"Like rearranging deck chairs on the Titanic"? Feasibility, Fairness, and Ethical Concerns of a Citizen Carbon Budget for Reducing CO_2 Emissions

Gisela Reyes-Cruz
gisela.reyescruz@nottingham.ac.uk
University of Nottingham
Nottingham, UK

Peter Craigon
peter.craigon4@nottingham.ac.uk
University of Nottingham
Nottingham, UK

Anna-Maria Piskopani
anna-maria.piskopani@nottingham.ac.uk
University of Nottingham
Nottingham, UK

Liz Dowthwaite
liz.dowthwaite@nottingham.ac.uk
University of Nottingham
Nottingham, UK

Yang Lu
y.lu@yorksj.ac.uk
York St John University
York, UK

Justyna Lisinska
justyna.lisinska@kcl.ac.uk
King's College London
London, UK

Elnaz Shafipour
esy1v21@soton.ac.uk
University of Southampton
Southampton, UK

Sebastian Stein
ss2@ecs.soton.ac.uk
University of Southampton
Southampton, UK

Joel Fischer
joel.fischer@nottingham.ac.uk
University of Nottingham
Nottingham, UK

ABSTRACT

Radical and disruptive interventions are needed to reach "Net Zero" by 2050 to avert the climate catastrophe. Although governments, companies, cities, and institutions have pledged to take action and reduce their carbon emissions, the idea of personal carbon allowances or budgets for individuals has also been proposed as a potential national policy in the UK. In this paper, we employ a Research through Design approach to explore the notion of a carbon budget. We present combined results from two studies: firstly a workshop with members of environmental organisations (industry, charity, and policymaking) discussing the concept of a Citizen Carbon Budget (CCB) and app, from the wide perspective of societal desirability drawn from Responsible Research and Innovation (RRI); and secondly, a one-month deployment of a CCB mobile app with twelve members of the public based in the UK. Key findings from the combination of these approaches showed that the CCB app was fruitful in supporting awareness of personal carbon emissions and reflections about people's lifestyles. However, several concerns were raised, including the unfairness of treating all people equally in environmental policy, regardless of their background and context. We provide considerations for policymaking and design, including intertwined perspectives drawn from the differing approaches of individual and collective action.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

carbon emissions, carbon footprint, sustainability, ethics, personal tracking, policy, research through design, HCI, responsible research and innovation

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1 INTRODUCTION

The accumulation of greenhouse gases (GHG), particularly carbon dioxide (CO_2), in the Earth's atmosphere is contributing to rising temperatures, extreme weather events, and other adverse environmental impacts such as ecosystems damage, water scarcity, food production disruption, and harmful effects on health and wellbeing [45]. In the face of the current climate crisis, decarbonisation (the process of reducing or eliminating carbon dioxide emissions from various sources) has become an urgent and critical imperative, leading to pledges by more than 140 countries to achieve the target of reducing carbon emissions by 45% by 2030 and reach net-zero emissions (i.e., cutting GHG emissions produced by human activity to as close to zero as possible) by 2050 [42]. However, the environmental science community unanimously agrees that efforts towards these goals have not been enough to address climate change so far [52]. It has been confirmed that 2023 was the hottest year on record, and there is an increasing possibility that 2024 will be warmer [58]. Systemic changes and policy interventions are essential, for instance, to address large-scale emissions from corporations, however, individual actions remain a crucial part of the solution too [11, 45, 55]. Whilst current UK government strategies acknowledge

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the need for individuals to adopt low-carbon lifestyles to achieve a net-zero goal, the specific pathways or policies to effectively facilitate such changes are not clearly outlined [55]. There is, therefore, an opportunity for developing measures to motivate and engage individuals towards sustainable practices regarding transportation, energy consumption, and dietary habits [45].

From a policy perspective, personal carbon allowances (PCA) were considered as a policy proposal in the 1990s [49]. PCA proposed that individuals would get equal, tradeable carbon allowances. However, this idea never took off, quoting issues such as low public acceptability and technological barriers [28]. They were also described as a solution 'ahead of its time' [24]. Nonetheless, with advancements in information and communication technologies, rising energy prices and living costs, as well as a worsening climate, there is a window of opportunity for the engagement with government and dialogue on a solution aimed at the individual level that could help achieve climate mitigation goals [28].

This work aims to respond to recommendations to explore avenues for public engagement and demand carbon reduction, focusing on people's lifestyles [15, 16]. The present work is part of a larger project that has sought to explore the viability, regulatory concerns, trustworthiness, and public acceptability of a Citizen Carbon Budget (CCB) app; a deliberately provocative app for testing the assumptions of suggested policies on PCA. The idea of the CCB entails that every person has a carbon budget that they can spend each month. Daily activities have associated carbon emissions that impact their budget. For example, the carbon emitted by travel will be impacted by mode of transport and distance.

Although public attitudes towards decarbonisation were previously investigated [22, 43], and there are other existing applications on the market (e.g. apps for tracking and offsetting carbon emissions such as Aerial [35], Capture [62], Commons [17], and carbon footprint information increasingly included in digital services such as banking and transport apps), this work frames the concept of a CCB app as a nation-wide scheme, to be deployed in the UK, aiming to tackle climate crisis (i.e., by potentially facilitating reduction of individuals' carbon emissions); we investigate its public acceptance (or resistance) and potential barriers to deployment and adoption. The CCB app integrates the budget feature without the trading functions. In this paper, we investigate the concept of a carbon budget employing a Research through Design approach, by conducting two linked studies: a Responsible Research and Innovation (RRI) workshop with members of environmental organisations (industry, charity, policymaking) and the research team discussing the CCB and app and a one-month deployment of a CCB mobile app with twelve members of the public based in the UK. Through these combined approaches, we aimed to answer the following research questions: 1) **What are the potential benefits and harms that may result from a CCB app?** 2) **What are the public's perceptions of, and practical experiences with, a CCB app?** Key findings showed that the CCB app was fruitful in supporting awareness of personal carbon emissions and reflections about people's lifestyles. However, several concerns were raised, including the unfairness of treating all people equally in environmental policy. We provide considerations for policymaking and design, including intertwined perspectives drawn from the differing approaches of individual and collective action.

