurants or food trucks claiming to cater to a coeliac diet but not being stringent on cooking practices.

“.... Like at the ploughing, food trucks cooked chips in the same oil as batter.” [Participant 4A].

One participant noted that a GF diet may not contain as much fibre as a non GF diet and as a result has to take fibre supplements and “tries to eat as much fruit as possible”. Participant 5A was the only participant to feel that they had a lack of knowledge on GF foods as she was only recently diagnosed. She concluded that she “needs to research about it, I think there's good options, but I just don't have a knowledge of them yet.”

The “variety” and “availability” of GF foods has improved over the past few years. Participants described feeling satisfied at the number of supermarkets now carrying GF food products and aisles. The parents of all the participants did the food shopping for the household

but participants did note that the cost of GF foods is more expensive than non GF foods.

A lack of education in the general population was brought to light during the interview process.

“Education in the general population could be better. The general population don’t understand coeliac disease, people don’t know what gluten is. People only understand if they know someone with the disease.”

Past Experiences & Emotions
Past experiences and emotions played an integral role during the interview stages as they helped to give a greater picture on the life of a coeliac and to shape experiences into a positive light for newly diagnosed coeliacs.

Isolation during youth was a major talking point for participants. 80% of participants recalled going to parties as children and bringing their own food in a lunch box. This led to participants feeling “left out” or “different.” One participant noted that she “hated cake sales in school” as she could not buy any of the cakes and GF stalls were not always feasible. Another participant explained that she felt under the microscope when eating in front of new people as she would be questioned on why she was eating different foods from the rest of the group. Participant 2A also agreed as feeling “slightly away from the group” due to having coeliac disease but feels that the situation is improving. Limitations were also noted on nights out with friends, as one participant explained that she can’t get the same food as her friends.

Changes to the kitchen upon diagnosis was a major lifestyle modification, not only for the participants, but their families. All households now contain “GF presses” and certain households contain “GF toasters” and “GF grills”. In all of the interviews the participants explained that the entirety of the family unit were now eating GF meals and therefore did not feel excluded or left out when having family meals. Participants also mentioned having their own “toaster bags” both for in the home and travelling.

Frustrations arose within the household when non – coeliac family members made snacks or prepared food that contained gluten. Participants described feelings of jealousy and that they “miss certain foods” but know not to deviate from a GF diet due to the severity of symptoms.

Eating out was again a difficulty in the past for coeliac patients. Participant 1A noted that when going abroad there were greater obstacles when trying to eat out due to language barriers and restaurant standards in different countries.

“When we were on holidays we had to eat in central tourist areas, you can’t go off the beaten track”

Compliance

As it stands, a GF diet is the only form of treatment or management for coeliac disease. Reasons and motivation for compliance or non – compliance can vary person to person, however, concern about symptoms was paramount in participants with strict adherence.

Participants diagnosed for greater than two years claimed to have the greatest compliance to a GF diet with one participant stating,

“I don’t have a choice not to comply, I’m quite sensitive to gluten. I would know within the hour whether I have ingested gluten”

Participants described symptoms of “bloating”, “nausea” and “vomiting” affecting them quite rapidly after ingesting gluten and felt that “it wasn’t worth it” not to comply to a GF diet.

Participant 5A had been diagnosed with coeliac disease less than a week prior to the interview. She had been on a GF diet but did not have strict adherence as she felt other food looked “decent” and wanted to eat it, and didn’t feel that it was “that severe”. The participant described having feelings of nausea after ingesting gluten but did not think or know about the long term implications.

Cross – contamination was a worry amongst participants due to the acuteness and severity of their symptoms. One of the participants described a recent episode of accidental ingestion of gluten.

“I’m quite good at sticking to it unless it’s something that’s not clear. I had ice – cream and the packaging wasn’t clear that the product [may] contain gluten. I felt really sick and like I was going to be sick. Mam read the label again and found that it said the product may contain gluten. That was the first time in two years [ingesting gluten]. That was a week ago and I still don’t feel right.”

Another participant agreed that they only ate food containing gluten by accident as symptoms were “too severe”.

