Driving user engagement with Consumer Carbon Footprint reports: Exploring barriers and facilitators via banking services

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Abstract

Amid the pressing global challenge of the climate crisis, developing digital apps that offer feedback on consumers' consumption patterns is a novel approach to carbon footprint calculators (CFC). Open Banking technology was developed to calculate the carbon footprint of consumers' spending habits by analysing their banking transactions and applying their carbon calculation models. It has seen a significant surge in recent years. Such banking apps enable users to actively track, evaluate, and improve their behaviours regarding their environmental impact. However, consumer uptake and engagement are limited and require optimisation to successfully facilitate more environmentally friendly behaviours by the public.

This study aimed to explore factors influencing intended engagement with this novel carbon footprint report (CFR) using behavioural science, specifically, the Capability Opportunity Motivation Behaviour (COM-B) model.

Methods. A mixed-methods online survey investigated influences on intended engagement with the CFR using a prototype digital banking app developed by a London-based technological company.

Results. The key influences identified were a preference for using banking apps rather than other methods of engagement with the CFR (e.g., e-mail or bank statement) and participants' understanding of the CFR. Influences related to Motivation (such as experiencing positive emotions towards the CFR, being interested in reducing one's carbon footprint, and evaluating the CFR as useful) significantly contribute to participants' intended engagement. Interestingly, participants who view their bank negatively score higher on intended engagement.

Conclusions. Optimising the software within banking apps by adding clear explanations and visual aids to enhance user understanding, engagement, and strategies (such as in-app prompts,

realistic goal setting, and gamification) can foster long-term, habitual user engagement. Lastly, providing practical solutions in climate change education can positively engage users' emotions and facilitate the desired behavioural changes.

Keywords: Climate Change, Carbon Footprint Calculator, COM-B Model, Sustainable Behaviour, Mobile Banking

Introduction

Amidst the escalating threat of climate change, urgent action is needed to mitigate its profound impacts on global ecosystems and societies (1, 2). The Intergovernmental Panel on Climate Change (IPCC) has emphasised the substantial influence of human activities on the escalating global warming crisis, attributing a 95% probability to human-induced factors (1, 3). Greenhouse gas (GHG) emissions, the chief driver of unsustainable atmospheric warming, are directly linked to human activities encompassing agriculture, transportation, and energy production (4). Hence, a shift towards 'net zero' emissions is imperative.

The UK Government has pledged to achieve net zero carbon emissions by 2050 (5). This has sparked advocacy from key financial bodies, such as UK Finance (the collective voice for the banking and finance industry in the UK) and the Principles for Responsible Investment network (PRI; the world's leading proponent of responsible investment), stressing the finance and banking sector's responsibility and ability to enable this transition. Banks can help to accelerate the shift towards net zero emissions due to their influence on capital allocation. Banks can direct investments and loans towards green and environmentally conscious initiatives by integrating sustainable finance practices. Signalling a recognition of their central role, many

major banks in the UK, such as the Bank of England, HSBC, NatWest, and Barclays, have individually pledged to achieve net zero by 2050 (6-9).

Although government-led and industry-led measures can be effective, their success partly depends on public engagement. “Engagement” is defined as “the voluntary investment of cognitive, emotional, behavioural and social resources” with a given subject (10). To achieve public engagement with climate change, behavioural changes are needed. However, human behaviour is complex and multifaceted, arising from an interplay of mental biases, emotions, habits, knowledge, and the environment (11-13).

