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The ethics of dietary apps: Technology, health, and the capability approach☆

Mark Ryan

Wageningen Economic Research, Wageningen University & Research, the Netherlands

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ABSTRACT

Dietary apps are said to promote better eating habits, improve dietary knowledge, and awareness about nutrition. However, their use has also raised a number of ethical and social issues related to their impact on individual freedoms, for creating power asymmetries, restricting end-users from expanding their knowledge of health, nudging individuals, and even having harmful effects on people's health. This paper will use the capability approach methodology to explore some of the most common criticisms directed against dietary apps to identify what steps need to be taken to ensure individuals' freedoms are protected, and their health is ensured.

While dietary apps democratise nutritional information, they must be developed and used in an ethically satisfactory way, that is respectful of environmental, social and individual differences among users (conversion factors). This paper will demonstrate that while some types of nudging within dietary apps are acceptable (because they are often used as a kind of 'extended will'), app companies should not nudge individuals in agency-infringing, manipulative, or forceful ways (for their own economic benefit). Altogether, this paper will provide a user-centric methodology (the capability approach) to demonstrate how food technologies should incorporate and consider the end-user in their development and use.

1. Introduction

The popularity and usage of apps to provide recommendations and document our lives is constantly growing. There are apps to avoid dating your cousin in Iceland (IslendingaApp SES); to indicate the best time to pee during a movie (aptly titled RunPee); apps that display an electric razor on your screen so that you can pretend you are shaving (Electric Shaver); apps that zip and unzip jeans (Zips Lite); and even an app that provides absolutely nothing else besides a blank screen (Nothing) [1]. There are apps for just about everything. However, what remains the most popular types of apps are health-related ones, with Google Play and the Apple Store holding thousands of apps in the area of nutrition and exercise.

One of the most popular sub-categories of health apps is the use of apps for dietary behavior and patterns, or 'dietary apps'[1] (e.g., MyFitnessPal, Lose It! Fat Secret's Calorie Counter, SparkPeople, Fooducate, Restaurant Nutrition, Meal Snap, FoodScanner, and HealthyOut) [2–4]. Dietary apps vary quite a lot and have a range of functions, target audiences, recommendations, and interfaces. While some are combined with other health features, such as exercise programs, stress relief methods, or mindfulness; most solely focus on diet and eating habits.

Dietary apps typically aim to promote better eating habits, improve dietary knowledge, and awareness about nutrition. However, they have also come under scrutiny for impeding our ability to choose; power asymmetries; restricting individuals from expanding their knowledge of health; and overall, have a harmful effect on users. This paper will explore some of the criticisms directed towards dietary apps to identify their merit and steps that can be taken to improve these apps.

This paper will examine dietary apps, using the capability approach as a methodology, to determine how ethical these apps are, potential issues or impacts of using them, and how they can be designed to respect individuals' values and freedoms. I will first give an overview of what dietary apps are, their purpose, and common functions within them (Section 2). This will be followed by a definition of health and healthy

☆ Present/permanent address: Wageningen Economic Research, Wageningen University & Research, Droevendaalsesteeg 4, 6708 PB Wageningen, the Netherlands.
E-mail address: mark.ryan@wur.nl.

[1] For this paper, when referring to 'dietary apps', I am referring to apps that allow you to input information about what food you consume, thus, your dietary habits. While a significant proportion of these apps are specifically targeted towards dieting and weight-loss, I will not limit myself to these applications. There is also a wide-range of dietary apps that allow you to enter your consumption patterns and provide recommendations based on specific health requirements, dietary preferences, or simply because one chooses to document their eating patterns. This paper will include these when referring to 'dietary apps'.

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eating (Section 3). Section 4 will outline the methodology employed in this paper to analyse dietary apps, namely, the capability approach. Section 5 demonstrates the results of analysing dietary apps through the lens of the capability approach, and how it responds to some of the main criticisms put against them.

2. The use of dietary apps

Dietary apps serve a variety of needs, but generally, they are united by the fact that they allow the end-user to enter information about their diet. It allows users to keep track of what they eat. Some apps provide recommendations about what one *should* eat, others allow the user to fill in these gaps themselves. Some apps provide food menus and recipes, lists of ingredients and nutritional benefits of food products, or how many 'points' are in each type of food or food product (so, you can only have a certain amount of 'points' per day). Overall, these dietary apps provide a wide diversity of functions (see Table 1).

However, monitoring one's dietary habits and nutritional intake is not a new phenomenon. People have been recording their diets with pencil and paper for quite some time. There have been weight loss clubs, programs, and affiliations for many years (e.g., Weight Watchers has been around since 1963). Dietary apps' popularity stems from the fact that eating healthily, controlling one's calories, or losing weight, is such an important factor in people's lives. Food logging is helpful for individuals to keep track of their diets and meet their goals [6]. 'Self--monitoring increases self-awareness with regard to targeting behavior and outcomes in relation to food intake goals. In addition, it can act as an early warning system, indicating whether a risk of becoming overweight is increasing' [3].

Apps digitalise one's diet, and provide visualisations, graphs, and spreadsheets of one's behaviours. They also provide more tailored recommendations and can retrieve a wide range of data about the user (e.g., through wearables: blood pressure, heart-rate, sleeping patterns, and so forth). Dietary apps often provide a more convenient, interesting, and detailed way to record one's diet than a simple food journal. They provide graphs, diagrams, statistics, and recommendations about one's diet. People use dietary apps to find out interesting information about themselves, others use them to set goals, and some use them for the sense of community they bring with others. Many use these apps to get healthier, lose/gain/stabilise their weight, or ensure a better distribution of nutrients and food types in their diet. Added functionalities help increase engagement and usage of these apps. For example, a recent study demonstrated that 'acceptance of wellbeing applications is positively influenced by the implementations of usage awareness functionalities, such as reminders, usage tracker, notifications, progress tracker and visual representations. [7], p. 10.

Table 1
List of Functions in Dietary apps ([3,5]).

List of Functions in Dietary apps
barcode scanning for calories in food
food calorie comparison with equivalent exercise required for consumption
real-time feedback
virtual personal trainer
diet plans
food recipes
foods that are suitable for certain people (e.g., someone with diabetes)
compare one's activities with others
compare one's current activity with past behavior
post one's activity on social media
push notifications to remind user to record diet
setting specific goals
statistics to compare one's behaviours to their goals (e.g., data, pictures, charts, bars, etc)
intangible rewards (points, badges, comments)
tangible rewards (coupons, gifts, discounts)
judgments on certain foods (scores, traffic light systems)

The demographic that use, or would use, dietary apps is also worth noting, as there is a wide diversity of views about them. For example, 57% of people said that they would use a fitness-tracking app if it resulted in lower health-insurance premiums [8,9]. Young adults, and individuals from high income households, were more likely to use fitness/dietary apps [10]. Another study [11] demonstrated that there is a split between age groups and their willingness to use dietary apps. Older age groups are less likely to use them, but many said that they were willing to try, while a significant amount said that they did not want to use them at all (approximately 19%) (see Fig. 1).

Dietary apps help users stick to their diets and often increase feelings of motivation. For example, West et al., 2017 [12] conducted a survey with 217 users of diet and nutrition apps, with most in the survey strongly agreeing that the apps increased their motivation to eat healthy, improved their self-efficacy, and their desire to set and achieve healthy diet goals [12]: 'The majority of participants strongly agreed that using diet/nutrition apps led to changes in their behavior, namely increases in actual goal setting to eat a healthy diet (58.5%, 127/217), increases in their frequency of eating healthy foods (57.6%, 125/217), and increases in their consistency of eating healthy foods' [12]. Altogether, dietary apps have been shown to make users more consistent with their healthy eating patterns [13,14]. While healthier eating patterns is the goal of dietary apps, this objective is value-laden and mired in debates on definitions of health, nutrition, and diet. Therefore, it is important to provide a definition of health and eating healthy, before analysing the impact on people using dietary apps.