Parents were interviewed as they were valuable stakeholders for the project and their input could lead to new and beneficial insights for their childrens’ lives and for app development. Parents were interviewed under the themes of; 1) Barriers and constraints, 2) Supports, 3) Attitudes & beliefs, 4) Past experiences & emotions, 5) Compliance, and 6) Technology. After conducting the interviews and analysing the research, subthemes were produced as seen in Table 2.2.

Themes and subthemes from parent interviews

Participant ID					
Code	1B	3B	4B	5B	Total
Barriers					
Health Impact	X		X	X	3
Support					
Friends	X	X	X	X	4
Family	X	X	X	X	4
Social media	X	X	X	X	4
Attitudes & Beliefs					
GF options have improved	X	X	X		3
Cost	X		X	X	3
Greater food preparation	X	X	X	X	4
Feelings towards diagnosis	X	X	X	X	4

Past Experiences/Emotions					
Kitchen Changes	X	X	X	X	4
Isolation when younger	X	X	X	X	4
Didn't want child to feel different		X	X	X	3
Label reading	X	X	X	X	4
Making food for events	X	X	X		3
Compliance					
Strict adherence	X	X	X		3
Lack of adherence				X	1
Parent food preps	X	X	X	X	4
Fear of cross contamination			X		1

Table 2.2 showing subthemes mentioned by participants (denoted by X)

Barriers

Many parents will worry about barriers and limitations that their child will face in life, this worry is increased in a parent with a child with any auto – immune disease. 75% of parents mentioned some form of health impact as the main barrier facing their children, but stated that it is not as limiting as other auto – immune diseases as there is “no medication involved”. Notably, many parents agreed that a GF diet can be “healthier” than a conventional diet as they are “more health conscious”, eat less “processed food” and “read the packaging [on food] more”. One parent had the mentality that the “longer you’re on a GF diet, the sicker you get when you eat gluten” and believes that to be a key factor in sticking to a GF diet.

Supports

Familial support has been an overwhelming form of supports for teenagers with coeliac disease. Parents have changed from preparing non – GF meals to preparing GF meals only as they don't want their child to feel excluded.

The parents felt that their childrens' friends were great supports and “looked out” for them and tried to find “gluten free alternatives” for their children. One parent noted that their son didn't feel any different about being coeliac at home but worried that he felt different when outside the home as “he knew what it was like to not have to follow a GF diet.”

All of the parents were members of the Coeliac Society of Ireland and two parents were members of a Facebook group for parents of children with coeliac disease.

Attitudes & beliefs

Attitudes and beliefs of parents were an important insight to get as their viewpoint is twofold; their own attitudes and beliefs, and what they think their child believes.

When the initial diagnosis was made, many of the parents felt “shock” but also “relief” at finally having a diagnosis as to why their child had been sick. One parent explained that they felt “sorry” for their child and had “mammy guilt” as they themselves were coeliac and knew that there was a chance of their child obtaining the disease. Parent 1B relayed that her child (male) was “upset at the diagnosis of coeliac disease because he knows how bad it is.” However, she described that her child, and a lot of other children, “don't realise how bad it is

until they feel better”. Parent 4B explained that the terminology surrounding coeliac disease can be difficult as you “don’t want to say disease as people may react badly, but saying GF, people may think you’ve opted for the diet.” It was felt that the parent may have previously felt that the GF diet and severity of the GF diet was not taken seriously by others. Parent 5B had two recently diagnosed children, the youngest of which was 14 (not interviewed), disclosed that said child was “not accepting the diagnosis yet” and was “still eating wheat [he] doesn’t want to be different.” She conceded that the change to his diet would have to be gradual. This mother also believed that an app would be a great idea for younger teens to give them a sense of “ownership” with their disease and that there should be more awareness of “ambassadors” for young teens e.g. Novak Djokovic as he is a “successful coeliac”.