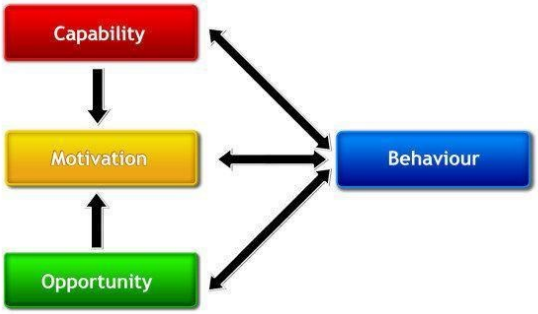
The contribution of behavioural science

Attitudes and intentions can predict pro-environmental behaviours, yet the well-documented intention-behaviour gap reveals that other factors, such as norms, convenience, or context, moderate their impact significantly (14-20). Adopting a sustainable lifestyle and pro-environmental habits requires conscious and sustained efforts (11-13). Consequently, despite 70% of the UK’s population believing in human-induced climate change and a cross-cultural trend towards sustainable brands, unsustainable consumption remains the main driver of environmental deterioration (21, 22). In sum, while being aware of climate change, perceiving it as a major risk, and favouring pro-environmental policies, the public remains mostly disengaged (23, 24). Theories and models of behavioural science explore the drivers of behaviour in a systematic way to offer evidence-informed recommendations for designing interventions that overcome the intention-behaviour gap, resulting in the desired behavioural changes (25-27).

Leveraging behavioural science models like the COM-B model (Figure 1) (33) can guide the design of interventions for behaviour change purposes (28). The COM-B model suggests that any behaviour arises as a function of Capability (psychological and physical), Opportunity

(physical and social), and Motivation (reflective and automatic) (28). It offers a structured way of identifying and categorising influences on the desired behaviour. One central barrier inhibiting individual, pro-environmental behaviour change is the inability to quantify the link between personal consumption choices and GHG emissions (29). Various studies have illustrated that technologies can be leveraged to give consumers feedback on their consumption patterns and their environmental impact to spark a reconsideration of the status quo, resulting in more sustainable behaviour (29-32). Among these technologies are carbon footprint calculators (CFCs).

Figure 1 The COM-B Model (33)



Source: Figure courtesy of Michie S, Van Stralen MM, and West R (2011)

Carbon footprint calculators (CFCs)

CFCs are a relatively new technology that provides consumers with a personalised assessment of their carbon footprint based on their lifestyle (34). CFCs can raise awareness of the connection between user behaviours and GHG emissions (29, 31, 35, 36). Thus, CFCs emerge as a potential catalyst for pro-environmental behaviour change, addressing the critical challenge of linking personal consumption to GHG emissions (29). Recent research supports this potential: providing individuals with personalised carbon footprint information increased their willingness to pay for offsets by about one-third (37). However, some CFCs are limited

in their ability to capture an individual's unique carbon footprint since they focus solely on a particular area rather than a holistic measure, such as smart meters measuring direct energy use. Another key barrier to behaviour change is that individuals systematically underestimate their carbon footprint compared to others, which may constrain the effectiveness of CFCs if users do not perceive their emissions as sufficiently impactful (37). Additionally, a review of 23 internet-based CFCs concluded that most are ineffective for behaviour change purposes (38).

Nevertheless, CFCs have evolved since then and are now more accurate and usable. For instance, the AI-driven Tanaffas app leverages GPS tracking, augmented reality, and gamification to enhance user engagement (39). While it successfully increased social influence (subjective norms), it did not lead to changes in behavioural intentions or attitudes (39). Furthermore, CFC effectiveness varies by demographics, with younger individuals, women, mid-income groups, and those with higher carbon literacy responding the most positive (37). However, high-emission consumers remain largely unaffected, limiting CFCs' impact on the most significant emitters (37).This aligns with previous research showing that the effectiveness of CFCs remains mixed (31, 35, 40).

