Motivating User's Understanding and Reflection on Their CO_2 Usage Based on Their Food Consumption

Project Report, 4th semester, Master of Science in Software engineering

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Abstract:

In this project, we develop an app that scans receipts and recognizes many types of meat, vegetables and fruits from the Føtex database. The app calculates the users total CO2 emission based on the different products. Icons depicting different transportation options convert the emission to help the user better understand their emission, together with a guessing game. This is together with an alternative page that suggest better alternatives for the products scanned to make them reflect and possibly change behaviour by using smileys. There is also a graph page with a suggested "optimal" CO2 emission. A 4-week long field study was conducted with 6 participants which revealed, that while the users total CO2 understanding didn't improve, understanding of individual products CO2 emission did improve. It also found negative smileys from the alternatives to be more efficient than the positive, while the graph page was ineffective due to lacking sufficient products in the database to capture all aspects of a users shopping habits.

Preface

This project was created by 3 Software students from Aalborg University during their 4th semester of Software, master of science in engineering during the period from the 1st of February to the 10th of June 2022.

We would like to thank our supervisor Dimitrios Raptis for helping us during the making of this project.

Summary

This project is a continuation of a previous project where the "FoodEmissions" app was developed [1]. The focus of the app was to make it easier to see which product variants were the most sustainable based on CO_2 (i.e. is an organic, non-packaged tomato more sustainable than a non-organic, packaged tomato from Denmark) and influence the users behaviour towards more sustainable food choices. The app enabled users to calculate the carbon footprint of their consumption of select fruits and vegetables by scanning their receipt. Users were able to see their carbon footprint as well as the possible reduction had they not chosen the most sustainable product variants. They were also able to view their purchases and their respective alternatives.

However, a field study of the use and impact of the app from the previous project showed that the participants didn't understand the carbon footprints and the app therefore had very little impact on their food consumption. We summarized the lessons from the study and decided to implement new features to motivate reflection and understanding.

The features implemented were an alternatives screen with smiley ratings, a graph screen, icons, a game, default values as well as a meat and meat alternatives category. The alternatives compares the individual products with each other, displays a smiley rating and gives recommendations for what to buy based on the purchased product's CO_2 footprint. The graph screen includes three graphs, one for the users weekly consumption, one for the users consumption over four weeks and one displaying the consumption based on different product categories e.g. beef, pork, vegetables etc. The icons are depicting cars, trains, planes and a tree with different text that showcases for example how long the user can drive in a car to produce the same CO_2 as their usage. The game is a guessing game based on the information from the icons in which the users must guess if if their consumption is higher or lower than a stated value. The default values were used to guess values that couldn't be extracted from the receipt in order to make scanning easier.

To test the new features a 4-week long field study was conducted with 6 participants who had to use the app after shopping at a grocery store. The study showed that the participants who used the app the most reflected more and got a better understanding of CO_2. The alternatives proved to be the most effective at motivating reflection and understanding by comparing individual purchases to each other. The users found the icons and game hard to relate to, but it did motivate understanding even though the users said it would require a longer time period than the study for it to be effective. The graphs were hard to use for the users since they where not able to input all their purchases into the app because the only product categories in the database were fruit, vegetables, meat and meat alternatives. The default values were helpful for some participants, while they didn't make much of a difference for others, as they were often wrong.

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Chapter 1

Introduction

Unsustainable consumption patterns is a global issue that contributes to pollution, climate change, loss of biodiversity and depleting resources[2]. One way to measure sustainability is via a carbon footprint. According to think tank Concito, Danish citizens emit 17 tons of Carbon Dioxide (CO_2) on average. Although 5 tons are societal emissions (e.g. from management of hospitals, schools and infrastructure), that still leaves 12 tons that individuals have some control over. Out of these controllable emissions, 25 % (3 tons) stems from the consumption of food. However, while surveys show that many consumers are aware of the need to change their food consumption and actively trying to do so, it often isn't easy to see, what the most sustainable choice is.[3][4]

Various apps have tried to visualise peoples' CO_2 food consumption such as the "CO2Food" or "Coop" app. However, they do not account for details such as transport distances, greenhouse cultivation and organic cultivation. Two of the authors of this report previously developed a similar app called "FoodEmissions" that accounts for these factors when calculating the CO_2 consumption based on the database "Den store klimadatabase" from Concito [1].

However, a field study of the use and impact of the app showed that the participants had a hard time relating to their carbon footprints as they didn't understand what they meant. Due to this, the app failed to motivate the users to reflect on their purchases and therefore had very little impact on their food consumption behaviour. The lessons learned from the study are summed up in Section 1.1.

Users are more motivated to change their consumption behaviour, if they have a clear benefit to be gained, such as saving money by reducing your electricity consumption or getting healthier from eating healthy food[5]. [6] points out some issues on this subject in relation to environmentally sustainable food consumption when compared to similar problem areas. For healthy food consumption and sustainable energy consumption, people get a more tangible reward for example in the form of monetary savings and short-term health benefits. Changing shopping behaviour for the sake of environmentally sustainable food consumption does not have these immediately evident benefits.

Hence, for the "FoodEmissions" app there is no guaranteed reward or validation to be collected from outside the app itself since it focuses on CO_2 food consumption. Users might experience a change in their physical health if the app causes them to eat healthier, and a climate friendly diet is typically also healthy [7]. But users may also settle for buying the most CO_2 friendly product variants (i.e. same product with different countries of origin, packaged or non-packaged etc.) and not change their diets. The economic consequences may be negative as for example mushrooms cost more than double when you buy the most CO_2 friendly variant from Denmark compared to the variant from Poland [8]. The impact of reducing CO_2 emissions on the climate and the environment takes a long time to be visible and the efforts of the individual is so small it is impossible to measure any improvement. Thus, it is important that the app provide the elements that motivates the users' to change

their behaviour.

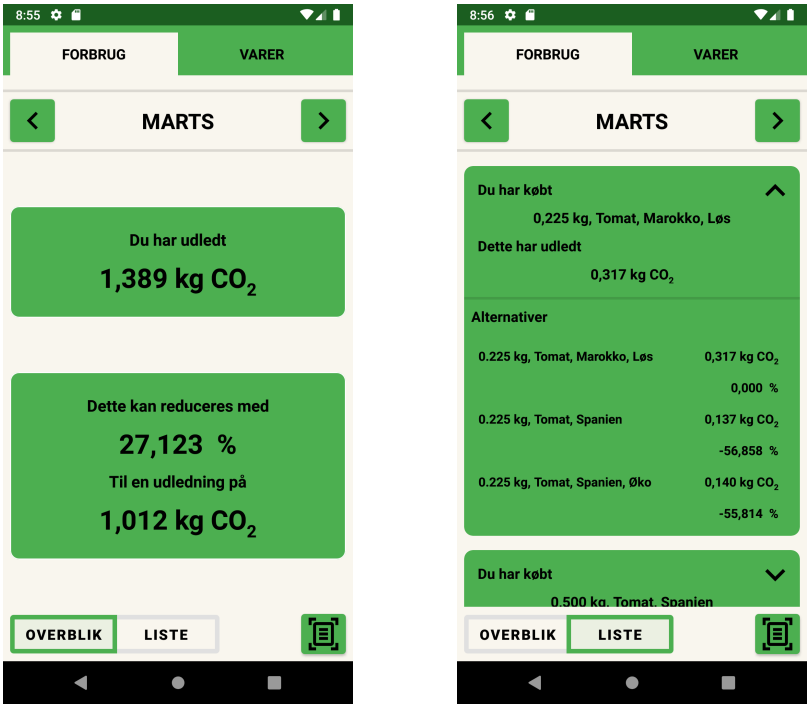
The focus of this project is to incorporate elements into the "FoodEmissions" app that motivate reflection and understanding to help behavioural change by solving the initial problem below:

How can a mobile application help users understand and reflect on their carbon footprint in order to motivate them towards more sustainable food consumption behaviour?

Our solution to the initial problem will be guided by the findings of the "FoodEmissions" study, which are described further in Section 1.1. Afterwards, Section 1.2 will look into other research that helps us answer the initial problem.

1.1 Lessons Learned From Previous Study

As previously stated, this project will continue the development of the "FoodEmissions" app, which two of the authors developed during the fall semester of 2021 [1]. The app was evaluated through a field study which focused on the purchase of select vegetables. In this section, we will describe the original app in more detail as well as the main takeaways from the study, which will guide further development of the app.



(a) The carbon footprint representation from the original implementation of the "FoodEmissions" app.

(b) The purchase list design of the original implementation of the "FoodEmissions" app.

Figure 1.1: The original design of the "FoodEmissions" app.

The purpose of the app was to communicate the sustainability of different product variants to users and motivate them to make more sustainable choices when shopping for food. The user would scan their receipt using the app which would then extract purchases from the receipt and prompt the user to fill in any data that couldn't be extracted (e.g. country of origin). Then the carbon footprint would be calculated and displayed to the user. The user was also able to view a list of all their purchases for each month, their respective carbon footprints and a list of alternatives. As shown in Figure 1.1, the UI relied on a number-based representation consisting of carbon footprints and percentages that compared different carbon footprints.

Once the app had been developed, a one-week study was launched. Data was collected in the form of a questionnaire, screen and audio recordings of app interactions, and an interview. From the analysis of this data, we learned the following lessons:

Lesson 1: Carbon footprints mean nothing without any context.

Lesson 2: Learning and change of habits happen slowly over time.

Lesson 3: Different users have different levels of commitment.

Lesson 4: Scanning and use of the app should be as simple as possible.

Lesson 1 is an important issue as understanding the carbon footprint is essential for the user to be able to change their behaviour. All of the previous participants stated that without understanding the CO_2 values it is hard to understand the environmental impact of the different products and there is therefore little to no motivation to change their behaviour. For example, if you bought some meat that emits 30 kg CO_2, how big is then the environmental impact of the meat? Is this a high value or a low value? If you get the same amount in vegetables it could be 1 kg CO2 and now the meat seems extremely environmentally harmful, but is this still a high value compared to other CO_2 sources such as a car or washing machine? Therefore it is important to make the users understand CO_2 in order to inspire reflections on their purchases.

Lesson 2 was mentioned by several of the participants in that their various habits had changed slowly over the years as they gained more knowledge. An example was a participant who previously bought caged eggs, but as he learnt more about animal welfare and conditions, he is now buying free range or organic eggs. Similar conclusions were reached by [9] and [10].

Lesson 3 relates to the different levels of commitment the participants had to buying sustainable products. Some participants prioritised buying Danish products and expressed reluctance in compromising this principle for the sake of lowering their CO_2 emissions, while others didn't care about where the food came from as long as it was from Europe. Another participant only looked at other factors if the prices of different product variants were close enough. Some also had specific items they cared more about, like eggs, were they always bought free-range or organic eggs as opposed to cage-free eggs. All these principles has to be leveraged and prioritised when shopping and choosing sustainable products. The users therefore have different levels of commitment for how much they want to change their behaviour to make sustainable choices. Thus, it is important not to push the users out of their

comfort zones too much when giving them alternative shopping suggestions, so the app is also usable by people with a lower or medium level of commitment.

Lesson 4 concerns how the inconvenience of scanning the receipt and inputting missing data affected the way users interacted with the rest of the app. Usually, the weight and country of a product can't be extracted from the receipt and the app therefore required the user to input this data. In the best-case scenario, this required the user to check the packaging of the product. In the worst-case scenario, the user would have to weigh the products and look up information on the retailer's website. We observed a lot of variation between how much effort users were willing to put into ensuring the reliability of the data. Two were willing to do what was required even in the worst-case scenario, while one was unwilling to commit to even the best-case scenario and simply guessed the values, compromising the reliability of the data. Two users only scanned small receipts and therefore had to input less data during each interaction. The third user scanned a very long receipt and consequently had to spent a long time inputting data. Due to the limited number of products in the app's database, users would also have to delete many scanned items as they had no match in the database. Naturally, the severity of this problem grew proportionally to the length of the receipt. The inconvenience and frustration caused by this process, resulted in the third user not really interacting with the rest of the app.

1.2 Motivating change Through Understanding and Reflection

In order to change the behaviour of users, the "FoodEmissions" app aimed to educate users of the sustainability of their food consumption by calculating their carbon footprint and the carbon footprints of the products they buy. It also suggested more sustainable alternatives to their purchases but as mentioned, we found that the "FoodEmissions" app failed to motivate the users to change their behaviour. As stated in Lesson 1, users attributed their lack of motivation to a lack of understanding w.r.t. their carbon footprint. This would indicate that the reason the approach didn't work is that the education is insufficient or poorly taught. This take is backed by other research such as [11] and [12], which finds dietary habits to be improved by more education on the subject.

How do we then improve the users understanding of their carbon footprint? According to Lesson 1, the answer is to provide context, which we also see other carbon footprinting applications do. However, as described in Lesson 4 understanding can also be obstructed by the inputting of data being too cumbersome. One way to mitigate this issue is to expand the database to include more products. *Including More Products* will look into how the database should be expanded. Afterwards, *Providing the Context* will describe how to provide context for the carbon footprint in more detail, with *Visualizing the Carbon Footprint* describing how it is possible to design visualizations that makes the carbon footprint more understandable. Finally, *Educational Games* examines different approaches for how the application can improve at teaching the users by using games.

Including More Products

As described in relation to Lesson 4, the process of inputting data into the "FoodEmissions" app caused frustration to the point where one user didn't interact with the rest of the app at all. One of the ways to mitigate this is to reduce the amount of purchases without matches in the database by including more products in it.

For the "FoodEmissions" app, we chose to focus on fruits and vegetables because variants of these products differ from each other in all possible ways (i.e. organic, packaged and country). The selection of products had to be limited as we had to manually fill the database with the product variants available in Føtex within a limited time frame. Since then Føtex has made their assortment available through their website [13], which allows us to automate the process to a higher degree.

An obvious first step is to add all other fruits and vegetables to the database. For the next step, we can look to the official diet guidelines of The Danish Veterinary and Food Administration, which was updated in 2021 to take account for climate impact as well as health [14]. The two first guidelines concerns the intake of fruits, vegetables and other vegan foods such as legumes. The third advises consumers to eat less meat, especially red meat, while eating more fish and legumes. These points also appear in among the top guidelines from madpyramiden.dk, which focus solely on reducing the climate impact of food consumption [15].

Based on these guidelines, we will expand the database with meat products as well as alternative products such as legumes. Although in order to have the intended effect, the alternatives for these products would have to function differently than fruits and vegetables, which only show product variants of the same product. This change may, however, be in conflict with Lesson 3, which will have to be considered when it is designed.

Providing the Context

As stated in the initial problem, our goal is to help consumers understand the carbon footprint of their food consumption. As stated by Lesson 1, the "FoodEmissions" app failed to provide the context needed for the user to understand their carbon footprint. In this section, we will look into what this context can consist of.

The "CO2Food" app [16], compares the carbon footprint of the user to the average carbon footprint for people in similar living situations. Comparing to the social norm has been shown to be a catalyst for behaviour change both generally [17] and in relation to sustainable food consumption [18]. The carbon calculator app, "Creen", which uses data from Internet of Things (IoT) devices to estimate the carbon footprint of the user's energy consumption, also compares the carbon footprint of the user to the national average [19]. A field study of the app showed that most users experienced increased awareness of their carbon footprints and that one participant (out of 8) expressed joy when their emissions where lower than the average.

Comparing the carbon footprint to some kind of standard would work towards solving our initial problem, as it would help the user gain an understanding of when their carbon footprint

is too high. However, in this context there are some issues with using social norms to support behaviour change. One is the need of data to figure out what the social norm is. Another, which is also relevant in the context of the "CO2Food" app, is that the social norm might not be the ideal to strive for. The Danish effort towards reducing the average meat consumption, for instance, lags behind that of other EU countries - especially with regards to beef [20].

An alternative could be to compare the user's carbon footprint to that of a recommended sustainable diet. The Mediterranean diet is touted as being sustainable for both health and environment [21]. Another option is to use the diet recommendation from the Lancet commission [22], which is designed to be healthy and environmentally sustainable as well. This proposed diet is shown in Figure 1.2.

An advantage of the Lancet's diet, compared to the Mediterranean diet, is that it is very detailed with regards to quantities of each food category, which will make it much easier to calculate a recommended carbon footprint. Another possible source is "Den Nationale Kosthåndbog" [23], which is even more specific regarding what a diet can consist of on a daily basis (e.g. specifying the type of chicken meat). This means that we have to make fewer decisions regarding which products from the different product categories, we want to base the carbon footprint on (e.g. ground chicken vs chicken breast) when calculating their carbon footprint. The diet from Figure 1.2 emits 2.1 kg CO_2 per day, while the one from "Den Nationale Kosthåndbog" emits 1.5 kg.

However, there is little point in telling the user when their carbon footprint exceeds the recommended level, if the user has no way of seeing why their carbon footprint is too high. The diet from Figure 1.2 makes it possible to calculate a target emission for each product category, which would help users pinpoint categories, where their consumption is too high. Additionally, the positive behaviour changing effects of comparing consumption to social norms would hopefully also be applied to each individual product category. One concern regarding transferring the effects of comparing with social norms to comparing with a recommendation, is that the recommendation may be too strict. For instance, Danes were estimated to consume 142 grams of meat per day [24] while the recommendation from Figure 1.2 is 43 grams daily. Some users may find this standard to be unfair and hard to follow. One of the takeaways from [9], is that it is important to respect people's understanding of what constitutes "proper food". According to [20], 45 % of Danes consider meat to be a part of what they consider a complete meal, so the standard proposed in Figure 1.2 may challenge the user's conception of a proper meal too much.

Visualizing the Carbon Footprint

In this section, we will look into how to visualize the carbon footprint in order to improve the user's understanding of it. One of the design guidelines proposed by [10] states:

"Use easily understandable visualizations for complex information while ensuring transparency"

However, what constitutes an "easily understandable" visualization? "CO2Food" [16] compares the carbon footprint to kilometers driven in a car, which we deliberately avoided in the "FoodEmissions" app, as we didn't personally feel that it created much of an understanding.

