Sustainability Apps and Social Practices: Exploring How Carbon Footprint Apps Seek to Change User Practices

Can Carbon footprint apps be significant tools in aiding the fight against climate change?

Maria Clara Oliani

Registration Number: 1033102

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MSc Thesis Environmental Policy Group

Name Supervisor: Sanneke Kloppenburg

Abstract

This study set out to expand upon the limited literature on carbon footprint apps, conducting a thorough examination of the available apps and contributing to the limited literature with regards to their effectivity of tools to change practices – and ultimately, contribute meaningfully to the battle against climate change. As such, it asked a two-part research question: How do current carbon footprint apps attempt to influence user practices, and to what extent do user practices become reconfigured into more sustainable ones when they use such an app? The methodology featured three main parts.

Firstly, a systematic search of existing apps to identify which apps are available and the most prominent. Eight apps resulted from this search. Secondly, the eight selected apps were examined using a conceptual framework elaborated from practice theory insights and pre-existing literature on carbon footprint apps. This allowed the apps to be examined in detail regarding how they seek to change user practices, facilitating the comparison of strengths and weaknesses. This revealed two main types of apps: (1) carbon trackers and (2) carbon footprint calculation and reduction apps. While the apps vary among themselves, all of them most heavily target meanings and appear most weak in regards to materials, as they can only make suggestions and cannot provide the users any new infrastructure or material. Furthermore, while they rely on various approaches and strategies, all apps also appear to be to some extent underdeveloped with regards to the social features available to the users. Lastly, a user test of one of the carbon footprint apps was conducted with the app Earth Hero to examine how the apps work (or fail to work) in practice. It was tested by 9 university students. The app was used mostly in participant's free time rather than alongside other practices, and users most often used it on their own. There was variation in how exactly the app was used, ranging from inspiration, planning, and reflection tool. The app was successful in informing and strengthening user meanings, capable of reinforcing the use of sustainable materials (or bring about the reconsideration of unsustainable ones), and somewhat mixed with regards to supporting the users in the building of new competences. The app had limited social features beyond recommending social and communication actions, which became particularly apparent during the user testing as it was conducted under lockdown restrictions. The users found the app to be sufficiently flexible, particularly as they could set their own goals and timelines and control the number of notifications. This flexibility was also apparent in the success of monitoring among users, which believed it to be reliant on their own willpower but did not wish for more rigidity. There were different reviews on the feedback provided by the app, with some users wanting more feedback as they tried to complete an action as well. However, other users did not want additional notifications. Disparity was partly a result of older model phones not receiving notifications. However, all participants enjoyed the immediate reduction in footprint they saw upon action completion.

Overall, the app use had limited impact in user practices and the related carbon footprint. Carbon footprint apps can be a useful tool in promoting lifestyle transitions but remain too individual focused in scope and have much room for improvement. It is possible that shifting some aspects of design or combining apps with wider scale campaigns for certain groups or the promotion of new infrastructure could increase their effectiveness in changing social practices at a greater scale.

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1. Introduction

1.1 Context and Relevance

Climate change becomes a more pressing issue for the planet and its inhabitants every single day. Anthropogenic greenhouse gas emissions have altered the global climate to such an extent that we can even see it in the weather: climate change's footprint can be found in the global temperature and moisture data of any single day of the year (Sippel et al., 2020). Recent research has demonstrated that climate change threatens Amazonian tree species (Gomes et al., 2019), is linked to the enhanced wildfire activity in California (Williams et al., 2019), and has likely already impacted global food production (Ray et al., 2019). These are only some among many factors that highlight its wide-reaching importance and urgency. Furthermore, it is important to note that there is no silver bullet or one solution to an issue as complex as climate change. Rather, it will require concerted and determined actions for both systemic change by governments and corporations, and for lifestyle changes by individuals (Mark, 2019; Rogelj et al., 2018; van Vuuren et al., 2018).

One recent and popular method to reach individuals in order to give them information and promote sustainable behavior change is using mobile applications - apps (Brauer et al., 2016). Recently, several carbon footprint *reduction* applications have emerged. These applications offer a generalized look at the user's sustainability practices through multiple domains (e.g., food, mobility, housing, etc.) and attempt to get them to reduce their carbon footprint through specific actions, pledges, or challenges. They go beyond standard carbon footprint calculators (apps or otherwise) in three ways. Firstly, they are available as mobile apps, close at hand and within reach of the user at any given moment. Secondly, they guide the user in reducing their footprint instead of merely providing them with the calculation of their footprint. Thirdly, carbon footprint apps are more convenient to use. Rather than having the users calculate their entire footprint every time they change an everyday practice, most of these apps track the actions registered by the user and simply calculate the equivalent reduction in their carbon footprint.

The literature on carbon footprint *apps* is extremely limited. From this narrow existing research, it can be inferred that carbon footprint reduction apps have a great potential as tool in influencing individual awareness and behavior with regards to their carbon footprint. Research by Salo and colleagues (2019) on the opportunities and weaknesses of carbon footprint calculators (not only apps) indicate that they are easily portable and accessible, as well as designed to be used more than once, meaning they could succeed where standard web-based calculators struggle. Long term user engagement is one of the main challenges of carbon footprint calculators indicated by Salo et al. (2019). Sagawe and colleagues (2016) look at carbon footprint apps and note they have a relatively small number of users and suggest a model to measure an individual's intention to use such apps. This model considers factors such as environmental concerns, concerns as well as perceived enjoyment, behavior control, and usefulness. A review of the effects of carbon footprint calculators conducted by TNO finds that there is limited research on their effect and must as such draws from health intervention studies to obtain insights on the effect of apps on behavior change (Dreijerink & Paradies, 2020). With regards to carbon footprint calculators, the review shows that they have potential to change user awareness and behaviors but are not always effective. Moreover, it finds that few people are interested in reducing their carbon footprint, that removing implementation barriers may contribute to behavior change, that users may perceive carbon emission goals as out of reach, and that calculators require content updates. This review by Dreijerink and Paradies (2020) is the first one to examine carbon footprint *reduction* apps. However, it does not distinguish reduction apps from calculator-only apps. Furthermore, it does not look at apps

alone (it lists some web-based calculators and one credit-card), and includes single domain applications (e.g. only food or mobility). In fact, the list of calculators included in the study indicates that its definition of a carbon footprint calculator is quite broad, including any app that gives the user any type of footprint information. For instance, it includes the online shopping app Greenswap, the barcode scanner app Questionmark, and the plastic footprint app My Little Plastic Footprint (Dreijerink & Paradies, 2020).

Besides the works discussed above, the only other research directly looking at carbon footprint *apps* are two master theses by Kisurina (2017) and Reick (2020), which examine two different carbon footprint reduction apps. Kisurina (2017) uses theoretical insights and practical user surveys in order to explore gamification (that is, tracking, points, rewards, etc.) as a tool for behavior change via the case study of the American app JouleBug. She finds that gamification is a process requiring much research and planning which can help stimulate behavior change dependent on certain factors, which she describes in a theoretical framework. Reick (2020) looked at the Norwegian app Deedster, using interviews with a set of test users to determine how effective the app can be at increasing awareness and bringing about behavior change. Reick finds the app can be successful in educating and bringing about behavior change – although it appears to be most successful for actions or changes that are smaller and require little effort.

There is more research available regarding other sustainability apps and digital platforms from which we can draw some lessons and preliminary ideas about what will work or fail in carbon footprint applications. Focus group research on potential sustainable food apps for dining out by Mu, Spaargaren and Lansink indicates consumers would prefer such a sustainability app to be integrated with existing mainstream apps (Mu et al., 2019). This is a rational outcome: if consumers were to have a new app for every single new facet of sustainability they care about (in the case of food, sustainable dining, sustainable shopping, sustainable diet, etc.) they would have to download and routinely use countless apps on their phone. Although a carbon footprint app is separate from other apps, it integrates multiple facets of sustainability, which may give such apps advantage over single focus sustainability apps. Furthermore, Mu and colleagues (2019) find that consumers want apps with reliable scientific information and that are simple, functional, flexible, and rewarding. The need for flexibility is echoed in the research of Fuentes and colleagues, which examines three Swedish ethical/green grocery shopping apps, featuring user tests and interviews on their experience (Fuentes, 2019; Fuentes & Sorum, 2018). They find that apps have the potential to facilitate green consumption by informing consumers and giving them agency capabilities to make ethical decisions (Fuentes & Sorum, 2018). However, not all sustainability apps are successful in changing user behavior, and failure is linked to app inflexibility – that is, the limited ability of users to configure apps for their own specific context and needs (Fuentes, 2019). As seen in the research by Kisurina (2017), the idea of gamification has also been gaining attention in the literature as a potential ally to change individual behavior towards sustainability. More research is needed in order to determine if gamification in practice is as successful as the theory implies, as well as which aspects are most essential or effective in achieving behavior change (AlMarshedi et al., 2015; Cardoso et al., 2019; Mazur-Stommen & Farley, 2016).

Lastly, health behavior application research indicates user friendly apps, real-time feedback, individualized elements, detailed information, and health professional involvement as some of the key factors for success in behavior change (Zhao et al., 2015). The literature review on the effect of carbon calculators by Dreijerink and Paradies (2020) mentioned previously takes insights from health intervention studies. They report that using more than one behavior change technique may be the most effective way to promote behavior transformation. Furthermore, they emphasize the importance of only targeting changeable factors, giving the

user concrete feedback, as well as taking physical and social context into account. They find it is important to focus on maintaining behavior rather than short term change, while at the same time highlighting that short term gains are essential in maintaining user motivation. Lastly, Dreijerink and Paradies (2020) find that it is important to tune in to which phase of behavior change the user is currently at, taking advantage of the fact that motivation is highest at the start and lowers throughout the process.

While this research is informative and useful, extrapolation cannot directly inform on the working and efficiency of carbon footprint reduction apps for a few reasons. Firstly, carbon footprint reduction apps combine multiple areas of sustainability rather than narrowly focusing on a single issue, such as plastic or food waste. This means that they have more reach in their user's lives through one single application, curtailing the need for user to download multiple other applications if they want to be sustainable in other areas as well. Therefore, general-focused carbon footprint apps could potentially bring about more change than narrow-focused ones. Secondly, this challenge or action-based approach in footprint reduction apps is different from the information-based nature of certain sustainability (or even footprint-calculating only) apps. Information apps can provide external product information, informing them of the environmental consequences of their activities or the products they purchase (e.g. barcode scanning and information apps such as the Dutch app Questionmark). While these are useful, they rely on information changing behavior, rather than actively promoting certain actions and tracking the user's progress. Lastly, while the insights from health intervention are useful, health applications have an extra motivational factor: completion of the challenge directly and personally impacts the user's health and wellbeing. This is not necessarily the case for environment related actions. For this reason, it is important to directly examine and research these novel carbon footprint reduction apps, to determine both how they intend to promote behavior change among their users and whether they are effective in doing so.

1.2 Research Objective

The objective of this research project is twofold. Firstly, it surveys the carbon footprint reduction apps in the market, so as to create a picture of what apps are available to users and how these apps attempt to change user practices. Secondly, this research aims to analyze in depth one of these apps to determine how successful they can be in transforming or reconfiguring the users' everyday practices into more sustainable ones. Due to the inclusion of the exploratory part of the research and the timescale of the project, it was only possible to analyze one of the carbon footprint reduction applications: Earth Hero. Therefore, the research itself will not be able to conclude whether these types of apps are generally effective or not in reconfiguring practices – however, the results of the study will complement the test research done by Kisurina (2017) and Reick (2020) creating a more complete picture of the potentials (or drawbacks) associated with attempting to change behavior via action-oriented carbon footprint reduction applications.

1.3 Research Questions

This study is guided by the following overarching research question:

> How do current carbon footprint apps attempt to influence user practices, and to what extent do user practices become reconfigured into more sustainable ones when they use such an app?

This question can be subdivided into two different parts, which are addressed by the two sub-questions below:

> 1. What are the current carbon footprint reduction apps, and how do they attempt to shape or change user practices into more sustainable ones?

2. How do users incorporate carbon footprint reduction apps into their everyday practices, and to what extent do their everyday practices become reconfigured into more sustainable ones?

It is useful to distinguish the separate sub-questions, as each will be addressed by a different part of the methodology (see Chapter 3).

1.4 Roadmap

This study is divided into 7 Chapters. Following the introduction of the context and relevance of the topic above, Chapter 2 will elaborate on the conceptual framework used to develop the study, which is based on social practice theory and the research highlighted in the context section. Chapter 3 will detail the study's methodology with regards to both the app exploration and the user test. Chapter 4 will present the results of the app exploration, whereas Chapter 5 will highlight the most relevant findings of the user test and its subsequent interviews. Chapter 6 will present a discussion of these findings in the context of the scientific literature, as well as examine the strengths and limitations of the study's results and methodology. Lastly, Chapter 7 will present the overall conclusion.

2. Conceptual Framework

The following chapter details the theoretical background that informs the methodology of this study. This will be done in two parts: first, by examining social practice theory as informed by the works of Gert Spaargaren (Spaargaren 2003; Spaargaren 2011) and Elizabeth Shove (Shove et al., 2012). Secondly, the study will draw on findings from previous research on the strengths and weaknesses of sustainable consumption (Fuentes, 2019; Fuentes & Sorum, 2018) and carbon footprint apps (Salo et al., 2019) with regards to influencing user practices. This will result in a more complete, literature-informed conceptual framework.

2.1 Social Practice Theory

The main theory used to develop this study and its approach on behavior and behavior change is social practice theory (hereby also referred to as practice theory). Practice theory is a body of work built over time and contributed to by a variety of different authors. This study will particularly reference the work of Spaargaren (2003; 2011) in order to explain practice theory, but it is important to note he is not the only author in the field. The elements approach of Elizabeth Shove (2012) is also a determining contributor to shaping the framework of this thesis.

According to practice theory, individual behavior is not solely dependent on interior factors (such as knowledge and beliefs) or the exterior system in which the individual is placed (Spaargaren, 2003; Spaargaren, 2011). Instead, as shown in Figure 1, behavior is situated between the individual actor and the system in which they are in (Spaargaren 2003). It is important to note, however, that behavior here does not inherently refer to isolated individual behaviors, as is the case in behavior (change) models such as the Attitude-behavior model (Spaargaren, 2003). Rather, the behaviors – rather, the practices – at the center of Figure 1 are **shared** with other people (Spaargaren, 2003). In this manner, the social part of behavior is much more inherent in social practice theory than in individual-centered theories of behavior change. In other words, at the center of social practice theory is the idea that behavior is shaped by social practices (Spaargaren, 2003).
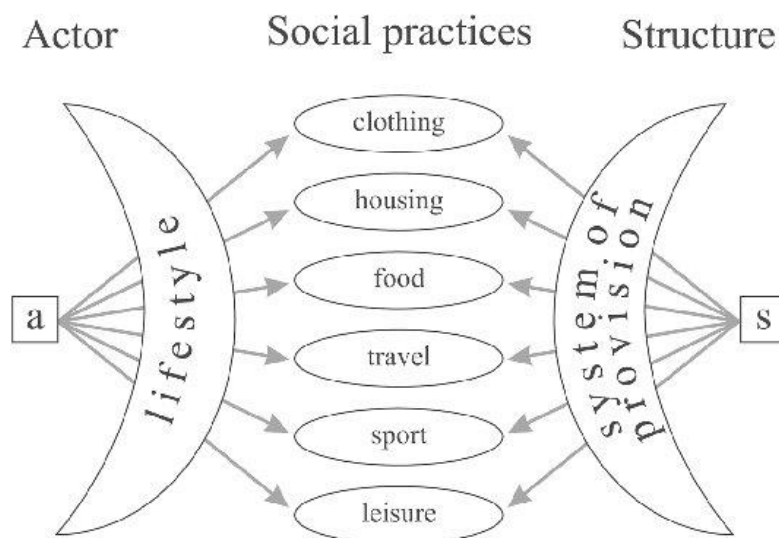
Figure 1: The social practices model (Spaargaren 2003 p. 689)

This approach of looking at behavior as a practice between individual and context makes practice theory particularly suitable for understanding the strengths and weaknesses of carbon footprint apps and their capacity to increase (or not) the sustainability of the users. While the carbon footprint is an individual metric, it exists within a real-world context that is not always

completely under an individual's control. For instance, not all regions have renewable energy providers. Another example is biking: a Dutch user can much more easily switch to biking as a form of mobility than a user from Brazil simply due to the available biking infrastructure. As such, the reasons for success and failure of a carbon footprint app may be rooted in how they approach the individuals that use them, how they tackle the systemic differences their users face, or a combination of both.

As discussed previously, individual behavior is shaped by social practices (hereby also referred to as "Practices"). However, what exactly is a social practice? Social practices are here defined as routinized (shared) behaviors that have developed in specific social contexts over a period of time (Spaargaren, 2011; van Koppen & Spaargaren, 2019). This is relevant for the study of carbon footprint apps as these deal with the impact of everyday actions and behaviors – everyday practices.

Practices can be influenced by individual or systemic factors, and can shape them in return (Spaargaren, 2003; van Koppen & Spaargaren, 2019). For this reason, the center of traditional social practice research – the unit of analysis – is not individuals and their behaviors or attitudes, but the practices in which they engage (Spaargaren, 2003). Traditional practice studies look at individual practices, such as cooking. This approach is not possible for this study, as carbon footprint apps target a variety of different practices, such as cooking, shopping, and commuting. Therefore, this is not a traditional social practice study, but rather a study which uses social practice theory to understand a tool supposed to make practices more sustainable. As carbon footprint apps seek to change certain practices in determined ways, practice theory can inform the understanding of their success or failure.