The majority of parents agreed that there is a lot more time given to the organisation and preparation of gluten free foods. One parent stated she feels like an “FBI mam” as she has to research restaurants before going out to eat, restaurants abroad, where to eat at events etc. and if she doesn’t she’ll “... either have sick or hungry children”. The same parent also only cooks and bakes GF foods at home as three quarters of the family have coeliac disease. This transpired to her son taking a keen interest in cooking GF meals and “constantly looking up new recipes” to try out.

Although GF products are “getting better” and there are “more products out there”, cost still remains an issue to parents of children with coeliac disease. GF bread was noted to be the most expensive product to buy and costs were still high “even with tax back”.

Past Experiences & Emotions
 Parents may be able to give a greater understanding into past experiences from when their children were younger, as well as an insight into their own lives and experiences with children with coeliac disease. In addition to supporting their child and wanting to “normalise” coeliac disease, all families have changed their kitchen layout to include “GF cupboards” or “GF zones”.

Many of the parents discussed not wanting their child to feel “isolated” or “different” when younger.

“He can’t just pop into the chipper for a quick bite to eat with friends. when getting treats in school [he] can’t have the same treats at grad party he has to have different food conscious as he’s a teenager coeliac disease will make him feel different”.

There was also a consensus among parents about being “awkward” or “extra” as there was a greater effort on the parents behalf to ring ahead to friends’ houses, school events, family events etc. to make sure that there would be a GF option available for their child, whether it meant preparing something at home and bringing it to said event, so that their child didn’t feel excluded or like the “odd one out”. Parent 4B spoke of a positive experience when it came to informing others of their child’s GF diet.

“She went to the Gaeltacht and I rang the woman who owned the house and said about [child’s name] being coeliac and she went and bought a new toaster just for [child’s name]. I was afraid of being awkward, but once you share and educate people it’s ok.”

(A)

Compliance

The majority of the parents interviewed believed that their child had a good compliance with a GF diet as their children “know better” than to eat gluten containing food. All of the parents were involved with food preparation in the home but many of them encouraged their children to get involved as it encourages “independence” and “a sense of responsibility”. Cross contamination was a fear for parents when children were “in school” and when “eating out”.

Parent 5B had two children recently diagnosed with coeliac disease and believed that compliance could be improved by making it “the norm” in the household e.g. rearranging the kitchen. This parent also encouraged her children to look up new recipes and to cook for themselves to improve compliance.

Appendix B

Barcodes

A barcode is a very rapid way of entering numerical data into a computer. The image acts as a unique identifier for each item by representing various information. The barcode was patented in the US in 1952 by Norman Joseph Woodland and Bernard Silver [13]. It was based on the idea of Morse code, which is a string represented by combinations of long or short light/sound signals. Barcodes became successful commercially when they were utilized for supermarket checkout systems. The first scanning of a Universal Product Code (UPC) barcode was a pack of Wrigley chewing gum in June 1974 [14]. The introduction of bar code scanning in supermarkets improved checkout speed by 40% [15]. Barcodes can be one dimensional (EAN-13, UPC-A etc) or two dimensional (QR Codes) and are usually printed directly onto an item or affixed with a label. Global Standards One (GS1) are the most widely used supply chain standards organisation in the world for barcodes. The organisation was formed in 2005. GS1 barcodes enable organisations of any size to order, track, trace, deliver and pay for goods anywhere in the world. [GS1](#) is recognised by the International Standards Organisation (ISO), the European Standardisation Committee (CEN) and the American National Standards Institute. Today, over two million member companies in 145 countries use GS1 standards. This represents some five billion scanning transactions a day [16].

EAN-13 Barcodes

Most retail barcodes in use in Ireland are EAN-13 (European Article Number – 13) barcodes. EAN-13 is the most commonly used of all GS1 symbols. These are thirteen-digit numbers that come from an international database and are encoded into barcodes using EAN-13 symbology [17].

The thirteen digits in the EAN-13 barcode are grouped as follows:

- 2/3 digits for number system or country code
- 5/4 digits for manufacturer (company) code or prefix
- 5 digits for product code
- 1 digit for checksum

The purpose of a check digit is to verify that the information on the barcode has been entered correctly. The barcode reader decoder calculates the checksum by performing a series of mathematical operations on the digits that precede the check digit. The result of the calculation is then compared to the value of the check digit [18].