	Macronutrient intake (possible range), g/day	Caloric intake, kcal/day
Whole grains*		
Rice, wheat, corn, and other†	232 (total gains 0–60% of energy)	811
Tubers or starchy vegetables		
Potatoes and cassava	50 (0–100)	39
Vegetables		
All vegetables	300 (200–600)	..
Dark green vegetables	100	23
Red and orange vegetables	100	30
Other vegetables	100	25
Fruits		
All fruit	200 (100–300)	126
Dairy foods		
Whole milk or derivative equivalents (eg, cheese)	250 (0–500)	153
Protein sources‡		
Beef and lamb	7 (0–14)	15
Pork	7 (0–14)	15
Chicken and other poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish§	28 (0–100)	40
Legumes		
Dry beans, lentils, and peas*	50 (0–100)	172
Soy foods	25 (0–50)	112
Peanuts	25 (0–75)	142
Tree nuts	25	149
Added fats		
Palm oil	6·8 (0–6·8)	60
Unsaturated oils¶	40 (20–80)	354
Dairy fats (included in milk)	0	0
Lard or tallow||	5 (0–5)	36
Added sugars		
All sweeteners	31 (0–31)	120

For an individual, an optimal energy intake to maintain a healthy weight will depend on body size and level of physical activity. Processing of foods such as partial hydrogenation of oils, refining of grains, and addition of salt and preservatives can substantially affect health but is not addressed in this table. *Wheat, rice, dry beans, and lentils are dry, raw. †Mix and amount of grains can vary to maintain isocaloric intake. ‡Beef and lamb are exchangeable with pork and vice versa. Chicken and other poultry is exchangeable with eggs, fish, or plant protein sources. Legumes, peanuts, tree nuts, seeds, and soy are interchangeable. §Seafood consist of fish and shellfish (eg, mussels and shrimps) and originate from both capture and from farming. Although seafood is a highly diverse group that contains both animals and plants, the focus of this report is solely on animals. ¶Unsaturated oils are 20% each of olive, soybean, rapeseed, sunflower, and peanut oil. ||Some lard or tallow are optional in instances when pigs or cattle are consumed.

Table 1: **Healthy reference diet, with possible ranges, for an intake of 2500 kcal/day**

Figure 1.2: The recommended diet for health and environmental sustainability from [22].

However, during the field study interviews, it came up as a possible solution to the users' inability to understand their carbon footprint. A study of the effects of an app similar to the "CO2Food" app, which depicts the carbon footprint in the same way, showed positive results with a decrease in the users' food emissions [25]. An alternative unit of measurement for the carbon footprint is demonstrated by "Creen" [19]. Similarly to us, they concluded in previous studies that the standard unit of measurement for the carbon footprint (tons of CO_2) is hard to understand for users. In order to overcome this, they opted to represent it as the number of trees needed to offset the footprint. They also use colors to signal, whether the carbon footprint is lower (green) or higher (red) than the national average.

Another app called "Smiling Earth" attempts to create an emotional attachment between the user and the app, while simultaneously showing the impact of the user's carbon footprint based on their energy and transport consumption [26]. For this, they use an image of Earth with a smiley face that varies depending on the carbon footprint. The higher the carbon footprint is, the unhappier the smiley is. At the worst point, the smiley is dead. A study of the app elicited positive results. The whole point of the design is to elicit a emotional response from the user, which fits well with a suggestion by one of the participants of the "FoodEmissions" study about implementing elements that provoked positive or negative emotions depending on the sustainability of the user's food consumption. However, other studies caution the use of negative emotions, stating that intense negative emotional states should be avoided [27], but that inducing more subtle negative emotions can be effective for motivating sustainable behaviour.

Guilt is shown to be an efficient emotion in this regard. The feeling of guilt should be induced subtly, as it can otherwise backfire. [28] describes a study that exemplifies this: the effect of two Fairtrade tea ads, one that explicitly shamed participants for buying non-Fairtrade products and one that didn't, were compared. The ad with explicit guilting was less efficient at getting consumers to prefer the Fairtrade tea and actually seemed to have the opposite effect.

[27] also highlights the importance of positive emotions to motivate behaviour. An advantage of the emoji visualization of "Smiling Earth" is that emojis can invoke both, depending on the particular emoji used [29].

The visualization used by "Deedster", an app which calculates the carbon footprint across multiple dimensions including food, relies primarily on the comparison to social norms to visualize the carbon footprint [30]. The carbon footprint and the social norms are visualized in a radar chart, where the areas are filled. However, it seems unwise to only visualize the carbon footprint together with a standard, if the standard being compared to is hard to live up to, which would be the case with the diet from Figure 1.2.

But it does present the question of how to visualize the carbon footprint together with the standard. Different apps use different approaches; "Creen" relies on color cues (text is green when lower than average) and the user's ability to compare numbers, while "CO2Food" and "Smiling Earth" use bar charts and graphs. The method of "Deedster" has the advantage of being able to compare several dimensions (e.g. food, transportation, energy etc.) with one

visualization. However, in this project we have limited ourselves to food consumption, so for the total carbon footprint, this is irrelevant, but it could be useful for comparing different product categories to the standard. One issue in relation to this, is that a radar chart representation makes it more difficult to compare the categories to each other. Comparing the categories could be useful for teaching consumers about the impact of one category compared to another [31].

Educational Games

An education game are game which are intentionally designed for education or games which have educational values[32]. Educational games vary from simple games like "Teach your monster"[33], where you teach your monster to read and do math, to more complex games like "CyberCIEGE"[34], where you play as a cyber security firm who has to operate servers and protect them from cyber attacks. Making a game similar to either of these would require more time than there is available for making a game during this project. The game we would make would therefore have to be very simple for it to be feasible for our project. Some educational games that fit under this is the "Higher or Lower" game[35], where the player has to guess if one website has more google searches than another and thereby teach you what websites are most popular, or "Stop the clock"[36], where the player gets a time and then has to stop the clock when it reaches the time. To use the "Higher or Lower" game in our app, the websites could be replaced with the player's CO_2 usage, and then they would have to guess if that was higher or lower then for example driving 5 km in a car or train. For the "Stop the clock" game the clock would have kg CO_2 instead of time. The players would get a product and then have to stop the "clock" when it lands on the correct kg CO_2.

"Deedster" [30] is an example of a carbon footprinting app that uses quizzes to teach their users about sustainable behaviour (e.g. how to recycle certain types of packaging). It could also be an option for our solution to mimic this and have the user guess how high a certain product's carbon footprint is. Or perhaps questions that teach them about the CO_2 impact of green house cultivation compared to field cultivation.

Games are closely related to gamification which is implementing game elements like badges, points and levels into a task or website[37]. Gamification is the act of adding game elements to contexts that normally don't use it. Gamification is usually understood by using the self-determination-theory (SDT). SDT states that there are two types of engagement; intrinsic and extrinsic motivation. Intrinsic is doing something because the task itself is enjoyable to do, while extrinsic is doing something you gain an additional outcome, like a reward or fulfilling an obligation. SDT also states that intrinsic fulfilled three basic psychological needs[38];

Needs 1: Competence, which is feeling capable of something.

Needs 2: Autonomy, which is feeling free to choose something yourself.

Needs 3: Relatedness, which is feeling connected with others.

By making the app fun or rewarding, we hope to motivate the users to use it and they there-

fore are more likely to reflect on their food behaviour. While the full effect of gamification is yet to be determined a lot of the current research indicate that it has a positive effect depending on the application [39][40]. Some research have looked into applying gamification to preventing climate change, but little attention have been given to gamification in food related areas[41].

An example of gamification is the Duolingo app that teaches languages by having the user answer questions, but everything around the questions is gamification elements like levels and points[42] which is an extrinsic motivation. Both games and gamification has been shown to have a positive influence on learning and it would be beneficial for our application to implement either a game, gamification or maybe both to improve learning[37][43].

Gamification could be combined with a game by showing badges, high score or level at the front page to encourage playing the game and thereby have a focus on encouraging learning. This could be done by getting a score for each question similar to the "Higher or Lower" game or Duolingo app. This would possibly encourage the user to reach for a better highscore by playing multiple times. Another solution would be to gain badges based on solving different tasks or goals. An example could be to take the quizzes from "Deedster" and give badges for completing certain sets of quizzes or for finishing a certain amount of quizzes. The same principles could be applied to gaining levels.

1.3 Problem statement

In Section 1.1, we looked at the various lessons we learnt from our work with the "FoodEmissions" app while in Section 1.2, we discussed various ways of solving the initial problem based on Lesson 1 and Lesson 4. We discussed expanding the database with meat and meat alternatives. We also discussed comparing the user's carbon footprint to a standard - either a social norm or a recommended diet - and how to visualize this comparison. Furthermore, we discussed possible visualizations of the carbon footprint itself, where we touched upon using emojis to express how bad the carbon footprint is and measuring the carbon footprint in other units, like km driven in car, which the user may have a better understanding of. Finally, we discussed enhancing learning by introducing a game or gamification elements.

Based on the initial problem statement, the lessons in Section 1.1 and the discussions in Section 1.2, we form the following problem statement:

How can we develop an app that helps users understand their carbon footprint and reflect on their food consumption choices?

- How can we use visualisations to help users understand and reflect on the carbon footprint of their food consumption?
- How can we use a game and gamification to help users understand and reflect on the carbon footprint of their food consumption?
- How can we include meat and meat alternatives in the app?

Chapter 2

Design

In this chapter, we describe the design of our application. Section 2.1 states the application's requirements, while Section 2.2, 2.3 and 2.4 describe the design of the overall architecture, the database and the user interface.

2.1 Requirements

In this section, we will describe the requirements of the app. The app is based on the "FoodEmissions" app and will reuse its architecture as well as some of its features. Like "FoodEmissions", the new app will show the total carbon footprint of the user as well as the carbon footprint of each individual purchase. The feature to be recommended sustainable alternatives for each purchase will also be included. Other than these base features that "FoodEmissions" also had, the new app will have additional features that aim to incorporate the lessons from Section 1.1. These features are defined by the following requirements:

Requirement 1: Use bar charts and graphs to compare the user's carbon footprint to that of a recommended diet as described in *Providing the Context* and *Visualizing the Carbon Footprint*.

Requirement 2: Visualization that relates CO_2 to common daily activities like hours or km driven in a car as described in *Visualizing the Carbon Footprint*.

Requirement 3: Use smileys to communicate how sustainable a purchase and its alternatives is to the user as described in *Visualizing the Carbon Footprint*.

Requirement 4: Incorporate gamification elements with a simple game to better help users learn and motivate them to continuously use the app as described in *Educational Games*.

Requirement 5: Implement a new meat and meat alternatives product category where it is possible to see alternatives across products in the category as described in *Including More Products*.

Requirement 6: Automatically input default values when scanning the receipt or when users changes a item's product type to simplify the scanning of purchases as described by Lesson 4.

Requirement 1

From Lesson 1 in Lessons Learned From Previous Study, we learned that the carbon footprint has to be put into some kind of context in order to be meaningful to the user. In Motivating change Through Understanding and Reflection, we described different suggestions of how to provide this context. We have decided to use recommended diets for comparison rather than the national average. This decision is based on a lack of data to calculate the national average

and a wish to challenge the user to see, how they react to it. As mentioned in Motivating change Through Understanding and Reflection, the user's concept of a proper meal shouldn't be challenged too much. Using the recommended diet for comparison will reveal whether adhering to that diet is too much of a challenge. We will compare the total carbon footprint to the more specific diet from [23], as this is the most challenging. The carbon footprint of each individual product category (see also Requirement 5) will be compared to an ideal based on the more general diet from [22].

We opted to use bar charts and graphs rather than a radar chart due to the disadvantages described in Motivating change Through Understanding and Reflection, as being able to compare the carbon footprint across product categories will visualise to users how unsustainable one category is compared to another.

Requirement 2

As mentioned in Lessons Learned From Previous Study, the "FoodEmission" app didn't inspire any reflections in the participants because of a lack of context. In Motivating change Through Understanding and Reflection, we discussed how visualisations can improve user understanding of the context and how in order to motivate users, visualisations are needed to convey their consumption in a way they are able to understand.

Last semester we made various illustrations that would help the users understand their CO_2 usage, but after initial feedback we decide not to use them since they where too complex and hard to comprehend (the illustrations can be found in last semesters report [1]). The illustrations also focus on goals other then aiding the understanding of the carbon footprint, which is the focus of this project. This semester we examined other work in *Visualizing the Carbon Footprint* where they compared CO_2 to kms driven by a car and to the number of trees needed to offset the carbon footprint. We therefore decided to adopt using common items such as kms driven by car or public transportation to make the CO_2 usage relatable. We also personally like the comparison to trees, although we find the use in [19] to be hard to understand. Therefore, we will compare to the number of days it takes for a tree to absorb the emission. We will in Section 2.4 discuss how this was designed visually.

Requirement 3

From Lesson 1, we found that better visualisations is needed to motivate users and in Visualizing the Carbon Footprint we discussed other work which used smileys to motivate users.

As mentioned in Motivating change Through Understanding and Reflection, smileys provoke a emotional response, which can motivate users to change their behaviour and also validate their sustainable choices. The smiley rating is well-known to Danish consumers as more and more businesses ask their customers for a smiley-rating after their visit [44]. The smiley rating is also used by the Danish Veterinary and Food Administration with the "smiley" publication scheme, which is used to indicate the findings of food safety inspections [45]. People in Denmark generally have a lot of trust in the "smiley" scheme. According to a investigation by Consumer Council 88% would definitely or most-likely avoid a restaurant

with a angry smiley[46]. Smileys would therefore be a familiar system to use for Danes.

Smileys will be used in the app to convey if a purchase has a high or low CO_2 emission so the users are able to get an emotional response when seeing which products they bought. The smileys should be defined for the individual product's category, so tomatoes and beef don't influence each others smileys. As an example, if they are grouped together all tomatoes will always have a green smiley, even though you might have picked the worst tomato because meat products have very large emissions compared to tomatoes. This causes any differences between tomato variants to become irrelevant when determining the rating. The meat and meat alternatives category from Requirement 5 would be the biggest category and would have the biggest range of CO_2 emission as it includes both meat and plant products. The smileys will therefore show that most meat have a more harmful effect on the environment than plant-based alternatives.

With the smileys, we hope to motivate the users to change their consumption behaviour by validating good purchases with a happy smiley and invoking subtle feelings of guilt with an angry smiley as described in Section 1.2.

In Section 1.2, we mentioned that the "Smiling Earth" app uses a smiley to visualize the total carbon footprint. However, as we will compare the user's carbon footprint to that of recommended diets (see Requirement 1), which may be hard to live up to, we fear that rating the total carbon footprint with a smiley based on these diets would provoke too many negative emotions. Also, the smiley rating should ideally be based on how many days, the user has bought food for. If we for example calculate the rating based on the weekly consumption and the user shops more than once per week, then the rating might be very positive until the final shopping trip of the week, even though the previous purchases of the week weren't particularly sustainable.

By only applying the smiley rating to purchases, the user will most likely always receive a mix of positive and negative feedback, which will hopefully provoke positive emotions along with more subtle negative emotions. We also feel that rating the purchases is a bit more constructive than rating the total carbon footprint, as we also suggest alternatives to the unsustainable purchases. Even if the user isn't emotionally effected by the smileys, it would still highlight unsustainable purchases to users looking to change their behaviour.

Requirement 4

To tackle the problem from Lesson 1 and Lesson 2, we could inspire reflection and learning through gamification. As mentioned in Educational Games, it is possible to use various types of games or gamification elements to reach a desired effect. We have chosen to go with a quiz similar to the "Higher or Lower" game because it is relatively simple to implement and might help users learn more about their carbon footprint in combination with the visualisations from Requirement 2. We also wanted to include other gamification elements like achievements or levels to motivate the users, but it was cut due to development time constraints. Our variant of the "Higher or Lower" game will instead include a high score to help motivate the users by extrinsic motivation.

Requirement 5

As described by Lesson 4, to make the app more usable for the average shopper there should be more products in the app. In Section 1.2, we discussed which products to expand the database with and decided on meat and meat alternatives. Unlike vegetables it is possible to substitute many meat products with each other. For example a steak could be substituted with a chicken breast or plant-based meat. It would therefore be interesting to have a meat and meat alternatives category, where the alternatives of each product can be any of the products in that category. In this case, plant-based alternatives would almost always be the most sustainable choice. To take into account Lesson 2, Lesson 3 and the lessons from [9] mentioned in Providing the Context, if the user wants to eat meat, then always suggesting a plant-based alternative isn't a good idea. This would also be the case for consistently only suggesting chicken as an alternative to beef. We will ensure that this is accounted for in the continued design of the app.

Requirement 6

The solutions for the issues behind Lesson 4 would be lessened by the application inputting more values automatically. This is also in line with one of the design guidelines in the article, *"Design Guidelines for Assistance Systems Supporting Sustainable Purchase Decisions"*, which is to reduce clicks while keeping the information at a glance[47]. Manually inputting product information, as the original implementation required, creates many clicks.

The app already inputs the values automatically if they can be extracted from the receipt but also if it discovers a product that is already in the database. However in the field study a limited number of products were in the database. The app also saves product variants entered manually by users so they won't have to enter the same product multiple times.

To reduce these interactions, default values could be used to automatically input the loose or unknown product's data if the user doesn't wish to input them. By using default values the precision of the data decreases, which goes against another guideline of [47] about using reliable and trustworthy data, but the benefit of reducing the interactions is higher than the small amount of precision lost. Loose products cause the greatest inconvenience as there is no packaging to read the actual values from, but these products will mainly be fruits and vegetables, which generally have a very low carbon footprint compared to other products. That means the climate consequences the total CO_2 emission represents would not change in any drastic way when using the default values since their impact on the accuracy of the total CO_2 emission is very low.

In order to maintain as much reliability as possible, we should keep displaying the default values as default values until the user actively inputs values. That way we continuously make the user aware that the data may be imprecise and give them the chance to correct it.

2.2 Architecture Design

In this section, we will describe the architecture of the application. The overall architecture can be seen in Figure 2.1 and Figure 2.2 on page 17 and page 18. We have used the model-

view-viewmodel (MVVM) pattern to separate the user interfaces, the views in the figure, with the back-end logic by using the viewModels as interfaces between the front-end and back-end[48]. According to the "Guide to app architecture"[49] from Android, we should use repositories as an abstraction layer between the viewmodels and the models, as well as Data Access Objects (DAOs) as an abstraction layer between the repositories and the database.

The diagram has been split in two with Figure 2.2 extending from the *Question* interface of Figure 2.1. The greyed classes are described in the previous semester's report [1]. We will therefore focus on the new classes and changes made to the architecture.

One of the changes is that we have removed *EmissionView*, since there no longer was a need for the screen it managed and *OverviewView* took over its responsibilities. The *EmissionViewModel* was still kept and is used by the *OverviewView* and *PurchaseView*. Three new view classes have been added that represent the graph, alternative and game interfaces. Each view class is associated with a class in the ViewModels component. The Viewmodel classes provide relevant and shareable variables to the views and update them automatically through data bindings as they are changed. To achieve this, each viewmodel class maintains associations with relevant repositories classes.

Each Repository class is associated with a DAO which queries the database for data. The DAO uses the data from the database to produce the model classes *Trip*, *Purchase*, *StoreItem*, *Product* and *Country*. *Trip* is a newly added class that manages the Purchases into *trip*s, so it in the *PurchaseView* is possible to group them into trips.