2 RELATED WORK

2.1 Measures for reducing carbon emissions

At COP26, the UK government set out its Net Zero strategy, outlining how to halve UK emissions in a little over a decade and eliminate them by 2050 [16]. However, while the strategy's focus on decarbonisation of energy and transport is necessary, it does not propose needed action on how to engage the public (in spite of acknowledging that public engagement is needed). The Climate Change Committee (CCC) has published a range of reports outlining advice on the actions for reducing the volume of GHG emitted by the UK [15]. The key recommendations include that people reduce the demand for carbon-intensive activities, which include diet, travel and energy consumption.

PCA and other policy proposals under similar names (e.g. Personal Carbon Trading) broadly involve assigning individuals a limited periodical (e.g. annual, monthly) carbon credit or budget, incentivizing them to make sustainable choices, and allowing individuals to buy and sell carbon allowances, creating a market-driven approach to reducing emissions [49]. Some proponents argue that the current global context, marked by increased environmental awareness, advancements in technology, and an imperative to address climate change urgently, presents an opportune moment to revisit the notion of PCA and similar proposed measures, in particular by technologically advanced countries who are higher carbon emitters [11, 28]. For instance, originally, PCA was outlined as a system where physical cards with the allocated carbon credits would be distributed amongst the population; nowadays, increasing smartphone uptake presents a relevant medium for deployment at reduced costs. Despite this, there has been limited empirical exploration of PCA, with many investigations relying on data modelling, simulations, questionnaires, or interviews, rather than real-world trials [48, 49]. This has resulted in PCA remaining largely a theoretical idea, prompting the need for updated and in-depth empirical investigations to inform their viability and social implications, helping to shape effective strategies to engage individuals in the broader decarbonisation agenda [28].

2.2 Technology for sustainability

Amid discussions about sustainability, technology, and specifically Human-Computer Interaction (HCI), has begun to play a pivotal role. Sustainable HCI (SHCI) has emerged as a vital field, aligning technological advancements with Sustainable Development Goals [41]. An analysis of a decade's progress in SHCI [32], underscores the role of HCI in addressing global challenges. Some have explored how HCI can catalyse change towards a sustainable future [6], highlighting the importance of continued research and innovation to effectively tackle environmental challenges. The role of HCI in fostering sustainability through user engagement and education has been emphasised [51]. Past work on energy literacy demonstrated the effectiveness of HCI methods in educating and engaging users. Focusing on the use of real-time, personalised recommendations to promote sustainable behaviours, innovative solutions for energy saving have also been explored [56], including applying serious games to thermostat interfaces to empower users in saving energy, representing an engaging and effective method for promoting

energy efficiency at home [40]. Carbon calculators have been designed and deployed to help to manage personal carbon footprints. Proponents of approaches for associating consumer behaviours with climate actions [8] advocate for more comprehensive and interactive tools. Some insights into users' experiences with carbon calculators that utilise transactional data [1] represent a significant advancement in estimating consumption-based emissions. Further, carbon footprint calculators, as interactive tools, can challenge and change everyday habits [3, 67], furthering our understanding of its influence on daily choices for sustainability. However, voluntary adoption of carbon calculators for carbon reduction presents barriers that urge for more ambitious climate mitigation policies [9].

2.3 Probing the future through design

Whilst the focus of this study is on a CCB facilitated through the provision of an app, the objective was not to advocate for its adoption, and design the app accordingly, but to explore it from different perspectives to provide a rich exploration of the implications of revisiting such a technology in relation to climate change. To do this, the project therefore drew inspiration from a set of interrelated design approaches, whereby a technological artefact is designed not to solve existing problems but to provoke critical reflection on the implications of technology. Primarily, we situate this work within the scholarship of Research through Design [69], which seeks to critique and engage with 'wicked' and 'under-constrained' problems (such as climate change) through designed artefacts (such as mobile apps), to which more reductionist or generalisable methods may be less suited. Other related approaches are Speculative Design and Design Fiction within this. As Coulton Lindley and Cooper [19, p. 9] say "*these approaches use design to ask questions. They do this by creating prototypes, but instead of being created to be put into production, these prototypes are used to encourage people to think critically about issues that design embodies. Speculative Designers and Design Fictionists ask how things might be in the future, why things might be that way, with a view to highlighting potential problems and opportunities*". A similar approach is that of 'provotypes' [5] whereby designers create prototypes as provocations about technology rather than prototypes to be developed for use. In common with design fiction, these reify ideas, concepts, and values for them to be grasped and explored in a more concrete real form. Whilst the work built for the current project revolves around a single entry point of the CCB app, the approach builds on previous work approaching 'ethics by design' to explore future implications of technology in the present day [20, 37] as described in the next section.

3 APPROACH

We employed Research through Design to explore whether having an allocated personal carbon budget and a supporting digital tool could help people reduce their individual carbon emissions, through two studies: first, a workshop with members of environmental organisations to discuss the concept of a CCB as a nation-wide scheme aiming to tackle the climate crisis, from the wide perspective of societal desirability drawn from Responsible Research and Innovation (RRI); and secondly, we conducted a CCB app deployment with members of the UK public to understand their individual experiences with the app *in practice*, and the potential acceptance and adoption of this type of intervention.

3.1 RRI Workshop

The project's consideration of a CCB was not solely conducted as a piece of HCI research assessing the use of an app, but it was multidisciplinary in nature. The broad conception of a CCB acted as a provocation to be considered from a variety of perspectives (e.g. policy, HCI, law, AI), through the lens of Responsible Research and Innovation (RRI) [54], which advocates for the work and products of research and innovation to be more closely aligned with the need and values of the society in which it is situated, moving from science *and* society to science *with and for* society [46].

3.1.1 Responsible Research and Innovation. This lens seeks to "*take care of the future through collective stewardship of science and innovation in the present*" [63] by asking '*what sort of future do we want science and innovation to bring into the world?*'. This has been framed as working to ensure that research and innovation, and its impacts, are societally desirable, ethically acceptable, and sustainable [66]. This mission, especially in relation to Information and Communication Technologies (ICT), is complicated by an observation known as the Colingridge dilemma [29] whereby when the nature of technology is emerging and changeable, the nature of its potential impacts and implications are to a great extent uncertain, rendering taking action to guide research and innovation down a desirable path difficult and unpredictable. Conversely, when the implications and consequences of technology are more certain and apparent, then the technology is more established and embedded and more resistant and difficult to change to a more desirable path. This tension has therefore resulted in the development of approaches attempting to influence the path of research and innovation to be more desirable, acceptable and sustainable, so that it can be made more 'responsible' at an early enough stage for its path and trajectory to be changed. To this end, tools and frameworks have been developed to help consider and engage with this. Perhaps the most well known was developed and proposed by Stilgoe et al., which advocated four processes of Anticipation, Reflexivity, Inclusion, and Responsiveness [63], which was then adapted to become the AREA framework of Anticipate, Reflect, Engage and Act [27]. These frameworks provide questions for stakeholders to consider throughout the research and innovation process.