3. Defining health and eating healthily

Health is something that most people, if not everyone, aspire towards. When we speak of health, it is probably intuitive, to most, what we are talking about. Definitions such as 'feeling good', 'free from illness', and 'functioning well', may commonly be used to describe health. However, precisely defining health and establishing measurements, metrics, and standards for it, are often more complex in practice. Health is often classified as an essentially contested concept, where there are so many varying disputes over its meaning, proper usage, and how to demonstrate it. While this section does not intend to resolve the diverging positions within the health debate [15–18], it aims to provide a preliminary outline of health for the purpose of this paper. Dietary apps aim to pursue the goal of health (through healthy eating); therefore, it is important to understand what is meant by health, before analysing dietary apps' impact on the end-user.

To begin with, one of the most-cited and known definitions of health comes from the World Health Organisation (WHO): 'Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' [19]. This definition was quite radical at the time (first put forth in 1948) because it departed from the traditional definition of health being confined to the more formulaic understanding of health in the biomedical sciences (as the appropriate functioning or malfunctioning of the body). The WHO viewed health as more holistic and should encapsulate the entire wellbeing of a person (physical, mental, and social wellbeing). Before this definition (and since it), it was common to associate health with its opposite, ill-health [15], or that health was being free from illness and disease; which the WHO definition veered away from.

This paper will use the WHO's definition of health to frame discussions around what constitutes healthy and unhealthy eating. This section will provide further clarifications on the definition of health to demonstrate how it relates to diet, specifically.

Health in the WHO definition is understood holistically. It is holistic because one does not assess one's health in isolation, but rather, the overall adequate wellbeing of the individual. Of course, one can describe the healthy or unhealthy functioning of individual parts, but taken in isolation, it does not accurately portray the health of the whole person. This is not to say that unhealthy functioning of certain parts cannot have

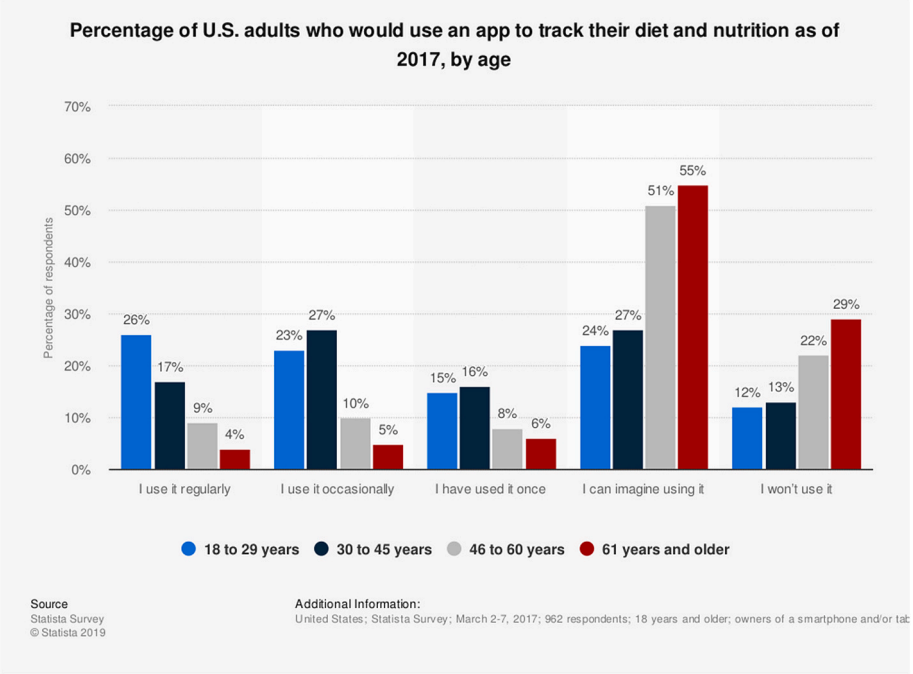

Fig. 1. Statista data on dietary app use: https://www.statista.com/statistics/698919/us-adults-that-would-use-an-app-to-track-their-diet-by-age/.

Table 2
World health organisation healthy diet recommendations.

World Health Organisation Healthy Diet Recommendation
1. 'total fat should not exceed 30% of total energy intake. Intake of saturated fats should be less than 10% of total energy intake, and intake of *trans*-fats less than 1% of total energy intake, with a shift in fat consumption away from saturated fats and *trans*-fats to unsaturated fats, and towards the goal of eliminating industrially-produced *trans*-fats'
2. 'Limiting intake of free sugars to less than 10% of total energy intake (2, 7) is part of a healthy diet. A further reduction to less than 5% of total energy intake is suggested for additional health benefits'
3. 'Keeping salt intake to less than 5 g per day (equivalent to sodium intake of less than 2 g per day) helps to prevent hypertension, and reduces the risk of heart disease and stroke in the adult population'
4. 'At least 400 g (i.e. five portions) of fruit and vegetables per day (2), excluding potatoes, sweet potatoes, cassava and other starchy roots'

a dramatic effect on the body, but it means that the individual parts should be analysed as part of the whole. While it is important to understand the health of one's heart in isolation; its relationship with the brain and nervous system, and its fundamental role for keeping the entire body is important when analysing health. As the WHO stated, it is the 'complete' wellbeing of the body.

Another important point of the WHO definition is the holistic approach between one's physical body, social wellbeing, and mental wellbeing. The WHO defines mental wellbeing when 'an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community' [20]; and social wellbeing as 'the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. These forces and systems include economic policies and systems, development agendas, social norms, social policies and political systems' [21].

There are many recommendations for living a healthy life, such as physical activity, avoidance of pollution and harmful chemicals, reduce stress in our lives, access to healthcare, and also, having a healthy diet. The WHO states that unhealthy diets and lack of exercise are the leading global risks to health [23]. Having a healthy diet is important for one's overall health, thus, those who want to be (or remain) healthy, should ensure that they are eating healthy. One's ability to eat healthily is (typically) reliant on having the resources to purchase healthy food (social wellbeing), the physical ability to obtain or cook healthy food (physical wellbeing), and the cognitive and motivational capacities to do so (mental wellbeing).

These are some of the tensions when defining healthy eating, but how should one do this in practice? What *is* healthy eating? How is it different from unhealthy eating, and how do we distinguish this? In a world of ubiquitous food advertisements, misinformation, nutritional gurus, health specialists, and snake-oil supplement companies, this is not an easy path to navigate. For the purpose of this paper, I will also use the WHO definition of eating healthy and dietary recommendations [23], most of which can be seen in Table 2.

The WHO takes a standardised approach to healthy diets, while not detailing what foods should make up one's fats, sugar, salt, and carbohydrates content. Most people know about these general recommendations, but once we include allergies, different cultures and religions food exclusions, food intolerances, accessibility to food, and food preferences, it becomes a lot more complicated. One of the aims of this paper is to use the capability approach, as a methodology, to examine how dietary apps can account for these differences, how they can be used to empower individuals to eat healthy, and what considerations should be taken into account when creating and using dietary apps to protect users' capabilities.

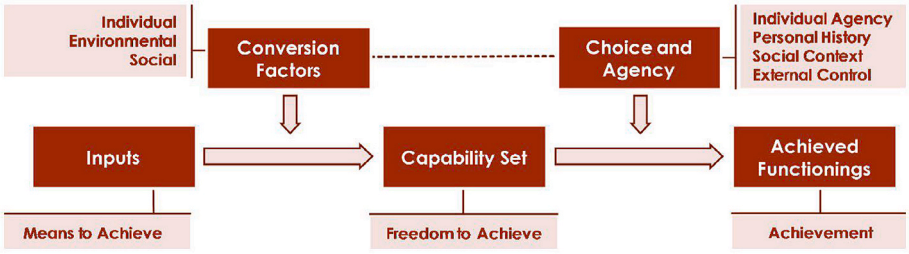

Fig. 2. The capability approach process (taken from Ref. [42], and adapted from Ref. [43]).