A new addition from Section 2.1 is the "Higher or Lower" game where the information is controlled by *QuizMaster*. As can be seen in Figure 2.2, *QuizMaster* manages all the questions, which there currently are four types *TrainQuestion*,*TreeQuestion*,*PlaneQuestion* and *CarQuestion*. The questions are created using the factory pattern, which says that the factory class, in this case *QuestionFactory*, should decide what class to instantiate, which it does based on information from *QuizMaster*. By using the factory pattern, QuizMaster does not need to specify what class to be instantiated with a constructor. The questions have different *QuestionVariant* and each question can contain either one or two variants. The variants also use the factory pattern with *QuestionVariantFactory* creating the *QuestionVariants*. The Enums component is also a part of the Tools component and is used with many of the other classes. There is not shown any connections since it would require a large amount of connections from the enum classes to classes in both Figure 2.1 and Figure 2.2. This makes the already big figures more complex and confusing, so we chose to emit them.

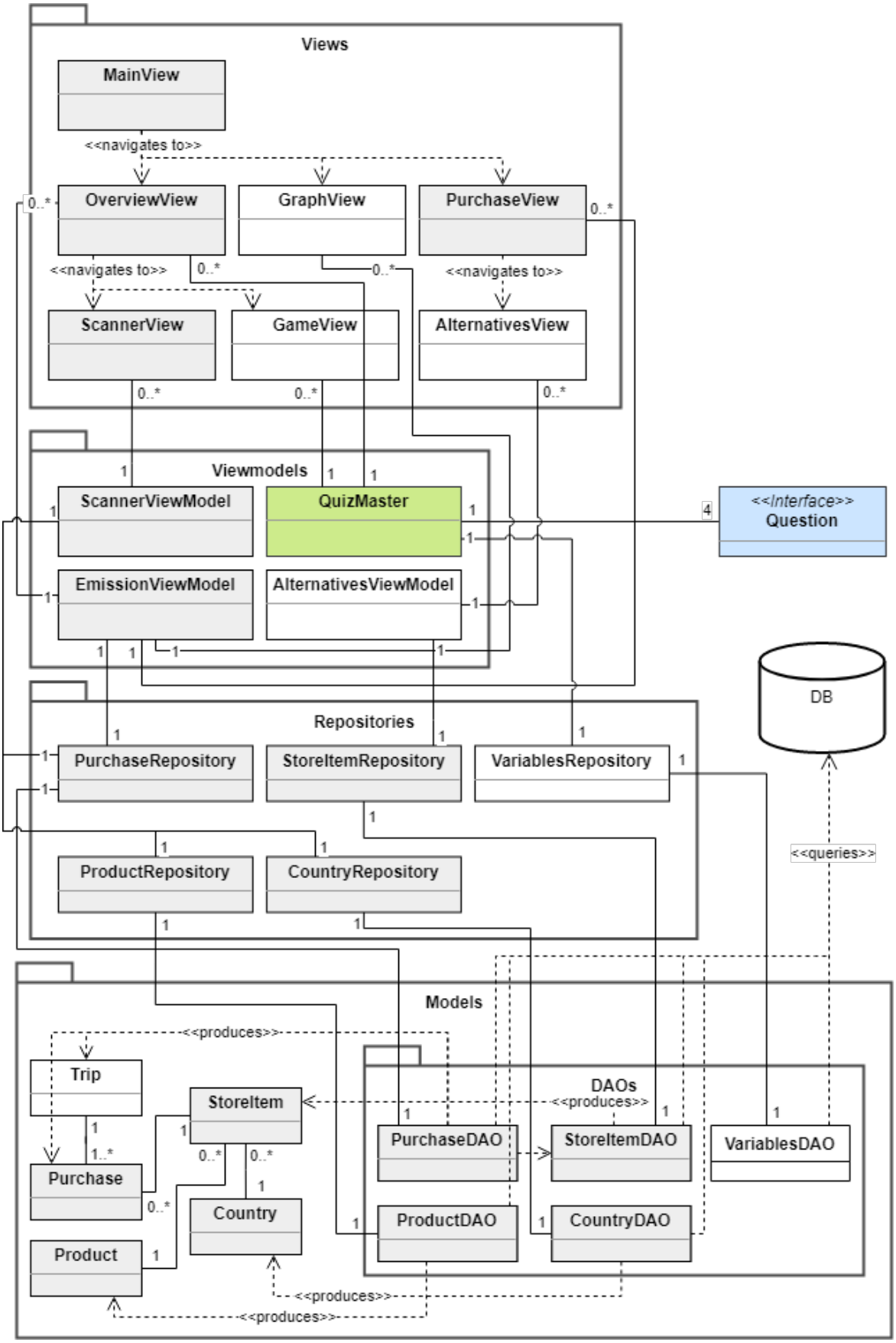


Figure 2.1: Diagram showing the architecture of components Views, Viewmodels, Repositories and Models. Grey classes originate from the previous project and are described in [1]. The shown components connects to the components in Figure 2.2 via the Question interface (marked with green), which is therefore displayed in both diagrams.

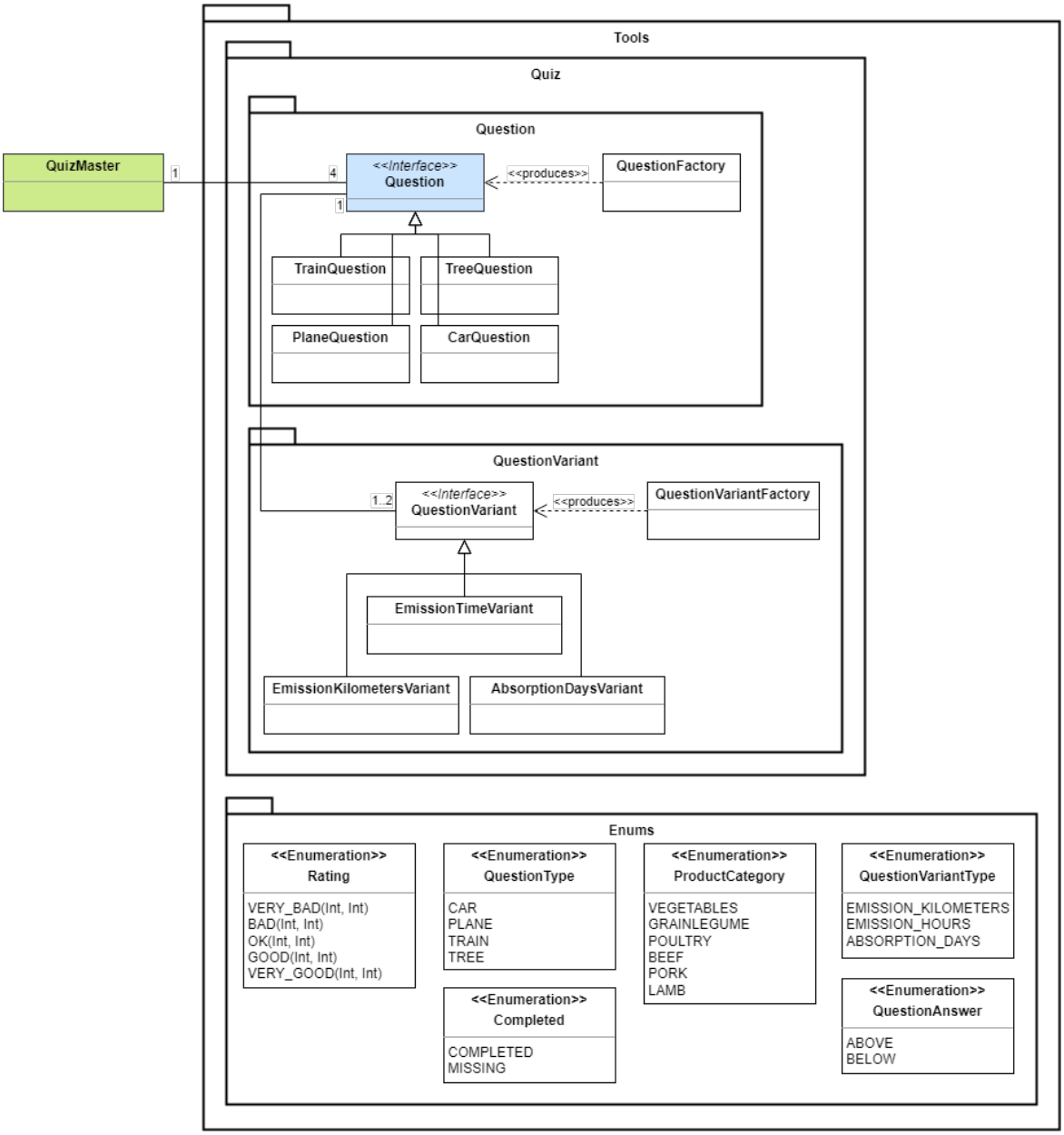


Figure 2.2: Diagram showing the architecture of component Tool which includes the Question, QuestionVariant and Enums components.

2.3 Database Design

We will in this section describe the design of the database, which is based on the design from the previous semester [1].

Figure 2.3 shows the Entity Relationship (ER) diagram and Figure 2.4 the schema of our database. The database has five entities and three relations all connected to STOREITEM. The PRODUCT entity represents the products while the STOREITEM entity represents the different variants of products. Some STOREITEM attributes will be put into the database before the app is launched and others will be gathered when users are inputting their purchases. The app will then be able to remember previously inputted STOREITEMs and use them as proposals if the same text is scanned again.

One of the additions to the database is the PRODUCT attributes *weight* and *countryid* which is used as default values when inputting purchases. To ensure reliability of the data, the default values are stored separately from the STOREITEMs in PRODUCT. That way, we would still be able to use the actual values, should we encounter a user willing to input the correct data for the STOREITEM. The two boolean attributes on the STOREITEM entity, *countryDefault* and *weightDefault*, keeps track of when the weight and country stored in a STOREITEM record are default values, so that we can keep displaying them as default values with the default colour chosen in Section 3.3. Ideally, data about STOREITEMs should be stored in a central server, so that it can be shared between users. That way, if one user is willing to input the actual data, the other users could use it as well, but we had to cut it due to time constraints, and it is not needed to fulfill the requirements.

The VARIABLES entity is the only one not connected to another entity. This is because the VARIABLES entity is used to store the score, which is used to find the highscore, and the boolean *showIcons* that determines if the numbers below the icons should be shown. The entity is therefore not relevant to the other entities. Section 2.4 goes into more detail about when icons will be shown.

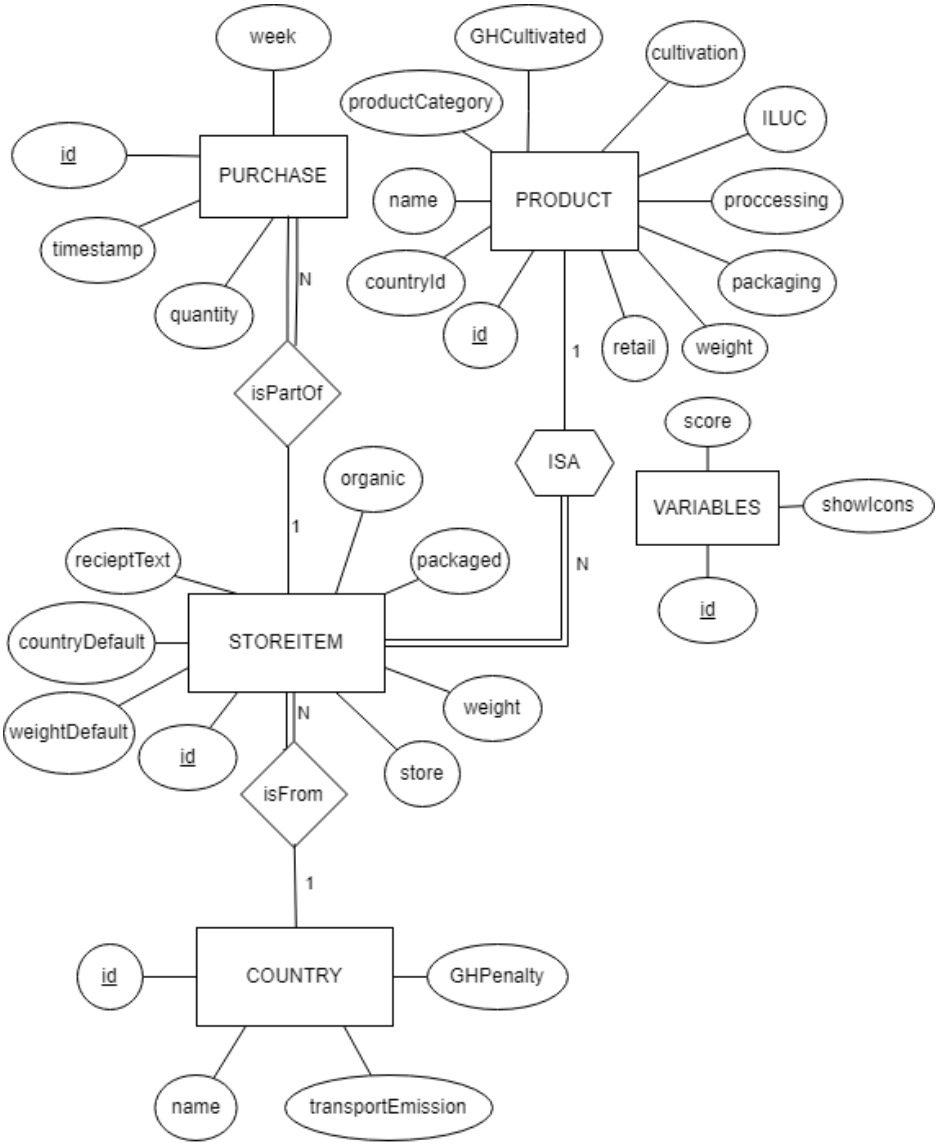


Figure 2.3: ER diagram of our database design.

```
country{[id: integer, name: string, transportEmmission: double,
         GHPenalized: boolean]}

product{[id: integer, name: string, cultivation: double,
         iluc: double, processing: double, packaging: double,
         retail: double, ghCultivated: boolean, countryID: integer,
         weight: double, ProductCategory: integer]}

storeItem{[id: integer, productID -> product, countryID -> country,
           receiptText: string, organic: boolean, packaged: boolean,
           weight: double, store: string, countryDefault: boolean,
           weightDefault: boolean]}

purchase{[id: integer, storeItemID -> storeItem,
           timestamp: timestamp,quantity: integer, week: integer]}

variables{[id: integer, score: integer, showIcons: boolean]}
```

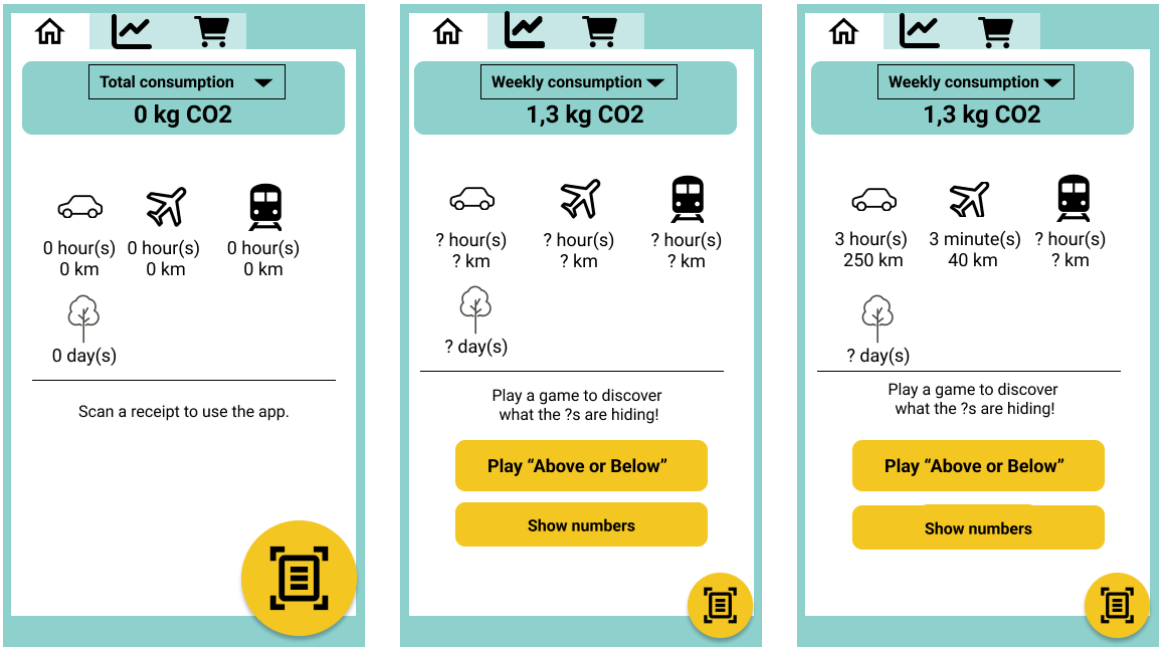
Figure 2.4: The schema of our database design.

2.4 UI Design

In this section we will describe our visualisation designs based on Requirement 2, Requirement 3 and Requirement 4. The prototypes are created in Figma.

Figure 2.5a shows the front page and how it would look the first time the app is used. No receipts have been scanned so all the numbers are set to zero. The buttons for playing the game (as seen on Figure 2.5b) are also hidden. The scan button as seen in the bottom right corner has been made bigger than the other prototypes to make it more noticeable, since it is the first time the user uses the app. The scan button is a floating action button which is meant to stay in the right corner across multiple pages. The "Total Consumption" can be switched to show their weekly consumption.

Figure 2.5b is the screen after items have been scanned. The four icons (car, plane, train and tree) is based on Requirement 2 about making CO_2 more understandable and is not showed initially in order to encourage users to play the game. The play button starts the game and can be seen on Figure 2.7a). In order to accommodate users who don't want to play the game or just want a quick look-up of the numbers, a button to just display the numbers is available. Every time items are scanned the icons' values will be hidden with the question marks to encourage people to play the game.



(a) Front page for when you start the app for the very first time, with no purchases inputted.

(b) This is the front page after items have been scanned. Here the game has not been played, so all the comparisons between the user's consumption and e.g. a car is blocked.

(c) This is the front page after the game has been played. In this case the user only finished two of the four questions so only these numbers are shown.

Figure 2.5

Figure 2.5c shows the front page after a user has either played the game or pressed the "Show numbers" button. Here the four icons is showing their values. The game is designed such that if you don't answer the question it won't display the values. In this case, the user only answered questions about the car and plane before quitting the game.