A novel approach to personalised carbon footprint measurements is CFCs that rely on financial transaction data. Recent research suggests that financial transaction data provides a scalable and objective method for estimating carbon footprints, closely aligning with survey-based estimates while offering higher-frequency, real-time insights (41). With a substantial user base relying on banking apps, CFCs that are based on banking data offer the possibility to more accurately measure and reflect consumers' carbon footprints (42-44). Barendregt, Biørn-Hansen (42) describe several such CFCs that are either already or that will be launched, for instance, 'Nordea', 'My Climate Goal tool', 'My Carbon Action', 'Joro', 'Doconomy', or 'Svalna'. Although these technologies are still novel and there is limited research, several

benefits and limitations have been noted (a comprehensive overview of opportunities and limitations can be provided as supplementary material). Common limitations include doubts about the CFCs calculation method and resulting accuracy, lack of granularity in the data, perceptions of risk related to online banking, problems maintaining long-term user engagement, and critiques about placing too much weight on individual responsibility (34, 43, 45-47).

Aims and objectives of the current study

In the current study, researchers from University College London collaborated with the London-based data start-up Envaluate, which developed a CFC solution to be embedded within consumers' banking apps. Based on a user's transaction data obtained via Open Banking, the software calculates an estimated carbon footprint of each transaction. It provides personalised CFR analytics that show users their monthly carbon footprint with a breakdown across several categories such as Travel, Food and Shopping and comparisons to UK averages (see Figure 2). The present research aims to utilise behavioural science to explore how this software could be most effectively incorporated into consumers' banking apps to drive sustainable behaviours. By marrying behavioural science insights with technology, this method of CFC holds promise in fostering sustainable behaviour shifts. Table 1 in the appendix summarises the potential advantages of this CFC over previous CFCs. One key opportunity is that users already interact with their banking apps, so they do not need to download or learn new software, which may facilitate more frequent engagement. Also, no manual data input is necessary. Thereby, the perceived and actual user effort is reduced along with the frequency of input errors, which can increase perceived and actual accuracy and may facilitate more frequent engagement. Previous research emphasises the importance of frequent engagement with climate-related issues to create and maintain behavioural changes that lead to reduced carbon footprints (48).

Our research question was "Which influences significantly impact a consumer's intended engagement with the novel CFC?".

Methods

Ethical approval

The University College London Ethics Committee (Project ID: 20777/001) granted ethical approval for this study. Written informed consent was obtained from all participants, and all methods were carried out in accordance with relevant guidelines and regulations.

Participants

The sample size chosen was 400, as this was deemed sufficient to achieve a 95% confidence level for a broad population, with the intention of assessing the viability of a CFR through banking apps and providing a direction for innovation. The target population for this product is the UK's adult population having and using banking and who care about climate change.

Design and Procedure

This study is a cross-sectional, mixed-method online survey conducted between July and October 2021. The sample was recruited through an online sample provider (Prolific) that reimbursed participants individually. Participants were informed that their participation was completely anonymous and voluntary. The survey questionnaire was programmed using Qualtrics. In a pre-screening questionnaire, the following inclusion criteria were checked: participants (i) were residents of the UK; (ii) were over 18 years old; and (iii) believed in human-induced climate change (supplementary materials). The last criterion was included since general climate scepticism or denial were considered likely confounders of our outcome variable.

Measures

We used a set of survey items to measure the key factors identified as relevant to our target behaviour. The survey items were organised and scaled to align with their respective COM-B components. Most items were purposefully developed for this questionnaire, drawing from insights from prior literature and the COM-B model (for examples see Table 1). The detailed mapping of all items can be found in the supplementary materials (File 2). Additionally, two open-ended questions were included to illuminate participants' reasons for (mis)trusting their personal CFR and for (mis)understanding what a carbon footprint is.