4. The Capability Approach

The capability approach stemmed from the work of economist Amartya Sen [24–28] and philosopher Martha Nussbaum [29–31], and was a response to many frameworks within political philosophy and economics that failed to capture human diversity, needs, and values.[2] Human diversity was often treated as an 'add-on' component, rather than being introduced as a fundamental aspect from the beginning. As a result, Sen claimed, we run the risk of acting 'deeply inegalitarian' in the name of 'equality' [25]. Essentially, 'inequality in terms of one variable (e.g., income) may take us in a very different direction from inequality in the space of another variable (e.g., functioning ability or well-being)' [25].[3]

Sen claimed that there is a fundamental difference between *achievements* and *freedoms* [25]: 'Achievement is concerned with what we *manage* to accomplish, and freedom with the *real opportunity* that we have to accomplish what we value' [25]. For example, having a bicycle may allow one person to cycle to work, meet up with friends, and increase freedoms. While the same bicycle would be of little benefit to someone who was unable to use it (e.g., someone paralysed from the waist down). Therefore, ensuring that everyone has a bicycle may uphold equality in one sense, but is of unequal benefit to all individuals.

What is important is *one's ability to convert resources and goods into freedoms and wellbeing*. If one is unable to convert the resources into useable and practical benefits for their wellbeing, then the equal distribution of resources does not equate to equal levels of freedom or wellbeing from using those resources. Focusing on the just distribution of primary goods may lead to grave inequalities because of the differences in abilities to use and convert those goods into benefits. Therefore, the *conversion factors* available to one are very important for realising equality. If one is unable to convert their inputs (because of environmental, social, or personal reasons), then their freedoms may be hindered.

Capabilities are the *real and practical freedom* to choose and obtain those things that contribute to one's wellbeing. A capability is 'a set of vectors of functionings, reflecting the person's freedom to lead one type of life or another' [25]. Capabilities are the freedoms that one exercises to achieve the functionings that constitute one's wellbeing. Instead of focusing on the achievement of certain variables, the capability approach concentrates on our *capacity to realise wellbeing*.[4]

One's freedom depends upon the ends one values, but also, 'what power she has to convert primary goods into the fulfilment of those ends' [25].[5] Inputs are affected by how individuals can convert them into real and practical freedoms. In the same sense as food, money, or other resources, *technology* is seen as an 'input' to allow individuals realise their capabilities. Technology requires conversion factors (individual, environmental, and social) to realise certain capabilities, such as computer literacy (social), access to computers or Wi-Fi (environmental), and cognitive and physical abilities to use these resources (personal) [41](see Fig. 1).[6]

As shown in Fig. 2, one's capability set is dependent upon inputs available and the conversion factors to make use of those inputs. Capabilities are the real abilities to fulfil functionings that are valuable to one's wellbeing. Functionings are the beings, and doings, of things that are consistent with human wellbeing (e.g., to work, to rest, be literate, be healthy, and to be part of a community, etc.) [44]. Therefore, the capability approach is the amount of freedom one has to achieve certain functionings. Instead of focusing on the means of our wellbeing or the functionings, it concentrates on the real freedoms to achieve these.[7]

At this point, some may ask: are the functionings not the important aspect within Sen's approach, rather than the capabilities to fulfil them? Why is the focus on the capability, rather than the functioning or end result? What makes the capability approach different is that it focuses on the *real freedoms* to achieve functionings. By focusing on functionings, we concentrate only on the achievements, rather than our freedom and ability to achieve them. Functionings focus on the *outcomes* and not the freedoms or decisions to get there. This is problematic because it does not consider the choices of the individual.

Sen illustrates this with an example: person A (is starving) and

[2] In *Inequality Reexamined*, Sen demonstrates how a wide range of frameworks promote some kind of equality: equal liberty or distribution of primary goods [32], treatment as equals [33,34], economic equality [35,36], equality of legal and political treatment [37,38] or equality of libertarian rights [39,40]. The reason for this convergence towards equality is that without it, judging social matters would be arbitrary, laden with bias, and would be difficult to defend. A position may cause certain inequalities, but to defend those outcomes, there needs to be equal consideration at some basic level, or the positions would be unjustifiable.

[3] It must be noted here that Sen used equality as the underpinning factor to guide the capability approach, Martha Nussbaum uses the idea that every individual should be guaranteed dignity [31].

[4] It must be noted here that Nussbaum and Sen diverge on whether or not to list capabilities for greater clarity and guidance, with Nussbaum listing ten essential capabilities and Sen preferring not to commit himself to a list. Nussbaum's list is the capability to: life; bodily health; bodily integrity; senses, imagination, and thought; emotions; practical reason; affiliation; other species; play; and control over one's environment.

[5] In the case earlier, the physically-disabled person should be provided with ways they can realise their capabilities in a similar way as the person who benefits from the bicycle (e.g., consistent, and affordable public transport, or automobiles designed to their needs).

[6] However, technology also has a transformative effect on what we value, how it shapes and develops our values, and how we interact with the world.

[7] However, it must be noted that not all capabilities are of equal importance, and some may be downright unethical (e.g., the capability of cruelty or murder), so there is a degree of ethical evaluation of capabilities required. This is important for Sen's position, as he claims because of the varying nature of situations and capabilities, it is not desirable to establish a definitive list of capabilities. Capabilities rely on purpose, context, and the capabilities themselves. Therefore, the desirability of capabilities is fundamentally contextual.

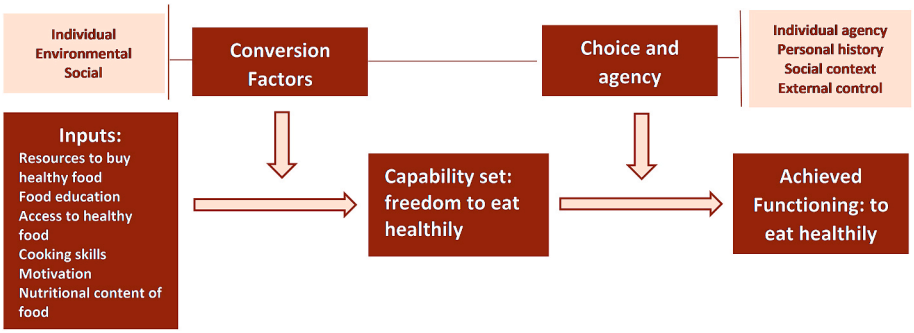

Fig. 3. The capability approach and the freedom to eat healthily (Adapted from the Figure found in Ref. [42], which was also, adapted from Ref. [43]) This paper will focus on the use of dietary apps to fulfil the capability of eating healthily. Dietary apps may promote a number of other benefits, such as being part of a community, lose/gain/maintain weight, or simply as a way to gain greater knowledge about oneself [9]. These factors may also be linked to eating healthily, but they do not necessarily have to be. For example, while many want to lose weight by eating healthier, some want to lose weight regardless of how healthy the diet is. While this paper accepts that there are other reasons for using dietary apps, they are usually designed and used for the purpose of healthier diets, or becoming healthier, and thus, this will be the *main* capability examined in this paper (I will also discuss a number of other capabilities, but to eat healthily will be the primary one).

person B (is fasting). If one concentrates on the functionings alone, one will propose that both person's functionings are being equally impeded (e.g., to be well nourished or free from hunger). Without analysis of their capabilities, it would give a misleading view of their wellbeing. Person B has the capacity to eat, but chooses not to, whereas, person A has no choice at all. Person B has the capability to eat, to be nourished, and normally is well nourished. They have capabilities at their disposal to be healthy, whereas person A does not.

Eating healthily relies on individuals having the relevant capabilities. This depends on what choices one has and what knowledge they have about those choices. For example, if one wants to eat healthily but they do not have the nutritional content of food at hand, are unable to cook dishes that are healthy, or do not know what kinds of foods they should limit, then their capability to eat healthily is impeded. Eating healthy requires knowledge, access to resources, and the ability to prepare and consume them (to name only a few requirements). Dietary apps aim to provide a service that will help individuals eat healthily, thus allowing them to fulfil their capability of being healthy. Thus, this paper will evaluate if the use of dietary apps truly help people to realise their capability to eat healthy (an approximate breakdown of eating healthy, within the constructs of the capability approach, can be seen in Fig. 3).[8]

5. The capability approach and dietary apps: critical perspectives

The effects of technologies on our capabilities is quite far-reaching, with both intended and unintended consequences; expanding the capabilities of some groups, while reducing those of others; or ensuring short-term capabilities, while ignoring longer-term ones [45]. Thus, it is often difficult to discuss the use of technologies as a whole and their effects on human capabilities. 'Therefore instead of making sweeping judgment on whether these technologies should be developed and adopted, it is more important to examine what capabilities (in a capability approach sense) can they generate, for which users?' [46]. This paper will focus on the specific impact of 'dietary apps' on our capabilities, with a specific focus on the capability of health, through eating healthily.