Figure 2.6 shows the scanning screen. Here each item scanned, is displayed with all the information that could be gained from the receipt. The cards are put inside the "Missing data" area at first, which allows the users to review the cards and possibly change any information. The card can then be moved down to the "Completed" area to clear the view. Each product has a default value for every metric such as country, weight and quantity as defined in Requirement 6. The default country is based on where each product is most commonly produced from denstoreklimadatabase.dk[50]. Weight is based on various averages from websites[51][52]. Quantity is set to one by default.

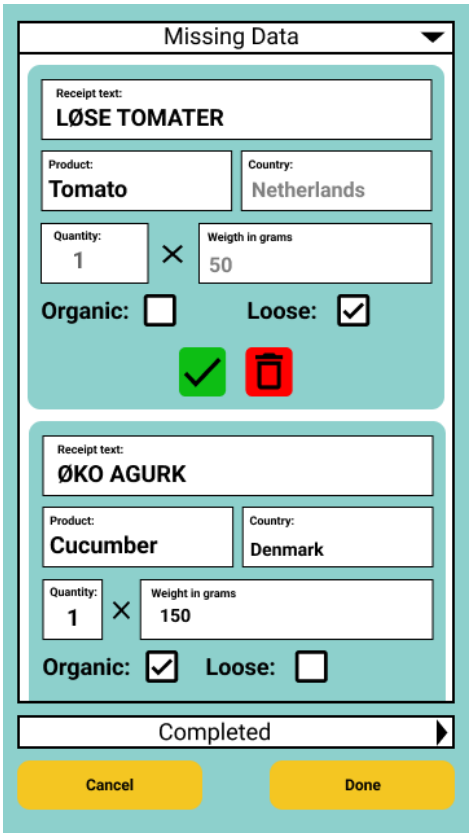
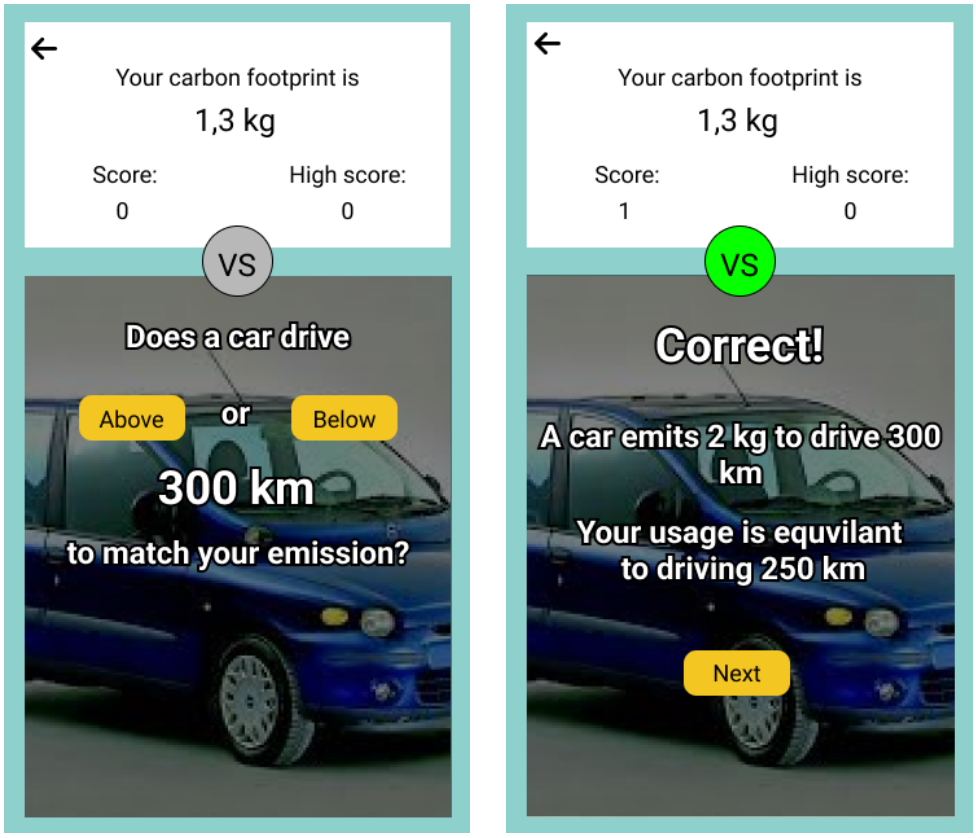


Figure 2.6: This is the screen when filling out the items that were missing information from the receipt. The grey text represents default values that the system have filled in for the respective product. These values can be edited if desired.

Figure 2.7a showcases the game, based on Requirement 4, which is a small quiz with questions regarding the user's CO_2 footprint in relation to the icons as seen on Figure 2.5c. Each

question is formatted so the user has to answer "above" or "below for every question, as seen on the figure. There are 7 questions, two for each transport option and one for the tree. The values for the game is randomly generated and is either higher or lower. The range of the generated numbers is from 1 to twice the actual value of the question. We chose this range because it is wide and there is an equal distribution on either sides of the actual value. If you answer correct you go to Figure 2.7b and if you lose Figure 2.8b.

Figure 2.7b shows the screen when answering a quiz question correctly. Here it tells you the correct values and displays green for guessing correctly. Your score also updates and you can move on to the next game.

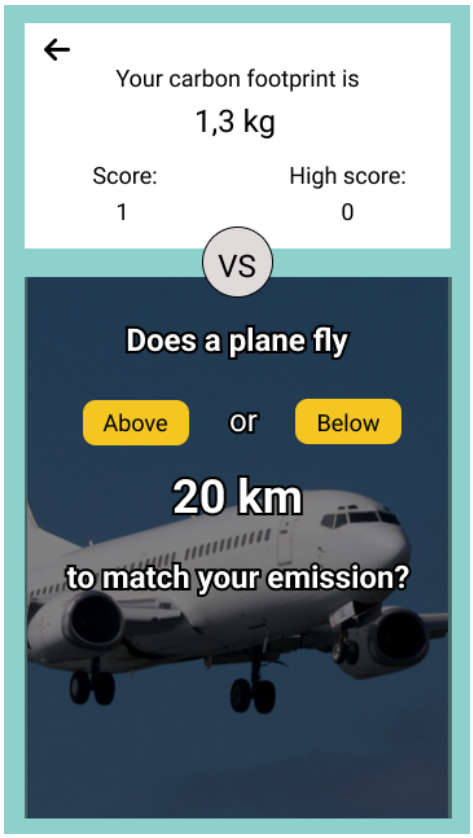


(a) This shows one of the game pages when a question is posed.

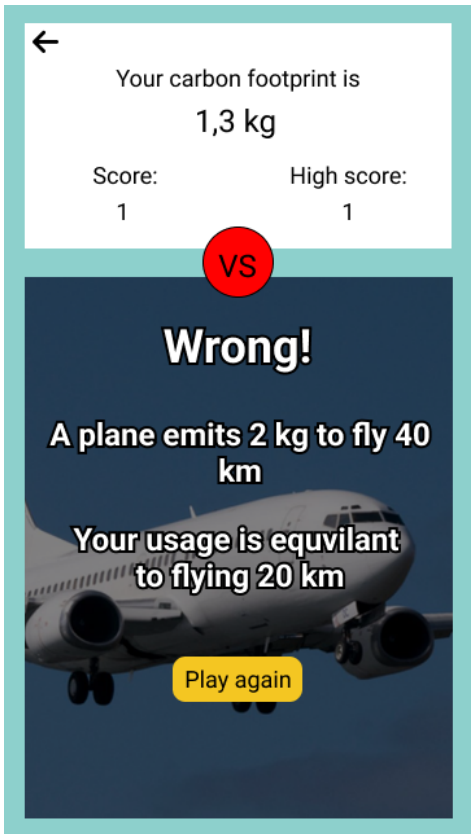
(b) This shows the page when the user answers correctly in the quiz. This updates your score and allows the user to continue with the next game.

Figure 2.7

Figure 2.8a and Figure 2.8b shows the same concept as the previous figures, but Figure 2.8b displays a red color when the user answers a question wrong.



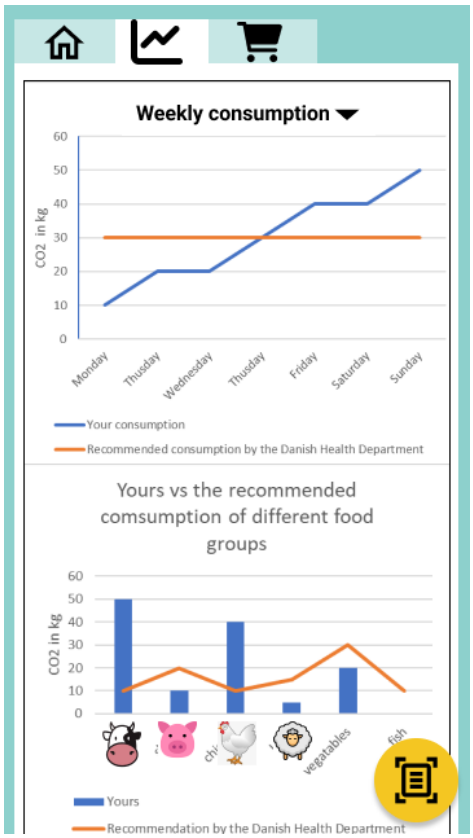
(a) This shows a question from the game. This is similar to Figure 2.7a.



(b) This shows the screen when the user answers a question wrong.

Figure 2.8

Figure 2.9a shows the graphs displaying consumption overviews of the user's data and is based on both Requirement 1 and Requirement 2. The top graph shows the users consumption throughout a week, shown by the blue line and the recommended consumption based on an normal average diet from the Danish Health Department, shown by the red line. The lower graph shows the user's consumption based on the different food categories such as, beef, pork, poultry, lamb and vegetables. The graphs can be changed to show the data over several weeks instead as seen on Figure 2.9b.



(a) This shows the graph page with the users weekly consumption compared to the recommended consumption by the Danish Health Department

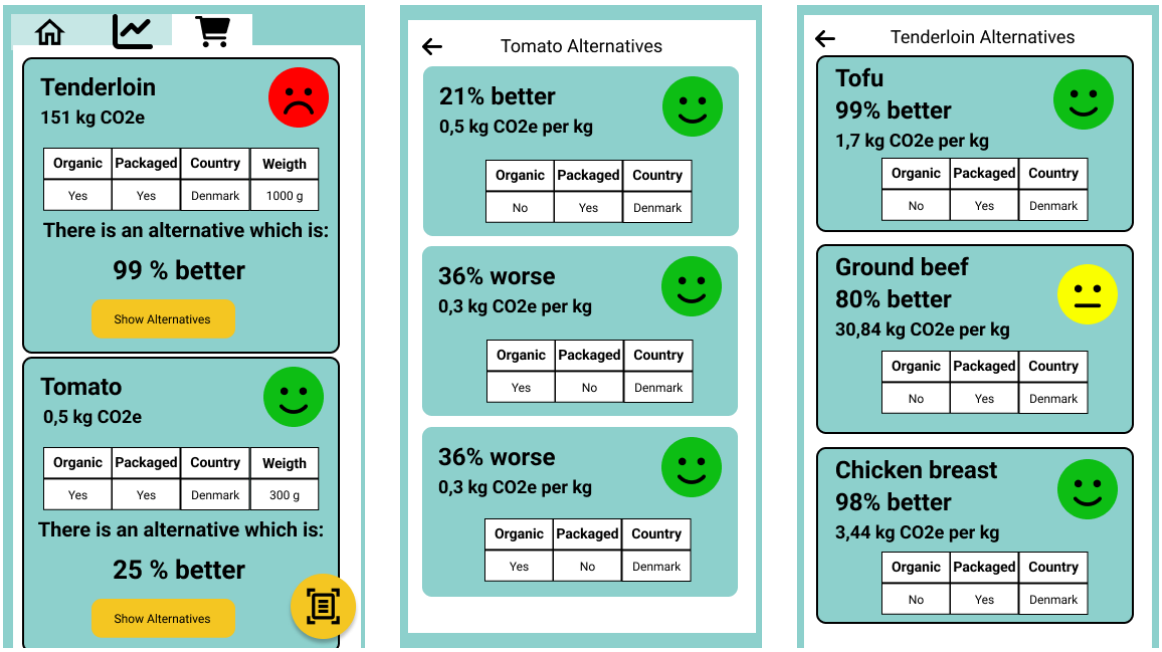
(b) Graph that shows the users weekly consumption compared to a recommendation.

Figure 2.9

Figure 2.10a shows the page with the users purchases and any alternatives. All the different purchases the user has made is displayed here with the different relevant parameters such as CO_2 emission, country of origin, weight and whether it is organic or packaged. Here the smileys, based on Requirement 3, are shown to give a quick indication of how bad a products CO_2 emission is. It also shows the best possible alternative by percentages. The "Show alternatives" button goes to either Figure 2.10b or Figure 2.10c, depending on if it is

a vegetables product or a meat product.

Figure 2.10b shows the screen for fruit and vegetable alternatives. As different fruits and vegetables aren't necessarily interchangeable, this screen simply displays different variants of the same product. Additionally, fruits and vegetables have a small carbon footprint compared to for example beef, so the gain from switching to other products is fairly limited. We do, however, consider different sorts of a species (e.g. cherry, plum, grape tomatoes) to be interchangeable, which is why we simply categorise them as one product. The only factors that differentiates product variants from each other are the country of origin, and whether its organic or packaged. As in Figure 2.10a, it also displays how much better each variant is.



(a) This screen shows the first page when navigating to the alternative screen. On this screen all products the user have bought is shown with their respective information. Here it also shows a smiley based on the products CO_2 emission. Each products tells if there exists a better variant of the product. These can be viewed by pressing the "Show alternatives" button.

(b) This shows the alternative screen for vegatables (here tomatos). This shows any relevant information and how much better the alternative is compared to the one selected. Only alternatives which is better than the original is shown on this screen.

(c) This shows the alternatives for meat products. This is slightly different from the vegetables screen as the name is included due to there being many different types of meat which have very different CO_2 data.

Figure 2.10

The meat and meat alternatives screen works differently than fruits and vegetables as seen in Figure 2.10c as described in Requirement 5. There is a vast difference between meat products, such as chicken breast or beef tenderloin, so it wouldn't make sense to always

display the best three variants, as this would simply show the same variants every time the meat and meat-free alternatives screen is accessed. Furthermore, meat-free products would be favoured, as they tend to have a low carbon footprint, which goes against the principles about not pushing people too far from their comfort zones as described in *Requirement 5*.

Instead the alternatives page will display three items, the first being a vegan product which is better then the purchased product, typically a vegan alternative such as tofu or similar. The second is a better product within the same category such as beef or pork, while the third option shows a better option amongst all meat products except its own category and meat-free alternatives such as tofu. If there is no better products for the second and third option it will fill the rest with first options, so that if you have chosen a product with low carbon footprint like kale it would still display multiple options. This was chosen to include some variance in what is shown to the user, while still trying to push them towards more sustainable products. The variance is important as only showing them meat-free alternatives might turn away specific users as they wouldn't be interested in only meat-free alternatives. This also complies with Requirement 5. A bigger variance of what users see also help user learn about differences between products from different categories.

Chapter 3

Implementation

In this chapter, we will describe some details about how the design from Chapter 2 was implemented. Section 3.1 describes how products were added to the database, while Section 3.2 presents some code snippets that show how the rating system was implemented. Finally, Section 3.3 describes how the UI was implemented, focusing on how the implementation differ from the design in Section 2.4. The language used to implement the app was Kotlin[53].

3.1 Database Implementation

To fill the database with products, so the amount of products that can be matched with default values increases, we created a node.js web crawler that fetched various items from Føtex's webpage. In the previous semester, the database only contained products of the most common vegetables and fruits. For this semester, the products have been expanded to include all vegetables, fruits, meats and legumes to improve the range of products for the users as described in Section 2.1. The product categories were found using "Concitos" database "Den store klimadatabase" [50], a database containing carbon footprints of many different food products. The "Concito" database does not include all categories, so the ones not found were omitted from our database even if they were sold in Føtex.

Figure 3.1 shows the output of the crawler with each pro duct being written as a *insertStoreItem* function call. *insertStoreItem* is a function in the apps database manager, which inserts the product variant into the database, so it can be used as an alternative. This makes a large task of manually inputting the products rather simple, since we can just copy the function call and run them when the app is first run.

```
// And
insertStoreItem(db, "And", "Frankrig", "berberiandebryst frankrig", false, true, 0.3)

// Appelsin
insertStoreItem(db, "Appelsin", "Egypten", "appelsiner egypten", false, , 1 * 0.160)
insertStoreItem(db, "Appelsin", "Grækenland", "appelsiner grekenland", false, , 1 * 0.160)
insertStoreItem(db, "Appelsin", "Italien", "appelsiner oko italien", true, true, 1.0)
insertStoreItem(db, "Appelsin", "Spanien", "appelsiner oko spanien", true, true, 1.0)
insertStoreItem(db, "Appelsin", "Spanien", "appelsiner spanien", false, , 1 * 0.160)
insertStoreItem(db, "Appelsin", "Spanien", "appelsiner spanien", false, true, 2.0)

// Blomme
insertStoreItem(db, "Blomme", "Chile", "blommer chile", false, true, 0.5)
insertStoreItem(db, "Blomme", "Sydafrika", "blommer sydafrika", false, true, 0.5)

// Blåbær
insertStoreItem(db, "Blåbær", "Argentina", "blaber oko argentina", true, true, 0.125)
insertStoreItem(db, "Blåbær", "Chile", "blaber chile", false, true, 0.3)
```

Figure 3.1: This shows the output of the crawler with it sorted into different product categories.

3.2 Smiley Ratings

In this section, we will explain how the rating works when selecting smileys.

The smileys are selected based on the product's CO_2 emission per kg. As the emission becomes higher, the smileys move from the happy green smiley towards the angry red smiley. The smileys can be seen in Figure 3.2. In order to know which smiley to use, we created specific chunks based on the different emissions from all the products. Two different ratings systems for the smileys where developed, one for vegetables and fruit, and one for meat and meat alternatives.