2.2 Materials, Meanings, and Competences

In order to understand what constitutes a single practice, this study refers to the work of Elizabeth Shove (2012). According to her work, there are three elements that constitute a practice: **materials, meanings, and competences** (Shove et al., 2012). Materials refer to the actual 'things' necessary for a practice, meanings to the motivation and feelings associated with it, and competences to the knowledge required to carry it out (Shove et al., 2012). These components of a practice are not isolated from each other – they are linked and interdependent (Shove et al., 2012). Figure 2 by Shove et al. (2012) graphically represents this model.
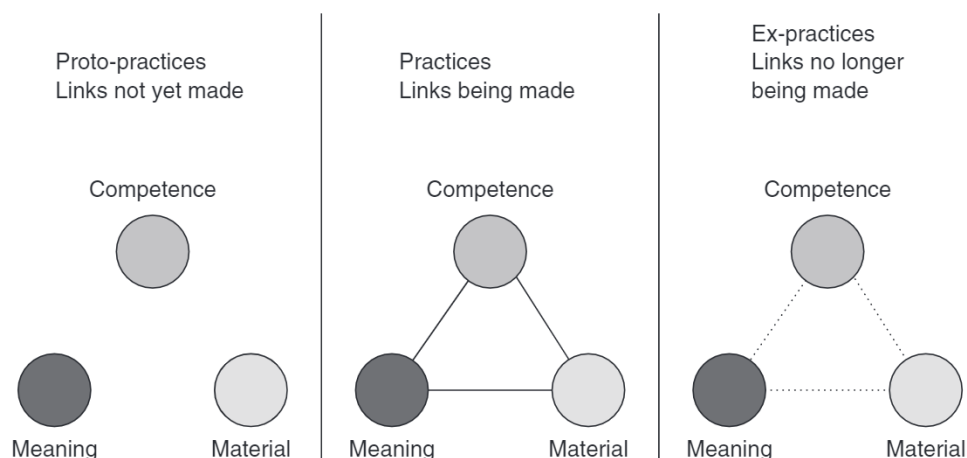

Figure 2: Elements of social practices before links are made (photo practices), when links are made (practices), and when links are broken (ex-practices) (Shove et al., 2012; p.25)

One context-relevant example can be made by looking at the practices associated with carbon footprint apps. As stated previously, this apps seek to change multiple practices – that is, there is more than one unit of analysis: food practices, mobility practices, energy practices, among others. The exact practices they target can vary a bit between apps depending on which actions or challenges they present to the user. Rather than look at every single practice, a common one can be used as an example: cooking. Cooking requires many different materials: ingredients, tools, a kitchen – as well as energy and perhaps even an internet connection if one would like to search a recipe (whether the recipes are coming from Google or the app itself). In terms of meanings, the cooking can have cultural meanings, sustainability motivations, notions on health, ethical or political motivations, and other such reasons or motives which vary greatly between individuals. The competences required would involve both the knowledge of using the kitchen and tools, the internet or application if that is being used for recipes, and the knowledge of how to combine ingredients into a (healthy/sustainable/complete/etc.) meal.

As mentioned in Figure 2 above, the elements of a practice can also be connected or affect each other. For instance, different materials (e.g. ingredients such as vegetables or meat, or appliances such as a heat or electric stove) will likely require different competences, different knowledge with regards to how to use them and/or make them into a meal. The differences in the competences associated with each material in the practice of cooking becomes particularly relevant when one is attempting to make the practice of cooking more sustainable. For instance, if someone knows how to cook burgers, it may be easier to switch to a meat free meal if vegetarian burgers are available in the supermarket. This way, the material changes but the competence stays the same. However, if the individual needs to make their own burgers or switch to an entirely different meal due to a lack of a vegetarian alternative, the transition to more sustainable cooking will be more difficult, as it requires additional, new competences.

As the example above highlights, practices are not static. This is implied in Figure 2: a practice only exists when materials, meanings, and competences are linked. These elements do not form a practice if they are separate, and as such practices can be formed or broken by making or breaking links. Furthermore, the elements that compose practices are themselves not static and may change over time (Shove et al., 2012). This is represented by Shove and colleagues (2012) in Figure 3. For instance, the availability of vegetarian alternatives might change an individual's ideas and beliefs regarding a full meal, thus shifting the practice entirely towards a less meat focused, more plant based one.

The non-static nature of elements and their role in changing or reshaping practices over time is another key reason why practice theory is relevant for this study. That is: understanding the theory's notion of why or how practices can shift or change over time will likely help in understanding why apps succeed or fail to change or reconfigure practices. It also reinforces the relevance of examining how the apps influence or fail to influence materials, meanings, or competences rather than looking at each practice as a whole, one by one: the changes of these elements and the relations between them are central in understanding the changes (or lack thereof) of the practices they make up.
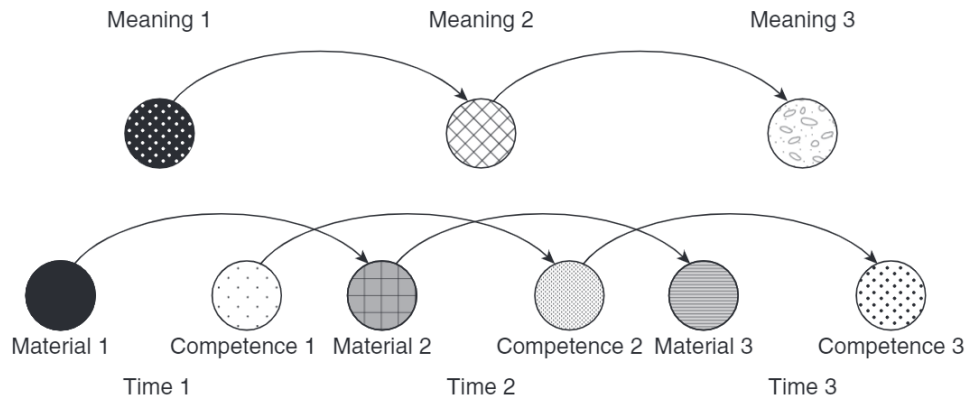
Figure 3. Elements of practice change over time (Shove et al., 2012; p. 33)

Figure 3 is perhaps overly simplified, as practices are made of more than one material, meaning and competence at once, and as such many of each element is interacting and changing over time. New associations can bring about new meanings alongside existing ones (rather than replace them). One example is a hobby baker learning about organic food or carbon footprints. Here the baker will continue having their meanings of happiness and pride associated with food and add alongside some meanings associated to its sustainability. That is not to say that it is easy to change practices. Practices are after all habitual activities routinized over time, and lessons from the attitude behavior model (Park & Lin, 2020; Gupta & Ogden, 2006; Mittal, 1988) show that it takes more than new information to change individual behavior – much less shared social practices.

2.3 Practice Theory Informed Conceptual Framework

The conceptual framework constructed here will involve the selection of some key elements that will be used in the subsequent sections of the study, in order to more systematically examine the carbon footprint apps and the interactions of users with them. The first elements of this framework come directly from practice theory: they are the **materials**, **meanings**, and **competences** that make up practices (Shove et al. 2012). Instead of looking at each individual practice the app targets, examining how the apps try to shape the three elements of practices will allow for a broader understanding of how they succeed or fail to shape practices in general. For example, instead of looking at eating, buying clothes, or waste habits individually and examining one by one what specific messages underlie each different practice targeted in general by specific apps, the study will look at every app tries to shape user meanings in general (e.g., via environmental or economic messaging). This will create a broad picture of the app and its overall strategies as viewed by the lens of practice theory, which will allow the strengths and shortcomings of the apps in changing user practices to be easily identified.

There is one shortcoming to this study due to the nature of mobile apps. They are designed to be used by individuals, as they are tied to mobile phones. This means mobile applications trying to contribute to social movements or create change at a societal scale have an inherent challenge with regards to reaching their goals. It also already points to a discrepancy between the social practice theory used to inform the study and the characteristics of mobile applications. This is not necessarily a limitation and can be seen as a pre-study insight regarding the shortcomings of apps as tools to change social practices. In order to make sure the conceptual framework as currently designed does not omit the social aspect of practices, however, a **social features** category will be included in the conceptual framework. This will

examine all ways in which the apps try to include the social aspect of behavior change within their design. This may be by including social features in the app (e.g. sharing or group features) or social activities or engagements by the users (e.g. hosting a climate friendly meal, or joining a climate group). Thereby the way the social aspects of practices will not be lost in either the conceptual framework itself, the examination of the apps, or the user test.

2.4 Sustainability App Literature Informed Conceptual Framework

Lastly, the conceptual framework used in this study will be complemented with the inclusion of insights from already existing studies on the subject of carbon footprint apps or similar topics. As discussed in the introduction, the literature on carbon footprint apps in particular is scarce despite such tools' rising popularity. Therefore, works such as that of Salo et al. (2019), which looks at carbon footprint calculators, becomes a valuable source of insight despite not looking specifically at mobile apps. In their study, Salo and colleagues (2019) use the ideas of practice theory to frame their digital examination of a variety of carbon footprint calculators that are available online. They note the user recruiting, knowledge, usability, and support associated with each of the calculators they examine. The ideas of usability and support are not included in the framework itself but will be included directly in the methodology: apps that have obvious technical issues or that have not been updated in the past year will not be taken into consideration (noted in Chapter 3). Furthermore, Salo and colleagues (2019) find that maintaining user engagement is one of the biggest challenges for carbon footprint calculators, which often see users look at their footprint only once and not return to track their progress or try to improve further. In order to examine how the apps attempt to keep their users on track and follow their progress with the app over time, a **monitoring and feedback** category will be explicitly included during the app analysis and the user test.

Finally, the last literature-informed addition to the conceptual framework will be the **flexibility and specificity** category. This stems from the work of Fuentes and colleagues (Fuentes, 2019; Fuentes & Sorum, 2018), which find that while apps can be successful in informing users and reconfiguring practices, they can also fail in creating this 'digital agency' – a failure which they link to inflexibility by the app with regards to allowing users to configure it to suit their own needs and preferences. As such, this flexibility and/or specificity category is included, which allows for direct observation of how much flexibility the apps allow the users or how specific the app can be made for each user. This specificity element is added because if the app is sufficiently specific to the user's context, the need for flexibility may be equivalently reduced as the app will already be configured to their needs and preferences.

2.5 Complete Conceptual Framework

The conceptual framework shaping this study is therefore informed by the ideas of social practice theory and complemented by recent findings in the scientific literature regarding carbon footprint calculators and sustainability apps. The theory and literature combination yield the following framework:

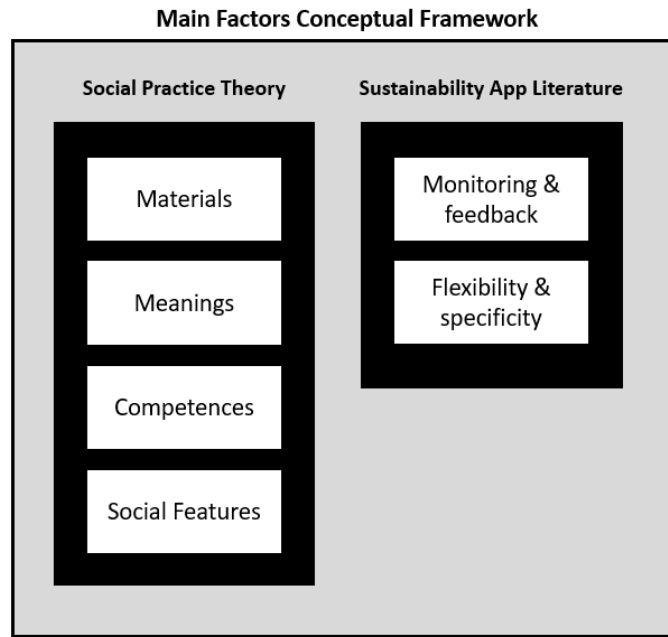**Main Factors Conceptual Framework**

Figure 4. Complete conceptual framework

These categories will be used in both the examination of the carbon footprint apps and discussed with the test users in a post-study interview, as will be detailed in the next chapter on methodology.

3. Methodology

The following chapter details the methodology used in this research project in two parts. This will be done in chronological order: first, the app exploration methodology, followed by that of the user test and concluding interview.

A qualitative study was selected in order to give precedence to the analysis of how the apps attempt to change user practices and the reasons behind success or failure. As such, the way in which the apps work or fail to work is the main focus, rather than a raw numerical study of how much they reduce user footprints. This allows the study to identify strengths and weaknesses of carbon footprint apps which can inform the understanding of what factors makes a successful app or practice changing tool. The systematic search and app examination allow for a general view of what applications are currently available to users, as such a record of the carbon footprint apps available does not exist within the literature. The app examination allowed for a deeper analysis of the similarities and differences between the apps, as well as their strength and weaknesses with regards to changing user practices (as informed by the conceptual framework described in Chapter 2). The user test was conducted as a case study which allowed for an analysis of how a carbon footprint reduction app works in practice, beyond that which what could be predicted and analyzed with the theory. Due to the lockdown restrictions in place during the time of this study, it was not possible to conduct participatory observation of the app and its related social practices as would be the more common approach of a practice theory study. Instead, online interviews were conducted with the participants at the end of the study period.

3.1 Systematic Search

The first part of the study was a systematic search of the Play and Apple stores to identify what mobile applications are available to the users. In order to make this search feasible and reproducible, a systematic search approach was used. The same key words ("carbon footprint", "climate action", "climate change", "carbon tracker", and "ecological footprint") were used in the Play and Apple Stores to direct the search towards carbon footprint related apps. Only apps which met the pre-set selection criteria were chosen for the final list and actual in-depth examination.

The first set of these criteria was based on insights from carbon footprint calculators and carbon footprint apps discussed in Chapters 1 and 2. These include:

> 1. The app could not be a one-time carbon footprint calculator – some type of progress tracking needed to be available to the users (monitoring and feedback)

> 2. Carbon footprint apps needed to focus on more than one footprint category and help users with their overall carbon footprint. An app that only tracked GPS mobility, for instance, would not be suitable as it would be narrow focused (limiting user options) as well as not comparable to the other apps (flexibility).

Other base criteria were determined based on practical considerations. These include:

> 3. The app needed to be available for both apple and android, which ensured it was available for all users who signed up for the user test

> 4. The app needed to be accessible in the English, the language of this research

> 5. The app had to be accessible for download in the Netherlands, which is where the study was carried out

6. The app could not require a password or access code to be accessed by user. This common feature in organization or workplace apps would make them impossible to examine or test.

7. The app needed to have a minimum of 500 downloads in the app store. This selection criterion was used to filter out the brand-new apps that were still in beta-mode, or that still had many usability bugs that needed to be fixed by the developer before any user could actually use them without hindrance.

8. The app needed to be active – that is, the app needed to have been updated in the year 2020. This criterion filtered out "abandoned" apps that no longer receive maintenance or give users new features/support.

Once the selection criteria were determined, the systematic search was carried out. The final list of apps taken for consideration is shown in Table 1. As seen in the table, these apps are all recent developments, with release dates ranging from 2018 to 2020. As per the systematic search requirements, all the apps listed in Table 1 were updated in 2020. The most notable exclusion due to this selection criteria is the American app JouleBug. At 50,000+ downloads, it is one of the most popular available climate footprint reduction apps - more than any other app that made it onto the final list, which range from 500+ to 10,000+ downloads. However, it had not been updated within the last two years. Another notable app excluded from the list was the Norwegian Deedster, which at 5,000+ downloads did not make the cut due to incomplete translation of all available actions into English. The country distribution of the applications shows a dominance of European countries in the development of such a tool. Lastly, all apps on the list originate from developed countries.

Table 1. Full list of currently active carbon footprint apps that made it past the systematic search specifications, including developer, release date, country of origin and listed downloads*

App Name	Developed by	Release Date	Country	Downloads
Carbon Footprint & CO2 tracker	The Capture Club	2019	Singapore	10,000+
ClimateActions	MYBLUEPLANET	2019	Switzerland	500+
Climatecompass by worldwatchers	Worldwatchers (twigbit technologies GmbH)	2019	Germany	10,000+
Earth Hero: Climate Change	Earth Hero	2019	United States	5,000+
Eevie	Humboldt	2019	Germany	5,000+
GoLow	GoLow	2018	Sweden	5,000+
The Donut	Spark Sustainability	2020	Finland	1,000+
The Planet App	Clean Planet Ventures	2020	Spain	1,000+

*as listed in the Google Play Store, December 2020

The apps beCon Live, NMF.Earth, and North made it through the selection criteria, but had to be removed from the final app list due to functionality issues with login or other app features (e.g. the app North featured integrations with apps not available in the Netherlands). As these apps did not work properly, it would be impossible to evaluate or compare with the other apps, hence their removal from consideration.

3.2 App Examination

Once the apps were selected, the following step of the study was to conduct a digital examination of the apps and their features. This process resembled the methodology of the studies of Fuentes (2019) and Fuentes and Sorum (2018) which analyzed sustainable shopping apps. This involves a straightforward procedure of going through the app, examining

its features and noting the messages and options it conveys to the users. The studies by Fuentes (2019) and Fuentes and Sorum (2018) made screen captures and videos of the process – this would be a lengthy and bulky approach for the purposes of this study. Rather, the apps were looked through thoroughly and notes were kept on the app approach, design, features, etc. This was not done at random: the categories of examination were designated according to the conceptual framework of the previous chapter. These will now be described.

First, there was the general examination of what the app did and targeted. These categories are important as they allow for the simple surface level distinction between the apps. They include:

- **Type of action / Level of change:** at the most basic, what type of action is the app proposing – actions, challenges, habit tracking? Are these one-time changes, or longer-term changes of habit?
- **Categories of action**: what domains of daily life can the user impact via their actions/does the app target? While each app had its own set of labels (e.g., "home" or "energy"), general categories were created beforehand so that it would be easier to compare the apps. These categories include: Consumption, Digital, Food, Home & Energy, Leisure, Mobility & Travel, Offsetting, Social/Communication, and Waste
- **Monitoring and feedback**: How did the app monitor the user's progress and what type of feedback did it offer them through the process?

The monitoring and feedback category allows for a comparison of app mechanics, and is also relevant as per the Salo et al. (2019) findings that carbon footprint apps struggle in maintaining user engagement for more than one app use.