Construct	**Question**	**Measurement**	**COM-B component**
Hope Climate Change	I feel hopeful that climate change can be stopped.	5 - Agree completely, 4, 3, 2, 1 - Disagree completely	Automatic Motivation
Trust in CFR	Would you trust in your personal carbon footprint report?	5 - Completely, 4, 3, 2, 1 - Not at all	Reflective Motivation
Frequency of engagement with banking app	How often do you engage with your banking app?	1 - Less than once a month, 2 - Once a month, 3 - Every few weeks, 4 - Once a week, 5 - Every few days, 6 - Daily	Physical Opportunity
Social Support	My close social circle supports pro-environmental actions/ policies.	5 - Agree completely, 4, 3, 2, 1 - Disagree completely	Social Opportunity
Perceived Understanding of CFR	Do you understand what this new feature would report?	5 - Completely, 4, 3, 2, 1 - Not at all	Psychological Capability

Table 1 Examples of constructs, measures and COM-B components

Source: Table created by authors

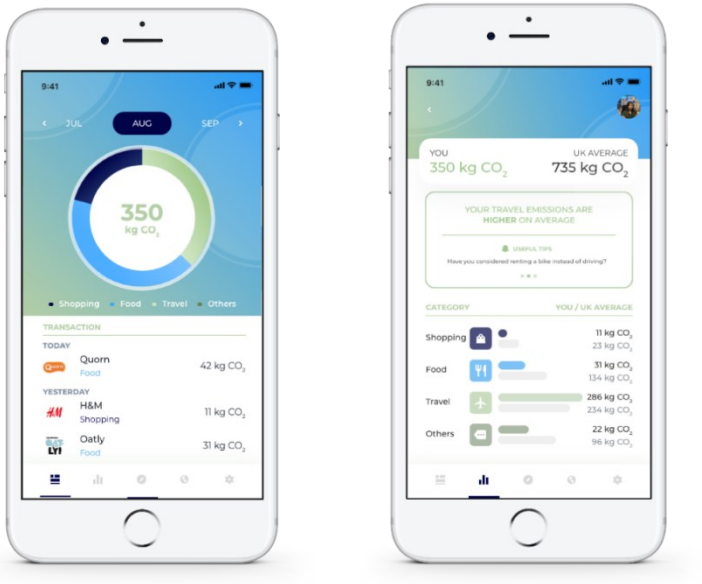


Fig. 2. Examples of the CFR technology provided by Envaluate that were included in the survey (Source: figure created by authors)

Engagement with the CFR

We added two distinct items to measure the outcome variable ‘engagement with the CFR'. The first item, labelled 'Intention to receive CFR,' assessed participants' interest in receiving a concise overview of their carbon footprint based on their spending patterns, utilising a Likert scale ranging from 1 (Not at all interested) to 5 (Very interested). The second item, ‘frequency of engagement with the CFR,' was about how frequently participants intended to interact with their carbon footprint data. This item provided response options ranging from 1 (Never, I am not interested in it) to 5 (It should always be available for me, continuously updating after every transaction). This composite outcome variable served as a crucial indicator of participants' intended engagement with the CFR, considering both their interest and frequency of interaction.

Influencing factors

Capability

Psychological Capability was assessed by asking participants questions such as how well they understand the CFR and carbon footprints, how confused they are when looking at the CFR or their banking app, and whether they think increasing their understanding would facilitate their engagement with the CFR.

Physical Capability was measured by one question asking participants whether learning to navigate their banking app better would increase their engagement with the CFR. It was deemed that using a banking app required similar skills to using the CFR within a banking app, so individuals who already used the banking app had the required level of "technological savviness," so no additional questions were included.

Opportunity

Physical Opportunity was assessed using questions such as when and through which medium participants would engage with their CFR and whether improving the banking app, receiving notifications or increasing the accessibility of the CFR would increase their engagement.

Social Opportunity was assessed by asking participants whether their social circle supports pro-environmental action and whether their engagement would increase if they were part of a group or had more social support.

Motivation

To measure Reflective Motivation, we asked about participants' values and their identity utilising standardised items adapted from the work of Bouman, Steg (49), capturing "biospheric (i.e., valuing the environment), altruistic (i.e., valuing the welfare and wellbeing of other human beings), egoistic (i.e., valuing personal resources) and hedonic values (i.e., valuing pleasure and comfort)" (p.1f) and other questions such as their interest in reducing their carbon footprint, how useful they perceived the CFR to be, their trust in science, their self-efficacy

regarding climate change, and their relationship to their bank (trust, satisfaction, commitment to remain a customer, recommending their bank to others).