[8] Dietary apps are not solely used for the purpose of ensuring the capability to eat healthily, they are also used by individuals to lose weight, gain greater control over their habits, a sense of community, and sometimes, simply curiosity of one's bodily functions. However, for the purpose of this paper, I will concentrate primarily on the capability to eat healthily, while making references to, and contrasting dietary apps with, these other capabilities. However, this is not meant to be an extensive or comprehensive analysis of all possible capabilities resulting from, or impacted by, dietary apps. This would go beyond the scope of this paper, a point I will reemphasise again in Section 4.5, when comparing the interaction of different capabilities.

5.1. Dietary apps and their effect on capability 'inputs'

Some claim that while digital technologies give us the ability to solve problems and to learn new things; there is a serious lack of critical understanding and skills development in this type of learning [2]. Technological solutionism provides quick fixes and cheap results that 'can easily undermine support for more ambitious, more intellectually stimulating, but also more demanding reform projects' [2]. There are two main challenges underpinning this criticism, which will be discussed in this section: the fact that the use of *other types of inputs*, and having *a diversity* of inputs, is beneficial to realising our capabilities.

5.1.1. The benefits of other types of dietary inputs

There is a possibility that individuals will rely on dietary apps as the sole purveyor of truth about diet, nutrition, and health [2]. Dietary apps may appropriate other inputs, or make them altogether redundant. However, have new technologies not always done this? For example, my smartphone allows me to do things that would have previously required numerous devices (e.g., a calculator, physical maps, a clock, a timer, a calendar, a notebook, a diary, etc.). Instead of going to my library and scrawling though several encyclopaedias, journals, books, and old newspapers, I can now find the same information in a few online searches. In the context of dietary apps, instead of buying articles on nutrition, recipe books, going to cookery classes, making appointments with nutritionists, the app allows us to do all of these things in one place.

Perhaps, through the arduous process of searching for information through all of these disparate sources, I find new information along the way, I learn skills, or enrich my experience and association with the new knowledge that I develop. There is something special about a lesson with a trained chef or getting tailored advice from a nutritionist, or something captivating about the effort, passion, and enthusiasm poured into the writing and design of a cookbook. Maybe the ease of using dietary apps will take away some of the very enriching activities that we would have otherwise experienced.

However, the reality is that the cost and time to do all of these activities is very burdensome for most, and it also limits this information to those who can afford it and/or have the time and effort to partake in these activities. Dietary apps bring this information together in one place, for a far lower price (often free), to a greater number of people. In addition, dietary apps are optional, so they do not restrict individuals from choosing other inputs (or both types of inputs), they simply provide *an alternative* for those who cannot, or do not want to, avail of them. Furthermore, dietary apps may actually allow individuals *more* time to spend on enriching these other capabilities (or even time to partake in these other inputs for pleasure). For example, if healthy recipes can be found in one place, one may be more likely to cook them than if they have numerous cookery books scattered around their house.

5.1.2. The benefits of a diversity of dietary inputs

Another criticism is that one may end up using *only* the dietary app, without receiving additional dietary information from elsewhere, i.e., it becomes a filter bubble for dietary information [2]. Filter bubbles are when individuals (either intentionally or unintentionally) disconnect themselves from a wider network or groups, communities, or information sources, whereby, they cannot be reached by new information outside of their 'bubble' [47].[9] Relying on one source of information is not always wise, as this information may be biased, it may provide information in an unclear way, it may not be tailored to the needs of the individual, or it is simply unhelpful.[10] If the data provided by dietary apps is inaccurate, it may have harmful effects on the user's health. This is exacerbated because users may continue using dietary apps, even if they are receiving inaccurate, or even harmful, recommendations.[11] Therefore, it is important that users have access to other information to support or challenge the recommendations of the app.

This is a significant challenge against dietary apps as they attempt to bring together many different dietary tools and recommendations in one place, while replacing other outlets of information. They should encourage users to seek out other sources of dietary information and not solely rely on the app itself. Even if developers use accurate dietary data from reliable sources, there is still the threat of a bug, glitch, or error in the system that will provide misleading information. The app should show where they are retrieving this information from, provide a list of dietary resources one can look up, and perhaps, advice on contacting professionals when necessary (e.g., nutritionists, doctors, and health experts).

5.2. Choice and agency of using dietary apps

There is a criticism that dietary apps limit our range of choices and freedom (i.e., they become the only source of information on healthy eating). However, more alternatives do not necessarily mean more freedom, and often, more choices may actually inhibit our freedom: 'The expansion of choices to be made is both an *opportunity* (the choices *can* be made by oneself) and a *burden* (the choices *have to be* made by oneself)' [25]. Often, we give choices to others to be made upon our behalf, so we do not necessarily have to be the direct controller of every action to express our freedom.

Sen states that an agent is 'someone who acts and brings about change, and whose achievements can be judged in terms of her own values and objectives, whether or not we assess them in terms of some external criteria as well' [49], p. 19. Exhibiting one's agency is an expression of acting or bringing about change based on our own values and objectives. It is grounded on our own choice to realise these goals, but as Sen noted earlier, it does not have to be carried out by our own hands, necessarily. Our choice to bring about something is heavily burdened by the choices we have available to us, and thus the level of intent we have. This is an important point to note in the context of dietary apps.

For instance, we use dietary apps with the assumption that they are retrieving information from different sources to save us the time and effort of looking them up ourselves (e.g., nutritional guidelines, monitoring our calorie intake, or collating recipes). This 'give us more power and more freedom to lead the lives that we would choose to lead. To confuse freedom with control can drastically reduce the scope and force of that great idea' [25]. Sen gives the example of a proof-reader taking out errors from his book. This is not an impediment of his freedoms as he is actively giving control to the proof-reader to do this job in his place, *as if* he were able to correct the proofs in such an effective manner [25].

There are some potential issues with this analogy, which may also shed light on issues related to dietary apps. For example, the author may have been nudged towards using a proof-reader (e.g., one searches online for proof-reading tips, but are bombarded by advertisements for paid proof-readers). Or, if they are working for a national paper in an authoritarian country, they could be forced to have it peer-reviewed, so that it tows the party-line. These examples may limit the agency of the individual. There are similar concerns when considering the level of control and agency one has when using dietary apps. For example, we may be nudged towards using them (e.g., limited functionality on the web version of the app), or forced to use them (e.g., health-tracking apps automatically downloaded onto your phone upon flying into countries during the Covid-19 pandemic). Ultimately, the question becomes: will individuals be nudged or forced to use dietary apps in ways that affect their choice and agency?

5.2.1. Nudging and dietary apps

A criticism against dietary apps is that they do not necessarily expand human agency, because they are laden with power asymmetries and ideological underpinnings [50]. They hold the potential to 'nudge' us in directions that we may not have chosen otherwise. Nudging refers to having an active influence over another's decision, without the use of force or coercion, and may be done by private or public actors, individuals or groups. Thaler and Sunstein defined nudging as 'any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives' [51].

This definition of nudging does not forbid, prevent, or manipulate the individual from making other choices. Thaler and Sunstein state that nudging is permissible if it is done with the welfare of the individual (who is being nudged) in mind. However, others are quite critical of nudging, claiming that there is an arrogance about claiming to know the welfare of another, that nudging can be done for nefarious means, and it undermines our liberty [52]. This paper does not aim to argue for or against nudging per se, but to evaluate its role in the use of dietary apps and its likelihood to harm users' agency and choice.

In the context of dietary apps, there are three specific types of nudging: nudging to buy, download, or install the app (*pre-use*); nudging within the app to do certain things (*use*)[12]; and nudging after one has deleted their account or unsubscribed (*post-use*). While pre- and post-nudging are important areas of analysis, they can often be covered under a more general analysis of nudging app downloads or re-subscribes, and are less context-specific as nudging during use. Therefore, the focus of this section will be on nudging during the use of dietary apps.