Next, there are the categories directly informed by social practice theory as discussed in the conceptual framework – particularly with regards to the work of Shove and colleagues (2012). These include:

- **Materials:** what are they physical items and infrastructures the app tries to get the users to use or reconsider the use of in their daily activities?
- **Meanings**: how does the app try to create or reshape the ideas, feelings and motivations of the users with regards to their daily practices?
- **Competences**: what are the skills or know-how the app attempts to impart to the users?
- **Social features**: as social practices are inherently social, through what type of social features does the app attempt to make its intervention on the users reach beyond the individual and into the community around them?

Using social practice theory to understand carbon footprint apps is not a novel approach and was previously in the study of Salo et al. (2019) on carbon footprint apps mentioned previously.

Finally, based on the findings of the work of Fuentes and colleagues (Fuentes, 2019; Fuentes & Sorum, 2018), the idea of flexibility also needed to be incorporated into the conceptual framework, as it is already known that sustainability app success is largely linked with how flexible the app is for the user's wants and needs. As such, one last category was included into the examination framework:

- **Flexibility and Specificity**: how does the app provide flexibility to the users, or alternatively how does it tailor itself, its information or guidance to the user's context?

The results of this examination are detailed in the first results section (Chapter 4). Based on this examination, the app Earth Hero was chosen for the user test, as it performed relatively

well across the examination categories, and was among the best performing apps from those listed in Table 1.

3.3 User Test

Once the app examination was complete and one of the apps was selected for the user test, the next step was to find volunteers to use the app for a 4-week period in order to test the impact over the app in their practices over a certain time period. In order to find users, promotional posters and information were shared on different social media related to Wageningen University and Research. This included the main Facebook student groups (e.g. the buy and sell group) and group chats of different study programs and groups/organizations (e.g. sports teams or the local Green Office). Furthermore, promotion was also put up on the main Facebook page for students of Leiden University College. This was done in 2 rounds, one in December 2020 and the other in January 2021. The goal was to obtain 10 volunteers. While 20 people got in touch after the promotions, only 13 followed through and began the test use period. Two of these volunteers dropped out during the study. This left a final 11 volunteers who carried through the 4-week test, 6 males and 5 females. Of these 11, 2 (1 male and 1 female) did not actually use the app besides the initial calculation for external reasons: an unwillingness to try a challenge during the holidays and COVID-19 diagnosis. All the test users were students at Wageningen University or Research or Leiden University College, aged between 18 and 25 years old. Most of the users tested the app in the Netherlands, although some also tested it partly or entirely in their home city or country when their test period overlapped with the university winter break.

The choice of advertising in Wageningen and Leiden university social media groups (and by consequence having an audience of young college students with pre-existing environmental knowledge or concern) was made partly due to practical considerations related to the Dutch lockdown regulations. However, having young college students interested in sustainability as the age group also made sense from a research perspective. This is because environmentally concerned people are most likely to find a carbon footprint app on their own, and younger audiences have the most ease with regards to using mobile phones and mobile phone applications. Their pre-existing environmental knowledge makes the users a more realistic sample, and also a best-case scenario sample: if the app cannot influence users who are highly interested in becoming more sustainable, it is unlikely to succeed in influencing users who are not so motivated.

Upon the start of the test period, users were asked to provide some simple data on themselves and fill in some basic expectations for the user test, as well as their personal perception of their level of sustainability prior to using the app. This was meant as a reference for the data provided above, as well as for the users to be able to better describe their experience during the final interview. This document became the user's logbook: they received a reminder every week to fill in some basic information. This included if they had used the app that week, what actions they had tried, and any other notes that they might find relevant. The logbook template is available in Appendix 1. This approach was selected because it allowed the users to make notes through the process so that they could recall details of the 4-week period during the final interview. Furthermore, it provided more information on the day-to-day use of the app by the participants, which was ideal as it compensated for the fact that the app used could not be observed live through participatory observation: the participants could not be followed/monitored as they used the app during the final interview (which had to be virtual) or in a sample real-life context.

The interview itself happened after the 4-week period was concluded, depending on the participant's specific availability. These were semi-structured: they followed a pre-determined

script of questions (Appendix 2) but remained relatively flexible. The themes of the questions followed the different categories of examination mentioned in section 3.2. That is, the questions referred to app use and materials, meanings, competences, etc. This flexible format allowed for the further exploration of different anecdotes and ideas of different users depending on their personal context or experience with the app use. All the interviews were carried out via video call due to the COVID-19 regulations and recorded for later transcription.

For the analysis of the interviews, the transcripts were manually coded by theme. These themes also largely corresponded to the categories discussed in section 3.2. The only exception were the first two categories (type of action/level of change and categories of actions), as these made more sense for the app examination than for the user interviews regarding their experience. Each of the separate coded categories were then analyzed individually and these findings are presented in the second results section (Chapter 5).

The limitations of the methodology will be addressed in the discussion (Chapter 6).

4. App Examination

The following chapter will detail the results of the app examination. It will begin by describing the differences in the basic app design between carbon footprint apps – that is, the surface level characteristics and how they vary between the apps. It will then proceed to examine the apps according to the categories of the conceptual framework, as described and detailed in the methodology (Chapter 3). As such, this study presents the first general overview of carbon footprint apps in the literature, the design differences between them, and their similarities and differences with regards to practice theory.

4.1 Difference in the Basic App Design

Although all these apps are carbon footprint apps, they have very different approaches in terms of base structure and design. Table 2 gives an overview of the surface differences between the app via the type of action or change they promote (as labelled by the app) and the categories of footprint reduction changes/actions available for the user to try (these labels were made homogeneous in Table 2 for easy comparison).

Table 2. Type or level of action proposed by the app to the user and the (footprint) category which these actions allow the user to target. Categories given uniform names for easy comparison and do not reflect how they are referred to within each individual app.

App Name	Type of Action / Level of Change	Categories of Action
Carbon Footprint & CO2 tracker	"Monthly CO2 Allowance" • Tracked mobility (GPS; distance and transport type) & daily diet habits (e.g., vegetarian, pescatarian) need to be kept within monthly CO2 budget. No changes directly recommended	• Food • Mobility & Travel • Offsetting
ClimateActions	"Challenges" •Different time-limited (a few days) challenges comprised of three different sub tasks, varying difficulties and scales (e.g., under the try vegan challenge, the sub tasks "try two vegan meals" and "surprise your guests with vegan burgers")	• Consumption • Food • Home & Energy • Mobility & Travel
Climatecompass by worldwatchers	"Challenges" • Complete specific one-time challenges (e.g., eat no meat 3 days in a row), habit-referenced ones are also time limited to be a one-time challenge (e.g., not using any plastic bag this month). Actions assigned different levels have different levels of impact.	• Consumption • Digital • Food • Home & Energy • Leisure • Mobility & Travel
Earth Hero: Climate Change	"Actions" • One-time changes (e.g., switch electricity) & commitments to long-term changing of habits and behaviors (e.g., get clothes second hand) of different difficulties and impact scales	• Consumption • Food • Home & Energy • Mobility & Travel • Social/Communication • Waste
Eevie	"Habits" • Habits you track over time (e.g., consume less dairy), tends to push for smaller scale changes due to this. One-time larger scale changes (e.g., renewable electricity) can be achieved if base footprint is modified	• Consumption • Food • Home & Energy • Mobility & Travel • Offsetting • Waste (within categories)

Table 2. Continued

App Name	Type of Action / Level of Change	Categories of Action
GoLow	"Challenges" & "Climate Tips" • Challenges mostly refer to big-impact specific continuous behavior (e.g., changing diet), some one-time challenges available (e.g. renewable electricity). • Some one-time habits and climate tips which you achieve by marking as "to do", without any completion confirmation. Includes small practices (e.g., bring your own cup) but also larger ones (e.g., take the train instead of flying)	• Consumption • Food • Home & Energy • Mobility & Travel • Offsetting/Climate investment • Waste (within categories)
The Donut	"Actions" • Small scale actions (e.g., take a break from streaming) & some medium-high impact actions (e.g., add a vegan day to your week). Set up in a way most are one-time actions or have a set goal number of times over a time period)	• Consumption • Digital • Food • Home & Energy • Mobility & Travel
The Planet App	"Habits" & "Actions" • Select 3 habits to observe per week (e.g., use the microwave instead of the oven) & 1 one-time action (e.g., switch electricity supplier). Impact of habits and actions level dependent	• Consumption • Food • Home & Energy • Leisure • Mobility & travel

The biggest difference noticeable at this surface level is that some apps code themselves as **carbon tracking apps** and use a daily tracking model similar to nutrition or exercise apps. These appear to be newer in their release date and therefore less well developed at the time of writing of this thesis – in fact, the only one of this type that made it past the selection criteria and to the final list of apps was "Carbon Footprint & CO2 Tracker" (Table 2). Either due to this relative newness or the difficulty of tracking certain practices, these apps tend to look at fewer categories of actions. The Carbon Footprint & CO2 Tracker app for instance restricted itself to food and mobility.

Meanwhile, the other apps listed in Table 2 present themselves as **footprint calculation and reduction apps,** where the user choses to commit to certain actions or try specific challenges that will reduce their footprint and help them live more sustainably. These are more numerous than tracker apps but are not homogenous. Firstly, as easily seen in Table 2, the selection of categories of actions available for the user are slightly different from one app to the other – and the apps also often distinguish these categories slightly differently from one another. For instance, some apps look at waste or digital consumption as distinct categories, while others either examine waste within other categories (e.g., food or consumption). Additionally, some do not look at digital or streaming related actions at all. For easy comparison this study created a homogeneous set of labels to apply to these categories: Consumption, Digital, Food, Home & Energy, Mobility & Travel, Offsetting/Climate investment, Social/Communication, and Waste.

Secondly, the different name the apps give to the changes they propose (e.g., action or challenge) reveals some disparity in how they approach one-time behavior change and habitual or continuous behavior change. Some apps, like Eevie, look only at habits, that is, repeated everyday behaviors. As such, it can only track activities such as eating less meat or refusing plastic straws/utensils. Furthermore, these apps cannot, under their current design, offer or reward the user for a big one-time action such as changing to a renewable electricity

provider. Meanwhile, other apps focus on one-time actions, such as the challenges suggested by ClimateActions, which do propose one-time changes such as switching to renewable energy, but also make challenges related to habitual practices into one-time activities. For instance, the "try vegan" challenge has you try to cook two vegan meals and share a vegan meal with friends. Climatecompass by worldwatchers uses a similar one-time challenge only design. The other apps try to bridge the gap of fitting the one-time actions and habitual practices within the same design in different ways, each finding different ways to fit between the two extremes of only offering one-time actions or habits. Some try to split the changes they propose the user into two different categories or types (The Planet App, GoLow), so that the users themselves can see both a selection of one-time actions and habits which they can chose from. However, particularly in the case of GoLow, it is possible to question why one action has been included into one or the other category. For instance, travelling by train is included as a one-time action to cross off as opposed to a recurring action. Other apps try a different approach, giving the user a particular time frame for which to attempt a challenge or maintain a habit (e.g., The Donut and some challenges of GoLow), so that you commit to a habit only for x weeks or months, or y days a week for a certain length of time.

4.2 Social Features and Monitoring/Feedback

Table 3 presents the more detailed functionality differences between the apps by looking at the type of social features they offer, how they monitor the user's practices, and how they give users feedback. It is important to note this is focused on how the app approaches feedback: the content of the feedback itself is more closely associated to meanings, and as such will be discussed in the meanings section (4.3).

Table 3. Monitoring & feedback the selected apps use in order to monitor user progress and give them feedback on this and their footprint, if applicable, alongside the social features made available for the users to connect, communicate, share, or form groups

App Name	Monitoring & Feedback	Social Features
Carbon Footprint & CO2 tracker	• Notifications • GPS tracking mobility, automated daily diet tracking which can be edited • Budget meter with a % of monthly allowance used and a round progress bar alongside the number of kg CO2 emitted during the current month so far • Footprint broken down by category • Comparison of start footprint calculation with global average emissions	• Company teams available if demo requested (PIN restricted)
ClimateActions	• User marks challenge tasks as complete • User gets points for each complete challenge part • User has a level for each category based on the number of challenge points achieved	• Home page ranking to other app users • Ability to create or join teams, ranking with & within other teams
Climatecompass by worldwatchers	• User can mark challenge as completed or failed • Footprint broken down by category • Color gradient (green to red) indicating how relatively high the number of kg of CO2 emissions are in each overall category of the footprint calculation • Climate points system; Different levels based on points from completed challenges • Barcode scanner provides CO2 information [Did not work with Dutch product barcodes]	• "Recommend app to friends" available a challenge when user reaches a higher level

Table 3. Monitoring & Feedback Continued

App Name	Monitoring & Feedback	Social Features
Earth Hero: Climate Change	• User sets challenge duration and marks the actions as complete or failed upon reminder or when viewing challenge description • Notifications • Footprint broken down by category • Footprint compared to user's country average footprint and global footprint • Shows how much each action would contribute to reaching the target (in %) • Progress chart of emissions over time • Progress to target in % bar • Points system & levels	• Invite a friend • Inclusion of social actions (e.g., talk about climate)
Eevie	• User marks action as complete and to what degree • Notifications • Footprint broken down by category • Footprint compared to country average and UN 2-degree goal • Possible to enable GPS tracking for mobility • Past actions timeline	• Ability to join community challenges (with a pin) or join/create a group (to see within group ranking) • Invite friends
GoLow	• User marks action duration and frequency, marks them as completed each day they have a reminder • Notifications • Progress badges • Footprint broken down by category • Comparison of each category emission component to average person in user's country and 2030/50 climate goals	• Organization and individual leader boards • Ability to create your own group and see its progress (group co2 average, change, or investment) over time
The Donut	• Notifications • Actions marked as complete by the users, some can have the frequency set by the user and these can also be marked as complete more than one time in one day • Footprint divided by category • CO2 reduction achieved by user also divided by category and compared to car km emissions	• Discussion tab (topic pre-set) • Invite friends
The Planet App	• Actions can only be marked complete by users 1 time per day when they open the app and get a reminder of the actions or habits they have selected previously • Levels • Progress page/timeline • Emission comparison to different types of people (e.g. scientific researcher)	• None

All the apps listed had relatively basic social features available to the user, if any at all. As such, right at the outset it is clear that the apps lean more heavily into the individual side of practices, which likely limits their efficacy due to the shared nature of practices. Some of the apps have prominent "invite a friend" button, thus urging the users to attract more people to become app users and potentially discuss the app with friends. Other apps offer group features, where the user can join a group where they can either compete with other groups or

among themselves. These group features are quite basic, with no in-group chat features or even detailed information on the team members or the other teams beyond a progress metric (be this points, kg of CO2 saved, or something else) or ranking. The only app which allows the user to compare themselves to other users within their team and other groups at the same time is ClimateActions. As stated earlier, these apps do not include an in-group communication feature allowing users to communicate with each other within the app. One app differs from the others in its community approach: The Donut offers a discussion page instead of a group feature. In this page, users can choose to comment and add to discussion threads made available by the app. This means the users can directly communicate within those discussion threads; however, they cannot form connections among each other to communicate beyond those posts, nor can they propose discussion topics or questions themselves.

In terms of monitoring, all the apps rely at least to some degree on the user accurately and honestly reporting their own data and progress. Users need to be honest about their practices in their initial footprint calculation input, to accurately state what they ate or did in the day for the habit focused apps like Carbon Footprint & CO2 tracker and Eevie, or accurately report whether they did a certain action that day or completed a challenge they committed to. Some apps allow the user to do this at any time: in The Donut, the user can just press a task as done at any time. Even actions that need to be done more than once can simply be marked as achieved multiple times in a row. Some apps only allow an action to be marked as complete once per day or according to the user-stated frequency or duration of their chosen action. In GoLow or The Planet App, the user can only mark an action as done when they receive these reminders and cannot edit this daily response or even access it afterwards. The apps which least relied on user reporting were Carbon Footprint & CO2 Tracker and Eevie (only for the mobility category), as they had the option for automatic GPS tracking for travel.

Most of the apps have notification features available to the user so they may receive reminders of their ongoing actions or challenges. The feedback the user receives on their footprint and challenges alongside this monitoring also varies. Most apps do the initial footprint calculation (to different degrees of specificity) – the only one that skips this step is ClimateActions. All the apps that do this allow the users to see their own footprint broken down by categories- Although their names and repartition differ in each app, the user may get a sense of the components of their footprint. The Donut app also categorizes the footprint reduction achieved by the user. Some of the apps (e.g., Earth Hero, Eevie) compare the user footprint to either the average of their country, their goal, or a climate goal. Be it via cumulative points, CO2 emitted or saved, or a timeline of actions, all apps allow the users to know their change over time. Points also add a new layer of meaning and way to stimulate CO2 saving actions – a topic which will be discussed in the meanings section (4.3).

The information provided in Tables 2 and 3 gives a starter overview of how the apps are designed to work, as well as how they try to fit into their users' lives and daily patterns – that is, their practices. Some, such as The Donut or climatecompass, try to get the users to challenge the status quo by attempting a few select, time-bound challenges (e.g. eat vegetarian for a week) that might then influence how they view or carry out the practice (e.g. cooking and eating) to which this challenge is related. Others, such as Carbon Footprint & CO2 tracker or Eevie, appear to attempt a more continuous approach where you track your emissions or monitor certain practices on a daily basis. Others still, such as Earth Hero, are more direct yet, and try to get the users to commit directly to changes in their practices, be these daily habits (e.g., using a reusable cup) or more permanent lifestyle choices (e.g., switching to a renewable energy provider). In order to examine these apps and their attempts to change their user behaviors within the context of practice theory, they will be examined in

relation to their approach regarding materials, meanings, and competences in the following section.

4.3 Materials, Meanings, and Competences

This section starts off by discussing the applications' approaches to the meanings components of social practices as presented by Table 4. The meanings examination is separated from materials and competences for practical reasons. That is, the meanings element is the aspect of social practices most targeted by the carbon footprint applications, therefore there is simply more to be detailed regarding them (both conceptually and in terms of space) than materials and competences. These in turn are detailed in Table 5.