3.1.2 Participants and procedure. The RRI activities of the project were focused on a single workshop held between the project team and the external partners, established at the beginning of the project, to obtain their perspectives on the CCB app being developed in parallel. They were not funders of this work, and there was no conflict of interest with their participation. They were contacted by email and invited to take part in the workshop. Four members of three different organisations, including industry (P3,P4), charity (P1), and policymaking (P2), attended the meeting in March 2023. The activities of the workshop comprised: an introduction to the CCB app idea, an introduction to RRI, a general discussion around issues and benefits of a CCB (e.g. is it a good idea? is it sustainable, ethically acceptable, societally desirable?), a demonstration

of the CCB app developed for the project, and a card-based exercise. This last activity involved discussing the ideas in response to the CCB demo, using a tool called the Moral-IT cards [65] to engage with potential positives/benefits and negatives/harms and ways of maximising and minimising them, respectively, as well as practical challenges of implementing these. The workshop was held online through MS Teams, with card-based activities and notes being captured via the online whiteboard platform Miro.

3.1.3 Data collected and analysis. The workshop lasted 3 hours in total, including presentations and short breaks. The online discussions were recorded and automatically transcribed using MS Teams, which also captured video of the activity on the online Miro board. Screenshots of the card layout and annotations by participants were taken, and the board retained to contribute to analysis. The transcripts from the session were then revised and corrected by the first author, and Reflexive Thematic Analysis (RTA) was conducted [7] (see 3.2.3 for details on the process, and past work for clarification on different types of generalisation [39], purposeful sampling [50], and misunderstandings in qualitative research [61]). The development of the CCB app within the project was in progress and near completion, so the workshop did not necessarily inform design features, nor was it meant to stand as a study on its own, but rather helped us to identify relevant topics to be explored in the subsequent app study, as well as reassess its aims and scope. A list of codes was defined from this data and used for the app study analysis, including CCB impact, requirements, complexity, inequality, and other concerns. Insights from the workshop are combined with the app study data, comparing and contrasting the views of project partners and members of the general public (see 4).

3.2 App User Study

The app deployment sought to investigate participants' perceptions of, and practical experiences with, the CCB app as a tool that could potentially help to reduce their carbon emissions, as well as understand the viability of its deployment and acceptance. We also set to investigate topics that arose from conducting the RRI workshop.

3.2.1 The Citizen Carbon Budget app . The CCB app is a non-commercial app, exclusively built for the purposes of this research and developed by project members affiliated with the University of Nottingham. A monthly carbon budget is allocated to every new registered user, based on estimated values of the UK average CO_2 emissions per person per year [36]. The budget value (1083 kg CO_2e) is the same for all users. This was attributed to individuals, not households. Users are required to enter information about their food consumption (i.e., if they ate any of the listed carbon-intensive foods on the day), their energy consumption (i.e., entering gas and electricity meter readings), and their transport use (i.e., type of transport and journey distance). Figure 1 shows most of the information requested to participants for logging food, transport and energy activities. Users can choose to save activities so that they can be easily recorded on future occasions (i.e., a regular meal or commute). The app uses the entered values to calculate an estimated carbon emission of the self-reported activities, based on government and commercial datasets for transport and utilities emission information [26] and food carbon footprints [14]. User's carbon emissions calculated from self-reported information are subtracted from the monthly carbon budget. Users can see their logged carbon emissions and the remaining budget for the month. Other features of the app include a history view of all recorded activities, analytics charts to visualise consumption across types of activity over time, and a monthly leaderboard (where the users with fewer emissions are at the top; see 7 for privacy measures). Users were provided with links to the websites where the information was obtained to calculate carbon emissions for each activity and item in the app. The remainder of the features such as streak count and badges were non-functional placeholders. We acknowledge some arbitrary design decisions in order to simplify and narrow the focus of the study, for instance, only a few food items and specific portions appeared on the app. Likewise, following ethical and practical procedures, we decided that no GPS would be used to log transport information, and participants were asked to manually enter their journey distance instead of locations or postcodes.

3.2.2 Participants and procedure. Participants were recruited from a pool of contacts from a previous survey study and other mailing lists and group contacts. The study was open to anyone over 18 years old and currently living in the UK. They were recruited on a first-come, first-served basis. No other prerequisites were defined. We only sought to balance gender in our sample, as per HCI research recommendations [44]. Participants were asked to use the app for four weeks, with the possibility of dropping out after two weeks, if desired, to encourage participation. They were asked to log the equivalent of at least one item per day but were encouraged to use the app as much as they wanted. Entry and exit interviews were conducted with participants, before and after their use of the app. In the first interview, they were asked about their environmental attitudes and habits, as well as prior experiences with similar carbon calculation apps (if any) and other personal tracking technologies (if any); the app was demonstrated to participants at this stage and instructions on how to use it were given to them. In the second interview, after the app deployment, participants were asked about potential changes in their habits and their overall opinions and experiences with the app. Demographic information was also collected. Twelve members of the public took part in this study between late June and early August 2023; all but one participant used the app for four weeks. One participant did not respond after the month's deployment, so their exit interview was not conducted. Participants' age range was 24–68 years old (mean 41.8, SD 16); 6 men and 6 women. Their reported living areas included cities (8) and towns or villages (4). Household composition range was 1-4 people. Country of origin included the UK (5), Greece (2), USA (2), Mexico (2), and Italy (1). All interviews took place online over MS Teams. Participants were compensated based on exit interview completion, length of participation and logged activities: £50 for two weeks –at least 15 logs; £100 for four weeks –at least 30 logs.