A typical EAN-13 bar code looks something like this:



Figure 1. Sample EAN-13 Barcode [19]

EAN 13 Specifications:

- Min. size: 29.83 mm x 18.28 mm
- Max. size: 74.58 mm x 45.7 mm
- Nominal dimensions: 37.29 mm x 27.85 mm
- X dimension at nominal size: 0.330 mm
- Magnification factor: 80% to 200% from nominal dimension.
- Light Margin: Left 3.63 mm, Right 2.31mm
- Min Bar Height: 22.85 mm at nominal size
- Target Location: Rear lower right quadrant



Figure 2. EAN-13 Barcode Specifications [20]

The Benefits

Barcodes provide a valuable way for businesses to improve efficiency and reduce overheads in a cost-efficient and reliable manner. Barcode use has numerous benefits including:

- Eliminating human error – data entry errors can be a significant source of problems for a business. The typical error rate for human data entry is one error per three hundred

characters. In comparison, barcode scanners have an error rate of one error per ten thousand barcodes scanned (varying slightly by barcode type used) [21].

- Reducing employee training time – the hand-held scanner for reading barcodes takes only minutes to master as employees do not have to be familiarised with an entire system of inventory and pricing. In turn, this reduces the cost of staff training as the business does not have to pay the individual for training time or another employee for their time training the new member.
- Data – the use of barcodes means that inventory can be tracked precisely. This allows businesses to reduce inventory levels; which translates into a lower overhead. The data that can be obtained using barcodes ultimately may save a business both time and money. For example, barcodes enable a retail business to quickly see what items are being stolen and take necessary measures such as moving the products behind a cashier checkout.

Reading 2D Barcodes

Barcodes give every item its own unique, classifying number so that an electronic scanning device can read it. However, decimal numbers are easy to confuse or misread. Barcodes provide a highly reliable way of printing these numbers so that they can be read at high speeds with great accuracy. In a barcode, each digit in the product number is given the same amount of horizontal space; seven units. To represent any numbers from zero to nine, those seven units are simply coloured with different patterns of black and white stripes.

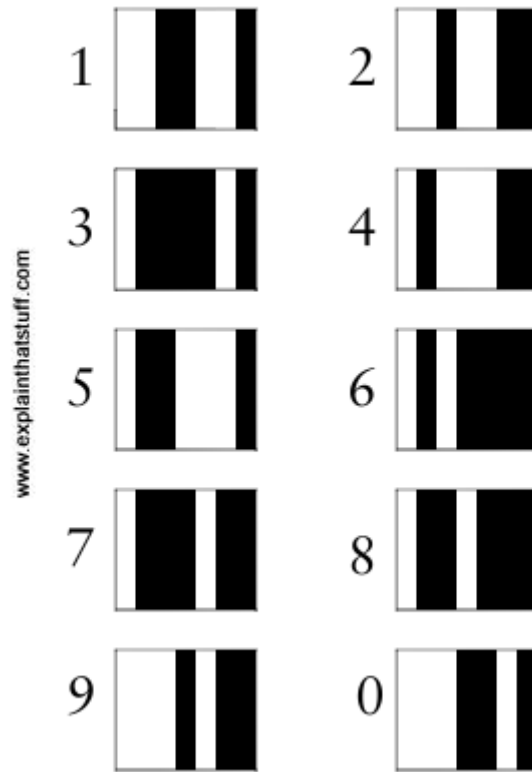


Figure 3. Illustration of barcode digits [22]

As mentioned previously, these numbers represent different kinds of information such as the manufacturer code and the product code. Barcode scanners must read the black and white lines extremely quickly and feed that information to a computer or terminal of some kind, which can identify the product using a database. There are various kinds of barcode scanners that range from the scanner used in retail to a camera-based scanner. Scanners used in retail are frequently mounted into a check out unit. These types of scanners use lasers to read the barcodes. Inside the unit, a laser is shot at a mirror. The mirror makes a movement which sweeps the laser across the barcode. A diode measures the level of reflection, which is translated into a digital signal readout of the barcode [23]. These types of scanners are extremely accurate, with only one error per ten thousand barcodes scanned. This contrasts hugely with manual data entry, which has an error rate of ten for every thousand keystrokes [24]. This project will utilise a camera-based barcode scanner in a smart device. These readers capture an image of a barcode and use digital image processing techniques to decode the barcode.