Automatic Motivation was measured with questions about participants' feelings regarding climate change, their habits, and their feelings concerning their banking app.

Data Analyses

The data was analysed using the R package Psych. We summed the values of two distinct items to derive the outcome variable 'intended engagement with the CFR'. The first item, labelled 'Intention to receive CFR,' assessed participants' interest in receiving a concise overview of their carbon footprint based on their spending patterns, utilising a Likert scale ranging from 1 (Not at all interested) to 5 (Very interested). The second item, 'Intended frequency of engagement with the CFR,' was about how frequently participants intended to interact with their carbon footprint data. This item provided response options ranging from 1 (Never, I am not interested in it) to 5 (It should always be available for me, continuously updating after every transaction). This composite outcome variable serves as a crucial indicator of participants' intended engagement with the CFR, considering both their interest and intended frequency of interaction.

The internal consistency of the COM-B scales was assessed with Cronbach's alpha (see supplementary materials). Cronbach's alpha for Reflective Motivation was 0.79, Psychological Capability was 0.71, and Social Opportunity was 0.61. Cronbach's alpha for Automatic Motivation (0.59) and Physical Opportunity (0.58) were just below 0.6. While these values are slightly lower than 0.6, they were still deemed acceptable given the complex and multi-dimensional nature of these constructs. The relatively lower alphas reflect the broad scope of

the constructs these factors aim to capture and therefore were retained due to their theoretical relevance.

Subsequently, a factor analysis was conducted for each COM-B component. A scree plot was first employed to determine the optimal number of factors for each component, then factor loadings below 0.3 were considered insufficient and consequently excluded from the factor.

In a series of regression models, items exhibiting collinearity were removed. Model 1 served as the initial regression model, encompassing all survey items and systematically employing a backward stepwise approach to eliminate non-significant predictors. Model 2 incorporated the identified factors, and all individual items not included in these factors or excluded for other reasons. Variable selection in Model 2 was accomplished through a backward stepwise procedure. Finally, in Model 3, the significant factors identified in Model 2 and any individual items that emerged as significant predictors in either Model 1 or Model 2 but were not already encompassed within the significant factors were included. Subsequently, non-significant variables were systematically removed, resulting in the final model encompassing the most influential factors impacting our outcome variable (Table 3).

Results

396 participants participated in the present study (Table 2). The sample was roughly representative of the UK population in terms of Age, Gender and Education. Participants were aged 18 to 50+ years, with an approximately equal proportion of females (50.5%) and males (49%). A majority was under 40 years old (79.3%) and indicated earning a yearly income above £30k (94.7%). Most participants lived in urban (41.7%) or suburban (45.2%) areas.

Table 2 Sociodemographic characteristics of the sample

Sociodemographic information of the sample	N = 396
Gender n (%)	
Female	200 (50.5%)
Male	194 (49%)
Other	2 (0.5%)
Age (years) n (%)	
18-24	87 (22%)
25-29	85 (21.5%)
30-39	142 (36%)
40-49	56 (14%)
50+	26 (6.5%)
Yearly income n (%)	
<£30K	375 (94.7%)
>£30K	21 (5.3%)
Highest level of education n (%)	
Lower Secondary Qualification	18 (4.5%)
Upper Secondary Qualification Without University Access	77 (19.4%)
University Entry Qualification	89 (22.5%)
Bachelor's Degree	138 (34.9%)
Master's Degree	60 (15.2%)
Doctoral Degree	14 (3.5%)
Area of Residence n (%)	
Rural	52 (13.1%)

Suburban	179 (45.2%)
Urban	165 (41.7%)

Source: Table created by authors

In the final model, Model 3, the coefficient of determination (R squared) exceeds 0.6, indicating a substantial degree of variance is accounted for by the model; therefore, the model is deemed acceptable. Density and Q-Q plots were evaluated to further validate the model, both of which displayed favourable results (supplementary materials). Subsequent to the removal of non-significant items, the analysis of coefficients revealed four highly significant variables ($p < 0.001$), three significant variables ($p = 0.01$), and two variables almost reaching statistical significance ($p < 0.1$). Table 3 summarises an overview of the final model and results.