3.2.3 Data collected and analysis. All the information logged by participants and calculated by the app (user ID, type of activity, carbon used per activity logged, date of log, and specific details per activity logged, i.e., food items and portions, distance travelled by type of transport, type of energy consumption and units) was exported as a CSV file. Participant interviews were recorded and automatically transcribed using MS Teams. The transcripts were later

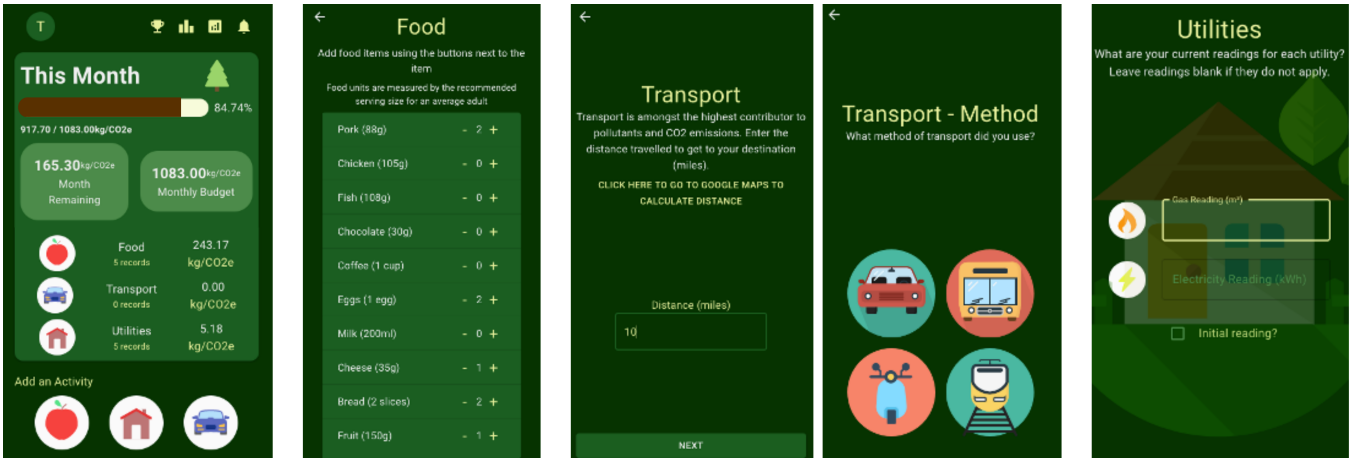

Figure 1: Main pages of CCB app: home and logging food, transport and utilities

revised and corrected by the first author. Reflexive thematic analysis (RTA) was conducted following Braun and Clarke's [7] phases: data familiarisation (i.e., listening to audio recordings, correcting and anoymising transcripts, organising and calculating initial app log values, making initial notes), iterative data coding (i.e., defining deductive codes from RRI workshop, labelling transcript excerpts using both deductive and inductive codes, searching and reviewing themes (i.e., clustering together related codes, identifying repeated ideas, concepts or meanings), defining, naming, and writing-up themes (i.e., refining focus and scope, selecting data extracts, using them as illustrative materials in the written report). We held reflective discussions throughout the process. Lastly, we also recognise that our personal standpoints and views in relation to the research topics inherently influenced the analysis (see 8).

4 RESULTS

Three themes relating to the CCB app were defined from the workshop discussion and participant interviews, and refer to its feasibility, fairness, and ethical and legal concerns. In total, participants logged 594 activities in the app (396 food, 163 transport, and 35 utility; see Figure 2). The minimum value logged was 1 cup of coffee (0.05025 kg CO_2e) and the maximum value 5800 miles travelled by plane (1786.4 kg CO_2e). Quotes indicate the study (W-workshop, A-app study) and participant number. The app data is used to support or contrast participants' accounts from the interviews.

4.1 Feasibility

This theme refers to the factors surrounding the viability of a national CCB scheme operationalised through a mobile app, and includes the subthemes: 1) purposes, responsibilities, and impact, 2) supporting awareness of own carbon emissions, and 3) conditions for acceptability and uptake.

4.1.1 Purposes, responsibilities, and impact. Different viewpoints in relation to the utility and effectiveness of a CCB app were reflected in the two studies. The RRI workshop participants had prominently negative or sceptical views of the CCB app, whereas the app study participants had more positive or hopeful perspectives. This might be down to the nature of the participants i.e., the workshop participants worked in environmental organisations and hence may be more experienced and distrustful whereas the app study participants did not have this prior knowledge or experience. W-P1 expressed: *"Is it a good idea? Broadly, in terms of its environmental impact, and I think organisationally we would say no. It's sort of rearranging the deck chairs on the Titanic*[1] *a little bit. We've got to a stage now where we need mass change at large level and this sort of shifts responsibility to the people who can't actually affect change on the more individual level"* (W-P1). Although four app study participants echoed this notion (*"Companies should be more accountable than individuals"*, A-P9), the overall sentiment was that of curiosity to try the app and willingness to consider it as a potential measure to help the environment (*"Everybody needs to do their bit, whether you're the chief executive or the man in the street driving a car or using electricity at home; we've all got our part to play, and if we don't play it, then the Earth is going to continue having very serious problems."*, A-P1; 120.49 total kg CO_2e). Six participants expressed being very worried about the current climate crisis, whilst the rest were less concerned but not necessarily indifferent. Whereas the former reported actively supporting the environment (e.g. buying from zero waste shops, buying local produce, having solar panels at home), the latter reported doing activities within their reach (e.g. recycling, walking or taking public transport) but often primarily motivated by economic reasons (e.g. reducing energy consumption). No participants reported beliefs of mistrust or denial towards climate change. Workshop participants expressed uncertainty about the actual impact of the CCB on the environment, however, they reflected on the possibility for the CCB app to be a tool aiding public engagement, especially those less involved with the topic (*"There are some solutions out there that target your, for lack of better definition, ecological warriors, that will have done this for the last 10 years, offset their whole lifestyle. We are almost hopeful that we're bridging that gap at the moment towards the majority, that there's more people seeing the need for this, obviously more it keeps being*

[1]Idiom: to do something pointless or insignificant that contributes little to solve a problem