Barcode Reading APIs and Databases

The barcode API that is needed for this project must be free or offer suitable free usage as there is no budget for this project. It must also support searching a database of nutritional information using either a barcode image or the identification number associated with the barcode. The nutritional information must either enable the application to deduce whether the product is gluten free or it must provide the information directly to the application. Gaining this

knowledge is a challenge as there is no universal database maintained that holds all barcodes [25]. The following APIs are being considered for use in the project.

BarcodeLookup

BarcodeLookup is an API with a product database that can be called using a UPC, EAN or ISBN number. It returns the products name, category, description, images, retail pricing and more. However, the API doesn't return the information the application would need to determine whether the product scanned is gluten free and as such is unsuitable.

Can I Eat It?

The API provided by the "Can I Eat It?" team supports searching products by name, barcode and basic product information from their database of products. It returns detailed nutritional data and allergen listings. However, the API is in the final stages of testing and is not available until December 2018.


🔍 **Search by Barcode or Product Name**
 /api?barcode=21045622

↓

```

{
  "productId": "6356",
  "title": "ASDA Chosen by You Baked Beans in Tomato Sauce",
  "brand": "ASDA",
  "image": "http://www.supermarketownbrandguide.co.uk/images/2/b54c2449e8f0bb3273a28cca5e845457.jpg",
  "description": "Want baked beans for tea? These are as good as the brand - put a can or two in the trolley. Tasted by Martin Isark. \nCompeting Brand: Heinz",
  "weight": "410g",
  "isFood": true,
  "barcode": "21045622",
  "ingredients": "Haricot Beans (49%), Tomatoes (34%), Water, Sugar, Modified Maize Starch, Salt, Onion Powder, Paprika, Sunflower Oil, Paprika Extract, Clove Extract, Bay Extract, Capsicum Extract, Cinnamon Extract, Garlic Oil, Natural Flavouring, Rapeseed Oil.",
  "score": "10",
  "price": "0.34",
  "properties": {
    "check": true,
    "energy": {
      "amount": "378",
      "per": "100g"
    },
    "carbs": {
      "amount": "14",
      "per": "100g"
    },
    "sodium": {
      "amount": "0.28",
      "per": "100g"
    },
    "fat": {
      "amount": "0.5",
      "per": "100g"
    },
    "satfat": {
      "amount": "0.1",
      "per": "100g"
    },
    "salt": {
      "amount": "0.7",
      "per": "100g"
    },
    "sugar": {
      "amount": "4.1",
      "per": "100g"
    },
    "contains": [
      "garlic",
      "onions"
    ],
    "organic": false,
    "fairtrade": false,
    "eco": true,
    "vegetarian": true,
    "vegan": true,
    "healthnotes": "Suitable for Vegetarians."
  },
  "category": "Food Cupboard",
  "subcategory": "Tinned Sweet & Savoury"
}
  
```

**Can I Eat It?
Tasting Notes
and Product
Information**



← **Nutritional Data**

← **Allergen List**

← **Vegan/Vegetarian Status**

Figure 4. Illustration of API Sample [26]

Scandit

Scandit Barcode Scanner SDK transforms smartphones into enterprise-grade barcode scanners. It provides lightning fast barcode scanning. It is available as a plugin for Cordova. However, it has no product information associated with it so if the application uses Scandit then it still needs a database that has product information with a corresponding GTIN (Global Trade Identification Number). Scandit offers a ‘Community Version’ to non-profit organisations and students.

Nutritionix API

Nutritionix is a search engine and the world’s largest verified nutrition database for nutritional information [27]. The Nutritionix API allows developers to integrate the functionality and data of Nutritionix and create new applications. They provide various subscriptions which include a free plan.



Figure 5. Illustration of Nutritionix API [28]

Appendix B References

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