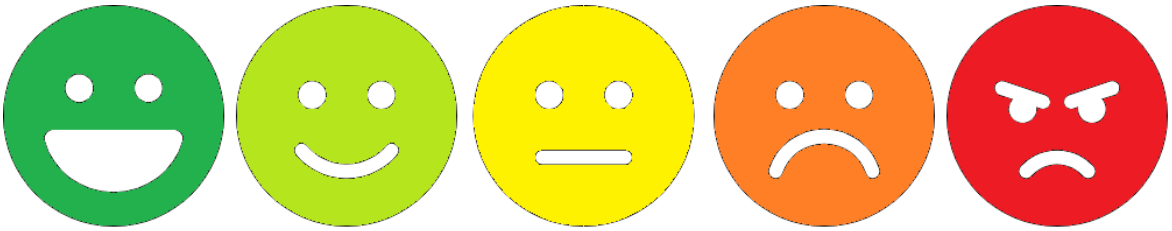


Figure 3.2: This shows the smileys from the ranges Very good, Good, Ok, Bad and Very bad respectively from green to red smiley.

```
1  fun rate(storeItem: StoreItem): Rating {
2      val emission = storeItem.emissionPerKg
3      if (storeItem.product.productCategory ==
4          ProductCategory.VEGETABLES) {
5          return if (storeItem.altEmissions!!.isEmpty()) {
6              Rating.VERY_GOOD
7          } else {
8              val difference = (emission -
9                                storeItem.altEmissions!!.first().second
10                               / emission
11             when {
12                 difference > 0.8 -> Rating.VERY_BAD
13                 difference > 0.6 -> Rating.BAD
14                 difference > 0.4 -> Rating.OK
15                 difference > 0.2 -> Rating.GOOD
16                 else -> Rating.VERY_GOOD
17             }
18         }
19     } else {
20             return when {
21             emission >= 47.8 -> Rating.VERY_BAD
22             emission >= 30.5 -> Rating.BAD
23             emission >= 15.5 -> Rating.OK
24             emission >= 3.1 -> Rating.GOOD
25             else -> Rating.VERY_GOOD
26         }
27     }
28 }
```

Figure 3.3: This shows the code snippet for the functionality that handles rating

For the vegetables we simply calculated the differences between a product's emission and that of its best alternative. This is done on line 7 to 10 in Figure 3.3. *altEmission* contains a sorted list of alternatives with the best being the first element. The elements are pairs containing ints and doubles with the int representing the database id of the alternative and the double representing its CO_2 emission. Depending on how large the difference is in relation to the original storeitem, it gets a different smiley as shown on lines 11 to 16. The split of 20% for each tier of smiley was chosen since we have five smileys and it provided sensible ratings when used. If a product doesn't have any alternatives, it gets the highest score as seen on lines 5 to 6.

```
1  fun rateAlternative(original: StoreItem, alt: StoreItem): Rating {
2      val emissionOriginal = original.emissionPerKg
3      val originalRatingOrdinal = original.rating!!.ordinal
4      val dif = (emissionOriginal - alt.emissionPerKg)
5                  / emissionOriginal
6
7      return when {
8          dif > 0.8 -> Rating.VERY_GOOD
9          dif > 0.6 -> Rating.values()[originalRatingOrdinal + 3]
10         dif > 0.4 -> Rating.values()[originalRatingOrdinal + 2]
11         dif > 0.2 -> Rating.values()[originalRatingOrdinal + 1]
12         else -> original.rating!!
13     }
14 }
```

Figure 3.4: This shows the code snippet for the functionality that handles the non-meat alternative rating

As shown in Figure 3.4, the vegetables alternatives' ratings are calculated based on the rating of the original. As the rating of the original is calculated based on the best alternative, we can see from the difference in emissions and the original's rating, which rating the alternative should have. If, for example, the original has a rating of Very Bad and the difference is 65%, then the alternative should have a rating of Good since it would mean the alternative is 65% lower. As we use enums, we can use the ordinal behind the enum value of the original's rating to calculate the rating of the alternative. Very Bad has ordinal 0 and Good has ordinal 3, so we can calculate the rating of the alternative by adding 3 to the rating of the original. This also works when the original's rating is Bad (ordinal value 1) in which case an alternative with a 65% lower emission should have a rating of Very Good (ordinal value 4).

Rating	% distribution
Very good	5%
Good	25%
Ok	40%
Bad	25%
Very bad	5%

Table 3.1: This table shows the distribution of each smiley

For the meat and meat alternatives the smileys are distributed with fixed CO_2 values as seen on line 21 to 25 in Figure 3.3. To find these values, we first removed the outliers from

the data set using Z-scores[54]. This gave us the lowest and highest emission of 0,6 and 50,6 kg CO_2 respectively. Then we needed to divide this range into 5 parts, one for each smiley. First we tried dividing them equally with 20% for each smiley, but this caused most products to be placed in the 'very good' category(green smiley) or 'good' category(light green smiley). Only the worst beef and lamb products would be placed lower than that. Instead we divided the categories with different distribution as seen in Table 3.1 which gave the values on lines 21 to 25 in Figure 3.3.

3.3 UI Implementation

In this section the implementation of the UI design will be described. This section will only show and discuss screens that have any changes from the designs shown in Section 2.4. All of the implemented designs can be found in the appendix in Section 7.1.

Figure 3.5: This shows the front page after a quiz has been finished. Here the icons text have been colored according to how you answered each quiz.

Figure 3.5 shows the front screen. The main difference from the prototype is that the tabs at the top have been moved to the bottom instead. This was due to some initial feedback from different peers that the bar wasn't particularly aesthetically pleasing, so we instead used the standard android tab layout design and moved it to the bottom. The scanning button was also previously a floating action button present on all screens, but have been changed into a regular button. Initially the floating action button was chosen to have easy access to the scanning functionality, but was changed as it obstructed the view too much on the graph and purchases tabs.

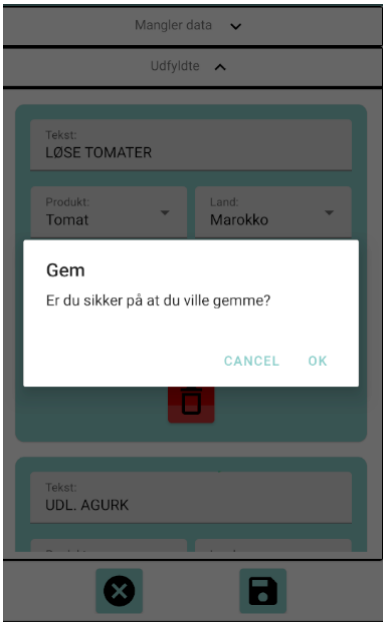


Figure 3.6: This shows the popup that appears when pressing the save button at the bottom of the save. This was added based on feedback from the pilot study. The exit button have a similar message.

Figure 3.6 shows the new popup screen when pressing the save button from the scanning screen. These were added based on feedback from the pilot study so users would not accidentally exit the screen. The exit button has a similar popup.

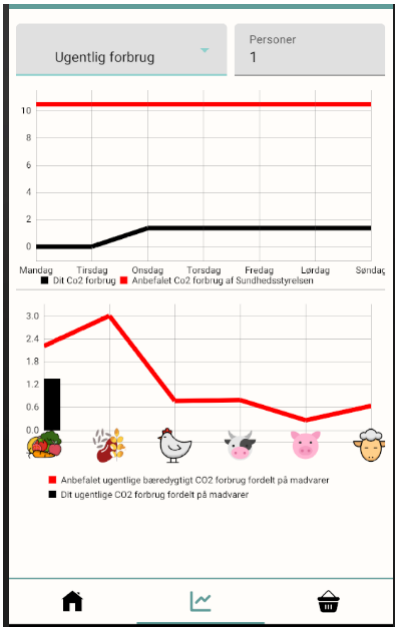


Figure 3.7: This shows the graph. This is largely the same as the prototypes, but now have the option of adding more persons in order to change the recommended diet to fit with multiple persons.

Figure 3.7 shows the graph screen. This is largely the same as before, but has the option of adding multiple people in case you shop for more than one person. This makes the recommended diet (red line) adjust to match the amount of people chosen.

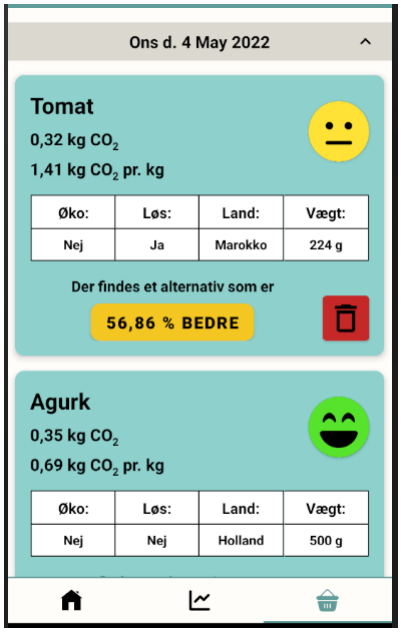


Figure 3.8: This prototype shows the user's purchases. A delete functionality have been added in order to remove any possible errors. Any banner with the date of scanning have also been added to better sort different purchases from each other.

Figure 3.8 shows the purchases screen. Here a delete button have been added to remove any errors made during scanning since one of the participants made a error during scanning but where unable to fix it. A small top bar has also been added for each receipt with the date to group the purchases into shopping trips.

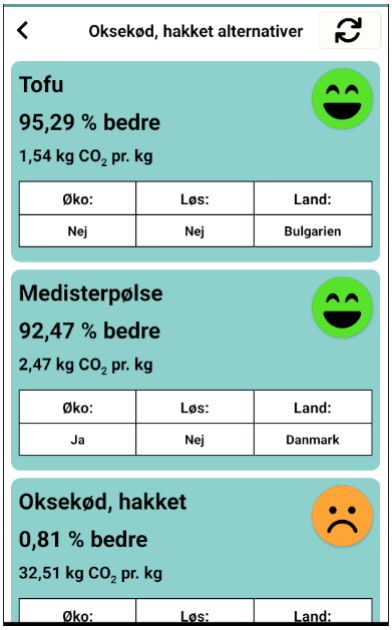


Figure 3.9: This is showing the meat alternatives which is also mostly the same as the prototypes. A small refresh button was added to get a new set of items to display.

Figure 3.9 is largely the same, but we have added a refresh button to display a new set of products. This was added after the pilot study, as the participant found it weird and counter-intuitive that he couldn't see different alternatives without closing and opening the app. While the screen still displays the three items with a different focus (vegan, same products, random non-meat-free products) as described in Section 2.4, the positions of the categories are sorted by emission with the best at the top.

Chapter 4

Field study

In this chapter, we will describe the field study that was conducted to evaluate the "CO2-Mad" app. Section 4.1 will describe the methodology of the study, while Section 4.2 describes the findings.

4.1 Methodology

In this section, we will describe the methodology of our field study. The aim of the field study is to answer the following research questions:

RQ 1: Does the app help users understand their food's carbon footprint?

RQ 2: Does the app motivate users to reflect on their food's carbon footprint and their purchases?

With RQ 1 we hope to uncover whether the different ways we visualize their carbon footprints improve the user's understanding of them. These visualizations includes the bar charts and graphs from Requirement 1, the comparisons from Requirement 2, the smiley ratings from Requirement 3 and the game from Requirement 4. RQ 2 examines whether the visualizations motivates users to reflect on their carbon footprints and purchases as well as whether these reflections caused any changes in their behaviour.

In the following sections, we will describe the procedure of the study, the participants and the pilot study that we conducted to evaluate the study procedure.

Procedure

The study includes two parts; a deployment period and an interview at the end. The deployment period lasted from 29/4/2022 to 25/5/2022 and included three questionnaires, one at the start, one at approximately halfway and a final one in connection with the interview. The questionnaires can be seen in Section 7.3. Prior to the deployment period, users were given instructions that included the duration of study, the overall procedure, when we wanted to conduct the interview, a link to the initial questionnaire and a link to the app in Play Store [55].

A period of nearly a month was chosen so the participants would have time to use the app over a longer period of time since RQ 1 examines if the users learn new information and RQ 2 examines if the users reflect on their behaviour. Even if they reflect on their behaviour it takes time for it to change as stated in Lesson 2 from Section 1.1.

The initial questionnaire includes, besides some basic questions about the participants, questions on how they prioritise and weigh different sustainability aspects against each other. It also includes questions for how much and what thoughts they have about their groceries' carbon footprint. Finally it includes questions for what amount of CO_2 they think 1 kg of minced beef, lamb, pork, chicken and spinach emits. Here we gave a range from less than

1, to more than 50 kg of CO_2 in increments of 5. The midway and final questionnaires ask these same questions again to see how their knowledge have changed over time while using the app.

During the deployment period, we checked in with the participants once a week to hear how it was going, if there were any problems and to inquire about their impressions of the app so far. By the end of the deployment period they were asked for pictures of their receipts, which we had programmed the app to save in their image folder. We instructed them on how to find these if they couldn't locate the files. The pictures where used to determine if the users shopping behaviour changed during the study.

The interview was a semi-structured interview[56] and was conducted in Danish. Semi-structured was selected since it has the flexibility to go off script if necessary. The interview is the primary tool to fulfill the research questions with RQ 1 and RQ 2 being supported by the questionnaires. The results from the questionnaires are used to prompt discussion and ask in-depth questions during the interview. The interview guide can be found in Section 7.2. Three interviews were conducted online through Microsoft Teams (Participant A, B and F) and the rest were conducted in person.

Participants

In Table 4.1 the participants and their relevant information is shown. We had a total of 6 participants of different ages, genders, occupation and how many adults and children they shop for.

Name	Age	Gender	Food sustainability awareness	They shop for	
				Adults	Children
Participant A	25	Female	High	2	0
Participant B	26	Male	High	2	0
Participant C	57	Female	Medium	2	0
Participant D	25	Male	Low	1	0
Participant E	25	Male	Low	1	0
Participant F	38	Male	Low	2	1

Table 4.1: This shows the table of participants including, age, gender, level of food sustainability awareness, occupation and how many they shop for.

The participants are between the age of 25 to 57, with the median and average being 26 and 32,6, respectively. The participants consist of 4 males and 2 females. Most live either with a partner or alone, with only one participant having children. The participants were recruited

from various sites and places. We posted to different Facebook groups, some focused on sustainability and others where groups made for finding test participants in Aalborg. We also recruited from www.forsoegsperson.dk. The research questions do not require a specific type of participant, so we tried to recruit a diverse group of participants. Our only criteria for participants was that they use Android smartphones and mainly shopped at Føtex as the app is only able to scan Føtex's receipts properly. Participant A was recruited from one of the Facebook groups, while participants B to F were recruited from our own networks.

Pilot Study

Before the main study began, we conducted a pilot study with a single participant. This participant was not a part of the main study, and was recruited independently from our network. He was a 30 year old male who shops for three adults. The pilot study was conducted over a week and ended with the interview. Due to the relatively short time frame and late start from the participant, there where only two questionnaires with the second being completed just before the interview.

From the pilot study we added some changes to the app. The first was some small warning popups whenever you save or exit the scanning function to ensure participants doesn't accidental exit the page. We also added the refresh button as described on page 37 in Figure 3.9.

The pilot study primarily tested the procedure and interview guide which generally worked well, despite him not getting the midway questionnaire. There were some changes made to the interview guide and research questions to better reflect what we wanted to learn from our participants. The research questions presented above are after the changes were made.

While the participant generally didn't change their behaviour or made any reflections, he did mention that his partner had seen the angry smiley from one of his purchases and had been fairly guilt ridden because of it to the point of never wanting to buy that particular item again. He also asked if he could keep using the app.

4.2 Findings

In this section, we describe the findings of our study. We collected qualitative data from questionnaires and interviews, as well as quantitative data from questionnaires. The qualitative data was analysed using thematic analysis [57], where codes were generated and assigned through emergent coding [58]. To establish a basic pool of codes and a shared understanding of the process, we coded one interview together, while the remaining five were coded separately. We evaluated each others codes before grouping them into themes together. The following sections will describe the discovered themes and Chapter 5 will discuss them further.

Questionnaires

As mentioned in Section 4.1, we asked participants to fill out a questionnaire at the beginning, the middle and the end of the study. The initial questionnaire asked questions about the

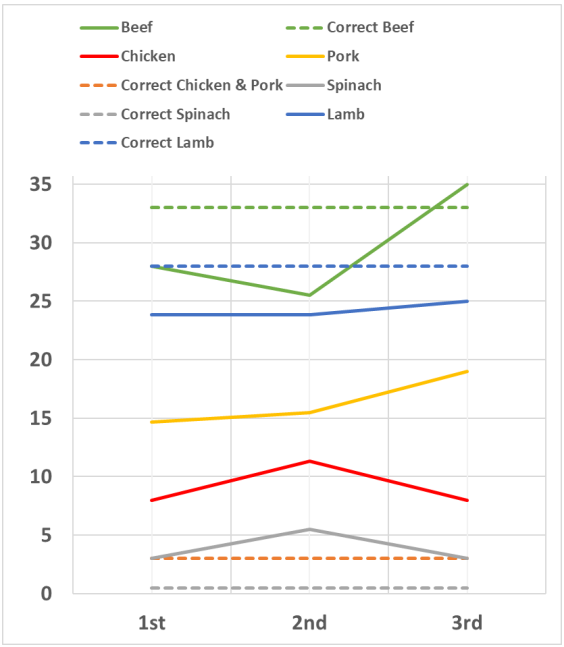
participants' current priorities when choosing products to buy and their general sustainability awareness in relation to their food consumption. The priorities consisted of 9 factors; price, climate impact, organic, country of origin, season, social conditions, health and nutrition, brand and packaging. These factors cover various aspects of shopping factors that consumers prioritize when choosing products which were based on the interviews and knowledge gained from the previous rapport[1]. It also asked them what the carbon footprint of minced beef, lamb, pork, chicken and spinach is. These carbon footprint questions were repeated in the midway and final questionnaire along with a question about how often they had used the app compared to how often they had shopped.

Price was the factor that generally had the highest priority with $\frac{3}{6}$ of participants giving it the highest priority and $\frac{2}{6}$ giving it the second highest. The final $\frac{1}{6}$ gave it the second lowest priority.

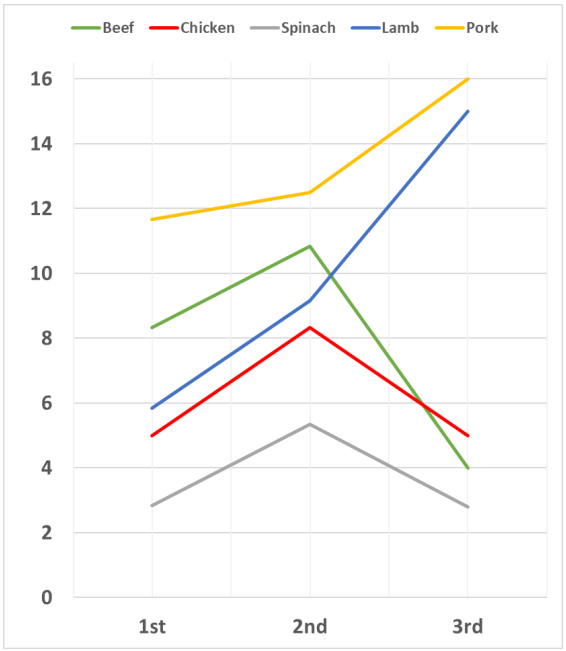
Health was also valued highly with $\frac{3}{6}$ placing it in the top 3. Interestingly, the remaining participants all placed it at 7th. These were our most sustainability aware participants and all prioritized climate impact 3rd. The remaining three participants assigned it a priority from 5 to 8 (out of 9). The factors that our 3 most sustainability aware participants prioritized higher than climate impact were social conditions, season, packaging and price.