Table 3 Final model coefficients and descriptive statistics

Coefficients	Coefficient est.	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.05174	0.60701	-0.085	0.9321
Relationship to Bank (Reflective Motivation)	-0.05582	0.02228	-2.505	0.0126 *
Values and Identity (Reflective Motivation)	0.22963	0.03006	7.640	1.73e-13***
Positive Emotions and Habits (Automatic Motivation)	0.26761	0.04614	5.800	1.38e-08***
Frequency of engagement with the banking app	0.12913	0.06133	2.105	0.0359 *
Preferred Medium of Engagement Banking App	1.33466	0.16999	7.851	4.10e-14***
Level of Education	-0.11543	0.05074	-2.275	0.0234 *
Overall understanding of CFR	0.33250	0.07861	4.230	2.93e-05***
Perceived personal score for CFR	-0.11227	0.06404	-1.753	0.0804
Confusion regarding the CFR	-0.11695	0.06863	-1.704	0.0892

Source: Table created by authors * $p < 0.05$; *** $p < 0.001$; *Adjusted* $R^2 = 0.5995$; *Residual Std. Error on 386 degrees of freedom = 1.167*

Two distinct factors relating to Reflective Motivation emerged in the analysis. The factor "Relationship to Bank" is composed of items measuring participant's views of their bank, such as trust, satisfaction, and whether they would recommend their bank to others. The factor "Values and Identity" encompasses items measuring participants' biospheric values, their interest in reducing their carbon footprint, their interest in discussing their carbon footprint with others, and how useful they perceive viewing the CFR.

Discussion

The present study investigated barriers and facilitators to intended engagement with a novel CFC designed by a technology startup, Envaluate, to be embedded within consumers' banking apps. We applied the COM-B model (50) to systematically analyse the target behaviour and better understand the influences on engagement in order to generate recommendations. To our knowledge, this is the first study applying theories and models of behaviour change to the development of this particular type of CFC, raising a variety of intriguing questions for future study. Our final model has a strong goodness-of-fit and accounts for a substantial degree of variance, i.e. 60% ($R^2 > 0.6$) in the outcome variable 'intended engagement with the CFR'.

Our findings highlighted four highly significant factors, including "Values and Identity" (Reflective Motivation), "Positive Emotions and Habits" (Automatic Motivation), "Preferred Medium of Engagement Banking App", and "Overall Understanding of CFR". Additionally, three significant factors ($p = 0.01$) were identified, namely "Relationship to Bank" (Reflective Motivation), "Frequency of Engagement with the Banking App", and "Level of Education". Lastly, two variables almost reached statistical significance ($p < 0.1$), "Perceived Personal Score for CFR" and "Confusion Regarding the CFR".

Sociodemographic Factors

Our findings indicate that intended engagement with the CFR is negatively related to participants' level of education, indicating that higher education may be associated with reduced engagement. Previous literature finds mixed results on the association between level of education and pro-environmental behaviours. Importantly, there seems to be a disconnect between environmental awareness, attitudes, intentions and pro-environmental behaviours. For instance, Lee, Markowitz (51) found that educational attainment was the single strongest predictor of climate change awareness. Additionally, two studies conducted in China and Thailand, respectively, suggest a positive association between higher levels of education and pro-environmental attitudes and behaviours (52, 53). Another recent study found that higher-educated individuals tend to be more responsive to receiving information about their emissions and more willing to pay for carbon offsets (37). However, other studies exploring the relationship between environmental knowledge, attitudes, intentions and behaviours suggested that more highly educated individuals produce more GHG emissions than people with lower levels of education (54-60). This may be partly explained by a correlation between education and income, as higher-income individuals tend to have greater consumption, more frequent travel, and higher energy use, leading to larger carbon footprints, despite potential awareness of environmental issues (61, 62). This suggests that the relationship between educational attainment and pro-environmental attitudes is complex and may be context-specific and mediated by other factors such as income.