To begin with, there are many examples of nudging that help people make decisions, which they (assumingly) would want to make, and that improve their own health or the health of others: graphic images on cigarette boxes reduces smoking, emotionally-charged advertisements reduce drink-driving, or 'children at play' road signs make drivers slow down. However, there are many examples of nudging that leads people

[9] However, filter bubbles are nothing new, but it is because of the prominence of technology, the speed and accessibility of information, the filtering of one's information sources, that filter bubbles become more apparent. For instance, a traditional filter bubble could come as a result of someone using a book on nutrition as their sole source of information on diet, or rely on their nutritionists advice, or only follow their doctor's recommendations.

[10] There is often an additional challenge against this, such as using only one source of information, or it being the only one available, limits our choices and this results in having a negative impact on our freedom to choose. For example, dietary apps limit our range of choices, thus, they limit our capability to choose otherwise. This criticism will be discussed in Section 4.5.

[11] This became evident in a recent study which showed that the accuracy of recommendations of dietary apps 'was not found to be a significant predicator of how much users intended to continue using the apps' [48].

[12] Nudging within use can be directed towards things that we want the app to help us with, namely, to eat more healthily; or nudging to do things that we do not want to do, or are altogether fraudulent, misleading, or exploitative (e.g., advertisements nudging individuals to buy dietary pills of dubious quality).

to behaving in ways that they do not necessarily want to and/or harm their own health or the health of others.[13]

One can provide extensive lists of different types of nudging, which indicates that not all nudging has the same moral equivalence [53]. Some nudging is more morally acceptable than others, depending of their benefit or harm, but also, what level of control and agency the individual has. Therefore, how does nudging affect one's agency and control in the context of *dietary apps*?

Sometimes people really want to be nudged, as it reminds us of ways to act morally or ways that we would like to behave in a given situation. It promotes our agency because it allows us to act more closely with how we would ideally like to behave. It also allows us to easily and/or quickly act, freeing up time to pursue other activities [54,55]. We use these nudges as a kind of 'extended will', whereby, we use the app to impose restrictions upon ourselves when our will may be too low to meet our intended goals or desires [22,56]. Therefore, nudges do not necessarily restrict individuals or remove other options [53]. Nudging within dietary apps may also allow individuals to counteract harmful nudging from other sources, such as food companies tempting us to eat their unhealthy, sugary, or fatty produce. Therefore, in many contexts, nudging allows us to 'achieve a better match between our decision-making propensities and our choice environments. Nudging would thereby strengthen rather than undermine rational agency' [53].[14] Contrary to this is the view that nudging will/is being used by regulators to make us act in ways that we do not necessarily want to.

5.2.1.1. Regulatory nudging and dietary apps. Some claim that nudging is insidious because it is always based on how regulators want us to behave, and that someday, these nudges will 'make it impractical not to do what's expected of us' [2]. However, dietary apps are usually created by private companies with the intention of making a profit, and to provide useful apps to the public. How much (direct or indirect) influence regulators have over this process, the types of decisions and recommendations that end up in the app, or how regulators control which apps get used or not, is unclear.[15]

While it is often national policy to encourage healthy eating and good dietary habits; the claim that dietary app companies are puppets for insidious regulatory nudging leans towards the conspiratorial. Even if there were a tangible link between regulatory nudging and dietary apps, this type of nudging is to improve dietary practices, which is, prima facie, neither nefarious nor harmful. The idea that privately-owned dietary apps will, in the future, become the engines for governmental manipulation and control is a possibility; however unlikely. While it is certainly *possible* that *some* governments may see the use of privately-run dietary apps as potentially valuable for manipulation and control, there is no real evidence of this occurring, or that it will materialise. It is also difficult to see in what situation *dietary apps* could be used for such nefarious purposes.

A critic may claim that it does not necessarily have to be nefarious or harmful deeds being carried out against citizens, but simply, nudging that is beneficial for the government and the economy. For instance, a healthy workforce means less sick pay, reduces strains on hospitals, and eases governmental spending on healthcare. There is certainly an added incentive to have a healthy population, as it sustains the basis of development. Of course, how this is brought about, and the context of how it is implemented, have a large impact on whether it is ethically acceptable or not. Governments generally want a healthy population, a strong workforce, and stable economic generation. There is nothing particularly unnerving if governments encourage healthy eating in the first place, and subsequently, through the use of dietary apps to achieve this outcome.

There is also the claim that an overreliance on technologies, such as dietary apps, allows governments to avoid implementing structural changes that are needed because individuals are viewed as being responsible for their own health. Why would a government implement regulation on sugar, fat, or food ingredients, when individuals are free to make decisions about what to consume themselves? Self-tracking technologies further encourages this split between governmental protectionist agendas and individuals' self-empowerment [2]. Foucauldians call this 'responsibilitisation' [57,58][16], where increased individual responsibility makes governments 'even less likely to address the real, underlying socioeconomic causes' [53].

As Schmidt and Engelen [53] respond, there is no need to create this dichotomy between individual responsibility and governmental action. It is not an either/or choice. We do not have to choose nudging over structural reform. It is misleading to state that governments will step back from policy implementation to concentrate on nudging, instead. Governments do not rely solely on anti-drink-driving advertisements to prevent drink-driving; they implement police stops, alcohol breath testing, punishment for these offences, and so on. Likewise, they would not rely on dietary apps to ensure a healthy population, they implement campaigns to educate dietary practices, implement taxes on sugar, encourage healthy eating in school canteens, and implement constant regulation on food quality and safety. It would be in most governments' best interests to tackle these issues from many fronts, rather than relying on one single way to meet their goals.

5.2.1.2. Private for-profit nudging and dietary apps. Dietary apps are often created by for-profit companies, whose interest it is to engage as many users as possible, retain a large user-base, to keep their users engaged, and have them interact with sponsored commercial content. While the app may help users to implement and follow better dietary practices, stick to their routine, and bring them wellbeing from eating healthier, there may be other nudges that benefit the company and not necessarily the end-user. The question becomes: do these types of nudges harm the end-user's choice and agency? Even if dietary apps bring about better dietary habits, do the nudges used by the company undermine the agency of the individual in making these choices? What level of trade-off is acceptable between the benefits of the company and the nudging of its users?

To begin with, it is important to reiterate the main reason why people start using dietary apps. The main intent of users using dietary apps is to sustain their diet or improve it. They use dietary apps to restrict, maintain, or increase their calorie consumption. Most want to do this to be healthy/healthier. They are implementing intentional action, by engaging with the dietary app, to achieve these aims.

Most for-profit dietary app companies use nudges to help users

[13] A relatively recent, and interesting example of this, is Derren Brown's 'Pushed to the Edge' documentary, where he stages an event with numerous nudges and social compliance tactics to lead an unwitting participant to end up committing murder by pushing a man off a building. Of course, the man is attached to cords and does not die, but the shocking thing about the programme is that three out of the four individuals committed pushed the man.

[14] However, this is still only referring to the nudges within the app to make better dietary behavior and practices, but one could also examine what type of advertised nudging takes place and use this as a criticism against dietary apps, but this is a topic for further research. Of course, dietary apps, along with all forms of digital communication that thrives on a freemium advertising model may be held accountable to the charge of potentially harmful advertisement nudging, but this is not the purpose of this Section, or this paper.

[15] Perhaps, this could be proven or disproven through extensive mining of funding sources, interactions, objective setting, and proof of influence between the public and private sector on this topic. It would certainly be an interesting study, but is far beyond the scope of this paper.

[16] Responsibilitisation means a process where individuals are placed as responsible for a certain task that would have previously been granted to someone or something else (typically, a state agency). It purports that the individual is responsible for their own welfare and the duty is on them, rather than the government or governmental agencies.

achieve these aims. Often, nudges are mutually beneficial for the company and user (e.g., the user engages in the app community, which increases usership for the company, while also making the user more focused on sticking to their diet). However, dietary apps may also use nudging tactics, which are beneficial for the company, but not necessarily in line with users' needs or wants: nudges to sign up to the company's promotional newsletters, inviting their friends to join the app, or provide more personal data than they feel comfortable with.