App usage was pretty consistent during the study with the midway questionnaire showing that $\frac{3}{6}$ used it every time they shopped, $\frac{2}{6}$ used it less often than they shopped and $\frac{1}{6}$ hadn't used it. In the final questionnaire, general usage had gone down slightly with $\frac{2}{6}$ using it every time they shopped and $\frac{3}{6}$ using it less often than they shopped. It should be noted that we never received an answer from the final participant, but we know from their interview that they never used the app.

Figure 4.1 summarizes the answers to the carbon footprint questions from all three questionnaires.



(a) Average questionnaire answers with dashed lines representing correct answers according to the app. Answers are recorded as the middle of the chosen interval (e.g. 3 for [1; 5]) and < 1 is represented as 0,5.



(b) Average absolute (i.e. non-negative) difference between questionnaire answers and correct values.

Figure 4.1: Answers to the questionnaire questions about the carbon footprints of selected products.

From Figure 4.1a we can see that on average users underestimate the carbon footprint of lamb and beef while the impact of spinach, pork and chicken is overestimated. For the most part we see no improvement regarding the average answers moving closer to the correct ones between the first and final questionnaire. Chicken and spinach are the same, while pork is higher. We do see a small improvement for lamb and a great improvement for beef.

However, if we look at Figure 4.1b, which shows the average absolute distance between answers and the correct value, this improvement for lamb cannot be seen. But we do see similar tendencies as in Figure 4.1a for the other product categories.

Based on this data, we are unable to conclude that the users have gained a better understanding of these different products' carbon footprints during the study.

Thematic Analysis

In this section, we will describe the findings of the thematic analysis. The final coding trees can be seen in Section 7.4 in the Appendix.

It Is Easier to Understand the Carbon Footprint for Individual Products Compared to the Total CO_2 Consumption
In our study, we observed that the participants found it easier to understand the individual products' carbon footprint than their total footprint. They would compare the individual products to each other and their alternatives using the alternatives screen. Participant C confirms this by saying:

"Looking at the individual products I have bought food and then looked at better alternatives. It is what has given me a better understanding"

It was the general consensus that the alternatives were better for learning compared to the icons and front page, since it was used to improve the users' shopping behaviour.

Participant E answered the following to *Do you think the icons would have helped you learn if everything could be scanned?*:

"Yeah I think it would over a longer period."

This match with the other participants who also found that the icons provided learning, but had a slower effect then the alternatives screen. However, what he followed up with, would indicate that it is more about being able to compare values over time, than learning from the icons:

"If you use it for a year and start to see on a monthly basis, you would be able to wonder about these numbers about how much, you can drive. Or it is the equivalent of driving this much, that would make sense. Then it would be easier from month to month to see that it is better to get a lower number."

The icons had some clarity issues with the tree icon being hard to understand without playing the game. But the main difference was that the participants found the icons harder to relate to than the alternatives since the participants find it hard to establish a connection between their carbon footprint and km driven in in e.g. a car.

Another way the participants learned was from the information gathering the app required for scanning. Participant C said:

"I have looked for country when shopping and it is important it comes from Denmark. But it is clear I have had more focus on it since we have to input it."

The participants used the app to evaluate their purchases after they had shopped and thereby learn which products have a better CO_2 footprint since the app taught them which country has the better footprint. This was not effective for all the participants since many voiced frustration with having to input and gather data. So while the data gathering provides learning, it also caused frustration for many of the participants who would rather have the app do it fully automatically.

Total CO_2 Consumption Is Still Hard to Understand
Many of the participants said that their understanding of the total CO_2 usages did not improve when using the app. As discussed in the previous section while the icons and game

did help with learning, it requires time, but many of the participants did not use it regularly even though they generally liked them, with Participant C saying:

" I think it is very smart. Now I don't drive a car myself, but it is more relatable than maybe other things like taking the train."

Most of the participants said icons are relatable, but the general attitude from most of the participants was that it was hard to relate the icons to the total CO_2. Participant B said:

"That it is better to take the train than the car, does not tell me anything about my total CO_2 usage or whatever."

Participant B understood the icons and learned that the train was better than the car for ones CO_2 usage, but he found it hard to connect that to his total CO_2 usage. He therefore continued to find his total CO_2 usage hard to understand during the study.

The icons were hard to connect to the total CO_2 and the tree icon was hard to understand, which show that they might have been wrongly used. Although, once its meaning was clear, the tree icon was the one users had the strongest reaction to when it was presented with realistic consumption data. The same participant suggested using the icons as a form of achievement or progress in another screen and then move the alternatives and graphs to the front page, since they are more relatable to the total CO_2. Participant A wanted a thumps up or smiley on the front page since they found the total CO_2 hard to understand.

Another factor for the difficulty understanding the total CO_2 was that some of the participants did not use the app more than a couple of times during the study. Since the icons and game need a long time to induce learning and some of the participants did not use the app they would not learn enough about their total CO_2 to help their understanding.

There Were Difficulties Motivating Reflection
From our data we have to conclude, that there were difficulties motivating reflection during the study. The features that turned out to be the most useful for motivating reflection is the purchase list with its smiley rating along with the list of alternatives. This is described in more detail in the following section. This section focuses on the participants who reported not to have reflected more on their food consumption during the study. Among them is Participant F who ended up not using the app at all. He had opened it and looked around in it, but as all features required the scanning of a receipt, there was little point in continuing to use the app, when there was no receipt to scan. To this he added that he had very little interest in the subject, stating:

*"...I couldn't care less if I'm spending 10 or 1000 kg CO_2. I don't give a sh*t about it."*

Although, this is not due to a general lack of interest or awareness of environmental issues, rather just not this specific issue.

Similarly, Participant D also didn't really use the app apart from the scanning feature, citing a lack of interest in the subject as part of the reason why. He did try on two occasions to scan a receipt only to find that none of his purchases matched any products in the database.

He also found the process of registering purchases too cumbersome, stating:

"The thing with matching the products and then you have to go in and find it yourself. Then if it has found something, you have to find the country and how much it weighs, which is a bit too cumbersome compared to how much I care about it."

When we inquired about the effect of the default values as a solution to this issue, which is their main purpose, he said that the default values often were wrong and had to be corrected anyway. Participant E also did not find the default values to be as helpful as we intended, stating:

"I don't remember the difference but last time I wondered about...110 grams. Yes maybe, I guess. But you also feel like you want to give correct information to the app. Then I look at how heavy my bell pepper is, and when you buy it non-packaged, then it no longer says where it is from. Then you have to look, when you pick it up, at the sign. When you get home, you can't really remember where it was from."

He suggested that the app hide this complexity from the user by not having them input weight for non-packaged products.

Unlike Participant D, Participant E did register some purchases, but similarly to Participant D, he encountered some issues with the limited selection of products in the database as only a few of the products he bought were in it. He also generally doesn't buy packages of raw meat, though more for the sake of health than environmental sustainability. This meant that only his fruit and vegetable purchases could be registered. Unfortunately these didn't have any better alternatives, so he didn't get any negative smileys and wasn't able to use the alternatives feature as much.

Participant B also eats very little meat and this is due to its CO_2 impact. He actually bought more meat during the study out of curiosity. When asked whether the application had caused him to reflect on purchases, he responded that his registered purchases were already very sustainable, which means that he wasn't exposed to the negative smileys:

"Other than buying some things out of curiosity. But no that has been rare. Many of the things I have bought have...there have been good smileys all over."

But he did have purchases with alternatives, which he looked at. However, it took a while for him to realise that the button leading to the alternatives page was indeed a button. We also encountered this issue with Participant E when he was shown the page during the interview.

Upon viewing the alternatives page, some of the information Participant B encountered did not fit with his existing knowledge and was met with skepticism, which prompted him to suggest that the app include more information about how the carbon footprint is calculated:

"I am not always sure, I understand these alternatives. I have for example bought a cucumber here and it says [...] 0,67 kg CO_2 and it's organic from Denmark. And then it says I have two alternatives... One is from Spain, it is organic, I would assume that when it is from

Denmark it's [...] I don't understand the logic of a cucumber from Spain being better than an organic one from Denmark. It would be nice to have an explanation of why that is."

He also expressed confusion over the rating system of the meat and meat alternatives category, wondering why a chicken with an 52 % better alternative has the best smiley. Another problem he ran into occurred when he would try to apply the information from the app by looking for a specific product variant, only to be unable to find it in Føtex.

Like Participants B, Participant A was also already aware of her food consumption's sustainability and had for example reduced her consumption of beef. She was among the most frequent users of the app during the study, but she completely overlooked the smiley ratings and the alternatives feature as she mistook the purchase list page to simply be a list of her purchases with no additional features:

"I looked at tab number two with the graph and then I just thought the last one was an overview of my receipts, which it also is, and then I thought that it was just for checking if purchases had been registered correctly, so I hadn't actually thought there was more information there."

A possible solution to this was proposed by Participant D who thought that the icon of the purchase list page didn't quite capture its functionality.

So in summary, many of the participants were not motivated to reflect on their CO_2 emissions due to various reasons. For some it was a lack of interest in the subject paired with features being too difficult to access, while for others there were incompatibilities between their food consumption habits and the focus of the app on fruits, vegetables, meat and meat alternatives, which limited their opportunity to interact with the app. When reflection occurred the information provided by the app was too sparse, leaving the user skeptic and unable to fully understand it. Even when the reflection led to attempts at changing behaviour, they were obstructed by a discrepancy between the data in the database and the availability of products in the supermarket. Finally, access to the features that proved to be most efficient at motivating reflection was in some cases unintuitive.

Negative Smileys And Alternatives Can Motivate Users to Reflect

As mentioned in the previous section, the app failed to motivate any reflection for some of the users. However, Participant C reported to have reflected more on her food consumption during the study, crediting the list of purchases with smiley ratings and the list of alternatives.

From our pilot study (see *Pilot Study*), we had two different kinds of reactions from the smiley ratings. The participant was rather indifferent to them, while his partner felt very guilty when seeing an angry smiley.

Participant C, however, found them to be useful, stating:

"I thought it was great. It was easy to understand and great if you quickly had to scroll down to get an overview, then you naturally looked... Or I primarily looked at the ones, where there was an angry smiley, so I thought that was very usable."

When asked whether the angry smiley was to aggressive, she responded:

"No I don't think so. It's a method you know from other places, so I think it [the angry smiley] is good."

She described how the application had made her focus more on the country of origin and how bad beef is for the climate, although she also noted that this was not new knowledge. The changes in her consumption behaviour were that she started focusing on choosing the most sustainable product variants, but not the most sustainable product:

"There is no doubt that we have focused on it for individual products, trying to find the best product [variant]. But we haven't chosen different products or bought other types of foods. We've still eaten beef."

Although, she hadn't taken any steps to reduce her meat intake, she still thought it made sense to include vegan alternatives for meat product. When probed a bit further on the subject, she did also suggest to make the selection of alternatives customisable so it would for example be possible to have only vegan alternatives. Participant A, D and E also found vegan alternatives to make sense, even when they had little interest in changing their diet.

As described in the previous section, some of the users were never exposed to the angry smileys and the alternatives. When showed these features during the interview, responds were generally positive, albeit in varying degrees. Participant A responded very positively, expressing her intend to continue using the app to try out these features. Participant D was surprised to learn how low the carbon footprint of chicken is and when asked whether he could imagine the alternatives page making him reflect on his purchases, he responded:

"I would probably think about it. But not something that would have a great impact on anything. Because a lot of the things, I already know. I know meat is bad. I like eating it anyway."

Although, he also indicated that the application may have had an impact on his behaviour if he had used it longer. Furthermore, he stated that he would have used it more, if scanning had been easier. One suggestion was a feature that could calculate the carbon footprint of a recipe based on a link to it. Participant B found the product dropdown difficult and suggested dividing the list into categories to make searching easier. The product dropdown also wasn't wide enough to show the full name of some products.

Similarly, Participant E stated that the alternatives feature might have caused him to reflect on his food consumption. However, he also felt that there wasn't much to gain from it, as he already eats very little meat and the selection of alternatives for fruits and vegetables in stores are limited. Although he was able to see its relevance with other users:

"I don't think that it is that usable for me, the app, but I can easily see, when you hear of statistics about ground beef being twice a week in an average family. Then I can see that there is something to be gained and you can say: 'hey, there are actually some alternatives'."

Participant B, suggested placing more emphasis on the alternatives feature, for example by

moving it to the front page or summarizing the take-aways from it and the purchase list into some recommendations.

Data Has To Represent Reality For the Graphs to Be Useful
Several of the participants didn't use the graph as much due to a lack of completeness of the data. This was due to some of them simply not shopping as much, mainly shopping for items not present in the database or shopping elsewhere than Føtex. This caused the graph to be skewed in various ways. Participant B said:

"...there is so little data from me that no black lines [their usage] are showing, it is almost only red [recommendations]."

Participant C expressed some skepticism about the recommendations in that she didn't think it was clear what the recommendation was based on and she couldn't perceive if it was a good representation of her lifestyle. She said:

"... i haven't studied what basis the recommendations from the public health departments are, what they contains...i need more insight into the fairness of the recommendation to let it guide my consumption."

Participant C also said she mainly shopped for meat at a local butcher, so she didn't have a receipt she could scan and therefore these items weren't shown in the app.

Participant D said that he thought it was somewhat misleading that he couldn't choose to spend his CO_2 "quota" across different categories. For example if he only ate pork and no beef, lamb or chicken, then the pork category would go over the recommended line, even though his overall consumption would still be lower.

Many participants, however, liked the idea of the graphs and having a recommendation to judged their own consumption from, but didn't feel they could use it during the study due to their limited scanned items as they didn't feel the graph currently gave a accurate picture of their consumption since multiple items weren't available in the database.

Chapter 5

Discussion

As stated in Section 1.3, the goal of the app is to improve the user's understanding of their carbon footprint as well as motivate them to reflect on their food consumption. In Section 4.2 we described the findings of the study, which are summarized in the following list:

Finding 1: The more users interacted with the app, the better their understanding became and the more they reflected.

Finding 2: Users learned and reflected more from the alternatives than the icons.

Finding 3: The alternatives were confusing for some participants when compared to each other, since there was no explanation of the CO_2 calculation and data

Finding 4: Negative smileys provide more learning and reflection than positive smileys.

Finding 5: The alternatives were difficult to find.

Finding 6: Learning from the icons comes from comparing values over time.

Finding 7: The tree icon caused the strongest reaction among the icons once meaning was clear.

Finding 8: The app may have adverse effects on curious users whose food consumption is already sustainable.

Finding 9: The selection of products in the database is incompatible with the shopping behaviour of some users.

Finding 10: If the selection of product variants in the app doesn't match that of the supermarket, it may obstruct attempts to change behaviour.

Finding 11: Participants bought items from other places than Føtex and did therefore not scan them.

Finding 12: Many of the participants did not feel motivated to use the app.

Finding 13: The app would have been used more by the participants, if the scanning was easier.

Finding 14: The graphs needs complete data to be usable.

The following sections discuss what these findings implicates for the future of the application.

5.1 Motivating Reflection and Understanding

One thing we can see from the study data, is Finding 1 that says the more user interacted with the app, the better their understanding became. Unfortunately, many users did not feel motivated to use the app to the extend that we had hoped as stated in Finding 12. One

ended up not shopping, while others didn't buy many of the products in the database or didn't shop that much in Føtex, which limited their opportunity to interact with the app.

The app did improve understanding but mostly regarding the carbon footprint of individual products by using the alternatives, as stated in Finding 2, rather than the total carbon footprint using the icons and game. However, the data also indicates that the improved understanding of individual products carbon footprints is focused less on the carbon footprint in isolation and more on the carbon footprints in relation to each other. The same kind of understanding could be achieved for the total carbon footprint through the graphs which compared it to recommended diets. But as Finding 10 says, the data collected by the app was not representative, so the users generally didn't gain anything from the graphs.

Finding 4 found that negative smileys provided more learning and reflection than positive smileys. This is because the participants who did use the alternatives would scroll through the list and mainly look at the products with a negative smiley, ignoring the ones with a positive smiley. This would indicate that the learning from the alternatives is dependent on there being negative smileys. For example participant D only scanned bananas, but did not learn from the alternatives since all the bananas had a green smiley. To avoid this we could increase the odds of a user having negative smileys by changing the rating range from Section 3.2 so more of the products get negative smileys. There is though still a need for positive smileys and them being obtainable. If it is impossible to improve ones smiley the users would be unsure of how to improve their CO_2 usage and it could cause frustration being unable to get a good rating.

The participants found it hard to relate to the graph as stated in Finding 14 and the graphs did therefore not motivate reflection and understanding. The reason for this was that the data was incomplete and the users shopped other places than Føtex so the graph did not match the users' CO_2 usage. In some cases, the amount of data being shown in the graphs was very limited since the users bought few products and the graph showed weekly usage, so the users did not have time to collect sufficient data to be able to properly read the graph. Users indicated that it would be more helpful to compare months rather than weeks as it doesn't take more than one package of beef to skew the data for that week, which would be balanced if viewed over a month. This wasn't possible for this study of course as it only lasted a month, but for further development for more long term use, it would be a good idea to include a graph that enables users to easily compare months to each other.

However, with the proposed graph users will only know how well they did in one month compared to another, once that month has passed, which can be a bit misleading if the user uses it to measure their progress before the month is over. The answer could be to add some kind of element that compares it to the corresponding time last month. But then we may run into the same problem with one package of beef skewing the whole picture.

Regarding the icons, while users found it hard to relate them to the carbon footprint, they also indicated that they may have improved their understanding over a longer period of time as stated in Finding 6. It was also indicated that this would be due to the ability to compare the values across months in which case the icon may be redundant as this is possible to

do with just the carbon footprint. Although as Finding 7 says the meaning of the tree icon wasn't as intuitive, users tended to react more strongly to the tree icon, than the other icons, when they saw it in connection to realistic carbon footprints. This indicates that even if the tree icon does little to improve the user's understanding of their carbon footprint, it could still be useful to communicate its impact and motivate reflection.