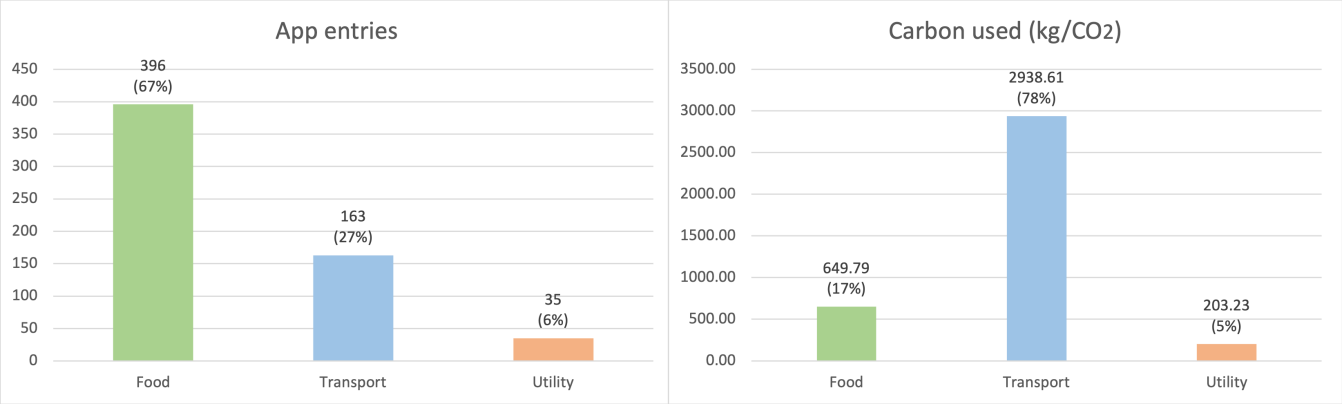

Figure 2: Left) Total app entries (n=594) that fall into each category; Right) Total carbon used (3791.62kg CO_2e) in each category

in the news, but I do think we are still talking about less than half the population", W-P3). The app study demonstrated the need and opportunity to raise awareness amongst the public, as described next.

4.1.2 Supporting awareness of own carbon emissions. Remarkably, at the beginning of the app study, all the participants expressed not having information or awareness of their own carbon emissions, nor the effect of their daily activities on the environment. Although workshop participants noted that there exist many apps and websites to help people reduce their carbon footprint, only two app study participants reported using online carbon calculators once in the past (*"You could put in like if you eat meat or if you drive, and it would do a rough estimate, but there wasn't any tracking over time"*, A-P8; *"It calculated your yearly emissions, but it didn't provide any feedback and didn't offer any comparison"*, A-P11), and three others mentioned having seen carbon emissions of journeys (e.g. car routes on Google Maps, flights when buying tickets) but not thinking much about them. In terms of general use of the app, most of the records were food and transport (by car), and most participants only used a small portion of their monthly carbon budget (less than half) given that some could not enter their utility information (e.g. people renting not having access to energy meters) or did not travel far during the study period. However, there were mixed reactions prompted by using the app. Two participants reported making direct changes to their daily life during the study as a result of using the app, including shorter showers (A-P11) and not eating beef: *"I remember seeing that the beef was 2.88 kg(CO_2e) whereas fish was 0.54, and that is a huge difference for something that builds me up the same amount. We know meat is not good for the environment, but here it was in terms of the actual figures. So we tried to cut down on that and I think that's something we can continue on, I don't think we would become vegetarian necessarily, but these things are easy changes and over the course of a year that would have a massive difference. But yes, the food for me was the big eye-opener."* (A-P5; 37.79 total food kg CO_2e). Many participants expressed feeling validation about some of their current lifestyles and obtaining an understanding of their environmental impact, by using the app (*"The food it seemed like no matter what I ate, it was like less than 1% of a month, so it didn't seem like by changing my eating would actually affect my carbon usage too much, but at the same time I don't really eat meat, so it wasn't putting the bigger factors in there. And then I was aware that like one flight was 30% of my usage for the entire month, and I guess the only way I compensate for that is by walking places from a day-to-day basis"*, A-P3; 98.85 total food kg CO_2e, 682.70 total transport kg CO_2e). Other participants recognised that the app was very simplistic and therefore was not entirely reflecting reality (*"It doesn't have all the options, so it doesn't actually represent the things I did eat... And not every cup of coffee is the same. The coffee I make at home, a coffee at a café, or a can from the grocery shop, maybe is different. So I'm sure that my actual carbon footprint is higher than what was shown in the app."*, A-P9; 49.93 total food kg CO_2e). Participants reflected that their activities greatly vary throughout the year, and that using the app during winter instead of summer would show higher carbon emissions (e.g. due to increased use of heating and lights). Although the app did not cause immediate behavioural change at large, it provided information not known at the start of the study, provoking a mix of feelings (e.g. validation, scepticism, surprise) and reflections on their lifestyles (i.e., continuing some activities, or considering changes: *"I knew that travelling by plane had a great impact, but not to what extent. We should all reconsider our travelling habits. There is one biannual transatlantic trip I won't give up, because it involves travelling home, but all the others I'll be doing locally"*, A-P11; 1817.82 total transport kg CO_2e).

4.1.3 Conditions for acceptability and uptake. There was a consensus among participants of both studies that incentives or clear benefits would be needed for the UK population to accept and adopt a CCB app if it were to be rolled out as a nationwide response to climate change. Incentives suggested by participants included tokens or vouchers for purchasing more sustainable products, general rewards if people stick to their budget, or discounts on utilities if people consistently self-report their consumption. Naturally, partnerships (e.g. with supermarkets and energy providers) would be needed to make this achievable and lower the barriers of use. Overall, persuasion would be much more preferred over coercion, and allowing people to opt-out from the scheme would be necessary. Some had a hard time picturing the CCB as a realistic mandatory scheme by the government (and several concerns were raised, as

explained in 4.3). A few participants expressed it would be imperative to widely pilot the app, not only to allow understanding of the CCB scheme before roll-out, but to inform policymakers on real data. Likewise, it was remarked that clear evidence would be needed for people to trust its effectiveness. Some highlighted that strong marketing campaigns and educational programmes would further encourage the use of the CCB app, and that appealing to social influence could drive uptake. Lastly, some participants noted that recommendation features would be better for aiding behaviour change: *"I could say to the app I'm planning to do X and the app could give me the amount of carbon emissions, but also give me an option, say if you do A, B, C; that will impact less. Help me to think about options"* (A-P10).

4.2 Fairness

This theme describes the disparities arising from the different circumstances of individuals, and it includes subthemes: 1) unequal opportunities for sustainable lifestyles, 2) it is unfair to treat all people equally, and 3) environmental justice.