Table 4. Meanings – Selected apps and how their design or features promotes or supports the creating of new or changes in meanings (ideas, feelings, motivations) of their user

App Name	Meanings
Carbon Footprint & CO2 tracker	• Link your mobility and diet choices directly to CO2 emissions • Learn page: A few articles by the app itself approaching different topics which can try to bring different themes of ideas and meanings to the app use and its associated activities (e.g. sustainability being good for the economy) • Comparing your emissions to global emissions to create meaning of you as an over-emitter or sustainable person • Offsetting emphasized as solution
ClimateActions	• Short info in each challenge tying certain action to emissions or emission reductions potential for an individual, a certain area in Switzerland, or the country. Alternatively, statistics of a specific activity (e.g. time spent commuting) in relation to Switzerland or the average Swiss person) • Each challenge targets the meanings associated with the relevant categories with this further information - for instance, food as local vs imported, or an environmental impactor • Point system creates positive feeling/association or sense of gain even when the action requires something to be reduced or stopped
Climatecompass by worldwatchers	• Short bit of information - description, potential saving, or statistic - for each challenge • Detailed calculation of footprint informs user of many parts of their life and many activities that can be more polluting than they imagine • Point system create positive feeling/association or sense of gain even when the action requires something to be reduced or stopped
Earth Hero: Climate Change	• Focus on emission reduction potential of actions rather than how polluting activities are; more "positive" approach to connecting actions to environmental benefit rather than damage • Social and collective meanings at the center: actions with "no impact" to discuss climate and disseminate knowledge also encouraged and emphasized • New quote about the power of individuals, collective action, or the environment when the app is opened • % each action can contribute to target shown on each action gives all actions/changes in practices a direct link to a achieving a goal or bigger mission rather than isolated action •Breakdown of footprint by category helps user create distinct associations between their activity in each category and environmental impact

Table 4. Meanings Continued

App Name	Meanings
Eevie	• Each habit log linked to how many kg of glacier ice you could save if you did the action permanently • Footprint compared to national average and UN 2-degree goal • Environmental impact information on each habit • Overview of relative cost, difficulty, and impact level of each action when you open it to see further information • Positive frame: track your positive impact environmental habits rather than negative ones • Profile indicates not just footprint, but number of trees planted (offsetting as a solution) and number friends invited (social)
GoLow	• Brief explanation and environmental information under each challenge and climate tip. Usually environmental related; health or cost occasionally referred to • Map vision allows to compare different country averages • Climate investments offered directly via the app as a solution
The Donut	• Footprint & footprint reduction breakdown allows user to link each category of their activities to both their emissions & their emission reduction • Each action comes with short environmental impact information, including kg of CO2 reduction completing it would cause • Crew page gives sense of a collective achievement by all the app users by stating their total impact and comparing this to an equivalent value to give the number meaning (e.g. hours of sauna) • Different meanings approached per discussion post - ex. the definition of a good life, how they feel about consumer culture, etc
The Planet App	• Short environmental impact information on each action in ton CO2 and % of your footprint, alongside a short description

As Table 4 details, all the apps put the environmental meanings at their center. That is, they attempt to shape the ideas, motivations, and feelings their users have towards their daily practices using environmental related information and messaging. In its most simple form, this can be by calculating their footprint, or by breaking this down and giving them the emissions associated with their current practices. Some apps try to take a more positive approach to this messaging instead, giving the users the emission reduction associated with each change of practice or new sustainable practice, thus creating a more positive environmental association with the practice changes (actions, challenges, etc.) which they propose. Apps like Earth Hero, Eevie, or the level-based apps add alongside this environmental messaging difficulty meters, which can bring together the feeling of something being relatively easy alongside the environmental impact, so the users do not necessarily associate environmental action with inherent high difficulty. A few of the apps try to make the raw numbers of kg footprint or footprint reduction potential more meaningful to the user by making them equivalent to other measures, such as cups of coffee (The Donut) or kg of glacier ice saved (Eevie).

Some apps shift away from the environmental-only motivation, trying to reach into different domains and/or themes in order to shift the user's ideas, feelings and motivations. For instance, Carbon Footprint & CO2 tracker's learn page offers articles on the economic benefits of certain sustainable practices, and within each habit's description and further information Eevie gives the user an idea of relative cost associated with each habit. Other apps do this less prominently by including savings information within the action/challenge description when applicable.

Other apps turn instead to the third pillar of sustainability, trying to appeal to the social feelings and motivations of their users. The Donut does this by giving the user a crew page, where they may see the collective impact of all the app users, while Earth Hero includes social-related actions involving spreading knowledge, participating in politics, and other similar no-direct impact but high relevance actions within the climate movement. It emphasizes the collective action messaging by giving the user motivational quotes when they open the app which often highlight the importance of collective action to achieve change. One example of these quotes is the following quote:

"We strive to empower all who want to care for our shared planet" - The Earth Hero Team

The social features of the app listed in Table 3 could, if more developed, also contribute to social ideas and motivations if they included more user-to-user interaction. The app that most facilitates this thus far is The Donut and its discussion threads, but as these are pre-set and the users cannot keep track of each other by connecting as friends, there is still much to be desired on the community building of all the apps.

Many of the apps try to use a comparison feature to create new feelings of motivation within the user. This can be by comparing their emissions to those of the average app user, the average citizen of their country, or of the average global emissions. Others try to take this strategy one step further, comparing the user's emissions to a certain climate goal, such as the UN 2-degree goal. Therefore, different apps frame the problem in different ways, from focusing on individual reduction alone to linking it to the global averages. As such, the apps can be said to appeal to the user's sense of responsibility in different ways (individual versus collective). Depending on how the users interpret the difference between their calculated footprint and the metrics the app chose to give them by comparison, the apps can even be said to appeal to the users' sense of competitiveness. However, such a claim is easier to defend for apps that directly calculate points or compare users to each other.

The idea of competitiveness leads to another approach: Gamification. Some of the apps listed give the users points, levels, or both, gamifying the app use and by extension the user's attempts to change their practices, rewarding them the more they succeed by giving them points and letting them level up. This gamification is more central to certain apps than others. For instance, it is core to the overall design and structure of ClimateActions, which does not even calculate the user footprint and skips directly to point based challenges. It is also prominent, although perhaps slightly less, on apps like climatecompass and The Planet App. Furthermore, some apps have it as a smaller feature, which is there to motivate the users but not central to the app's core design. Given the group features of the apps are all basic and involve simple rankings or point comparisons, they can also be said to participate in this attempt to use gamification to create motivation and feelings rather than the more social, community or discussion-based approach discussed earlier.

Lastly, a couple of the apps provide the users a carbon offset features. While a carbon offsetting projects are valuable and important, providing them prominently at the same time as trying to get the users to change practices may provide conflicting messaging. As carbon offsets are an easy pay-to-fix way for an individual to deal with their footprint when compared to the higher effort requirement of changing practices, it is simply reasonable that some users might prefer paying for their emissions than attempting to reduce them at all. The apps that provide offsetting are listed in Table 2, and as this may also contribute to the meanings created by the app, these are also noted in Table 4.

Table 5 looks at how the selected applications deal with the other components of practices – the materials and competences associated with them. At a cursory glance, it appears that

materials and competences are significantly less developed and targeted by the apps in their efforts to change user practices. Indeed, this is not unexpected since environmental activists and movements are prone to focus on information provision to bring about changes in practices. However, as discussed in the introduction, information alone is usually not sufficient to change practices, as a change in attitude is not all that is necessary for a change a person's behaviors.

Table 5. Materials & Competences – Selected apps and how their design or features gives their users new insights into the materials or support for creating the competences involved in their practices

App Name	Materials	Competences
Carbon Footprint & CO2 tracker	• The app itself functions as a GPS tracker for mobility • App itself as offsetting tool	• How to pay to offset your emissions (directly via the app) • Learn Page: periodical articles on how to be sustainable in certain areas or reduce your emissions
ClimateActions	• Tries to get users to select alternative or rethink the need of certain materials for some practices	• Tips for each challenge, link to own website or external resource when applicable (for example to a recipe)
Climatecompass by worldwatchers	• Barcode scanner [Germany] proposes itself as a new material in shopping or as a tool for users to replace or reconsider certain materials in food practices • Tries to get users to select alternative or rethink the need of certain materials for some practices	• Not much guidance (only short info) on how to complete each challenge. • Barcode scanner can be said to be guiding during shopping/food (but it is not directly associated by the app to any one challenge)
Earth Hero: Climate Change	• Tries to get users to select alternative or rethink the need of certain materials for some practices	• Tips given for each action, link to additional resource linked when action is more complex (ex. Plant based diet)
Eevie	• The app itself as a GPS tracker for mobility • App itself as a habit tracker • Tries to get users to select alternative or rethink the need of certain materials for some practices	• Tips for each habit, always including links/additional resources if the user taps on the tip (some within the app and some external); same support not available for big one-time changes for which the user must change the base footprint calculation to record • How to offset emissions (directly via the app)
GoLow	• Tries to get users to select alternative or rethink the need of certain materials for some practices	• Tip of the day offers user a daily sustainability tip, although this is not necessarily tied to their ongoing challenges. • Small info on the "Climate Tips" can be information or tip on how to carry it out
The Donut	• Tries to get users to select alternatives or rethink the need of certain materials for some practices	• Guidance dependent on action. E.g., climate smart recipe action provides a new recipe each week; same support not necessarily available for all actions
The Planet App	• Tries to get users to select alternative or rethink the need of certain materials for some practices	• Short info on each habit/action can include tips on how to carry it out • Tip of the day related to your ongoing habits, can include link to external resource (e.g., recipes) if applicable

With regards to materials, the apps are potentially limited due to simply being apps. As such, they try to offer themselves as a material – some as a reflection tool, some as a planning tool, and some as a tracking tool like health apps. However, as they try to change and relate to many practices, it is difficult for them to find a way to integrate themselves as materials into all of the practices that they approach. Climatecompass attempts to do this for shopping via its barcode scanner, but shopping and cooking are only some of the practices that the app attempts to change. As such, most of these apps focus on their own use as a reflective or planning tool for the user, rather than trying to become a material embedded into each of their practices. In this way, they try to provide users advice on how to obtain new, change, or reconsider materials within the practices they are choosing to challenge themselves to change. For example, the app can suggest the user eat a vegetarian burger or use a reusable coffee cup or water bottle. In order to actually provide the users with access to new materials in a more straightforward manner, they would likely have to be paired with a related government initiative or policy that could more directly and externally influence the materials involved in the practices of the users. Some of the apps attempt to provide themselves as offsetting tools to the users, directly linking them to offset investment options and projects. However, as discussed previously, this may hinder the app's mission to change their user's practices. This can better be understood if discussed in the context of competences, rather than materials. The apps give the user the skill to directly offset their emissions, and if this skill is more effectively transmitted to the user than the skills required to change practices, the users are likely to choose the one easiest for them to achieve, thus diminishing the app's effectiveness unless the offset is very carefully designed and managed by the app creators.

The approach towards creating new competences (skills or know-how) is better developed by the apps than that regarding materials, although not as extensive as that regarding meanings. Most of the apps tend to give the users some type of tip(s) in order to achieve the practice change which they are currently targeting, although the detail to which these tips may be offered can vary from basic information to longer lists with more elaborate advice. A couple of the apps link the users to external resources for particularly difficult practice changes, such as guides or recipe websites when the users are trying to change their diet (ClimateActions, Earth Hero, Eevie). Some of the apps offer a separate page where they provide information or tips to the users regarding being more sustainable in different ways. These are generally useful tips and information but they are not necessarily directly tied to the actions the users are trying to complete or the practices they are trying to change. As such, they provide useful information but do not necessarily contribute to creating the competences required for the users to change the practices that they are currently trying to make more sustainable.

The Donut offers a slightly separate approach, where the challenges they offer can be directly competence related, such as "try a vegetarian recipe." Its benefit is giving the user the chance to build the know-how directly rather than for instance the Earth Hero app's "eat fully plant based" challenge, which proposes a substantial change for the user without in between steps, despite its link to external resources including guides and tips for how to achieve this. However, this approach is only used for the food domain, and as the user can set the frequency of this action, it can also be tried with so little frequency (e.g., one time per month) that the user must use the app for a really long time for it to make a difference in their daily practices, let alone their emissions. Apps like ClimateActions and climatecompass can be seen as in between in this regard, since they have longer duration challenges designed to build competences (e.g. eating vegetarian for one week or three days are challenges in each of these, respectively), but without the same amount of guidance or links to external resources provided by Earth Hero or The Donut. As such, the apps have different approaches when it comes to helping their users build new competences. The balance between slow-build and trying to achieve large scale changes in one go (and how much information to directly give or

link the user to in each case) is a formula that has not necessarily been figured out by any of the applications examined. It is worth noting, however, that not all actions need a long piece of information – for instance, climatecompass suggests shorter showers, which is self-explanatory and does not require tips or additional guidance.

4.4 Flexibility and Specificity

Lastly, Table 6 discusses the flexibility each app has to adjust to users' needs and contexts. The necessity for flexibility comes from the work of Fuentes (2019). This study featured a user test and found that for sustainable shopping apps, the failure to create ethical consumers was often linked to inflexibility with regards to how the users could adjust and customize the apps to fit their own needs or the way in which they wanted to use the app. The specificity label has been added because these apps often start by collecting information on the user, and whether they use that information to adapt themselves to the user's current practices is a companion concept to flexibility – that is, if the app can specify itself to the user's information, it may not need as much flexibility as an app that does not.

Table 6. Flexibility – Selected apps and how their design or features give their users flexibility or allow the app to become specific to each user's context

App Name	Factors affecting flexibility and/or specificity
ClimateActions	• Simple/non-comprehensive starter questionnaire • Number of actions limited: One challenge per category can be selected at a time, and cannot be changed before the week is over even if you complete them • Challenge sub tasks pre-set, however user gains points for sub-tasks of challenges even If they cannot complete the entire challenge • Duration pre-set: Challenges last 1 week • "already did this action" option *not* available • Location specific: Swiss phone number and post codes required; Swiss-related tips given to users • Users can create their own teams
Climatecompass by worldwatchers	• Long questionnaire/starter footprint calculation • Footprint can be recalculated or adjusted at any time • Actions/habits locked behind levels • Challenges at each level pre-set, regardless of starter info & can't be dismissed • Location specific; German data used in footprint and comparison to German average footprint, Barcode scanner did not work in the Netherlands
Earth Hero: Climate Change	• Medium to long starter questionnaire • User set annual reduction target • Free action choice • Free action duration: user choice of challenge length • Actions cannot be repeated • Some actions can be marked as "not for me"
Eevie	• Medium starter questionnaire • Free habit duration; however, habits need to be tracked 5 times to be complete • Big one-time changes (non-habits) not suggested, and can only be recorded by changing starter footprint, • User can opt-in or out for GPS travel tracking • User can opt-in or out of habit nudges (notifications) overall or for each specific habit under learn more

Table 6. Flexibility and Specificity Continued

App Name	Factors affecting flexibility and/or specificity
GoLow	• Longest starter questionnaire • User set climate goal • Auto-customized challenge selection based on carbon footprint information • Climate tips can be marked as "not for me" or "to-do" - no complete button, user receives a badge when they mark a tip as "to-do"; • Challenges however not dismissible • Free challenge duration and free customization of number of times action must be repeated • Challenges can be repeated, to mark definite changes user must edit their footprint (e.g. users must edit their diet from vegetarian to vegan even if they complete eating vegan actions many times)
The Donut	• Long starter questionnaire • No goal, only comparison to own budget over time • Free action choice • Duration pre-set: weekly challenges, however number of times an action must be done to complete the challenge customizable • Actions can be selected multiple times, but big one-time changes can only be changed by editing overall footprint (e.g., users can complete the vegan challenge many times, but must edit their yearly donut to change their diet to vegan) • Discussion page topics pre-set
The Planet App	• Medium length starter questionnaire • Actions/habits locked behind levels • Challenges at each level pre-set, regardless of starter info & can't be dismissed • Number of actions limited: 3 habits and 1 action each week • Duration pre-set: Weekly. Number of times a habit needs to be done for a challenge to be complete pre-set at 3 • Cannot change weekly plan once selected

The apps that most lose with regards to flexibility appear to be apps that split actions into different levels, which require the user to reach some threshold (of points or actions) to select (e.g., The Planet App) or even see (e.g. Climate compass) the actions assigned to the higher levels. This is because they make a very small number of actions immediately visible or selectable to the user. While these are supposed to be low-difficulty and accessible actions, there are some underlying assumptions required to designate them as so and depending on where the user lives or their current situation, some actions can be much harder than for other people. For instance, switching to a renewable energy contract is nearly impossible for a student who lives in university housing, but is relatively simpler for homeowners. This problem could be resolved if the apps with level-restricted actions were highly responsive to the user's starting input. That is, if a user indicates they are a user living in a rented home, the difficulty of switching energy type and points associated with it could be higher, or simply not visible to avoid them seeing actions they cannot do. However, it appears that even apps with a highly detailed starting footprint calculation have pre-determined which actions/challenges belong to which level, and as such the difficulty of the practice changes proposed to each level pre-assumed. For instance, The Planet App does not allow a vegetarian user to select "eat less meat" in the first level nor mark it as already done, even after this being indicated in their starter questionnaire. Similarly, actions the app considers easy might be inaccessible for a user and thus prevent them from proceeding onto the next level and seeing or trying other practice-changing challenges or actions.