Behavioural Factors

Capability - Psychological Capability

Perceived understanding of the CFR was one of the most significant influences on intended engagement. Participants with a lower perceived understanding of the CFR described the data presentation to be visually complex and overwhelming in their open-ended responses. Additionally, our results indicate that participants who were confused while looking at the CFR reported lower intentions to engage with it. Participants expressed that their confusion was triggered by a lack of explanation for a high or low carbon footprint and a general lack of understanding about how carbon footprints work. Previous research on carbon footprint labels and CFCs reaffirms this result; people frequently misunderstand what a "carbon footprint" is, and some carbon footprint labels can be too complex and confusing for most consumers (63, 64). In a similar vein, Khan, Iftikhar (65) found that higher green confusion (consumers misjudging a product's environmental qualities) is associated with lower intentions to purchase a given product. These findings align with research on carbon footprint labelling in Thailand, where low public awareness and confusion about carbon footprints were identified as the most significant barriers to engagement (66). Many consumers were unfamiliar with the term itself, and companies saw little market benefit from labelling due to this lack of understanding (66). These findings indicate that the concept of carbon footprints is currently not well understood and may negatively affect users' intentions to engage with the CFR.

Interestingly, participants' perceived understanding of their personal performance was not found to be significant, indicating that this factor did not influence their intended engagement.

Motivation - <u>Reflective Motivation</u>

One of the most significant influences on intended engagement with the CFR was the factor "Values and Identity", encompassing various items related to reflective motivation, the ones with the largest factor loadings in descending order being interest in reducing one's carbon

footprint (0.8), interest in discussing the carbon footprint in social circles (0.6), biospheric values (0.6), and the perceived utility of viewing the CFR (0.6). Our results indicate that participants scored highest on hedonic values (i.e., valuing pleasure and comfort), followed by altruistic values (i.e., valuing the welfare and wellbeing of other human beings). Biospheric values (i.e., valuing the environment) were noticeably lower, and egoistic values (i.e., valuing personal resources) were the lowest (measures adapted from Bouman, Steg, and Kiers (44)).

Furthermore, almost two-thirds of the participants report high self-efficacy, and the majority of participants indicate being interested in reducing their carbon footprint. Nevertheless, 74% of all participants indicated that they rarely considered how sustainable brands are when making consumption choices. However, these results illustrate that despite acknowledging their role in climate change, believing that they can make a difference, and expressing interest in reducing their impact, most participants do not behave accordingly, thus showing what has been termed as the 'attitude-behaviour' gap (14-18, 20, 67). The open-ended responses add further insights to this: Several respondents express that individual choices have a relatively small impact on the environment compared to the responsibility of large corporations. Additionally, a few participants mentioned that the emphasis on individual carbon footprints can lead to unnecessary shaming. They believe that the focus should be on corporations and government policies that drive systemic change. In line with these findings, previous studies show that low self-efficacy can be a barrier to engagement (31, 35, 36, 40). Specifically, research on engagement with digital technologies suggests that users may disengage with technologies in situations where they experience low agency, when "they feel frustrated, overwhelmed and unmotivated" (68). This form of "negative engagement" might be particularly important in the context of the presented CFC since users are expected to engage in a task "they are not truly invested in", where they are "passively learning […] boring or irrelevant material" (68).