4.2.1 Unequal opportunities for sustainable lifestyles. The RRI workshop discussion strongly focused on the complexity and systemic inequalities involved in leading a sustainable lifestyle, raising concerns about a CCB scheme reproducing the disparity (*"There's a concern that this could just simply be a middle-class pursuit and people at the lower end of the spectrum who are struggling to make ends meet, they're not necessarily gonna be thinking about the carbon budget to survive"*, W-P2). Some app study participants echoed the concern when talking about their particular situations (*"I'm a single parent, I'm not at a particularly good wage, and much as I'd love to do more for the environment, I can't afford to go and change my car to get one that's more economical."*, A-P7; 146.76 total transport kg CO_2e). In addition, the app study showed tangible examples of some people having fewer options to reduce their carbon emissions, particularly concerning transport and commuting (*"I've got to use a car because I start early and finish late, so there's no public transport. If you're in London, you're laughing because public transport's plentiful, but where I live, it's pathetic."*, A-P4; 38.44 total transport kg CO_2e). Conversely, participants that logged fewer or no transport activities reported having no need for it (*"I already live in a 15-minute city. All the shops and everything, cinema, pubs, parks, everything is within walking distance to where I live. I'm very fortunate"*, A-P6; 0 total transport kg CO_2e).

4.2.2 Unfair to treat all people equally. The RRI workshop discussion also established that it would be extremely unfair to place the same expectations on everyone. The app study participants raised similar concerns about their personal circumstances (*"I'm at home most of the week, so my usage will be different to others who are barely at home"*, A-P12; no utility data provided) and particular needs (*"I'm member of various groups of people that have serious health issues that will increase their carbon usage, and so if it were forced on them, I'd want to be comfortable that there were enough allowance for people that are going to use more energy, but just to stay alive"*, A-P7). Participants recognised differences between individuals, including the 'average citizens' (*"I'm a low energy user, I don't have a car, I work from home, and I'm just a single person. But other people have more busy lifestyles, or they have family"*, A-P6; 26.25 total utility kg CO_2e), and the privileged sector of the population (*"What about Shakira landing her plane because she wanted to give her ex-husband a kiss? "* [47], A-P11). Moreover, although the idea of defining budgets based on household size was discussed, the app study also demonstrated that family compositions can be complex (*"My son lives with me some of the time, but not all the time... when I'm here with a child, there's an awful lot more water and electricity use"*, A-P7; no utility data provided).

4.2.3 Environmental justice. A few app study participants were sceptical of the effectiveness of a CCB app, solely based on the belief that those who most need to reduce their carbon emissions would not agree to take part in the scheme (*"Probably the worst offenders are people who wouldn't be involved in a mandatory scheme or people who would find ways to avoid it. Like, have you heard about Taylor Swift and her private jet?* [4]. *I think if every person in the UK stopped going on international holidays, that would cut back a lot of emissions, but if 3 millionaires stopped using private jets, you may have the same impact"*, A-P8). Likewise, some participants in both studies criticised the focus on individualistic solutions for the large-scale challenge that is climate change, calling for wider measures and policies targeting beyond the average citizens, and for considering global disparities and responsibilities too (*"This whole app made me research a bit more and Africa for example, the whole continent makes like the 3% of emissions [in the world]. I can't think of a solution that goes to the individual because we're speaking of a continent. I, in the UK, produce more carbon than my mom in Mexico. She eats bananas that come from the state next to her; I eat bananas that come from Africa. I think we need to take that into consideration before anything because it's like, what does that mean? That in the UK we cannot have bananas and watermelon any more? Is this country gonna live off carrots, parsnips and potatoes again? And the answer probably is going to be no, because of immigration and privilege, but what does that mean, then, for the people in the third world?", A-P11*).

4.3 Ethical and legal concerns

This theme describes participants' worries about the CCB app 'provotype', and it includes subthemes: 1) fear of a restrictive or punitive system, 2) data protection, privacy and surveillance concerns, and 3) unintended consequences.

4.3.1 Fear of a restrictive or punitive system. Overwhelmingly, the app study participants expressed that some sectors of the UK population would outrightly reject the notion of a mandatory CCB, due to fears of restrictions on their individual liberties and compromises to their current lifestyles (*"My fear is that, apart from impairing that freedom, then my mental health, my finances [would also be affected]"*, A-P10), as well as potential sanctions (*"This app can be a very useful tool for the government, for example, to punish you if you're overusing [carbon]"*, A-P2). Therefore, for some app study participants, it was important to have a CCB app that takes into account their sustainability efforts if a budget limit were to have significant effects on their day-to-day activities (*"The electricity was an issue because we are putting back into the grid far more than we're taking out [through solar panels]. I think over the whole course [of*

the study], I probably used about 7 units of electricity from the mains, but we probably put in at least 50. So [the worry] is that imbalance", A-P1; 5.54 total utility kg CO_2e). On the other hand, participants expressed that if the CCB app were to be a voluntary scheme, it would only be used by the sustainable-minded and/or with access to sustainable lifestyles, unless strong incentives (see 4.1), and the infrastructure to offer sustainable options to the public (see 4.2) are put in place.

4.3.2 Data protection, privacy and surveillance concerns. Overall, there was a range of attitudes towards CCB data gathering and use across the app study participants, naturally influenced by their experiences with other tracking technologies and internet activities in general. Three participants felt very strongly about not wanting to feel monitored or controlled (*"Who really cares from the government what I eat and how many times I use the bus? This is important data for legislation, but I think just the idea of being monitored by the government, I don't like that"*, A-P2), one was concerned about the data allowing to infer aspects of people's lives (*"I've got a PlayStation or a TV that uses a lot of energy. It would need to be really secure. It's gonna want details about the house and about consumption, but it's just about making sure that doesn't get into other people's hands"*, A-P5), one was strictly worried about data inaccuracies (*"The data doesn't fully reflect what's going on in our home"*, A-P1), and the rest expressed not being too concerned due to perceiving the data entered on the app as abstract enough (*"I didn't have to be specific of the location that I'm going. I don't mind telling you my miles"*, A-P10) or due to a general loose attitude towards personal data (*"I'm really open with any of my personal data, so it doesn't really bother me"*, A-P3). Reasons for the latter included not having experienced any data leakages in the past or not having the same level of cultural concerns towards data (e.g. US vs UK/Europe). Overall, however, there was a sentiment of despair or disenfranchisement towards not being able to prevent their data from being used for monitoring, advertisement, and unknown or non-understood purposes. Lastly, it was recognised that there is a tension between making the app easier to use (e.g. by connecting it to card purchases) and data concerns (*"It'd be nice if it just used all my banking data cause all my transactions are there and then just does it by itself. But then, I would have some concerns over who is using my data and how. I don't know where is the happy compromise between those two"*, A-P9).