Given the level-hierarchy apps do not specify the practice changes they propose to the user's starter footprint, apps where the users can browse through and select from all the possible

challenges/habits seem to be more accessible. Some apps go slightly beyond this, and allows the user to select certain actions as already done and/or not possible for them, which allows the user to further personalize the practice changes suggested to them. Some apps increase user choice by allowing the user to determine the duration and/or frequencies of certain actions or challenges. On the reverse side, some apps do not let a user cancel an action (e.g., ClimateActions), and other do not allow the user to open and edit if they have done or not done an action after they make the selection in the reminder the app sends them upon its opening (e.g. The Planet App). It is difficult to directly compare the flexibility of each app given their different designs, but these are some of the details that give the user more or less flexibility to tailor the app use to their own needs or preferences. Of the apps that propose the user reach a footprint reduction target, some allow the user the choice of what the target is. Some allow actions to be selected multiple times, but this does not necessarily mean more flexibility, as the design of the apps differ in their recurring or one time actions approach (as discussed previously). Lastly, some apps simply had more suggestions (apps, challenges, habits, or otherwise) to offer the user, and more choice is likely to mean more flexibility for the user, as they can find more things accessible to them but also try different things in a way to keep the challenges and activities the apps propose new, fresh, and exciting.

4.5 Concluding Remarks

The results of the app examination provide a few basic understandings of the carbon footprint apps currently available to users. Looking at basic design, the apps can be separated into two different types: carbon tracker apps and footprint calculation and reduction apps. The latter category is both the most prominent and well developed. Secondly the apps differ in their view of change, with some promoting one-time actions or challenges and others focusing on repeated, habitual tasks. All apps offer users some type of self-monitoring feature(s) with different degrees of flexibility and variation with regards to when, what, and how often users may monitor themselves. Some apps attempt to facilitate self-monitoring by offering GPS tracking or automated inputs of certain values (most commonly daily energy use, but could also be meal type, such as vegetarian or omnivore).

The social features of the apps are all relatively poorly developed. Some apps allowed the users to participate in discussions, and others gave them basic group features. Others take a different approach, giving the users communication based or social actions to engage in (e.g. communicate about climate change) rather than only direct emission reducing practices.

While the three elements (meanings, materials, and competences) have equal weight in the definition of a practice, the meanings element receives the most attention by the available apps. These meanings are primarily environmental, but on occasion can turn towards economic, social, or other ideas and motivations. Furthermore, most of the apps examined attempt to do some bare minimum regarding competences, from giving them simple tips on how to be sustainable to more comprehensive guides or support tools. The last element, the materials, appear to be the weak spot for apps seeking to change practices. Due to their nature as apps, footprint apps must limit themselves to suggestions and trying to motivate the user to switch to more sustainable practices and alternatives. They cannot directly provide the user with new materials or infrastructures, after all.

Lastly, the flexibility and specificity category sees the success in most apps examined. The exceptions come from apps that lock certain actions behind levels, making it so that the user cannot select or even see behind them. This weakness of level-locked apps becomes even more noticeable if do not adjust their contents or recommendations in response to their users' base information. For instance, when users tell the app they are vegetarian but are still be given the option to eat less meat upon unlocking the next level of action.

The app examination showed that, despite their common goal, there are differences between carbon footprint apps, as well as their potential strengths and weaknesses. It is important to note that both the app design and the analysis provided here on how carbon footprint apps may or may not influence or try to influence practices is influenced by assumptions on how the users will actually use the apps. As such, it is important to see an app in action to verify and complement this examination. This is why this study also conducts a user test of the app Earth Hero, the results of which will be discussed at length in the following chapter.

5. User Test

The following section will detail the results of the user test of the app Earth Hero, which were obtained via interviews with the participants after 4 weeks of test use (see Chapter 3 for further details on the process). It will begin with an overview of when, where and how participants used the app (Section 5.1), which was particularly important to discuss as COVID restrictions prevented the real-life observation of the app use and the practices associated with it. It will follow by discussing the user perceptions of how the app shaped the materials (5.2), meanings (5.3), and competences (5.4) associated with their practices. Next, user interaction with and perception of the social features will be examined (5.5), followed by the results regarding app flexibility and specificity (5.6), and then the interview results regarding monitoring and feedback (5.7). The chapter will be concluded with a look at the overall reactions of the users to the test and the experience of using the app itself (5.8).

5.1 When, Where, and How Participants Used the App

Understanding the nuances of when, where and how participants used the app is important in order to understand how the app becomes configured in or shapes the user's practices (or how it fails to do so). All the participants reported that they used the app during their free time or between other activities. Two specifically mentioned using it while they were procrastinating other work. Most users used the app exclusively at home. One mentioned using it when they were in the train, and another on the toilet as it is where she most often looks at her phone. One user noted it was easier to focus and use the phone at home, and that it would be inconvenient to use the app while they were shopping or on a walk. The app was used a few times per week for brief 10 to 15-minute intervals. There was no preferred time of the day among users to open the app: some chose the morning, some in the middle of the day or evening when they had free time, and others whenever they received a reminder. As such, using the app appears to constitute a new practice in the daily lives of the participants, rather than embedding itself into one of the activities the participants were trying to change. In terms of practice theory, this means that the app itself isn't embedding itself into each practice as a material, but rather that it is an entirely new practice which, due to its reflexive nature, can cause reflection on unsustainable practices, thereby affecting them. This is an expected outcome, as the app targets many practices and tries to reduce the user footprint in general rather than being a daily tracker for specific activities.

As the users used the app at home, app use was also mainly a solo activity. A small part of users did open it or scroll through with a friend, but these were only a few causalities due to sharing the same living space. One user even mentioned thinking it would be rude to use the phone when spending time with others. As the COVID-19 pandemic constrains most people to living at home or stay in their student housing, the fact that users used the app mostly at home and on their own is also not unexpected. It is possible that the pandemic is a particular limitation for the app, as casual interaction in school hallways or classroom breaks with acquaintances could lead to more discussions or use of the app in social situation with like-minded acquaintances. This is, however, speculation, and therefore it can only be concluded the pandemic is a limitation for the study itself, as it cannot verify how or if the app comes up in regular every day casual interactions. Another potential limitation to app use emerged for two users, which indicated that using the app conflicted with their desire to reduce their screen-time or use their phone less. This was likely a product of or heightened by the amount of online and on-screen events that result from the Dutch corona measures. Both of these participants were students of Wageningen University, which now conducts most lessons remotely.

How participants used the app, however, was more varied, despite them all using it mainly at home. One user described the app as having a dual purpose:

> "So that's maybe also the thing that I think about the app, so it has maybe two functions. So one is maybe <u>inspirational</u> in a way that it kind of inspired me on some specific points, um, to maybe become more interested in doing that, like in terms of the plant based diets, the gifts maybe and also the documentaries for example. Um and the other point is maybe more <u>organizational or planning or logistical</u> in terms that it can also give you a framework to kind of set targets and try to move towards that." (Interview M (m))

Many users indeed identified the app as a tool to find inspiration or ideas, as it offered a great and varied selection of potential actions they could take. Meanwhile, others used it to plan in a more intentional manner. This could be the softer, less structured planning of choosing an action for the day/week or putting a reminder on actions they wanted to recall in the future, such as looking up the policies of politicians in a few months during local elections. For some of the users, planning could also be more structured, as they incorporated checking the app and/or the actions they wanted to accomplish in their schedule. One user noted that the lack of integration was a disadvantage for using the app, as it would be easier to embed into everyday actions if it was possible to link the app to a calendar or other app more involved in daily activities.

Some users struggled to use it as an inspirational or planning tool because they were already familiar with many of the actions, and as such found it difficult to find new practices that would interest them and at the same time be accessible to them in their current situations. Situations like these discouraged a couple of users from passionately using the app, describing the changes they made as "*minor*" and "*not extreme*" (Interviews N (m) and R (m)). As most users had a previous environmental-related education, it is not surprising that many reported that a big part of the actions they marked as complete were done right after their first footprint calculation, as they selected the actions or practices that they already did. Most users described the app as a reminder tool for the sustainability knowledge and practices that they already knew or were attempting to engage in – keeping them "on top of their game" (Interview M (m)). This is not necessarily a conscious choice or product of the app's actual notifications, but simply an effect of using the app, as seen in the case of the following user:

> "Uh, I would say I first looked at the action and then I kept that in mind when I do my normal day like activities. And... It's not necessary planning it's more like a reminder; it's not that I'm going to plan that I'm going to use cold water to wash my clothes. It's just, uh, it's more, it happens more unconsciously". (Interview N (m))

In the best-case scenarios, these reminders provided by the app lead to the consolidation of new practices (regardless of whether this was a novel practice one or simply of consolidation of a sustainable behavior the user already knew or was trying to do):

> "It's kind of like a reminder, but you know, after weeks it's more like a habit." (Interview N (m))

Lastly, some users also saw the app use differently, thinking of it as a reflection tool. These users were interested in seeing how they were doing in terms of their current footprint and seeing how their completed actions (before or during the app use) lowered the footprint. This perspective was not mutually exclusive from the planning or inspiration perspective, since users could see the app as serving different functions and therefore using it in different ways. Furthermore, it was possible for the way the user approached the app to change over the test period. As one participant notes:

> "Maybe that's the first time I've used it, I use it as a planning. I got like, hey yeah, I'd love to like work on that the next couple like weeks or months. But then the rest of the time was more like reflection like oh how am I doing? Am I keeping up with this, with what I wanna do? Is there like new stuff I could work on or something I already do?". (Interview E (f)).

5.2 Materials

Looking at all the practices the app tries to change at an overall level, the app itself could be conceived of as a new material in the users' daily practices. This is because it is a tool or a resource that users can carry around with them, as one user describes when asked if the app changed her perception or awareness of her carbon footprint or sustainability level:

> "Yeah, I would say so because often when you look up your carbon footprint, it's like a one time thing you do on a website and then you kind of forget about it. Whereas what's nice with the app is that you can always go back to it. You know you always have it on you, which I think is super important when you're trying to improve your footprint because it's something that you always carry with you, so it makes sense to have an app that you are literally carrying with you to have a look at it." (Interview E (f))

However, as discussed in the previous section, the app did not actually integrate itself into the practices it was trying to change. Rather, app use emerged as a separate practice in its own time that could influence other practices of the user's life. Furthermore, each participant approached how to use the app somewhat differently.

App use may also have affected the materials that make up the practices the users were trying to change. Of course, the app itself cannot give the users new materials or access to new infrastructures beyond itself as a tool. As such, the main way in which the app can affect materials involved in practices is by trying to influence which materials the users use and the manner in which they use them. One way in which this happens is by giving the user ideas about new materials to use in their daily practices, such as reusable cups or bamboo toothbrushes. As many users already engaged in sustainable practices, none got a brand-new material idea from the app. In most cases, in fact, users stated that using the app did not result in a change of material use, as they already knew about or were already the alternatives suggested by the app. The app simply reinforced the use of such alternative materials in users who were already using them, with the best-case scenario being to remind a user of a material they had forgotten as exemplified by the following user:

> "I think if anything it reinforced it because I used to be like, very like sustainability and then… The more I lived alone, that kind of the harder it became, because then, like student budget really kicks in and you start just buying the cheaper thing rather than the more ecofriendly thing. So yeah I think it like reinforced those habits in me so that was like quite nice to see myself, 'cause then I start feeling better about myself and yeah and I become more aware of what I have. Like a really small example is I used to be like for example, obsessed with bamboo toothbrushes like that was just one like little obsession and I've just completely like forgotten about using them 'cause I couldn't find them in The Hague. And then when I went back to Hong Kong and use the app I like found one in my drawer and I was like 'Oh my God, yes' like that gave me so much happiness when I used that. So like it reinforced those old habits." (Interview I (f))

Another way that the app can affect materials used in daily practices is by having users reconsider some materials they regularly use. One example is the use of animal products in food via its plant-based diet action, which was referred to a few of the users who were already trying to reduce meat consumption and were then further motivated to look at their dairy consumption. Another example would be the use of renewable electricity, which was commented on by many users despite no one feeling able to complete this action in their current student housing situation. The most common way to make users reconsider their materials was by suggesting they become conscious gift givers, compelling many of the users to re-assess their gifting choices in the holiday season from traditional gifts to more eco-friendly ones. This conscious gift-giving materialized in different ways: it could mean a local gift instead of a shipped one, gifts from a zero-waste store, or any other form of sustainable gift. One user regretted buying a plastic wrapped gift when they remembered the app, which

shows that the app can affect the user even retro-actively and motivate a change in material choice in the future (the user did indeed follow up with a sustainable gift the next time they needed one).

In some cases, the app cannot make the users opt out of a material use entirely – such as the washing machine, as users must wash their clothes. In situations like these, the app targeted the manner of use of the material. Examples include the report of a couple of users that the app influenced them to do their laundry in eco-mode, and others buying clothing, gifts, or house items second hand. One user reconsidered where they stored food, putting it in more visible places to avoid food waste. Another common example is heating. Many users reported trying to lower their heating, which could also lead to the consideration of surrounding factors:

> "So I definitely worked on decreasing my heating consumption, like I was more aware of like when I was turning on the heater. If you know I was opening the windows I would make sure my heater was on- off for like a while so I wasn't… and I would make sure to like trying to put more like sweaters or socks on." (Interview E (f))

This deeper analysis of everything that surrounded the use of certain materials resonated with many users, which is best exemplified by the following user's comment on considering *"the whole experience of it"* (Interview I (f)) in relation to gift-giving:

> "[…] you're actually mindful of what like gifts you're getting, how you're getting them, where they're coming from, how you're wrapping them, and like everything else that goes along with it" (Interview I (f))

It is important to note that because these users were already aware of or trying to implement sustainability into their daily lives, the changes mentioned above were frequently not big leaps, but an extension, continuation, or reminder of ideas or behaviors that they were already trying to apply. Two of the users were already trying to shift their consumption towards secondhand materials, a few already did not eat meat, and one was already attempting to gift zero-waste gifts to her friends. Furthermore, the Dutch infrastructure means that at least one action of the app – biking – was already the norm for all the users testing the app in the Netherlands. Similarly, the availability of vegetarian or vegan products certainly advantaged the users trying to reduce their animal product consumption in comparison to a test user that may be using the app in another country – particularly so in the university environment. Therefore, the app is also more of a reminder in regards to materials, either reminding users of certain materials or of using them in a specific way.

One challenge among users in changing materials hinted to earlier with the energy example is the issue of authority or power to make a change in materials. For instance, in the case of switching to a renewable energy contract, many users felt like this was not possible for them as they could not change what the student housing providers chose. Only one user even considered the change possible, nevertheless stating that this would be a considerably large effort involving a lot of work, lobbying the housing corporation with time and effort that they did not necessarily have. Students staying with their families also struggled to feel like they were able to make change, with many stating that they did not have the authority to change appliances, lightbulbs, or other materials in their parent's home. The authority to change house items issue was less prominent in student housing, with one student replacing broken glasses in her common kitchen with secondhand ones. This demonstrates that there is a difference in students' feeling regarding the ability to select items in shared housing versus family housing owned by someone else.

A few students noted a different issue in the energy provider switch example. A couple noted they were unaware of the origin of energy they used, as well as not knowing where to find this information. A similar information issue was a language barrier for a test user who carried out

the app test in her parent's home in Hong Kong. As she could not read the packaging in the products in the store, she was sometimes not sure how to apply the material changes despite having some knowledge.

5.3 Meanings

At its most basic, the app shows the user a large array of ideas of practices they can implement or change to reduce their footprint and live more sustainably. A lot of the users appreciated the app for offering all of this information, giving them a large repository of ideas to increase the sustainability of their lifestyle. As such, they did not value simply receiving information, but information directly relevant and targeted to this goal:

> "And also I think one thing I was really surprised about is how much information that it provided, 'cause I think that in general there is so much information about the climate in about the environment. But then because there's so much, is hard to find what's relevant. And I think that the app just gave you that information that you need. Like you know, people who want to make a change. Yeah, so I thought that the information that was given is very relevant and I think that's what mainly contributed to the good experience I had." (Interview A (f))

A couple of users specifically mentioned they liked that the app helped them learn tangible, albeit small, ways to impact the environment in their daily life, with one specifically describing how it allowed them to feel like they could make an impact where they felt like they were powerless before:

> " […] it definitely did make me aware about small changes I can make that I didn't know it before, like for example in high school and we're talking about things you can do to reduce your impact on the environment we would come up with stuff like you know, switching to solar energy or like carpooling stuff like that, but those are sometimes actions that you can't really control and that are dependent I guess living with your family or like how much money you have, but I think that the app made me aware of short like, you know, small thing- changes that I can make that I didn't think we necessarily that we're necessarily impacting the environment? So for example, the gifts you buy, I would have never thought that that would impact the environment in some way. Or, like you know, the clothes you buy. So I think it did definitely make me aware of the smaller things that like I should consider when I'm thinking of the environment." (Interview A (f))

By offering this list of actions, the app connected many different practices to environmental meanings, ranging from small ones such as the cup they use for coffee to larger ones, such as the food they eat or the energy they use. By offering a detailed description of each action, each user could immediately tie in the practices they were trying to change to a concrete environmental impact, with one user detailing how every time they opened the app they were reminded of the long term benefits with keeping up with their decision not to eat beef. Others found environmental connections in unexpected actions, such as reviewing sustainable businesses or making sustainable investments. One field that was mentioned as positively surprising by some participants were the social-related actions such as talking about climate, which is not often presented as an action that can help the environment as it does directly reduce emissions but is still perceived as important by the participants.

While the app provided some users with new ideas, others saw shifts in or expansions of already existing behaviors. For instance, one user already avoided single-use plastic bottles, but had done this because of the connection to plastic pollution. As such, even if they already knew of this action, they now also connected their practice of using a water bottle to their carbon footprint as well. Other users saw their meanings broadened, with one user stating they were already sustainability minded but that they had not paid close attention to their

electricity usage before using the app. Using the app, therefore, expanded the meaning of sustainability for this user.