An suggestion to make the front screen more understandable was to rate the total carbon footprint. The original suggestion was to use thumbs up or thumbs down, but this was before they saw the smileys on the purchase list page. The pros and cons of adding a smiley rating to the total carbon footprint has already been discussed in Section 1.2 with the main issue being, determining what it should be based on. When we inquired the user about it, they suggested to base it on average of their consumption, which has the same problem as the social norms, as described in Section 1.2; what if that isn't sustainable enough? Basing it on the recommended diet could instead make it feel unachievable. One solution could be to give it a score on all three accounts, which would add some complexity, but the rating being better than the month before could lessen the negative response of still not living up to the recommendation. However like the graph, it wouldn't be easy for the user to tell how well they were doing until the end of the month.

Another suggestion made during the study, was to move the graphs to the front screen to make the total carbon footprint understandable, although we worry that placing both graphs on the front page might be too much information at once. Therefore it might be best to focus on the one depicting the total carbon footprint.

Perhaps the app could take the user's previous shopping data into account and tell them how many average shopping trips they have left on the front screen, before they exceed previous month's emissions. It could generate proposed shopping lists based on previous purchases or help them make one that stays within the emission limit, be it previous month's emissions, recommended emissions or a social norm. Although these features may be a bit much to put on the front page.

For Participant B the app had an adverse effect as stated in Finding 8, since he bought less sustainable food to see how the app reacted. To combat this the app could have a feature to explore the products in the database without having to buy them. This could be incorporated into a shopping list feature were the users could plan their purchases and see their expected purchases CO_2 footprint.

5.2 Increasing Interaction With The App

As stated by Finding 1, the study data showed that the users who learned and reflected the most, were also the ones who interacted with it the most. However, for many users interaction with the app was limited by various factors. In this section, we will discuss the findings that indicate why that is.

One of the reasons is described by Finding 5, which is derived from various participants. One didn't find the tab with the purchase list and alternatives (see Figure 3.8 and 3.9) at all,

while others didn't realize that the button leading to the alternatives was actually a button.

During the interviews, a redesign of the tab icon was suggested as a solution to this problem. It was also suggested that we put a much larger emphasis on the alternatives, which would make sense to do, as these were the most successful at improving understanding and motivating reflection. One idea was to place a button on the front page with text advertising the alternatives. Another was to simply bring them to the front page by for example showing the latest shopping trip or simply the most unsustainable purchases. However, one issue in relation to the purchase list is that no matter how much (or little) the user buys of for example beef, they will always receive negative feedback for it. This isn't ideal to put on the front page as having beef in your diet isn't necessarily unsustainable.

Another solution could be to look for unsustainable consumption patterns (e.g. buying an unsustainable amount of beef over several months) and give recommendations of the front page based on these. For this, it is important to consider how far to take it. If users switch out beef with chicken, should the app then start suggesting to buy legumes instead? This may be in conflict with their understanding of "proper food" (see *Providing the Context*). However, if buying legumes instead of chicken is what it takes to bring emissions down to a sustainable level, it should still be suggested to users.

Regarding the alternatives button being hard to recognize as a button, the current design was chosen to save space and it was observe during the "FoodEmissions" study, that users would try to press the percentages anyway. The design could be changed to have the text indicate more directly, that the button is clickable. On the other hand, other users had no issues with the current design, and the participant who experienced the issue during the study also figured it out eventually. So perhaps some kind of walk-through should be implemented to introduce users to the various features.

As mentioned in Finding 3, the lack of transparency regarding how carbon footprints and ratings were calculated had a user feeling skeptic towards the information they were presented with. E.g. Participant B didn't understand why a Spanish cucumber had a lower carbon footprint than Danish one despite them both being organic. This is due to cucumbers being grown in green houses in Denmark which uses a lot of power to heat them up. While this information is not available to any users currently, it would potentially be a good feature to display information in order to promote learning.

When users downloaded the app, it came with a basic assortment of product variants in order to show them alternatives. While this data was based on observations in Føtex and information from their website, it was not kept updated, which resulted in Finding 10 as users would attempt to buy the alternatives suggested by the app, only to not be able to find them in the store.

The most obvious solution to this, is to collaborate with stores to be able to continuously update the database with the current assortment of product variants and their receipt text. We did inquire about the possibility of this to Føtex, but it was unfortunately not possible. Finding 11 presents a complication to collaborating with stores, as users naturally don't

shop exclusively in Føtex. The system would have to account for which product variants are in which stores. This adds a level of competition between collaborating stores, which may make them more focused on the sustainability of their assortment and promoting it through the app, but may also discourage them from collaborating in the first place.

An alternative to store collaboration would be to setup the alternatives so that it would be much clearer what the next best alternative is and perhaps pair it with allowing users to delete or archive product variants. But that also entails making them responsible for re-registering them, when they become relevant again. This is unfeasible with the current setup but would be more acceptable with a large user base and data stored in a central server, so the same user wouldn't be deleting and registering the same product variant repeatedly. An alternative solution to Finding 11, would obviously be to accommodate receipts from other stores. One study participant also suggested a feature for registering a purchase without scanning a receipt.

Another important reason why users' interactions with the app were limited, is described by Finding 9. We described in *Including More Products*, why the database expansion focused on meat and meat alternatives, however we did not think that many of our participants would buy meat in the form of cold cuts, sausages and bacon rather than fresh. All features of the app were dependent on purchases being registered in order to be of any use, so when users don't buy any fresh meat and a limited amount of produce, there is little to be gained from the application. The solution to this is naturally to expand the database even further, ideally to include as many products as possible. If we stick to https://denstoreklimadatabase.dk/ as the source of data, we have included 111 out of 500 possible products with the current implementation.

Although, for each new product added to the database, we have to consider which category it should belong or whether it needs a new category, in which case we have to decide how the alternatives should work for this particular category. Should we show alternatives from other categories or just variants of this particular product. Furthermore, the more processing a product has gone through, the harder it becomes to ensure the correctness of the data, as product labels may only display where the final product was produced and not where its ingredients came from. This makes the individual transport emissions more complex to estimate. There might therefore be a practical limit to how much the database can be expanded while still having precise data.

It was found in Finding 12 that many of the participants were not motivated to use the app. The app therefore needs elements that motivate people to use it. In Section 1.2, we touch upon gamification, but only a score for the game was implemented. Instead of having a game it could be more effective to introduce achievements for the CO_2 usage. Achievements could be implemented by reaching certain goals either set by the app or by the user themselves. An example could be to limit their consumption of beef products below a threshold. Another example could be to stay on or below the recommended line for X amount of time. As mentioned in Requirement 4, we wanted to include achievements in our app, but weren't able to do so due to time constraints.

Another suggestion that came up during the interviews was to introduce features that didn't require users to scan a receipt in order to access. This could for example be some general recommendations for eating sustainably or a feature that estimates the user's monthly emissions based on general information about their diet (e.g. how much beef they eat).

As mentioned in Finding 13, multiple of the participants would have preferred the app to gather the information directly via digital receipts or something similar to eliminate the need to manually scan items. While this does remove the learning aspect from the data gathering as mentioned, this will prompt more users to use the app on a more regular basis and eliminate a lot of work on the user's side. This could naturally be combined with the previously mentioned collaboration with various stores to gain access to their product database and get more accurate data regarding weight and names. The app would also need small updates to accommodate the extra product categories such as the icons on the graphs.

Other participants mentioned having the ability to scan items directly to look up various information in the store, but other literature [18] states this to generally be a bad idea as people shop impulsively and don't make long term plans when shopping for food.

5.3 Limitations with the field study

There ended up being some limitations with the field study like that most of the participants are friends or family of the authors. We did try to recruit people with no affiliation but only got three respondents and two of those dropped out so only one actually participated. Some of the participants might therefore have done more like Participant C that said she would not have used the app as often if she had no relation to the authors.

Another limitation is the range of the participants relating to age and families. The age of the participants being fairly low with one being above 50. There was therefore also no families and the one participant with a kid did not use the app. It would have been relevant to see how the app interacted with a family and if it can change a family's behaviour.

Chapter 6

Conclusion

In this project, we have developed an app with multiple features to help users understand and reflect on their CO_2 usage. The app enables users to calculate their carbon footprint by scanning their receipts. They are able to view the sustainability of their purchases via a smiley rating, which was implemented together with a list of alternatives and graphs to provide users with feedback and make them reflect on their purchases. A game and icons that compared the carbon footprint to various modes of transportation as well as how long it takes a tree to absorb the emissions were implemented as a visual tool to help users understand their carbon footprint. The app covers produce as well as meat and meat alternatives category, with individual systems for ratings and alternatives. We have succeeded in implementing all our requirements from Section 2.1.

We have conducted a 4-week long field study with 6 participants were it was observed that the more the users used the app, the more they understood and reflected on their CO_2 footprint. The alternatives with the smileys proved to be effective at making the users understand and reflect on their behaviour by focusing on their individual purchases. The icons and game was found to be mostly ineffective at helping users understand their total CO_2 usage as it required a longer period of time to be effective. Although users reacted positively to the idea of the graphs, they also did not motivate understanding and reflection, as users found them irrelevant without a sufficient amount of data, which they were unable to collect due to limitations of the app and its database.

We therefor managed to fulfill our problem statement and it's sub problems from Section 1.3.

Chapter 7

Appendix

7.1 All implented UI pictures

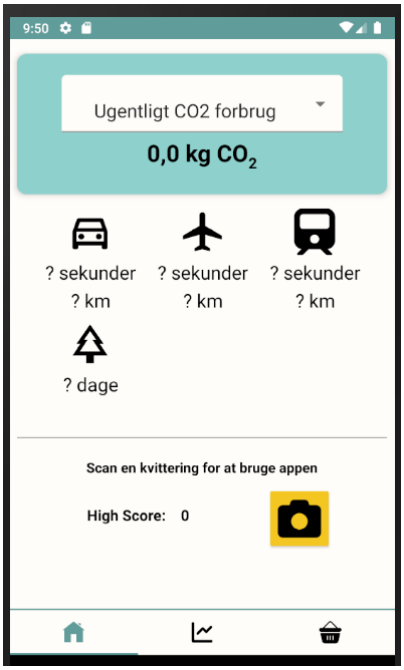


Figure 7.1: This shows the implemented front page. It is almost identical to the prototypes except for moving the taps from the top to the bottom.

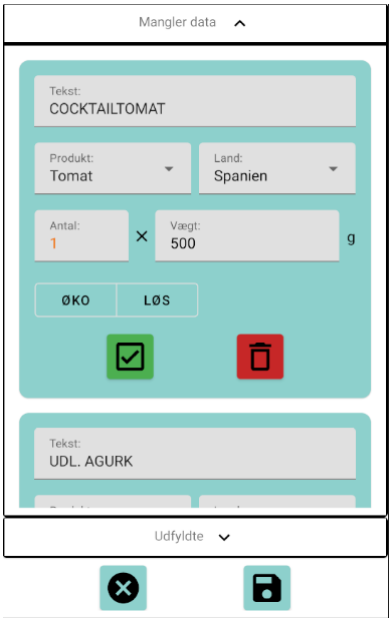


Figure 7.2: This shows the implemented scanning page. This is more or less identical to the prototypes.

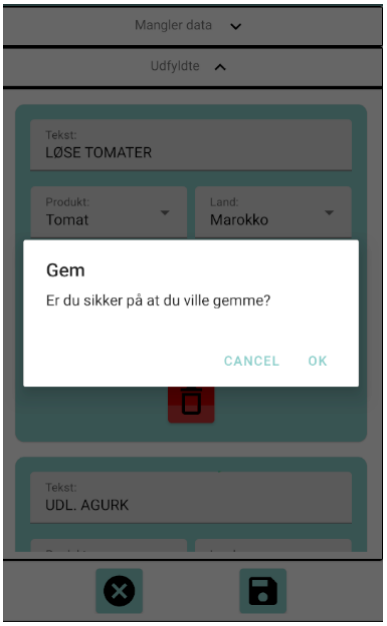


Figure 7.3: This shows the popup that appears when pressing the save button at the bottom of the save. This was added based on feedback from the pilot study. The exit button have a similar message.

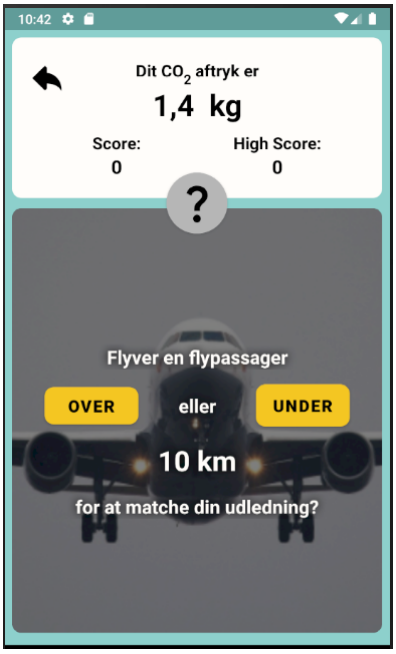


Figure 7.4: This page shows the page with the quiz. This is more or less identical to the prototypes

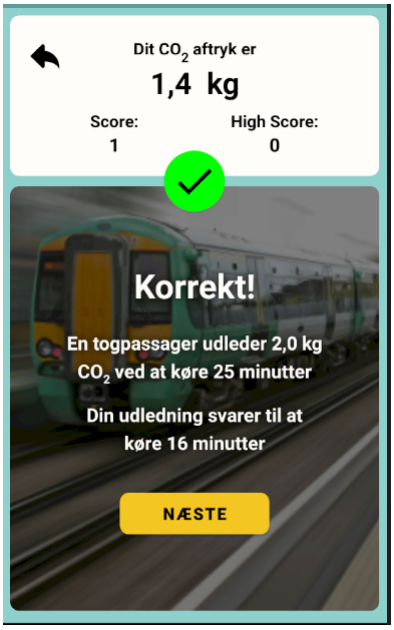


Figure 7.5: This page shows answering the quiz correct. This is more or less identical to the prototypes

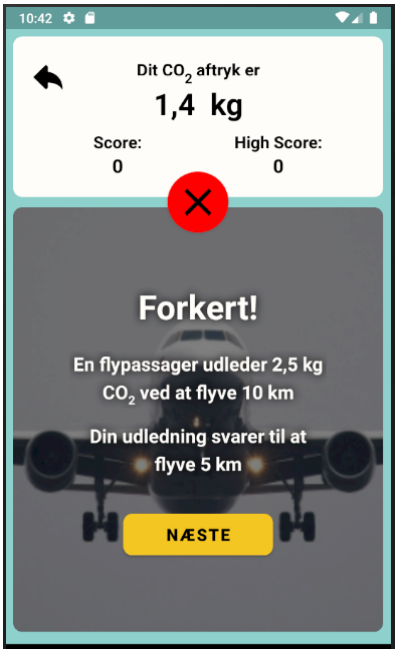


Figure 7.6: This page shows answering the quiz wrong. This is more or less identical to the prototypes.

Figure 7.7: This shows the front page after a quiz have been finished. Here the icons text have been colored according to how you answered each quiz.

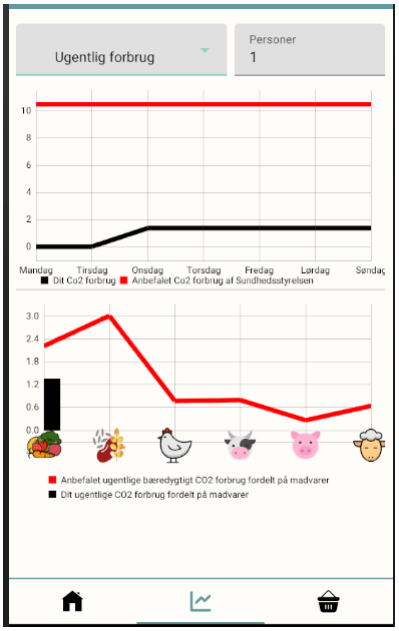


Figure 7.8: This shows the graph. This is largely the same as the prototypes, but now have the option of adding more persons in order to change the recommended diet to fit with multiple persons.

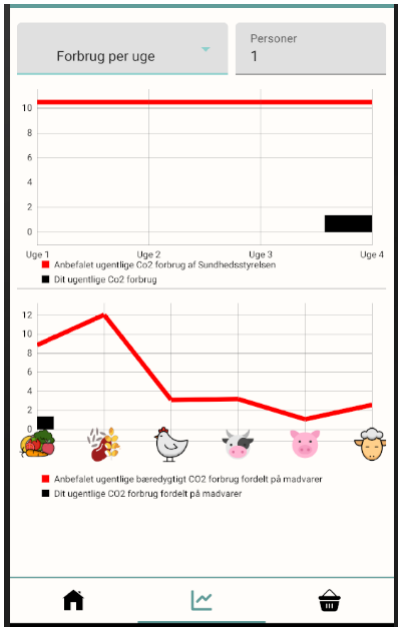


Figure 7.9: Same as previously, this is similar to the prototypes, but for the option to add multiple people.

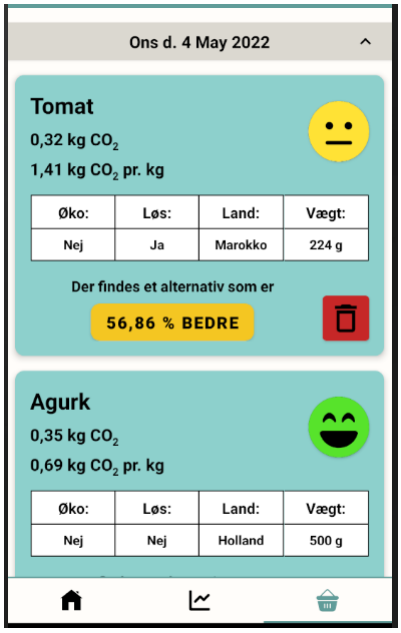


Figure 7.10: This is the page that shows the alternatives. A delete functionality have been added in order to remove any possible errors. Any banner with the date of scanning have also been added to better sort different purchases from each other.

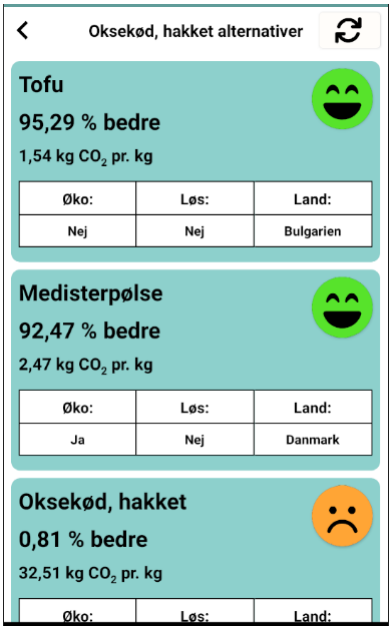


Figure 7.11: This is showing the meat alternatives which is also mostly the same as the prototypes. A small refresh button was added to get a new set of items to display.