4.3.3 Unintended consequences. The RRI workshop discussion also covered some unwanted outcomes from the CCB app, such as promoting behaviours that are detrimental for the environment (e.g. saving up budget to later splurge, buying unnecessary products) or the community (e.g. rewarding dishonesty, putting people against each other). Likewise, a concern was raised about misleading people (*"Greenwashing at an individual level; is that a possible thing? That'd be quite a nice thing to look at, people convincing themselves that they're doing well"*, W-P1). Notably, the app study gave us a window into this notion. Almost all participants' emissions were well below their assigned monthly budgets (for a variety of reasons including sustainable lifestyles, good living infrastructures, the study taking place during summer, and a simplistic app design); for some it was a validation of their lifestyles (*"We've got a very, very low carbon because of the solar panels. And we're retired, we don't get lots of varied foods"*, A-P1; 120.49 total kg CO_2e), while others approached this with scepticism, recognising that the app was not comprehensive or entirely accurate (*"I was getting nowhere near to the budget, and it almost made me feel I was being good for the cause. It's probably because I can't put every bit of food I have down, and it doesn't have absolutely everything. So maybe it was a false impression of how environmentally friendly I am. I found myself thinking this isn't actually going to encourage me to be better. Having said that, it would let me see, 'last time I ended the month with 950 remaining, let's see if I can end with 960 remaining'. Track your own progress of how better you are becoming in terms of your carbon"*, A-P5; 155.14 total kg CO_2e).

5 DISCUSSION

One of the biggest challenges facing the world today is climate change, and exhortations to reduce carbon emissions to prevent dire consequences. Doing it in an ethically acceptable, societally desirable, and sustainable way is key to making the task of reducing carbon emissions as achievable as possible. We discuss the findings from the two studies conducted in light of past and current measures and outline some considerations for design, policy, research and innovation.

5.1 Reflections from a speculative CCB app: simplistic design choices for a complex issue

Although data collected through the app has limited accuracy given its self-reported origin, the main objective of this work was to prompt people's perceptions, feelings, and experiences with the app and the concept of a CCB. In our exploration of a speculative or 'provotype' CCB app, several key reflections emerged, shedding light on the challenges and opportunities associated with its design and implementation. One notable observation pertains to the app's simplistic approach to data input and calculations, which, naturally, does not comprehensively account for all aspects of carbon footprints, as some app study participants pointed out. Working on unpacking such complexity for the public is crucial, given that past research found it to be a main factor affecting public support of PCA [28]. Furthermore, the budget assigned to participants, based on a current estimation of the UK average CO_2e emissions per person per year (1083 kg CO_2e) [36], was found to be disproportionately large, raising concerns about the effectiveness of the app in promoting meaningful behavioural change. It should be noted that the main issue encountered was not necessarily with the app itself, but with the carbon budget assigned. Future work could explore trials with varying budgets (e.g. halving the budget herein used) and deploying the prototype over longer periods of time and across other seasons where energy consumption greatly changes.

A key finding of this research was the critical need for increased carbon awareness amongst the UK population, as none of the app study participants had a concrete understanding of the carbon emitted by their daily activities, even those who actively engage with sustainable practices. This contrasts with other more environmentally conscious countries, as evidenced by studies on carbon calculators in Scandinavian contexts [3]. Facilitating this knowledge of numerical carbon emissions is highly needed in order to increase individuals' feelings of self-efficacy for addressing climate change [33], as people tend to underestimate the most impactful climate

actions they can take (e.g. avoiding air travel, plant-based diet), and overestimate the least impactful ones (e.g. recycling, low energy lightbulbs) [30]. However, it is imperative to avoid inadvertently misleading individuals, as emphasized in 4.3.3. Our findings also highlight promising opportunities for integrating recommender systems within the app, offering a potential avenue for enhancing user engagement and promoting more sustainable choices [18, 25]. Future work could also explore gamification features that were not within the scope of our app (e.g. streak count, social features) [3, 12, 60]. Although a functional leaderboard was included in our app, most participants did not use it, as they were mostly interested in their personal activities and expressed doubts towards the calculations being fully representative of their carbon emissions. Future work could explore these social computing elements amongst inner circles, such as families or workplaces, rather than or alongside comparisons between the whole user base.

5.2 Considerations for policymaking: CCB as a wider sociotechnical system

Past research on PCA has discussed how to fairly allocate budgets [59]. A carbon market proposition suggested that with an equal budget allocation, those who use less carbon (i.e., normally, low-income people) could sell it to those who use it the most (i.e., normally, high-income people). When the carbon trading feature is removed from the carbon budgeting scheme, such as in our CCB app, allocating identical budgets to all users underscores the crucial difference between equality and equity and the importance of safeguarding the needs of the most vulnerable [38]. Incentives embedded within the system should be crafted to specifically target systemic inequalities, and policy design would require careful engagement with different sectors of the population [45]. Further, defining individual budgets becomes complex due to the shared nature of diet, transport, and energy consumption. To tackle this, our findings advocate for a flexible approach, allowing for options at both the individual and household levels. Moreover, voluntary self-reporting of activities is preferred over mandatory tracking schemes. Although technology advancements such as AI can help to automatically estimate personal carbon emissions, research and innovation on this front should take into consideration the ethical and legal concerns outlined in 4.3, and approach fairness (and equity) as a socio-technical problem that needs to be addressed from a multidisciplinary perspective [10, 64].

This research emphasizes the significance of supporting awareness by making carbon emissions visible, potentially employing contextual comparisons to represent environmental impact in more comprehensible ways (e.g. one holiday travel equals X period of veganism [13]). Numerical representations of carbon emissions alone are insufficient in promoting an understanding of the environmental impact of everyday actions. We argue that using the CCB app and comparing personal activities and their associated carbon, provided participants with a more grounded understanding of the most impactful actions they could take to reduce their personal emissions. As an interesting note, briefly, after the study ended, P8 reached out to share a follow-up reflection: "*I was browsing flights and I noticed that they have the same kg CO_2e measurement, and oh my god, it is much higher than anything else I have consumed on the app the last four weeks. That's crazy. This is quite enlightening, having that information*". This research connects with broader discussions surrounding the environmental costs of AI [21, 23]. Advocating for the visibility of carbon emissions of personal transport, energy use and diet, so that individuals can alter their lifestyles, while the development of AI and other digital systems poses significant environmental consequences, raises critical ethical questions about climate change responsibility and sector regulation[2, 31, 53].