Furthermore, using the app made the users not only more conscious of environmental impact of their actions, but also the implicit feelings and motivations behind their practices. One user exemplifies this when discussing becoming more aware of the feelings or mindsets behind her heating consumption:

> "Like the heating thing, it's just something that when you're cold you just want to be comfortable. You really don't want to think about anything else but it made me rethink and made me just be more aware and more conscious of like my yeah my feelings." (Interview E(f))

Whereas another user found themselves more aware in the opposite scenario, becoming more conscious of the meanings associated with an already sustainable practice:

> "I think a lot of the things I do in my everyday life are always with in that regard, like with that afterthought [sustainability]. So I wouldn't say that changed, that my behavior really changed, but it was just more, maybe more… yeah I was- it stuck with me more, or I thought about it more than I did before using the app. Like what specific contributions a choice or a single action might have. Um, as opposed to just doing it because that's how I always do it" (Interview S(m))

It is important to recall that due to their previous knowledge of sustainability, all the participants involved in the app test already had some degree of motivation or some type of environment or sustainability meanings before beginning the app use. This is clear in the quotes by of the following user:

> "I was actually super excited at first because I love, you know, trying to like challenge myself and try and improve because, I know someone who is studying environmental science I feel like I know a lot already and so it's always nice to see… to try to challenge yourself in new ways and see what you can do better." (Interview E (f))

A couple of users struggled to find any new ideas from the app, as they were already interested and engaged in trying to apply sustainability to their daily lives. In these situations where users did not find ideas that interested them, the app was not as successful in helping them create novel meanings. Rather, it served more as a reminder tool to maintain them "on track" (Interview R(m)) of their pre-existing sustainability minded or oriented practices. This difficulty was not the case for all the participants which considered themselves to already have a high sustainability level before using the app. One user specifically mentions that the app reminded her there are still things she can do despite already considering herself quite sustainable. Another noted that the app helped spread his sustainable secondhand clothing habit to another area of his life when he went searching for a gift for a family member. This participant also applied another idea from the app into a different area. Inspired by the "calling natural gas methane action", he also questioned calling pizzas his family make for dinner "normal" and "vegan", as opposed to "meat" and "normal":

> "Um…Yeah, maybe this calling natural gas methane, like that you can also apply that to other areas to highlight that the way things are at the moment are not necessarily normal or the most efficient way to do things. For example my brother, he's mostly vegan. And so sometimes when my mom cooks something and she says yeah, I made a normal pizza and then there's a vegan pizza or so. And then I said, OK, so there's a normal pizza and a non-vegan pizza." (Interview S (m))

One participant stated that despite not finding many actions suitable to him during the test period, he thought it was very useful that the app tied in the actions to an impact level, which gave him a better idea of how the actions he already knew compared to each other in terms

of effectivity and environmental benefit level, by extension helping him have an idea of what to prioritize. This impact level assigned to the actions can, however, be an area for conflict if a participant disagrees: one mentioned disagreeing that sharing the app on social media as an action with any impact assigned to it and stated that this disagreement made him question the legitimacy of the app as a whole.

With regards to the app keeping users on track, however, most participants indicated they found using the app very motivating to keep up with their sustainability habits. This was particularly thanks to the feature which shows the footprint reduction when an action is marked as complete, directly tying an action to a footprint reduction. Observing this feature was directly linked to users stating they felt happy, good, or satisfied about themselves. Some participants expressed doubts on how the footprint reduction was calculated, particularly when they considered an action to be more long term or habitual. These users were also those who expressed less excitement with regards to seeing the footprint reduction. While seeing carbon footprint as a metric for sustainability of actions is a somewhat narrow focus, the participants that had been attempting sustainability through different lens (e.g., plastic waste avoidance or purchasing items second hand) did not note any conflict with their preexisting idea of sustainability actions and the carbon footprint framing of the app – particularly as those were often complementary. One example is the user that was already avoiding single use plastic mentioned earlier in this section. Only one participant mentioned also enjoying seeing their points increase and their level go up, as the increasing level names reminded her of a growing plant. This may change the meanings of that participant with regards to those actions. However, the points system was but a small, new feature of the app accessible under a secondary tab of the "My Progress" page. As other participants did not mention this feature, it will not be discussed at length.

The starter footprint calculation was also an effective tool to create new meanings for the users regarding their own footprint, making them more aware of the link of specific categories or areas of their lives to a portion of their footprint. Furthermore, the comparison of the user footprint to the country and global averages were also considered motivating for the users. These aspects will be discussed in greater detail in the monitoring and feedback session but are they are briefly mentioned here to note the comparison added some meanings or motivations for some users. One participant worried that getting a good score in the starter footprint may lead some users to being complacent and not trying to reduce their footprint further. While many users did indicate enjoying performing well in their footprint calculation, none state that this was a reason for which they were not motivated to try and use the app. Rather, users that performed well stated they struggled due to the difficulty in finding not too high effort actions that interested them, rather than because they were happy with their current footprint. Only one participant found their own footprint demotivating. This user found it discouraging that flights, which they perceived as a practice that they could not change, was such a large part of their footprint. They indicated that this was demotivating because it meant that any actions they completed would only have a minor impact on their overall footprint in comparison.

5.4 Competences

Looking at the app as a tool to help users find ways to reduce a footprint, participants found the app satisfyingly varied and thorough. Participant opinion differed, however, in regards to how much the app helped them in terms of know-how or skill required to complete each new action (and as such, make a practice more sustainable). Only a couple considered the information the app provided sufficient and specific enough to complete an action:

> "I feel like it was, they could give some pretty specific advice which was nice. Especially like the changing like energy providers too it was pretty like, like oh, you can look into this, this and this, like you could see you could get very specific if you wanted to on some stuff." (Interview E(f))

Meanwhile most thought the app was more focused on giving information, rather than developing a new skill. One user describes the app as giving the starting push, getting the users to start trying a new sustainable practice and figure it out as they go along:

> "I think the app mostly gives the actions with the motivation on why you should do the action and not necessarily how you could do it. Like also for example for composting, it really says just start and, um, learn while you're going, so that was…yeah, it was like it motivated me to start the action but then once I was doing it also for the plant based one, I'm like doing the plant based I'm looking like in other things like on YouTube or on just Internet to see like how I could do it better, how I could make it work for me. Um… So mainly it motivates me on why I do it instead of like telling me how to do it, but I think that's also like good because there are many ways of doing it. So if you're interested in doing a specific action, you should just yeah, look into it yourself to see what works for you […]" (Interview S(f))

It is not seen as a drawback, as the user considers there may be many ways of doing something and that everyone must find what works for them. This sentiment was echoed by another participant, which indicates that if he were to try the plant-based option it would likely make sense to download another app or find a resource specifically tailored to guiding the user into going vegan. This means the app does not necessarily assist the user in creating new competences. Although this could align with the user's view of the app as an inspirational tool mentioned previously, it means that some of the more complex actions could need greater guidance or, in the case of going plant-based, an in-between step (such as go vegetarian) or more closely tracked challenge beforehand (go vegan for a month).

It is important to note that the necessity for how-to information greatly varies depending on the complexity of the action selected by the user. For instance, the "using the washing machine on eco-mode" challenge does not require further competences – the idea or name of the challenge itself is enough, and all the user needs to do is press the appropriate button. Going fully plant based, however, might require more underlying skills – how to include enough protein in a meatless meal, how to use novel ingredients, etc.

Finally, using the app possibly results in one "unintentional" new competence: many users reported feeling more confident in carrying out their sustainable actions and also discussing them with friends and family, despite not necessarily selecting the talk about climate action. Some indicated this was because they now had the information to back up their ideas either at their fingertips or fresh in their minds since they were looking at the app regularly. Others instead simply felt this because using the app validated their attempt to be sustainable as a good thing to do – that is, using the app itself could make them feel more sustainable or more confident in being sustainable. This finding contrasts with the opinion of some users on the talk about climate action, which one user indicated was hard to complete as they thought the topic should arise organically rather than be introduced by him, and which another indicated as highly ambitious and difficult for someone who is not comfortable in a speaking position. How the app equips user to deal with social situations will be further explored in the social section (5.5).

5.5 Social Features

As stated at the start of the results section, app use was mostly a solo activity. Only a few users showed the app to or used the app with other people. One user even said it would likely be rude to use the app in front of others. While discussing the app – or, most likely, the challenges they were trying to complete – with other people occurred more often, some users

did not discuss the app or any actions with other people at all. As such, the app has a limited success in regards to the social domain. This is possibly due to user perception of their use of the app as a test of the app instead of considering themselves regular users:

> "I think yeah, like if I was to use it more or if I was to download this app just as a normal user rather than for a test participation, I think I would be more inclined to use it more, so therefore I would be able to discuss it in a social setting more too." (Interview I(f))

Those who did discuss the app mentioned it to their housemates or brought up what they were doing in the event of relevant contexts, such as buying gifts with family members or when refusing meat at certain family or housemate meals. As discussed previously, some users found the inclusion of social actions in the list offered by the app refreshing, while others found confidence in their actions or in discussing sustainability related topics due to their app use. However, others found talking about the climate much more difficult, and did not feel themselves as equipped by the app to deal with these social situations. One user thought it was strange to bring up topics like the climate with friends unless they arose naturally in conversation – particularly since meeting with friends are now much less frequent and online, and therefore less casual. Others find talking-related actions much more personally ambitious and did not feel like the app necessarily helped them overcome this barrier. Interestingly, users also mentioned the people around them now that they are out of university as being less interested about sustainability or climate topics, which led them to be less able to discuss it with those around them. This is particularly relevant, as it is likely more impactful to discuss climate with people who do not know much about it than with people who agree with you. Therefore, it would be important for the app to give the users more guidance to bridge the invisible talking gap. One user suggested making comparisons (such as making a certain amount of CO2 equal to kilometers driven by a car) to help make the information more palatable or accessible.

This concept of a bubble emerged also in an opposite way during the study: one student stated the app kept them sharp in Wageningen University after having left their previous, more everyday sustainability-minded bubble. In this case, the app provided support for a user to keep up their sustainable practices and goals in what they considered to be a less welcoming social environment. However, this user did not attempt the talk about climate action, so it is not a directly comparable type of bubble. Furthermore, all users were slightly disadvantaged in the talking about climate action or in the number of opportunities to casually bring up the app in a social context with friends and university acquaintances due to COVID-19 lockdowns. After all, students who did not discuss the app much at home would more likely have brought it up with their peers in university given the greater likelihood of common interests related to their education.

With regards to the social features of the app itself, only a couple of participants used the "invite a friend" feature. Most participants simply did not think about it. It would likely be more effective if sharing the app or inviting a friend was included as an action the users can complete. Others, as seen in the previous quote, felt like they needed to test the app before they could recommend it to someone else. One user stated that they find it highly unusual to share apps among friends – and in any case, that he did not consider the app high enough quality to share with someone else.

Many users mentioned it would be nice if the app had more social features, be this the ability to connect and follow other users to see what they are up to, join groups where you can compete, or have some type of social platform/discussion forum where they can share ideas and actions, counsel each other based on what work or did not work in their different experiences. This last discussion platform idea is provided by a user who gives an example

of using the app with ten people he knows, which would raise the app from a narrow focus on the environmental dimension to adding a social component with other components. This would allow the user to feel as part of a group when they use this app as opposed to perhaps completing a task. Another user leans in instead to the competitivity or social media angle:

> "So in that you can follow your friends and then you can have a competition. The more points you earn it keeps you on the top of the leaderboard or something. There are also fitness apps like that I don't know yeah, I think Google Fit also does that. Some other companies, fitness apps, also do that, Fitbit also. So it tracks not only your actions but also say your peer group. Maybe your friends, family, or also people in your region. So if a feature like that is added in this app, it will keep you on your toes. So it's not just you that you are competing against, if you have a peer group, then she has done this thing, he has done that thing, I also want to do this. So that competitive is, I think, would trigger people to do more." (Interview R(m))

Lastly, another suggested social feature would be the ability to rate the actions of other users in the app so as to create some type of community evaluation of the community-submitted actions available in the app.

5.6 Flexibility and Specificity

After discussing the theory-based categories, the interview analysis moves on to categories on the part of the framework constructed from the literature on sustainability apps. The first of these is the concept of flexibility from the work of Fuentes (2019), which indicated that failure to create ethical consumption by sustainable shopping apps had to do with inflexibility, and the lack of ability of the users to customize the app to their wants and needs. While the app was pre-approved with regards to flexibility in the app examination (that is, an inflexible app was intentionally not included in the user test), it is important to see how users themselves perceive the flexibility or lack thereof of the app.

All participants expressed satisfaction with the flexibility allowed by the app, in particular with regards to the setting of duration and reminders for actions. On the one hand, it allowed users to plan actions to fit their schedule, even setting reminders for months in the future if a certain action would only be relevant later in the year. On the other hand, it permitted users to reschedule and not feel too excessively pressured when they were not able to complete an action in time. One user even indicated there may have been too much flexibility, as he gave himself a few weeks to complete the watch a documentary action and ended up finishing it much earlier than the action length he had set.

Even participants who struggled to find actions that they were interested in and/or which were accessible to them still did not believe that the app had a flexibility issue, as they considered there was sufficient variety for anyone to find at least one thing they could do. Therefore, even though some users noted some actions mentioned in the app were not relevant for them, they could mark it as not for them as well as scroll through many others, and as such did not think that the app was any less flexible because some actions did not apply to them. This "not for me" feature also enabled users to filter out what they considered to be COVID-incompatible actions such as joining a protest. This made the app more effective and flexible for the users in the unexpected COVID situation than if the app had added more categories at the start and only showed them actions based on their status as renters and landowners. Furthermore, as one user put it, seeing actions they cannot do yet is not necessarily a problem, as it gives them things to think about or keep in mind for the future. While this user was referring to keeping the long-term action of installing solar panels in mind when they own a house, another was more short-term and wanted to keep some actions in mind for when she went back to university after being home for the family holiday. Finally, the users noted that it is possible to add your own action to the app, which would help users who disliked the ones available, and

which would make the pool of available actions even greater (as well as prevent them from becoming narrow-minded and only thinking of the sustainable practices or practice changes listed in the app).

The only inflexibility encountered by the users was a detail of physical design: if a user scrolls down the list and opens an action to read more about it, when they press the back button to look at the list again the app will automatically scroll them back to the top of the list. Multiple users indicated this was bothersome, as it tired them to scroll multiple times and encouraged them to close the app and do something else where they maybe would have continued exploring. In response, one user suggested a shuffle button for the list to change order. Furthermore, at least two users indicated the list of actions felt limited after their first few scrolls, and that they were later surprised to see more actions. One of these users suggested the app could notify users when new actions are added, so the users know instead of having to go down the list.

With regards to specificity, users also expressed satisfaction. One user outside the Netherlands described how the process was made easier by being able to use her local currency in the calculation. Furthermore, most participants liked the comparison of their footprint to their country average. Only two participants had comments about this, and they were opposite criticism. One thought it would be nicer to have a comparison closer to home, such as a comparison to the average person in his city or university. Another thought it would be good to see a comparison to other countries alongside local and global, so as to allow users from different regions to realize they may be "living at the expense" of other regions.

One user stated that the specificity of the app also varied among the different actions. The same user also stated that the points system could be better, as even people who started with a relatively low footprint would be a beginner when they may already apply many sustainable measures already in their daily life. Another user, one of those which struggled to find actions for themselves as they already did some of the beginner actions, stated they believed it was possible the target audience of the app was too broad. Lastly, as mentioned previously, one user believed the app would have been better if it were integrated with other apps or a calendar, and such a feature would allow the users to make the app both more flexible and more specific to themselves personally, which is why this is mentioned here.

5.7 Monitoring and Feedback
At last, it is also important to discuss the monitoring and feedback used by the app. As discussed in the Introduction and Conceptual Framework (Chapters 2 and 3), user retention is one of the main challenges of carbon footprint calculators. Due to their portable nature and possibility to send notifications, apps have the potential to bridge this user retention gap. Whether this potential actually becomes reality can be analyzed in the user test, which goes beyond theory and predictions.

With regards to monitoring, participants using older phone models were not able to receive notifications from the app. As such, there is some disparity in how users discuss notifications in the interviews. Some users also disabled app notifications, as it is their custom to do so for all apps. The effect of this was slightly evened out by weekly reminder they received to fill out their logbook, which means the study is slightly biased: it is possible more of the participants would not have completed the four weeks had they not received those logbook reminders. The users who did not receive notifications naturally felt like there could have been more monitoring on the app's behalf, with some stating it was quite easy to forget the app if they did not open it, and others saying they would have liked a reminder to open the app. However, the users all agree that receiving too many notifications would not be ideal, and a one per

week rate would be ideal for notifications. One user identified seeing the app in the home screen alone as a source of reminder or motivation.