These examples and distinctions are not clear-cut, self-evident, or universal for all users. While users engage with the app to eat healthy, the methods of nudging may have different impacts on their level of agency to fulfil these goals. How nudging will impact the agency of the user depends on: 1. how they are implemented, 2. the degree of nudging involved, and 3. how aware the end-user is about the outcome of the nudge.

Firstly, nudging can be done in ways that play on one's insecurities, fears, and aversions. For example, constantly showing pictures of morbidly obese people, indicating that their supplements will make them healthy, or guilting users to invite their friends to use the app as well, are some questionable examples of nudging practices. There are different scales of nudging and the harm that it places on one's agency when interacting with the app.

Secondly, dietary app companies could have affiliate products in a separate tab, which the user is free to click into or not, or they may create annoying pop-ups of these products, which are very difficult to click out of. There are degrees of agency within the use of the app and the level of nudging taking place by the company, where nudging turns to shoving [52].

Thirdly, some users will be more aware of nudges, others will be completely oblivious, and many will rest somewhere in-between (sometimes aware, other times oblivious, with most of the time having a general awareness of nudging). The impact on one's agency will be shaped by the degree of awareness, acceptability of the trade-off of availing of the service, and the freedom to choose otherwise. The more conscious we are of nudges, the more aware we are of their influence in our decision-making process. 'Since we are never totally free of outside influence, what gives us (part) authorship over our own actions is that we regard our own reasons for acting as authoritative' [59]. The more hidden, or unaware we are of, nudging, the less agency we can typically exert. However, even if we are (vaguely) aware of nudging, companies may still 'effectively steer your behavior as long as they have successfully figured out which of your buttons are especially sensitive under which conditions' [22].

These three factors have an impact on the level of agency exhibited by users when engaging with for-profit dietary apps. These apps typically aim to promote users' agency (by being able to better control their diet), which may also be beneficial for the company. However, there may also be times where the company uses nudging that is beneficial for the company, and less aligned with the reasons that the user is using the app, and thus, veers away from users' intentions for using the app.

There are a few precursors to direct dietary app development in the direction towards protecting, or ensuring, the agency of the end-user. If dietary apps aim to support the agency of users to eat healthily, most of the nudges that are used within the app should be directed towards this goal, rather than *only* for the profit of the company. The level of nudging should not play on users' insecurities, fears, and aversions, as it would harm their emotional and psychological wellbeing, which are parts of the overall health of the user. The degree of nudging should not make choosing otherwise difficult or cumbersome, which would negatively impact the users' options and agency to choose otherwise.

The use of nudging in dietary apps should also be transparent enough that the user can engage with the nudging, and be 'able to understand and autonomously endorse current or future restrictions and steering influences. So the transparency should not necessarily be absolute, but there should be enough transparency for users to make a truly informed decision' [22], p. 129. The level of transparency also depends on the type of nudging taking place. If nudging leans more towards benefits of the company (e.g., affiliate marketing for exercise brands), then there should be greater transparency because these individuals are not giving over an extended will for this nudging in the same way as recommendations for better dietary behavior [56].

These three factors are far from straightforward to identify in practice, due to the common entanglement of the company and users' interests and the levels of agency exhibited by the end-user in contrast to how, when, and what is nudged upon them. As Sax notes, the bottom-line for health apps to be respectful of the autonomy and agency of the user, they should 'collect data and design their app in order to (make a genuine attempt to) serve the real, authentic health-related interests of their users. In a commercial context, where health apps both seek to help users and want to make a profit from doing so, we should ask how the aim to profit from health advice can be reconciled with a respectful treatment of the users' decisional health sphere' [22], p. 136.

Therefore, it is very difficult to make sweeping statements about the agency-enhancing or harming effects of for-profit dietary apps, and their use is very contextually-dependent and will vary on their implementation. While the difference between the two is often not self-apparent, there are clear opportunities for app companies to ensure that their devices are agency-enhancing or protecting, which can also be supported by adequate policy that protects the end-user from deceptive, harmful, and manipulative nudging done through these apps.

5.2.2. *Force and dietary apps*

One concern is that the process of implementing dietary apps is harmful to citizens' freedoms and choice, because they are done in a forceful way. Thus, the means of achieving better dietary practices may be illegitimate and harmful. As Nussbaum notes, forced healthy dietary habits is contradictory and against other important capabilities, such as the capability of practical reason. It would be undermining to adopt such an approach where citizens are devoid of choosing a healthy diet themselves: 'If people are well-nourished but not empowered to exercise practical reason and planning with regard to their health and nutrition, the situation is not fully commensurate with human dignity: they are being taken care of the way we take care of infants' [31].

Governments may actually *force* individuals to use them in particular circumstances, so '[t]here is a fine line between consensual, pushed and imposed self-tracking' [9]. This is a very serious concern and is a challenge to individuals' freedoms. Recently, the tension between protecting citizens and infringing on others' freedoms has become apparent during the Covid-19 pandemic. For example, there has been controversy around forced health-status apps on your phone when you enter certain countries (e.g., South Korea) or vaccination passports, it raises concerns about paternalistic governments prohibiting movements and access, unless one abides by their policies.

This overall idea is nothing new, but is an essential component of living within society, generally. We must abide by certain rules and policies to avail of freedoms and benefits from doing so. The tension lies in how much freedom is restricted, in what respect, and is the trade-off favourable for the benefits that it brings. Because we have no real-life examples of how freedoms have been affected from forced dietary app use, it is difficult to postulate on the freedoms that may be restricted, the context in which they would be limited, and if the trade-off is fair or not. It is important to evaluate ways that dietary apps may be used in such circumstances and how we can pre-empt and prevent freedom-inhibiting uses of these technologies. However, it is beyond the scope of this paper to create very speculative scenarios to defend or reject the use of dietary apps based on this.

Despite there being no clear indication of malicious uses of dietary

apps by governments, there has been examples where one's data, from similar applications and contexts, has been sold to others[17] and/or used against them. For some, this is abhorrent and a complete invasion of privacy, while others look upon this favourably, believing it will lead to an improvement and personalisation of their healthcare [61]. Individuals should be allowed to choose if they want to share their data through these apps and there has been a number of steps taken towards ensuring this, such as the EU General Data Protection Regulation (GDPR). However, many countries around the world do not have ways to ensure privacy protection, and there are many regions in the world with little to no data protection regulation at all.

Ultimately, greater efforts need to be made to protect the data of users of dietary apps, with opt-in procedures, clear explanations and informed consent, and the right to withdrawal if they choose to. This is down to ensuring adequate data protection regulations for all apps, so it is not solely relevant for dietary apps, but all types of technologies that retrieve and use personal data. This is also relevant for dietary apps and certainly warrants a separate legal analysis on the topic, but is beyond the scope of this paper.

5.3. Conversion factors

The traditional skills required to eat healthily are an understanding of nutrition and knowledge about healthy diets, such as which foods one should buy and how to prepare them. To convert this knowledge into the capability of eating healthily, one would need cognitive skills to process this information, the ability to go to the shop to purchase this food, being allowed/enabled to go out and get this food, the training to prepare and cook dishes, and living in an environment where one can cook and consume this diet (this is only a *few* possible conversion factors). Much of these conversion factors are the same for dietary apps as other dietary methods. The main difference between dietary apps and traditional methods is the informational *processing stage* of the conversion; if the informational *content* is largely the same (e.g., digital recipes will have the same words and stages as printed/physical recipes, nutritional information collected from books will be the same as that on the dietary app, and the nutritional [oral] recommendations from nutritionists will largely be the same as digital ones on the app). Therefore, the main question that needs to be addressed is what *new*, or *different*, conversion factors are needed when using a dietary app?