Engaging third-party organisations, for instance through partnerships with entities such as supermarkets, was highlighted as a potential avenue to explore. In a current context where companies are not only encouraged to be sustainable but demand for holding them accountable increases, policy design should consider integrating incentives that promote the consumption of sustainable products (e.g. plant-based). Finally, the potential impact of policy measures spanning various fronts, including not only companies but also higher emitters, is a relevant factor that can also encourage public acceptability of CCB. Proposals such as implementing taxes on frequent flyers serve as examples of comprehensive policy interventions that could complement the efficacy of CCB systems [45].

5.3 Beyond rearranging the deck chairs: on collective action

A major tension encountered in our study emerged from the individualistic nature of the approach employed by the CCB app (and approaches such as PCA) and systemic issues related to major actors such as governments and big corporations. However, these are not mutually exclusive. Despite the consensus among environmental scientists and reports that individual behaviour change towards low-carbon lifestyles is indispensable [11, 45, 55], a significant gap exists in conveying this urgency to the public, from a policy and nation-wide perspective. Not only there are sectors of the population who do not believe in climate change, but those who do and care about it, often do not think they can have an impact [33]. Some have argued that this may be explained by the political risks associated with radical measures targeting the public, but perhaps we have reached a point in history where said approaches are likely to be positively embraced by the public [28]. Findings from this study show that some participants are willing to take further action and adapt their lifestyles, albeit to varying degrees, once they are presented with the tool to assess some of their daily activities and reflect upon them. Participants expressed a desire to act towards the collective goal of saving the planet, suggesting that governments should empower individuals with the means to make tangible contributions, lowering the barrier to acting sustainably. Besides awareness of carbon emissions, a CCB app or other forms of visualisation could promote further civic engagement by providing empirical evidence for policymaking and regulation. Further, if individuals better understand where limitations to sustainable lifestyles are (e.g. limited public transport), they could be empowered to seek (and demand) solutions in collaboration with environmental organisations and governments.

Promoting individual behaviour change should be intertwined with fostering broader public engagement and collective action.

Others have remarked on the role of social norms and social desirability in the goal of reducing individual carbon emissions through influencing individual attitudes and actions, sometimes being more effective than individual analytical reasoning about the causes and effects of climate change [33]. Voluntary but widespread tools such as this CCB app could help encourage lifestyle changes. Future work and policy design could encourage and reward social usage. For example, learnings from grassroots groups (e.g. Carbon Rationing Action Groups) can provide relevant pathways for exploration [34]. A key finding highlights the diverse nature of individuals' commitments and carbon capabilities [68], as not everyone can commit to the same goals due to variations in lifestyles, living infrastructure, personal circumstances, and wider context. Participants expressed a willingness to tailor their actions, but in different specific ways; for instance, some can reduce their emissions in certain aspects such as transportation whilst maintaining their current diet or energy consumption, or vice versa. The RRI workshop participants advocated for a CCB approach that focuses on individual improvement (e.g. reducing own carbon emissions by 50%) rather than stipulating the same budget goals for everyone, recognising the varied capacities and contexts of individuals.

6 CONCLUSION

We presented combined results from two studies, situated within Research through Design, investigating the concept of and practical experiences with a CCB app. Starting with an RRI workshop with stakeholders from different sectors, and subsequently a one-month deployment of the app with members of the public based in the UK. Rather than solely focusing on eliciting behaviour change, we provided insights into the feasibility, fairness, and ethical considerations of a CCB approach for reducing personal carbon emissions. Employing a combined approach provided both macro and micro perspectives, addressing systemic concerns emerging from discussions at the RRI workshop and individual experiences from the app study participants. Deliberately simplistic app design, limited participant diversity, a small sample size, and a relatively short app deployment point to a need for further work. Despite these constraints, our research sheds light on the need for increasing efforts to raise awareness of individual carbon emissions, and provides evidence that a voluntary carbon budget approach can contribute to that goal, while our findings also underline the need to more broadly foster public awareness and promote collective action to reduce carbon emissions.

7 ETHICAL CONSIDERATIONS STATEMENT

The studies were approved by the School of Computer Science ethics committee at the University of Nottingham in the UK. Participants voluntarily agreed to take part in this research and signed a consent form before the corresponding study took place. App study participants were informed that they could withdraw from the study at any point without any consequence. In terms of the design of the app, participants were informed that no AI component was used, ads did not appear on it, and information was not collected for the purposes of advertising. An email address and display name were required for registering on the app. The email address was not displayed or shared elsewhere. The display name appeared on the social feature of the app, i.e., the leader board, but only if users opted in (most users did not). All the information logged through the app was stored on a server at the University of Nottingham.

8 POSITIONALITY STATEMENT

Our areas of research include HCI, AI, policy, and law, with prior work and experience in design fiction, market research, incentivisation, data privacy and regulation, ethics by design, and AI for smart grids and trading. We have a keen interest in the adoption and application of Responsible Research and Innovation approaches. We are all based in UK higher education institutions; the first author is from Latin America, one author is from Asia, one author is from the Middle East and the rest from different countries in Europe. Moreover, all participants from both studies were UK based, although some were from North America (4) and other countries in Europe (3). Therefore, this research can be categorised as WEIRD (Western, Educated, Industrialised, Rich, and Democratic) [57].

9 ADVERSE IMPACT STATEMENT

In this paper, we have presented the case for the need of taking a step back from merely developing and deploying a tool, and also considering its impacts, social desirability, and ethical acceptability. This combination of an approach inspired by critical and speculative design and the societal focus of RRI provided for particularly rich insight around acceptability, fairness, and unintended consequences (as described in the results), elements which may be missing from consideration were the app considered solely from an HCI perspective as a prototype to be tested improved and potentially implemented with the wider vital ethical and societal implications unexplored, demonstrating the value and richness of the approach described here.

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