7.2 Interview guide

Researchspørgsmål		**Interviewspørgsmål**	
Hvad er brugernes oplevelse af appen		Hvordan synes du forsøget er gået?	
		Hvad synes du om appen?	Hvad kan du lide/ikke lide ved appen?
		Hvor meget har du brugt appen?	
		Hvordan har du brugt appen?	Efter eller før indkøbsture? Hvilke features har du brugt mest?
		Har du tænkt dig at blive ved med at bruge appen efter forsøget?	
1	Hjælper appen brugerne med at forstå deres mads CO2 aftryk?	Føler du, at appen hjælper dig med at forstå dit CO_2-aftryk?	Hvad i appen hjælper dig (ikke) med at forstå dit CO2-aftryk?
		Er der noget, der har overrasket eller forvirret dig i forhold til dine indkøbs CO2 udledning?	Graf? Alternativer?
		Savner du noget i appen i forhold til at hjælpe dig med at forstå dit CO2 forbrug?	Flere ikoner? Anderledes grafer? Længere/andet spil? Andre ideer?
		Hvad synes du om ikonerne?	Er der nogle, der fungerer bedre end andre?
		Følger du, at en indkøbstur for dig der har brugt 20/40/60/100 kg CO2 er meget?	

2	Motiverer appen brugerne til at reflektere over deres CO2 aftryk og indkøb?	Har du reflekteret over dine indkøb mens du har brugt appen?	Hvad i appen har fået dig til at reflektere over dine indkøb?
		Efter at have brugt app'en er du begyndt at tænke mere over dit CO2 forbrug?	F.eks. når du handler?
		Føler du, at du har ændret indkøbsadfærd pga. appen?	Hvilken produktkategorier har du ændret adfærd i? Hvilke produktkategorier kunne du forestille dig at ændre adfærd i? Hvilke er lettest? Er der noget du vil ændre i din adfærd uafhængigt af appen?
		Føler du, at appen har presset dig til at ændre indkøbsadfærd?	Presser den for meget?
		Savner du noget i appen i forhold til at hjælpe dig med at reflektere over dit CO2 forbrug?	
3	Individuel spørgsmål fra spørgeskema og kvitteringer		

7.3 Questionnaires

Spørgeskema om indkøbsvaner

Dette spørgeskema handler omkring dine indkøbsvaner og hvilken faktorer du overvejer når du handler ind.

*Skal udfyldes

1. Hvad er dit navn? *

Dette bliver kun brugt til kæde dette spørgeskema sammen med dit interview og vil ikke blive brugt i nogen rapporter eller tilgængeligt for nogle andre.

_____

2. Alder? *

_____

3. Køn *

Markér kun ét felt.

- ◯ Mand
- ◯ Kvinde
- ◯ Andet: _____

4. Hvad er din beskæftigelse? *

Er du under uddannelse? Hvilken uddannelse? Har du et arbejde? Hvad arbejder du med?

_____

_____

_____

_____

_____

5. Hvor mange voksne handler du ind for til daglig? *

Markér kun ét felt.

- 1
- 2
- 3
- 4
- 5
- Mere end 5

6. Hvor mange børn handler du ind for til dagligt? *

Markér kun ét felt.

- 0
- 1
- 2
- 3
- 4
- 5
- Mere end 5

7. Hvor ofte handler du ind i gennemsnit? *

Markér kun ét felt.

- Hver dag
- Et par gange om ugen
- En gang om ugen
- Færre end en gang om ugen

8. I hvor højt grad vægter du de forskellige faktorer når du handler fødevarer? *

Markér kun ét felt pr. række.

	I meget høj grad	I høj grad	Delvist	I ringe grad	I meget ringe grad
Pris	◯	◯	◯	◯	◯
Klimapåvirkning	◯	◯	◯	◯	◯
Økologi	◯	◯	◯	◯	◯
Oprindelsesland	◯	◯	◯	◯	◯
Årstid	◯	◯	◯	◯	◯
Samfundsmæssige forhold	◯	◯	◯	◯	◯
Sundheds- og næringsforhold	◯	◯	◯	◯	◯
Mærke	◯	◯	◯	◯	◯
Emballage	◯	◯	◯	◯	◯

9. Hvad prioriterer du højest af disse faktorer?(1 er højest prioritet, 9 er lavest prioritet) *

Markér kun ét felt pr. række.

	1	2	3	4	5	6	7	8
Pris	◯	◯	◯	◯	◯	◯	◯	◯
Klimapåvirkning	◯	◯	◯	◯	◯	◯	◯	◯
Økologi	◯	◯	◯	◯	◯	◯	◯	◯
Oprindelsesland	◯	◯	◯	◯	◯	◯	◯	◯
Årstid	◯	◯	◯	◯	◯	◯	◯	◯
Samfundsmæssige forhold	◯	◯	◯	◯	◯	◯	◯	◯
Sundheds- og næringsforhold	◯	◯	◯	◯	◯	◯	◯	◯
Mærke	◯	◯	◯	◯	◯	◯	◯	◯
Emballage	◯	◯	◯	◯	◯	◯	◯	◯

10. Hvor ofte spiser du kød i gennemsnit *

Markér kun ét felt.

- ◯ Mere end en gang om dagen
- ◯ En gang om dagen
- ◯ Et par gange om ugen
- ◯ En gang om ugen
- ◯ Mindre end en gang om ugen
- ◯ Aldrig

11. Hvor meget tænker du over dit CO2 forbrug, når det gælder dine indkøbsvaner? *

Markér kun ét felt.

- Hele tiden
- Ofte
- Sommetider
- Sjældent
- Aldrig

12. Hvis du tænker over dit fødevarers CO2 forbrug, når du handler ind, hvilke tanker gør du dig? *

Uddyb gerne.

13. Hvor stor en CO2 udledning tror du 1 kg hakket oksekød gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 - 5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

14. Hvor stor en CO2 udledning tror du 1 kg hakket kylling gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 -5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

15. Hvor stor en CO2 udledning tror du 1 kg hakket spinat gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 -5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

16. Hvor stor en CO2 udledning tror du 1 kg hakket lam gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 - 5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

17. Hvor stor en CO2 udledning tror du 1 kg hakket gris gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1-5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

Spørgeskema om indkøbsvaner - Midtvejs

*Skal udfyldes

1. Hvad er dit navn? *

Dette bliver kun brugt til kæde dette spørgeskema sammen med dit interview og vil ikke blive brugt i nogen rapporter eller tilgængeligt for nogle andre.

2. Hvor ofte har du brugt appen i løbet af forsøget? *

Markér kun ét felt.

- ◯ Oftere end jeg handler
- ◯ Hver gang jeg har handlet
- ◯ Færre gange end jeg handler
- ◯ Aldrig

3. Hvor stor en CO2 udledning tror du 1 kg hakket oksekød gennemsnitligt har ? *

Markér kun ét felt.

- ◯ Mindre end 1 kg co2
- ◯ 1 - 5 kg co2
- ◯ 6- 10 kg co2
- ◯ 11-15 kg co2
- ◯ 16-20 kg co2
- ◯ 21-25 kg co2
- ◯ 26-30 kg co2
- ◯ 31-35 kg co2
- ◯ 36-40 kg co2
- ◯ 41-45 kg co2
- ◯ 46-50 kg co2
- ◯ Mere end 50 kg co2

4. Hvor stor en CO2 udledning tror du 1 kg hakket kylling gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 -5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

5. Hvor stor en CO2 udledning tror du 1 kg hakket spinat gennemsnitligt har ? *

Markér kun ét felt.

- Mindre end 1 kg co2
- 1 -5 kg co2
- 6- 10 kg co2
- 11-15 kg co2
- 16-20 kg co2
- 21-25 kg co2
- 26-30 kg co2
- 31-35 kg co2
- 36-40 kg co2
- 41-45 kg co2
- 46-50 kg co2
- Mere end 50 kg co2

6. Hvor stor en CO2 udledning tror du 1 kg hakket lam gennemsnitligt har ? *

Markér kun ét felt.

- ◯ Mindre end 1 kg co2
- ◯ 1 - 5 kg co2
- ◯ 6- 10 kg co2
- ◯ 11-15 kg co2
- ◯ 16-20 kg co2
- ◯ 21-25 kg co2
- ◯ 26-30 kg co2
- ◯ 31-35 kg co2
- ◯ 36-40 kg co2
- ◯ 41-45 kg co2
- ◯ 46-50 kg co2
- ◯ Mere end 50 kg co2

7. Hvor stor en CO2 udledning tror du 1 kg hakket gris gennemsnitligt har ? *

Markér kun ét felt.

- ◯ Mindre end 1 kg co2
- ◯ 1-5 kg co2
- ◯ 6- 10 kg co2
- ◯ 11-15 kg co2
- ◯ 16-20 kg co2
- ◯ 21-25 kg co2
- ◯ 26-30 kg co2
- ◯ 31-35 kg co2
- ◯ 36-40 kg co2
- ◯ 41-45 kg co2
- ◯ 46-50 kg co2
- ◯ Mere end 50 kg co2

7.4 Coding Trees

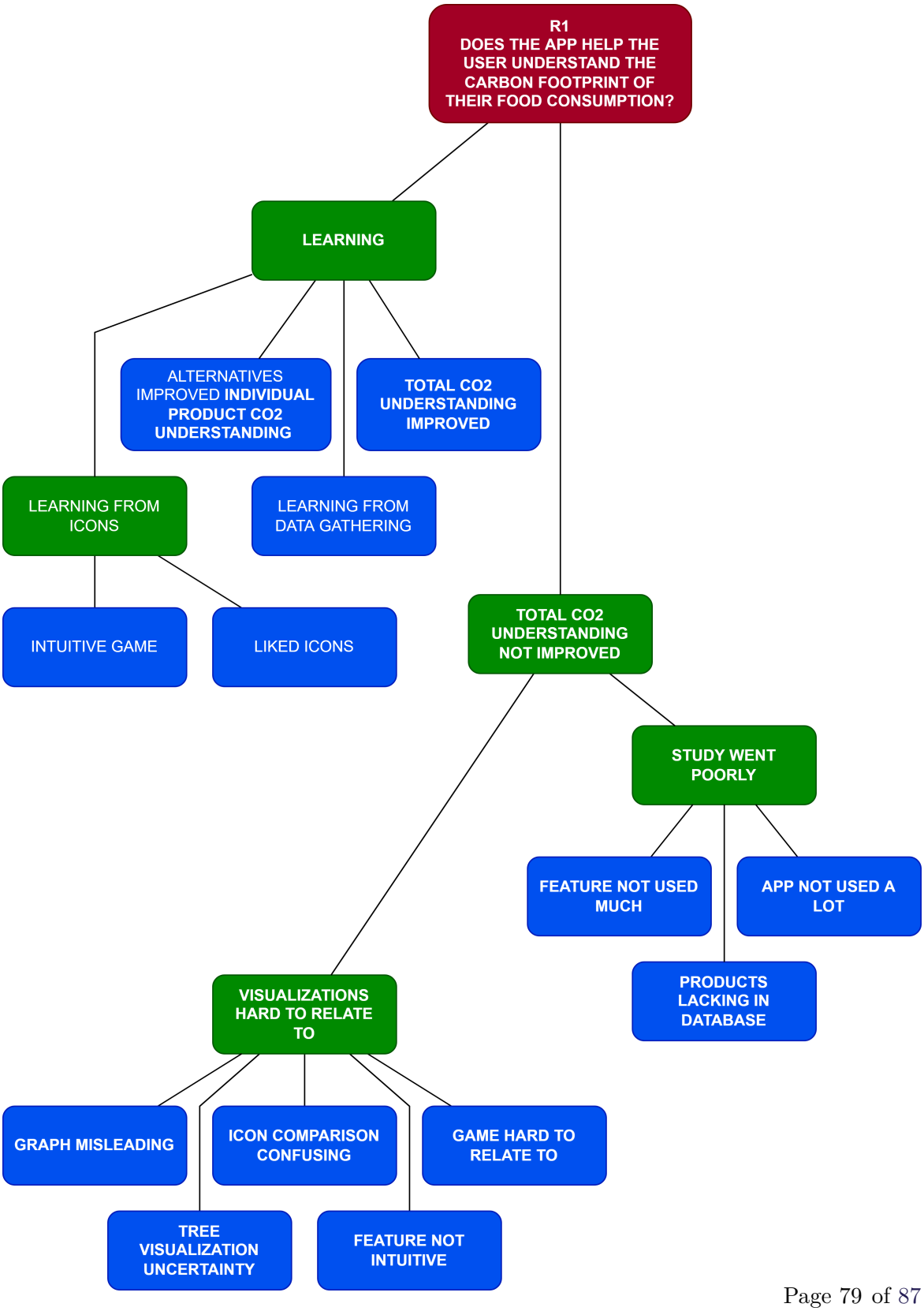

R1
DOES THE APP HELP THE USER UNDERSTAND THE CARBON FOOTPRINT OF THEIR FOOD CONSUMPTION?
LEARNING
ALTERNATIVES IMPROVED INDIVIDUAL PRODUCT CO2 UNDERSTANDING
TOTAL CO2 UNDERSTANDING IMPROVED
LEARNING FROM ICONS
LEARNING FROM DATA GATHERING
INTUITIVE GAME
LIKED ICONS
TOTAL CO2 UNDERSTANDING NOT IMPROVED
STUDY WENT POORLY
FEATURE NOT USED MUCH
APP NOT USED A LOT
PRODUCTS LACKING IN DATABASE
VISUALIZATIONS HARD TO RELATE TO
GRAPH MISLEADING
ICON COMPARISON CONFUSING
GAME HARD TO RELATE TO
TREE VISUALIZATION UNCERTAINTY
FEATURE NOT INTUITIVE

Figure 7.12

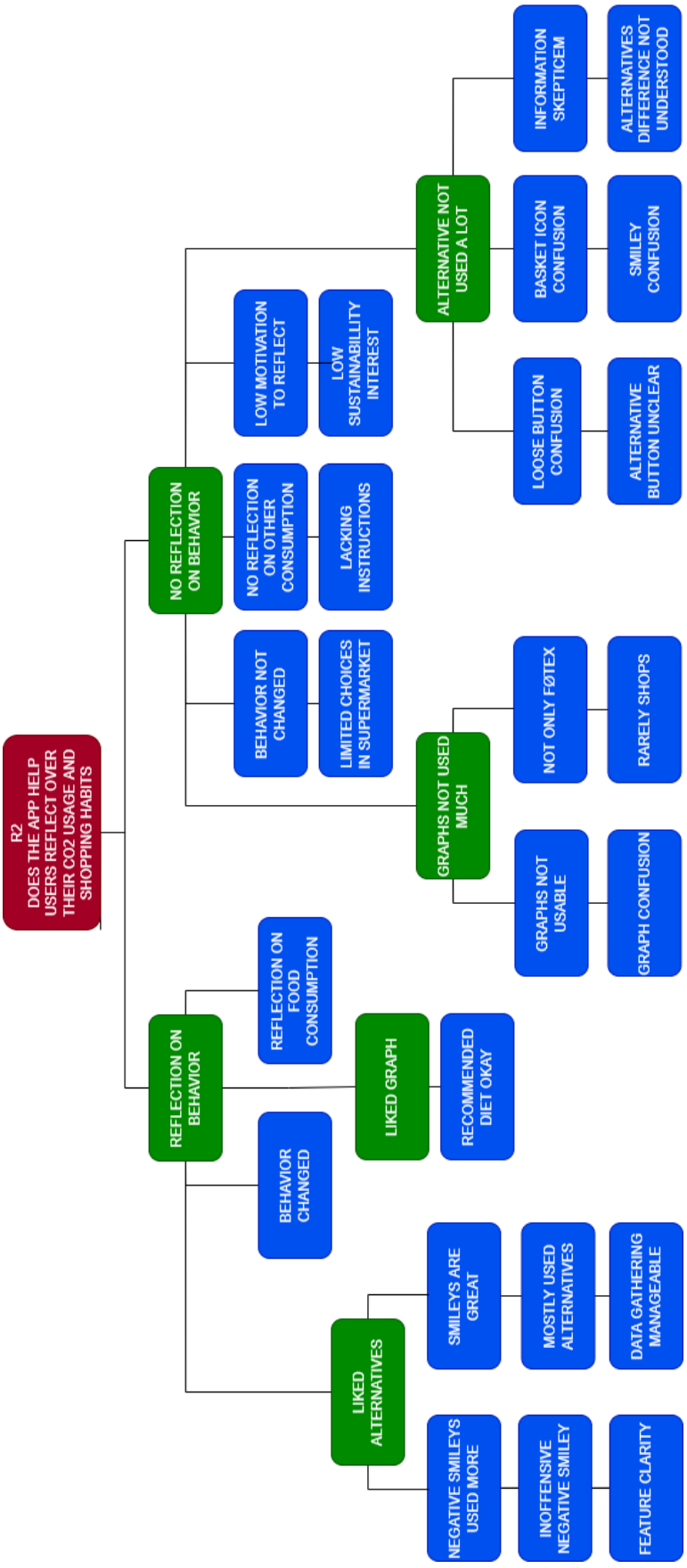

R2
DOES THE APP HELP USERS REFLECT OVER THEIR CO2 USAGE AND SHOPPING HABITS
NO REFLECTION ON BEHAVIOR
LOW MOTIVATION TO REFLECT
LOW SUSTAINABILITY INTEREST
NO REFLECTION ON OTHER CONSUMPTION
LACKING INSTRUCTIONS
BEHAVIOR NOT CHANGED
LIMITED CHOICES IN SUPERMARKET
ALTERNATIVE NOT USED A LOT
INFORMATION SKEPTICEM
ALTERNATIVES DIFFERENCE NOT UNDERSTOOD
BASKET ICON CONFUSION
SMILEY CONFUSION
LOOSE BUTTON CONFUSION
ALTERNATIVE BUTTON UNCLEAR
GRAPHS NOT USED MUCH
NOT ONLY FØTEX
RARELY SHOPS
GRAPHS NOT USABLE
GRAPH CONFUSION
REFLECTION ON BEHAVIOR
REFLECTION ON FOOD CONSUMPTION
BEHAVIOR CHANGED
LIKED GRAPH
RECOMMENDED DIET OKAY
LIKED ALTERNATIVES
SMILEYS ARE GREAT
MOSTLY USED ALTERNATIVES
DATA GATHERING MANAGEABLE
NEGATIVE SMILEYS USED MORE
INOFFENSIVE NEGATIVE SMILEY
FEATURE CLARITY

Figure 7.13

Glossary

CO_2 Carbon Dioxide. 1, 3, 6, 8, 9, 12–15, 22, 23, 26, 27, 30–33, 38, 39, 43–46, 48–51, 53, 55

DAO Data Access Object. 16

ER Entity Relationship. 19, 20

IoT Internet of Things. 5

MVVM model-view-viewmodel. 15

SDT self-determination-theory. 9

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