To begin with, there is a need for users to have adequate eHealth knowledge and literacy to use these apps [48]. Users need to have the specific abilities to receive information (hearing, seeing, reading, etc.), the technical ability to use the app (understanding how to download it, enter details, how to update it, etc.), and the ability to understand the information that the app is providing. The perceived ease of use of dietary apps influences the take-up and continued use of the app, so it is important that it is easy to use from the very beginning [62]. Another fundamental component of apps' usage is ensuring their 'accessibility' to users. Accessibility entails developing apps suitable for people with auditory; cognitive; neurological; physical; speech; and visual impairments [63]. This appears to *mostly* be a technical challenge of ensuring the app's usability, but is very important so they can realise the capability to eat healthily.[18]

If dietary apps are responsive to the diverse needs of individuals, then they offer greater opportunities for individuals to fulfil the capability of eating healthily. For example, the availability of diverse cooking books with braille may be limited, or it may be challenging for deaf people to find nutritionists who can do sign language, or very time-consuming for wheelchair-users to make trips to their doctor for dietary advice. Dietary apps may actually help reduce the burden associated with traditional conversion factors to retrieve nutritional food advice. If developed and implemented with end-users in mind, dietary apps may provide a valuable way to provide individuals with the freedom to eat healthily. Therefore, the impact on individuals' conversion factors largely depends on the particular app in question, and if the developers integrate an inclusive and accessible design for a wide diversity of users.

5.4. The capability of eating healthily

Morozov states that technological solutionism is an ideal that encourages the overuse of technology to solve all of the world's problems. Technological solutionism entices us towards a utopian ideal where technology can rid us of our human flaws. Even the attempt to do so is repugnant for Morozov and contrary to a life worth living. In fact, it altogether takes away our freedom to choose: 'Imperfection, ambiguity, opacity, disorder, and the opportunity to err, to sin, to do the wrong thing: all of these are constitutive of human freedom, and any concentrated attempt to root them out will root out that freedom as well' [2]. If we apply this to dietary apps, any attempt to root out imperfection or ills in our diets, through the use of such apps, will actually root out our freedom 'to err, to sin, to do the wrong thing'. Morozov states that in a democratic society we should be allowed to question whether it is 'right' to eat smaller portions of food, become thin, or overweight if we want to Ref. [2].

Morozov claims that trying to be perfect is undesirable and some of the most important things in life do not need to be fixed or changed, despite their imperfections. Technological solutionism finds faults with everything. The more we use technologies to resolve our imperfections, the more imperfections we discover, and the more problems we create for ourselves. However, Morozov is not claiming that we should discard technologies altogether or that imperfections and errors are better than their opposite, he is stating that *sometimes* they are. Our flaws are what makes us human, and treating ourselves like machines that need to improve or be perfect, impinges on our very humanity. The Internet 'has become the chief enabler of solutionism, supplying the tools, ideologies, and metaphors for its efficiency crusades' [2].

In the context of dietary apps, one could intuitively follow Morozov's line of argument, as diet and eating patterns are often problematic, leading to eating disorders, body dysmorphia, and health-related side-effects; all in the pursuit of what one should eat to look a particular way or achieve certain dietary goals [9]. Often, there is a great deal of concern around appearance, which sometimes leads to diet fads, diet tablets, surgery, obsessive exercise patterns, and so forth. At this stage, it is also important to reiterate that dietary apps are *not only* or *primarily* used for weight management or weight loss. This is only one reason for dietary app use, with many using them for healthier diets, to combat health-related issues, and for greater self-control over one's eating patterns.

However, Morozov's claim may still be applicable because individuals who use dietary apps are striving towards a type of perfectionism, when they should be embracing their imperfections and enjoying the diversity and non-formulaic aspects that life has to offer. I think Morozov would claim that constantly worrying about one's diet or trying to be the master over oneself takes away from randomness and fun in our lives. Therefore, do dietary apps contribute to, or exacerbate, this obsessiveness, this striving towards perfection, which leads us to finding more imperfections that we would not have seen otherwise? Do dietary apps impact our freedom to choose, and do they have a harmful impact on our attitude towards eating? Ultimately, do they bring more harm than good?

One of the main issues here is that self-monitoring technologies will

[17] There have been cases already, where American hospitals have purchased data on their patients' credit card transactions to predict high-risk patients, so that they could contact them in a pre-emptive way to improve their health [60].

[18] For example, Dudharejia [63] gives a few preliminary ways of how this can be done, such as: add images with alt text, allow users to enlarge font sizes, keep contrast sensitivity in mind, add keyboard navigation, make video and multimedia accessible, use descriptive URLs, use ARIA roles, avoid using placeholder texts in forms, and minimize the use of tables.

lead individuals to over-monitor themselves. The intrusiveness of monitoring technologies and apps holds the potential to track almost everything we do in our lives. For some, 'there is no rest from self-monitoring' [2]. While some would find this absolutely repugnant, others relish in such opportunities to self-monitor. For example, the Quantified Self movement is a loose affiliation, which prides itself on adopting technologies to monitor a wide range of activities. Members claim that their data brings them comfort, a sense of community, better insights into their body, greater self-control, improved wellbeing, and better health [9]. However, there has also been numerous people who have had terrible experiences with self-monitoring technologies, or hate the thought of something so intrusive in their lives.

In terms of dietary apps, some claim that they give them greater control over their lives, better insights, and greater independence; while others become obsessed using them, feeling bad when they do not make progress, leading to disappointment and frustration [9,64].[19] Some state that they have greater autonomy and control over their choices, while others claim they limit their autonomy, making them feel guilty for not using them, or feelings of incompleteness, insecurity, or that their efforts are in vain unless they are recorded [9]. Essentially, these apps will make 'some people feel athletic, others fashionable, still others fat and self-conscious about their bodies' [9].

Most people usually fall somewhere in between these two extremes: they use these apps sometimes, rarely, or not at all; with experiences ranging from generally favourable, slightly annoyed by them, to general indifference.

Altogether, it is difficult to have a clear-cut answer about what needs to be done in relation to dietary apps, if their use is not compulsory, they appear to largely be down to personal preferences, and links to harms from using them are quite tenuous. Of course, if they provide incorrect, unscientific recommendations, or altogether harmful advice, then they should be regulated against to protect users. However, in much of the empirical research around dietary apps, the feedback is generally quite positive, with individuals claiming that they feel their diets have improved, they have greater control over their diet and lives, they feel better, and their health has improved [3–6,14,48]. However, these studies often only analyse a limited number of apps, so it is worth emphasising that not all dietary apps are the same and certain ones may cause more harms than others. In these instances, they should be amended, regulated, or altogether discontinued, depending on the severity or the fixability of the app. These harms may originate from inaccuracies in the data provided to the users (which will be discussed next) or their impact on other capabilities (which will be discussed in Section 5.5).[20]

If dietary apps do not provide accurate and helpful information then they may cause harm to the end-user, which can range from something inconvenient (e.g., spoiling their meal that they are cooking), to short-term harms (e.g., by recommending foods that the user is intolerant or allergic to), to more serious and long-term issues (e.g., health-related issues from continuous poor dietary advice). If one does not verify the truth and accuracy of the recommendations from the app, one could receive false, misleading, or downright harmful dietary advice.

Therefore, it is important to question: 1. What sources and data is the dietary app using to formulate its recommendations and is it accurate and based on respectable dietary information? 2. Does the data that is being given to the end-user consider their personal situation, dietary preferences, health, and medical conditions?

Firstly, the type of dietary data that the app uses is important for the accuracy and legitimacy of its recommendations. Dietary advice is a much-debated and controversial field of study, with new insights and recommendations being developed regularly. Where this dietary information is retrieved from, and what is inputted into the dietary app is clearly very important for the recommendations that it provides to end-users. For example, if one is developing a dietary app based on data from Atkins or Paleo diets, the recommendations of what is healthy will probably be different than one based on intermittent fasting, low-fat diets, or a vegan diet.

It is important that diet-apps are grounded on valid scientific information and the latest in nutritional practices [5]. As illustrated earlier in this paper, the WHO provide some basic, foundational, nutritional guidelines, but these are very vague and simply outline upper thresholds and daily reference intakes. There are many more detailed guidelines on dietary requirements for individuals, with some countries providing their own recommendations (such as the US Department of Agriculture and Department of Health and Human Services). These are regularly updated to provide recommendations and best practices related to diet, nutrition, and food intake. Unfortunately, there is no universally accepted set of nutritional guidelines, but many national bodies' recommendations (e.g., the USDA Dietary Guidelines for Americans). Even within these guidelines, there has been much controversy over their validity, with some recent publications claiming that there is a serious lack of scientific validity behind these food recommendations and that the food industry manipulates these policies, and in turn, our choice and dietary practices [66].