The users agreed that tracking their progress via their app added to their motivation to complete the actions. However, all users recognize that ultimately the drive to follow through must come from them: the app cannot replace their personal drive or motivation to try new practices or follow through their actions. Therefore, it is not surprising that most users still identified motivation as one of the biggest challenges in changing their practices. As discussed previously, most users were satisfied with the flexibility in the monitoring of the app. However, there were some doubts regarding the monitoring method. The uncertainty of some users on how the carbon footprint reduction was calculated did not only conflict slightly with the meanings the app was shape to create (see section 5.3), but also raised some concerns about the method used by the app for monitoring their actions. This was particularly the case for actions that they thought were more closely aligned to long term habits that they can get wrong after marking as complete. This is clearly detailed in the following quote:

> "Maybe also one thing is, um, related, to kind of feedback and monitoring with the actions, that I also find it just quite hard to see how… Especially things that are kind of ongoing, like becoming a more conscious gift keeper. How would that be monitored? Because it's in a way something that you can never really finish because basically you could see it as a lifelong effort. And even if you buy a bit more sustainable then you could still make more leaps forward so… I found it in those things a bit…difficult to kind of monitor that. So then I would almost think that that would need something additional if you really wanna monitor or self-monitor that, to translate it into more concrete goals in a way. For example, this year I'm going to give 10 presents which will be, you know, donations to Greenpeace or whatever instead of something else, and then by the end of the year I can reflect on whether I completed that or not." (Interview M(m))

One user thought the app did not do much monitoring (they did not receive notifications) but thought that this could still work if the app gave the users tools for self-monitoring – such as calendar integration. Besides the notification struggles, most users believed the monitoring appropriately matched the app's intentions:

> "I think for like how the app works, I think it was sufficient enough because it's basically just seeing what new actions do I want to do and how am I doing the actions that I want to do. Uh, if it was, for example, something that will give you or would keep track of your daily footprint, for example, like if you would keep track of how much water did I use today, like today, I showered this many minutes and today I had the lights on for so long, then it would be useful to actually look at the app every day, but I think for this it's fine to look at it once a week and just have that as like a reminder or reflection moment. Yeah. And also I don't know if I like I might have liked it for like a week to track how much water I used or how much energy I used, like using lights for example but that's not something I would do for like longer than a week for sure. So uh yeah, I think this app fits, suits, like the workloads very well." (Interview S(f))

When it comes to feedback, as discussed previously, the users were highly motivated by seeing the reduction of their footprint following the completion of each action. As discussed previously, the exception to this are some users who had uncertainties on how some reductions were calculated, in particularly for long term or habitual actions. Some participants were (positively or negatively) surprised by their initial footprint, and all participants enjoyed examining the disaggregated footprint in its categories, as exemplified by this participant:

> " [..] one thing that I found quite interesting is all the way in the beginning when I had to fill out this questionnaire about my footprint in app, I did find that actually quite interesting. Also to see what the average of the Netherlands was and also how my footprint was built up out of these different parts. And there for example, I don't remember exactly what it was, but I think it was the category of waste that was still quite high, just in the Netherlands average and also in me I thought, "hm, that's something I didn't

really think about before as a substantial category". Um, yeah and also it was just shocking to see how high the average of the Netherlands was, that was just… Yeah, I already knew it, kind of, from different numbers, but to see it kind of so spelled out was quite interesting." (Interview M(m))

One user noted that the chart could also allow you to see the comparison of your own goal, rather than the country 2030 goal, as it would be more personal, more relevant and motivating.

The feedback during the completion of the action themselves was not addressed specifically by most users besides the discussion of notifications and monitoring. Only one addresses this point, stating he would have liked more feedback throughout an action's completion, rather than simply their description or seeing the emissions go down afterwards:

> " I don't know why when I use the app, I don't feel like it gives me a lot of feedback. It's just that something because they kind of mention oh something is in progress. But it doesn't give you like certain feedback on you know 'on OK, have you done this' or 'are you still doing this' or um, 'make sure you do this'. It's just I don't think I don't think it's there, or maybe it's just me. But I don't quite feel like, uh, yeah, the feedbacks are that helpful apart from the first time I I saw the action" (Interview N(m))

Lastly, only one user mentioned the motivational quotes given when the user opens the app, saying:

> "For me, the little the better, although I do always like when you open it there is like always some sort of like information popping up or I think for me. Um… Which was nice, like there was almost like a quote or like this piece of information, which is nice to have-" (Interview S(f))

As such, while not perfect, the monitoring and feedback received generally positive reviews from the user, who enjoyed the numbers associated with each action, and the flexibility allowed to them in their self-monitoring.

5.8 Overall Reactions

All of the test users had positive initial reactions to the app, believing it to be a clever tool with great potential to help reduce their footprint. One user noted:

> "I actually really liked it, like I thought the concept of it was really, really interesting and like when I was going through it, I just kept wondering to myself like, how have I not like thought of needing something like this before or like how has this not been like on the market and like actually advertised before? 'cause I think it's so useful and it's such like an easy way of being mindful about all of those things, so I really really enjoyed it" (Interview I (f))

However, not all users were equally as impressed by the app. Three users expressed doubts regarding the methods behind certain calculations for footprint reductions or the impact score associated with certain actions. One user simply thought the app was not sufficiently useful or effective to recommend to other people.

Despite this mixed overall reaction, all of the users indicated that they believed using the app had indeed reduced their footprint at least to a small extent. This indicates that the app must have impacted at least one of the practices (or combination of small ones) carried out by the participants in their daily life. When questioned about the difficulty of the actions they selected (and by extension, the practices they were trying to change), the users were split into two groups. One group stated they chose a medium or mixed array of actions, while the other stated they chose easier or lower ambition actions. Even those who selected the mixed range of difficulty actions did not think their emissions were greatly impacted – likely due to (1) their relatively sustainable starter level resulting in them finding many fitting actions (some users already did not eat meat, for instance), (2) the fact that higher impact actions such as changing diet are longer term actions they did not yet complete, or (3) the inaccessibility of some actions

(such as changing to a renewable energy provider) in their current housing situation. The overall impact of the app is perhaps best summarized by the following participant:

> "So I wouldn't say that the app was a complete game changer in that regard. It was maybe rather something that could help me to stay on top of my game [...]" (Interview M (m))

However, as seen in Sections 5.1 through 5.7, the user test picture becomes more nuanced when examining category by category. The participants revealed that they did not integrate the apps into their existing sustainability practices. Rather, app use can be seen as a new, reflective practice which in turn could influence other practices in the users' daily lives. Users indicated using the app when they had free time, between tasks, or procrastinating other tasks. They used the app most often alone, and viewed it as an inspirational, reflection, or planning tool (or a combination of two or more of these).

The different elements of practices were affected to varying degrees of success. In terms of materials, the app had limited effectivity, as it could not provide anything besides itself. However, users did find the app to be of some influence to the materials elements of certain practices. They reported the app strengthened their resolve to use sustainable alternatives (e.g. reusable coffee cups) or caused them to reconsider some of the material or infrastructure use in their daily practices (e.g. amount of heating). The app was successful in its approach to meanings, bringing users that were ostensibly already engaged with sustainability new ideas and motivations regarding their everyday actions. In terms of consequences, reviews were mixed, with some believing the advice from apps could get sufficiently specific and detailed, and others believing it was only a starting push requiring the user to follow up with their own research. Users also differed in their perspective of how much guidance the app needed to give to be successful. This reveals that participants tried various types of actions with different complexities. Expectations around the amount of work the app needed to do or not do for the user regarding researching and figuring out how to implement new practices varied as well.

The social element of the app was possibly the weakest, as it did not offer group features. It's approach of encouraging the users to do social or communication-based actions could be successful, but it was not possible to ascertain due to the limited social contact resulting from COVID-19 lockdowns. Participants found themselves using the app most often alone and not discussing it much with family members. However, a potential increase in effectivity outside of lockdown conditions could be present, though at this stage it remains speculation and would require further testing.

The users reported a lot of satisfaction with the flexibility the app allowed them, in particular the flexibility with regards to setting action durations and controlling the frequency of notification. That is, they liked setting their own goals and timelines, as well as being able to edit these at will. This is clearly linked to monitoring, as this flexibility allowed them to self-monitor themselves as they saw fit. This was a double-edged sword: the reviews for monitoring were mixed in part because users recognized that they were dependent on their own self-motivation. Furthermore, users with older phone models did not receive app notifications at all, meaning that the experienced was uneven among test users. User experiences on the amount of feedback received was more positive, but not homogeneous. While most enjoyed the immediate reduction of footprint they could see at the completion of each action, one user in particular noted that it would have been nice to receive feedback throughout an action's completion rather than only afterwards. That is, receive a reminder, tip or a suggested action plan to complete the action.

While these insights and findings are based on the Earth hero app, the nuance within user reaction, as well as the strengths and weaknesses identified by the users, will likely resonate with user experiences of other carbon footprint apps. That is, they can also be used to improve the experiences of other apps beyond the one tested. This is because carbon footprint apps have similar (even if not identical) approaches and designs with regards to changing user practices.

6. Discussion

The following chapter will present a discussion of the findings of this study. It will be split into three sections: first, a discussion of the findings within the context of the existing academic literature. Secondly, it will look at the strengths and limitations of the study design, which in turn will inform the reader on the generalizability of the findings. Lastly, it will discuss the suitability of the conceptual framework, looking at where it suited the study objective and in what areas it was less suitable or lacking.

6.1 Literature

This study conducted an exploration of the most prominent carbon footprint reduction apps, as well as a user test on one of these apps: Earth Hero. As discussed in the introduction, the literature on carbon footprint reduction apps is scarce, there is not much literature with which to compare the results of either result section (examination and user test). Therefore, the following section will also draw upon existing studies on carbon footprint calculators and health intervention apps. This is because these studies can inform us on the strengths and limitations of apps as a tool to achieve behavior change, even if they are not directly on carbon footprint reduction apps.

The results of the app exploration are in line with the practice theory informed study on carbon footprint calculators by Salo et al. (2019) which finds that such calculators have a limited capacity to influence the **materials** aspect of social practices. Both carbon footprint calculators and footprint reduction apps are limited to making suggestions for users with regards to rearranging materials and cannot actively influence the environment the user is in or what infrastructure is available to them. That is, a user in the Netherlands will find biking a much more accessible and low-effort action than a user in a country with poor infrastructure. The same concept extends to other fields – such as whether they have access to green energy, meat substitutes, or even just cafes willing to accept reusable cups. The Earth Hero user test further consolidates this finding: while some users were very positive about the material replacement or reconsiderations made by the app, not all participants reported significant changes in how they used or viewed the materials that were part of their daily practices. This is likely to some degree due to their pre-existing background knowledge on the environment or sustainability. For the materials element, the best-case scenario was for the app to inform and inspire the user to change their materials, and there is not much it can do in terms of actually providing a material or infrastructure beyond itself. Potential avenues for improvement in this regard will be addressed in the recommendations section of the following chapter (7.2).

In regard to meanings and competences, however, the results are not exactly in line with Salo and colleagues (2019). While the findings of the app exploration indicate apps as currently designed have most potential to influence meanings, Salo et al. find the most potential in influencing competences. This does not necessarily come down to differences in the actual findings, but to differences in the categorization of the elements that constitute practices – in particular to which element "knowledge" should be assigned to. While this study considers knowledge as part of meanings (the ideas, feelings, and motivations that underlie a practice), Salo et al. (2019) assign knowledge to the competences element, referring to competences as "knowledge and skills". As such, where this study considers users learning about the CO2 emissions associated with one's impact as a transformation of meanings, Salo et al. attribute this to the "knowledge and skills" category, their competences equivalent. This is potentially a limitation with Shove's (2012) elements distinction and the broad nature of information. As competences have to do with the skill needed to carry out practices, this study considered only such *how* type of information as fitting under competences. This distinction is possibly also due to the unit of analysis. Salo et al. study footprint calculators, and the main focus is

the user understanding their own footprint. Therefore, it makes sense footprint related knowledge would be considered under the competences/knowledge and skill category, as the user would be learning how to comprehend their footprint. Meanwhile, carbon footprint reduction apps focus on changing the practices that form the footprint. As such, different *how* information is involved when the focus is changing the practices (as opposed to understanding the footprint). For instance, understanding the footprint of natural gas/methane can be a competence or *how* information if someone is trying to understand their overall carbon footprint. However, if someone is trying to change their energy contract, information on the footprint associated with different energy sources is more closely associated to meanings. In this case, competences would involve the practical *how* to change an energy contract.

Another distinction between the two studies is that Salo et al. (2019) include the examination of social features under meanings, while this paper separates social features from the meanings and observes them individually. The user test of Earth Hero confirms the idea that such an app is most effective at helping the users transform their meanings in relation to materials and competences, as predicted by the app examination. If we take this to mean "knowledge," it does not necessarily contradict the potentials identified by Salo et al. (2019), as discussed earlier. Even users who did not create new meanings associated to their daily habits obtained at least one new idea from the app. The meanings element of practices is indeed both what apps like this have most potential to change and what they appear to appear to aim for most directly through their current design. While it is important to target meanings, it can also be a downfall to look at them alone, as lessons from the attitude-behavior model show that information alone is often not sufficient to change behavior (Park & Lin, 2020; Gupta & Ogden, 2006; Mittal, 1988).

With regards to the competences element, there was some disparity among the users. Some considered they obtained new competences due to the knowledge and action ideas provided by the app, while some thought that after the initial idea from the app the research or know-how depended on them finding external resources. The distinction between these user attitudes suggests the same oscillation that occurs between this research and the Salo et al. (2019) study perception of whether knowledge is informing meanings or skills. Some users saw the actions listed in Earth Hero as a new skill, as it was something they could do and had not thought of before, and as such was a new skill or know-how to reduce their carbon footprint. Other users thought the actions listed gave their practice a new meaning, such as "eating plant based" to the practice of eating, or "composting" to throwing away food. However, carrying out these actions would require an additional guide or trial and error. Even though the user which gave the composting example described being pushed to simply start trying something without overthinking as a positive feature of the app, the need for external resources could mean a reduced efficacy of the app itself as an all-purpose tool. This disparity among users could also be due to the different nature, difficulty, or complexity of the actions they tried.

As elaborated in the conceptual framework (Chapter 2), this study includes a flexibility category due to a study by Fuentes (2019) which indicated that the failure of ethical shopping apps to create user agency was linked to inflexibility to customize apps to fit user interests and needs. Fortunately, this study finds that flexibility is inherent to the design of many of the prominent carbon footprint reduction apps, where users have the freedom to choose which actions they want to engage in, and in many cases for how long as well. This was reflected in the user test of Earth Hero as well, where no participants reported situations in which they found the app to be inflexible for their intentions or needs. Of course, not all apps are equally flexible. In particular, apps where users cannot see or select certain actions until they reach a predetermined number of points of level need to become more customizable. Otherwise, there

are situations such as vegetarian users being unable to complete actions of, for example, eating less meat upon starting to use the app. Indeed, while levels contribute to the gamification experience, there is an assumption of what the starting user will be like – for instance, a meat eater, which does not necessarily match with the profile of someone who is interested in sustainability and looking into downloading a footprint reduction app to begin with. Furthermore, they carry assumptions on what is easy or difficult for the average user to do or change, which may vary greatly depending on where the user is from.

Additionally, the conceptual framework also includes a monitoring and feedback category. This was informed by health app studies on the importance of real time feedback (Zhao et al., 2015), as well as the Salo et al. (2019) study highlighting that continuous or repetitive use is one of the main difficulties of carbon footprint calculator apps. On this point there is not much to discuss: all apps found had a monitoring feature, and the participants in the user test reported a sufficient level of monitoring and enforcement by the app. Therefore, even though the users recognize there is some inherent degree to which self-motivation impacts their success or failure in using the app, the user test indicated a general sentiment that there is as much enforcement as possible from the app. More enforcement might hamper the level of satisfaction of the users in regard to flexibility, as the ability to set their own goals, reminders, and deadlines was mentioned as a positive by many participants. While it is possible to make monitoring more automated without making it stricter (e.g., via GPS tracking), this approach runs into the risk of being seen as an intrusion on privacy. It was not mentioned by the users testing Earth Hero, and therefore the extent of user receptivity to such tracking would need to be evaluated. Zhao et al. (2015) also mention the involvement of a health professional as one of the factors that may contribute to the success of health apps. Such an authority or guiding figure which the user frequents with some regularity could help increase the willingness of users to monitor themselves more actively. However, this is only a hypothesis, and might have to do with the social aspect of the app rather than the monitoring itself or an authority or guiding figure. For instance, an open discussion forum or group community feature in the app or the building of an offline group or community around app use could also increase willingness of the users to self-monitor.

In order to observe the impact of the app on practices in general, it is useful to look at the user test. Although the user test was not quantitative, its results indicate that Earth Hero's impact on participants' practices – and by extension, their carbon footprint – are in line with the study by Reick (2020) on the Norwegian app Deedster. That is, while app use can increase awareness and influence the user's practices, the actions chosen by them were most often small or required low effort. However, both Reick's user test on Deedster and this study's user test on Earth Hero witnessed some higher effort practice changes. Further, users of both studies indicated they had learned about sustainability and gained knowledge on the impact of their everyday practices. While two studies are not sufficient to conclusively state the overall impact of carbon footprint reduction apps, these findings support each other, and as such begin to construct a general understanding of how using these apps influences user practices and footprint. Differently from Reick (2020), however, the users testing Earth Hero did not report as many conversations on the app or the practice changes they were undertaking as those testing the Deedster app. As this study was conducted during the COVID-19 pandemic, it is not possible to say whether this is due to differences between the apps – rather, it is more likely the users talked less about the app with others due to the decreased rate of social contact. Most of the test users were based in the Netherlands, which was in lockdown throughout the test period. This situation hindered the potential for creation or change in socially shared meanings that carbon footprint apps have as identified by Salo et al. (2019). No offline activities meant less opportunities for groups to form where users would share learnings and experiences beyond the individual or household level.

One of the most important findings of this study with regards to the potential effectivity of the app itself may not lie within the realm of practice theory. Rather, it is may be the "pre-existing interest paradox." Users who are interested in sustainability and already somewhat active (or intending to be) with regards to sustainable practices are the ones most likely to naturally seek out and download an app such as Earth Hero. However, these same users may find a higher entry barrier to implement new actions. As they were already trying to implement small changes in their daily lives before using the app, they will likely mark the easiest and most accessible actions as "already done" immediately after their first footprint calculation. As such, the actions left for them to try at the start of their app use will likely be the more challenging ones, meaning they will try simple things they hadn't thought of (such as watching documentaries) and otherwise be stuck not finding something that is immediately interesting or suitable for them. This is especially a disadvantage for such apps, as the people most likely to seek a carbon footprint app out are exactly those people who are already interested in sustainability and likely already engaging in a few sustainable practices.

This target audience is indeed a small one. It is unlikely a general audience (or even sustainability interested audiences who simply do not think to look for a sustainability app) will seek or stumble upon a carbon footprint app without external advertising or influence – and particular interventions or campaigns might be necessary to increase the number of users that use the carbon footprint app. Ideas for such campaigns will be further elaborated on the recommendations section in the following chapter (7.2).

Overall, as they are currently designed, carbon footprint apps have a small impact on their users' footprints and also a minor influence on the footprint of society overall. On the individual scale, users still appear to stick to lower effort actions. Although the social and communication actions help push the change in practices beyond the individual, it is not certain these actions alone are successful in doing so, as the COVID-19 pandemic and associated lockdown meant it was not possible to fully evaluate how the app can permeate or fail to permeate through the user's social circle. This, combined with the current poor integration of groups in Earth Hero, made it difficult for the app to reach beyond individuals in its quest to change *social* practices. While this approach is a useful way to reach people, it is important to combine them with other campaigns to increase the audience of the apps, allow the users to change higher difficulty or impact practices, or tie promotion of the app use to promotion of the local structures. Most importantly, apps as interventions (and individual changes overall) cannot replace, only complement, holding large polluters and governments accountable for their footprint and demanding change.