Identifying accurate sources of dietary information is problematic for developing dietary apps and where it retrieves this information will have a fundamental impact on what kinds of recommendations the end-user will receive. There is no straightforward solution to this problem. Following national dietary recommendations, although not perfect, is probably a better option than creating an amalgamation of dietary recommendations from a wide range of different sources. This would be arbitrary, the recommendations may be contradictory, and there may be a lack of unified support for such research. There needs to be improvements to current national dietary guidelines, an evaluation of the power and influence of the food industry on such policy, and better scientific research on diet; but these factors go beyond the scope of those creating dietary apps, and certainly beyond the scope of this paper, as well.

Secondly, it is also very important to consider diversity among dietary habits and allergies. For example, '30% of Americans have specific dietary preferences, 20% have food insensitivities, and 5% have food allergies' [4]. An effective dietary app must take these factors into account to ensure individuals have adequate information to eat healthily. 'By offering several options, the app would not be restricted to specific group of users. Instead, it would give them the freedom of choice' [3].

While it is important to implement a standardised best practice to ground nutritional recommendations, as suggested earlier; it is also important that dietary apps acknowledge the end-user's personal tastes, preferences, allergies, intolerances, cultural variations, and also, opportunities to acquire food variations from place-to-place. This responsibility is mutually dependent, as it also relies on the end-user accurately inputting their data into the app. While the app developers have an onus of responsibility to provide accurate recommendations and robust technologies, end-users also have a responsibility to enter information honestly in order to receive the most accurate recommendations in return. Similarly, with a doctor or a nutritionist, if the end-user is not reflecting the full picture, it is difficult to give precise recommendations and guidance.

5.5. *Dietary apps effect on other capabilities*

Technology offers the potential to advance capability sets, or

[19] This point was also demonstrated in recent research that evaluated the use of ICTs by patients to self-manage their diabetes. Respondents stated that they felt a much greater level of empowerment by having greater control over their illness and how to respond to it [65].

[20] It must be noted here that negative impacts on other capabilities may arise from inaccuracies of the data or completely aside from this (e.g., accurate data, but end-users become obsessed with this data, thus impacting other aspects of their lives). Negative impacts on other capabilities are not solely the cause of data inaccuracies.

transform them, entirely (e.g., cognitive capacities, mobility, and communication with others). Not only do technologies provide input for allowing us to achieve certain capabilities, they also hold the potential to transform what we value as capabilities in the first place: 'For instance, the global spread of the Internet may affect forms of expression to such an extent as to deprive humans of social diversity' [42]. When applied to dietary apps, the question becomes: do dietary apps have an effect on other capabilities and are these changes desirable or not? And do they transform or change the capabilities that we value and consider worthwhile?

To effectively answer this would require empirical analysis to validate the impact of dietary apps on values. However, even within this empirical analysis, it would probably only give a partial picture as it would be limited by the number of participants, countries/cultures, the types of capabilities discussed, and range of apps being used, and many other variants. The range of capabilities is extremely broad, and the use of dietary apps may touch upon many directly or indirectly. For example, they may impact many capabilities directly related to the functions within the app, such as our capability to cook, to learn about diet, to understand our bodies, and capabilities of self-control. They may also impact capabilities indirectly, such as our capability for social interaction and dialogue, our capability of imagination and playfulness, or our ability to enjoy nature and its beauty [31].

Many people using self-tracking devices feel like they are part of a community: 'Some self-trackers find that sharing their data with a small group of intimate others helps their relationships and garner support for the changes they are attempting to make' [9]. Thus, dietary apps may affect community-building, association, and being part of a group.

In other instances, dietary apps may influence our ability to make decisions by ourselves. In previous studies, people started to doubt their own feelings about their bodies, or their mood was influenced by the app. The feelings of comfort, discomfort, happiness or discontent, are so closely related to the app, that users are unsure whether these are their own feelings demonstrated through the app or whether the app is influencing them to feel these ways [9].

These questions open up opportunities for further research in the area, but are outside the scope of this paper. While this paper has briefly touched upon how dietary apps impact our capabilities; for example, bodily integrity (Section 4.2 and 4.4); practical reasoning (Sections 4.1, 4.2.2, and 4.4); control over one's environment (Section 4.2); more work needs to be done in the area of comparison of capabilities impacted through dietary apps.

6. Conclusion

This paper set out with the intention of evaluating dietary apps, using the capability approach as a methodology, to identify some of the most common challenges against these apps. It was shown that dietary apps are a specific type of input within the capability approach, but one which has a transformative effect on conversion factors and our capabilities. One of the main capabilities that dietary apps encourage is the freedom to eat healthily. This was not the only capability, but the most significant one. Some dietary apps encourage users to be involved in a community, while others focus more on the ability to lose or gain weight.

One thing that became clear was that many of the criticisms levelled against dietary apps may not be accurate. For example, simply because dietary apps incorporate many of the inputs required for healthy diets in one place, does not necessarily mean that this is something problematic or concerning, in itself. The issue arises if this cuts users off from accessing and incorporating other inputs, opinions, and viewpoints on dietary practice. Dietary apps should encourage users to develop their overall knowledge of nutrition and diet (e.g., by providing links and alternative sources of information), but it also provides a cheap and easy way for users to improve their diet, with much of this information collated in one place.

Some of the concerns raised in the paper are more applicable to data regulation and protection over apps, rather than specifically being issues especially pertaining to dietary apps. For example, data protection and regulation can ensure opt-in procedures, adequate informed consent procedures, and that users' data is not used in ways that they have not agreed to or benefit them. Dietary data must be used for the benefit of the user and in line with their wishes.

The paper also demonstrated that not all nudging is bad. It highlighted that there are typically three stages of nudging, pre-use, use, and post-use, of dietary apps. The most important one that strongly relates to the context of use is the use stage of nudging within dietary apps. It was shown that dietary apps may actually promote our freedoms by enabling us to act how we would ideally like to, or remind us about our moral preferences in situations of temptation, frivolity, or excess.

It was also shown that the claim dietary apps will lead governments to a form of responsibilitisation, whereby, they stop implementing health regulations and leave choices solely to our own discretion (a claim that dietary apps will enable) was shown to be largely unfounded in other situations and would be unlikely to occur in the context of dietary habits and governmental policy.

A more challenging topic is nudging being done by private companies developing dietary apps, and how to identify when, and how, these nudges enable or inhibit the agency of the end-user. As was demonstrated in Section 5.2, who benefits from in-app nudges is vital to determining how ethical they are. In addition, this Section demonstrated that judging the ethical acceptability of in-app nudging should be evaluated by determining how they nudging itself is being implemented (e.g., what types of methods, language used, tactics); the degree of nudging involved (how restrictive is it from making other choices); and how transparent is the company about their nudging to the end-user.

Developers of dietary apps should be aware of the needs of different users, such as health status, age, sex, physical conditions, to ensure inclusiveness and reduce discriminatory output. They should also be designed to allow more people use them, such as people who are blind, deaf, physically impaired, and so forth. Dietary apps should be grounded on valid scientific findings and the latest dietary information, but should also integrate users' dietary restrictions, intolerances, and overall, personal preferences, to truly allow them to reap the benefits of such apps, while reducing potential harms or issues resulting from them. Overall, this paper has shown that there are many benefits for improving and helping our freedoms to eat more healthily through dietary apps, but there are a number of factors that should be considered and implemented to reduce potential harms.

Author statement

Contributions to the paper using the relevant CRediT roles: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing. Authorship statements should be formatted with the names of authors first and CRediT role(s) following. All of these roles were solely fulfilled by the sole author of this paper: Dr Mark Ryan.

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Declaration of competing interest

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Mark Ryan is a Digital Ethics Researcher at Wageningen Economic Research, focusing on areas or robotics, AI, and digital developments and responsible innovation. He has published on a wide range of digital ethics topics, such as: smart cities, self-driving vehicles, agricultural data analytics, social robotics, and artificial intelligence.