6.2 Conceptual Framework

This study is not a typical practice theory research. It is informed by practice theory but is not centered around a single practice which it observes and studies in depth. Rather, it uses practice theory to inform itself on the potential reasons for success and failure of a tool (the carbon footprint reduction apps) which tries to change multiple user practices. As the user is free to choose which practices it will use it is not possible to conduct this study as a classic practice theory study. This is not inherently an issue: practice theory can be used to understand why different attempts at sustainability (particularly, ones that target habits and behaviors) succeed or fail, even if such studies do not have a conventional, single-practice centered design. This study modelled its use of practice theory on Salo et al. (2019) to understand carbon footprint calculators, and as such was able to gain a much more nuanced understanding of the elements of practices that apps can most or least successfully impact. As the conceptual framework was also complemented by the flexibility findings of Fuentes (2018), it was further specialized to suit the needs of the study. As such, there were no findings

or insights created through the process which could not be understood via the conceptual framework, and it was not found to be lacking for the purposes of the research.

It is an inherent limitation of this and other practice theory informed studies of sustainability apps that the research done will be at least to some extent individually focused. It is individuals who use apps, after all, and group features of apps (beyond individual approaches) are still in their infancy. This is not necessarily detrimental of the study. Using practice theory to understand the app will in fact increase the researcher's aware of when the individual focus and approach of apps may be detrimental to their own mission. That is, that individuals use the app and that apps are too individual focused can be a limitation for the app in changing social practices, but not a weakness of a study seeking to understand the strengths and limitations of this same app. Rather, being aware of the shared nature of social practices gives the researcher an idea of where the app may not be as successful. A researcher using an individual-only behavior change theory such as the attitude behavior model would not have this critical starting lens, and would potentially have a harder time identifying why the app may not be yielding the desired behavior change results.

While the conceptual framework served the purposes of this research, it can always be argued that it could be improved or made more comprehensive. One of the downsides of centering the framework around a single theory is that some of the insights on success or failures of the app in promoting sustainable practices may be missing. For instance, where this study understands the results in term of supporting competence creations, creating new meanings, and promoting the change of materials, other theories (such as nudging theory) may have different approaches to keeping the users engaged and by consequence different ideas or strategies to improve app performance. Even branching away from social theories, using more of the insights from health studies such as those reviewed by Dreijerink and Paradies (2020) could lead to novel ideas and approaches to make such apps more successful. In fact, one of the main insights from their 2020 review was that combining behavior change techniques could aid the success of interventions and achieving behavior change. Therefore, developing a more comprehensive framework which encompasses learnings from more theories *and* studies regarding behavior change might be a more effective way to not only understand why such apps may fail, but suggest effective strategies to make them more effective.

6.3 Strengths and Limitations

The main strength of this study is its combination of practice theory informed examination and a user test. This combination prevents the app examination of the first part from being purely hypothetical. Furthermore, the study adds to the very limited body of literature that comprises the field of study of carbon footprint apps, both with a social theory insight and a direct user test, expanding it in two different directions.

The app examination's main strength is being the first attempt to catalogue and describe available carbon footprint apps, creating a picture of the apps currently accessible to users and how they seek to change user practices. However, the analysis is not perfect. Firstly, examining the apps through the lens of practice theory was useful for the purposes of this study, but may not be valuable in the case of a future researchers looking to examine aspects of these apps that are not a focus of practice theory. Furthermore, while it includes some of the most used carbon footprint apps, its results were not comprehensive due to the criteria used to select an app. While this criterion was useful in making the study feasible and ensuring the selection of the most relevant apps, it also means the examination is not comprehensive. Notable examples of apps not included are exactly the two other apps which have been examined by the pre-existing studies by Kisurina (2017) and Reick (2020) which were discussed in the introduction (Chapter 1). These apps are JouleBug, which had not been

recently updated and was examined by Kisurina (2017), and Deedster, which was not fully translated into English and had been examined by Reick (2020).

The user test was conducted with a sample of university students with pre-existing knowledge on sustainability due to their environment-related studies. This is both a strength and a limitation. It is a strength because these proactive, sustainability minded young participants are the main type of user which would most likely seek out such an app and attempt to use it outside of the realm of a scientific user test. It is a limitation as well, however, because these students already have a pre-existing interest in becoming more environmentally friendly, which means they will be moved by intrinsic motivation beyond that provided by the app itself. As such, it is possible the users were overly positive about their experience or the effectivity of such an app when compared to a regular audience. However, as discussed earlier, the audience most likely to independently seek out such an app already has interest in sustainability, and as such a comparison to a "regular audience" is not necessarily useful. This factor depends on the app itself and the audiences they are attempting to reach or would like to reach in the future.

The COVID-19 pandemic was an inevitable interfering factor in this study. As discussed in the previous section, it hindered the social aspect of this study, and social interactions are highly important in social practices theory, where meanings are socially shared. Even outside the context of practice theory, word of mouth and sharing among friends and colleagues is one of the networks through which new ideas, technologies, or movements spread. As the world has found in the past few months, social networking and virtual communication alone cannot quite replace regular communication avenues. Furthermore, it meant that participatory observations more typical of practice theory studies could not be carried out. However, this is not inherently a limitation. Carbon footprint apps are tools which seeks to change multiple practices, the choice of which is dependent on the user. As such, it would actually have been quite challenging to conduct participatory observations even if lockdown regulations had not been in place: it would be difficult to predict which practices users would try to change, and a participatory observation approach might bias the users into using the app in more situations then they would if they were not being observed.

Lastly, one element of the study design gave the users a positive bias in terms of recurring app use. The weekly reminders they received to fill in the logbook most likely functioned as an extra reminder to use the app, which may aid the user retention rate of this study. This became especially apparent during the user test interviews, where participants with older model phones reported they were not receiving the app's weekly notifications. That is, users who might have forgotten about the app after two weeks were reminded of it and completed the study period thanks to the interference whereas in real life they would not have used it for so long. It can be argued, however, that this is also an inherent limitation of having participants sign up for a user test to begin with, as they signed up for a four-week study period at the outset even without the reminders. Furthermore, this was not a quantitative test, and although it is interesting to see how many users made it until the end of the test, it is not a good measure or sample of user retention in such apps.

7. Conclusion and Recommendations

The following section will conclude this paper by giving the overall conclusions, as well as providing recommendations for future research and areas of improvement in carbon footprint apps.

7.1 Conclusion

Climate Change is a complex problem that becomes more pressing for humans every day. Due to its nature as a complex problem, there is also no single solution that can solve it. Rather, effective climate change mitigation and adaptation action will necessitate systematic and targeted change to both individual lifestyles and the larger governmental and economic systems on which they are built.

One method to reach individuals rising in popularity with the rise of mobile phones are mobile applications. Recently, carbon footprint focused apps have been increasing in numbers and user base (despite remaining relatively niche). These seek to track users' carbon footprints, change certain habits, or complete certain actions or challenges in order to reduce the footprint of their everyday practices. The literature on these apps is scarce. As such, not much is known about their ability to impact user's practices beyond what can be extrapolated from other types of mobile applications.

This study set out to begin bridging the existing gap on carbon footprint app literature using a practice theory conceptual framework. The factors in the framework were taken from practice theory literature (Materials, Meanings, Competences, Social Features) and existing literature on sustainability apps (Monitoring & Feedback, and Flexibility & Specificity).

The aim of the study was two-fold. Firstly, it sought to conduct an examination of currently available carbon footprint apps to create a picture of which are available and how they attempt to make user practices more sustainable. Second, it conducted a user test of one of the carbon footprint apps – Earth Hero – to observe the strengths and weaknesses of such an app in practice and determine how successful it can be in reconfiguring practices into more sustainable ones. As such, the research question it sought to answer was the following: How do current carbon footprint apps attempt to influence user practices, and to what extent do user practices become reconfigured into more sustainable ones when they use such an app? This was subdivided into two separate parts:

> 1. What are the current carbon footprint reduction apps, and how do they attempt to shape or change user practices into more sustainable ones?

> 2. How do users incorporate carbon footprint reduction apps into their everyday practices, and to what extent do their everyday practices become reconfigured into more sustainable ones?

The study began by conducting a systematic search of the 8 most prominent carbon footprint apps, followed by a practice-theory informed examination of their designs and features. This revealed that while carbon footprint apps are similar, they are not identical. All the apps put most emphasis on the meanings element and struggle the most with regards to materials, as they cannot provide materials to the users but only suggest alternatives. Furthermore, all of them are relatively underdeveloped with regards to social features, despite some performing better than others. They differ in their designs and basic approach, and also with regards to their emphasis on or performance in each category of the conceptual framework. For instance, each app offers different amounts of flexibility to the users, and different levels of autonomy in self-monitoring.

In order to take the understanding of carbon footprint apps beyond the theoretical strengths and weaknesses, a user test was conducted with one of the apps: Earth Hero. The user test was completed by 9 volunteers. The four-week test was followed by an interview, in which the participants detailed their experience of the app. The interview was semi-structured, and the questions asked were related to the categories of the conceptual framework. The interviews revealed that while users were positive about the app, they had varying levels of success in changing their practices. Users reported that the app did not necessarily become integrated into their existing practices. Rather, app use was a new reflective or leisure practice, usually undertaken alone while relaxing, in between tasks, or while procrastinating other tasks. The app functioned first and foremost as a reminder to keep up their sustainable ambitions.

The user test results become more nuanced when considered with the categories of the conceptual framework. With regards to the elements that constitute practices, the meanings component was the most successful among users. Even though most already had environmental or sustainability background knowledge, they found the information and ideas the app promoted very interesting and motivating in their personal quests to decrease their footprint. The materials element was not as unsuccessful as one would predict based on the app's inability to offer anything except itself and recommendations. Many users noted that the app reinforced their use of alternative, sustainable materials, and some reported it made them reconsider some of the materials (or amount of materials) involved in their practices. The competences element was less consistent, with users giving mixed replies on whether the guidance provided by the app on how to start or switch certain practices was detailed enough or simply a starting push requiring further user research. The users were not able to experience the apps in a regular social context, due to lockdown regulations. As such it is hard to ascertain the app's effectivity in this category. However, as participants tended to use the apps mostly alone, did not have access to in-app social features, and tended to choose actions they found most comfortable or accessible, it is likely that there is still room for improvement regarding the social element of social practices. The users had no complaints with regards to app flexibility, as they enjoyed setting their own timelines and controlling the notifications. The self-monitoring approach also had positive reviews, despite the fact that this means monitoring was to a great degree reliant on users' own willpower. Lastly, the users had mixed reviews with regards to feedback provided by the app. The instant visibility of how much the footprint was reduced following each action was appreciated, but some users felt that they lacked feedback through the completion of an action as well. This is not a general user perspective however, as some participants prefer to have no notifications at all. It is possible some user disparity arose due to a technical defect of the app which results in users with older phones not receiving the notifications.

Overall, users attempted low and medium or hard impact actions, ranging from secondhand consumption to eating less meat. The most high-impact practices, such as changing to a renewable energy contract, were not under user control. Participants who had a pre-existing interest in sustainability and had already tried some simple sustainability actions found it difficult to find accessible actions that interested them, as they had already done the easier actions before trying the app. Apps have great potential to aid in the transition to a more sustainable society, but have much room for improvement, as they currently have a limited effectivity and are overly focused on the individual side of social practices.

7.2 Recommendations

This study shows that while the apps can be useful to a user who wants to change their practices, there is still room for improvement in the app design and workings. As the apps are already quite meanings-focused, these recommendations will relate to the improvement of non-meaning aspects of practices. First and foremost is the inclusion of either group features

or open discussion forums, which can be particularly relevant for users to feel like part of a community. This is especially the case in the COVID-19 lockdown situation in which the apps were examined and tested. Secondly, the materials limitation could be bridged by combining promotion of the app use with real life campaigns or interventions. For instance, if a city were to introduce a green energy initiative at the same time the app launches a challenge or campaign in the city or region. This way, the app can collaborate with existing initiatives and efforts and help bring users new infrastructures and materials despite itself not being able to provide any. This would also allow the app to reach new audiences, and find people who might be interested in the app despite not being so immersed into the sustainability field that they even think of searching for sustainability apps. Another strategy to compensate the lack of direct influence on materials would be for such apps to provide other tools, such as GPS tracking or other such location-based data collection to give users recommendations of actions specific to their location. This could include connecting them to local bike rentals or shared car services. This location data could also be used as a filter which would exclude non-accessible actions, and would work in a similar way to using their initial input on their living situation and existing practices to filter out some actions. For instance, users who live in an area without biking infrastructure would not be suggested biking, or the recommendations for changing to a more sustainable diet might change depending on what is most sustainable and available in their geographical context.

Based on the work and findings of this study, it is also possible to make recommendations for future studies on the topic. Firstly, it is important to reproduce this user test with other apps, and examine how their strategies may compare and contrast to each other in terms of effectivity in changing user practices. Secondly, presuming carbon footprint apps seek to reach wider audiences, it would be relevant to see how the impact of the app changes with different target groups, besides the one examined by this study (young college students interested in sustainability). Finally, in order to investigate how powerful apps can be, it would be interesting and relevant to investigate how successful the app could be in combination with a local campaign, such as the green energy city campaign conceptualized earlier. Carbon footprint apps are an emerging phenomenon increasing in number (both in terms of apps available and interested audience). Mobile phones and applications present novel opportunities for sustainability interventions, and it is important to use the literature's social theory to inform how these real-life interventions are succeeding or failure – as well as how they can be made more impactful, effective, and powerful.

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Appendices

Appendix 1 – Logbook template

Email address for contact:
Name:
Sex:
Age:
App Test Location:
Start Date:

EXPECTATIONS - Before you start, write a short reflection on your perception of your current knowledge and action in regards to being sustainable or reducing your carbon footprint. This can be short bullet points or a long text. Think of questions such as: How aware are you of your carbon footprint? How much knowledge do you have regarding how to reduce it? Do you actively try to reduce your footprint or to live sustainably?
Answer

[Interactive Menu] Table of contents - click where you want to go or scroll down

WEEK 1

You have used the app for one week now! Note down some reflection points so you don't forget how your journey proceeded and can discuss easily during the interview.
Did you use the app? If so, (1) how frequently and (2) when/where did you use it?
Answer
What actions did you pledge to this week? Did you complete any actions?
Answer
Have you noticed any change in your daily practices due to your using the app? Which ones, and how?
Answer
Did any part of the app design or features help you complete the actions and/or change your practices? If yes, which ones? If no, why not?
Answer
Other comments/notes - Did any other factors affect your app use, action selection and/or completion? Are there any other relevant details you would like to note down regarding your app experience?
Answer

[Repeat until WEEK 4]

Appendix 2 – Semi-structured interview prepared questions script

Introduction
- General impressions how did the test go? (briefly)
- Which actions did you try? Which did you complete? (Get a sense of whether they focused on a particular domain such as food or mobility)

Materials, Meanings & Competences
- When and where did you use the app?
- Can you describe one/some of these occasions in which you used the app?
- How do you normally engage in these situations (practices ex. Cooking, shopping, etc as described previously) & did the app change that?
- Did you start using/buying new things? Or, did you change the way you use certain items related to your daily activities?
  - If yes, can you give me a specific example?
  - If no, did you consider doing this? Why do you think it did not happen? Can you give me a specific example?
  - [Get into the practice with them:] How do you normally select the items you use in your activities (ex. Which ingredients? Which meal?) How did that change (or not change) with the app?
  - How did the app itself fit into this particular activity? Did you use it before to plan, during? Why did you decide to use it this way?
  - [Flexibility: Was the app specific enough to your situation in this context? Was it sufficiently flexible to support your needs? What did or didn't work?]
- Did using the app change your ideas, feelings or motivations regarding your daily activities or a few daily activities in particular?
  - If yes, can you give me a specific example?
  - If no, why do you think this was the case? Can you give me a specific example?
  - [If relevant, get into the practice with them – how do they usually do that practice, how did it change or not, etc: see questions above]
- Did you learn new things that helped you carry out certain activities? A new base piece of information, a certain skill or know-how that helped you change or adjust your daily activities?
  - If yes, can you give me a specific example?
  - If no, why do you think this was the case? Can you give me a specific example?
  - [If relevant, get into the practice with them – how do they usually do that practice, how did it change or not, etc: see questions above]

Monitoring and Feedback
- How did the app monitor your progress? (In what way, how often, etc.)
- How did the app give you feedback on your footprint and challenges?
- What did you think about the monitoring & feedback you received? (Was it sufficient? Compelling? Too much/too little? Right type? Etc.)
- How did this monitoring and feedback support or get in the way of changing your everyday practices (or completing challenges)?

[Flexibility – only if not previously addressed
- Do you think the app was sufficiently specific or tailored to you in the situations we discussed?
- Was it sufficiently flexible to fit your needs? What worked or did not work?

Social
- How did the app fit into your social life?
- Did you use or discuss the app in a social setting? With friends, family, housemates?
  - If yes, how? Can you elaborate/give an example

- o If no, why do you think this was the case?
- Did the app offer you support for using the app in these social settings?
  - o How or how not?
- Did the app itself offer social features and/or actions (connect with other users, group discussions or challenges, encourage you to invite friends)? Did you use these?
  - o Why or why not? How did it go? How do these features support (or not) you in changing practices?

Conclusion/Overall
- Did using the app help you reduce your footprint?
- Did using the app change your awareness or perception of your footprint/personal sustainability level?
- How difficult were the challenges you selected/changes you tried to implement in your daily activities?
- What were the biggest challenges in changing your daily activities? AND/OR
- What were the biggest advantages/benefits & challenges of using the app?
- Feedback?