Moreover, participants who perceive a utility in viewing their CFR are more likely to intend to engage with it. Previous literature shows that tailored information, compared to general information, is more effective at changing behaviours as it is more personally relevant and, thus, perceived as more useful (30, 35, 69, 70). Neale and Bowen (71) support the hypothesis that the perceived personal relevance of information presented in the app can increase user engagement. The authors report that users' engagement decreases when they cannot relate to or identify with the app's content, thus deeming it not to be useful to them (71). Since the CFC described here is based on the user's personal spending habits, it could boost perceived personal relevance and, ultimately, behaviour change.

Interestingly, our findings indicate that intended engagement with the CFR is negatively related to participants' overall positive perceptions of their bank. This result suggests that individuals with a more positive perception of their bank may exhibit slightly lower engagement with their CFR, and vice versa; participants with a more negative perception of their bank may exhibit higher engagement with their CFR. Where participants have high overall satisfaction with their bank and banking app, this might be a barrier to engagement with the CFR. However, the open-ended responses stand in contrast to this finding. Some participants express trusting their banks to provide reliable information and services, and thus, they believe that, by extension, features offered by their bank, such as the CFR, are trustworthy and could facilitate engagement. Previous research demonstrates a halo effect for brand image, suggesting that consumers' attitudes and perceptions of specific products and product attributes are influenced by their perceptions of a brand (72-74). Additionally, previous studies find that product labels and brand names have a halo effect both on the perceptions and attitudes towards a product, as well as on consumption behaviour (75-78).

Additionally, our open-ended responses reveal that many participants support the creation of an ideal or goal carbon footprint. Loock, Staake (79) confirm that goal setting can positively

affect energy conservation. However, the authors point out that having default goals that “are set too low or too high with respect to a self-set goal” might be detrimental to the target behaviour (79). Van Houwelingen and Van Raaij (80) point out that setting too difficult goals can result in the externalisation of outcomes. Similarly, recent findings suggest that while providing individuals with information about their personal carbon footprint increases willingness to pay for offsets, emphasizing the gap between their footprint and the 1.5°C target has little effect, likely because overly ambitious goals discourage engagement (37). Consequently, people might deflect blame and attention to third parties such as governments and businesses (35, 36, 80).

Furthermore, our results suggest that most participants express not being sure whether to trust their CFR. This might be because trust in brands is low, and the CFR relies on brands providing correct information to the bank. The open-ended responses indicate three common concerns for participants who did not trust the CFR. Firstly, they are sceptical about the methodology and accuracy of the CFR and mention that they need more information or evidence to trust its accuracy and usefulness. They mention that if the CFR were based on factual information and scientific data, they should be able to see details of how the data is gathered and the methodology behind the report. Previous literature suggests that improving the "transparency, consistency and data quality" of CFCs is important in optimising them for behaviour change purposes (70). Secondly, a few participants expressed concerns about data privacy and security, as they were unsure about the extent to which the app would track their spending habits. Lastly, a few participants expressed scepticism about financial institutions' commitment to reducing carbon footprints, questioning whether the CFR would be in the banks' and companies' best interests. Previous literature on banking apps shows that a lack of emotional and human aspects accentuates users' risk perception and can contribute to doubts (10). Thus, for users who

perceive the CFR as untransparent and where there is no identifiable human contributor, scepticism may increase.

Motivation - Automatic Motivation

Another significant influence on intended engagement with the CFR was a factor encompassing various items related to automatic motivation, including feelings of interest and empowerment when looking at the CFR and three potential facilitators to engagement with the CFR (our findings indicate the following may increase their engagement with the CFR: routinised usage behaviour, a sense of enjoyment from engaging with it, a sense of 'need' to engage with it). Interestingly, most participants indicated that they were already using their banking apps in a habitual and routinised way, which presents a facilitator for CFCs embedded in mobile banking apps. Such automatic, unconscious, and pre-existing behaviours might cause users to overlook the CFR. A recent exploratory literature review confirms a strong correlation between habit formation and user engagement (81). The authors of that study explain that user engagement may be increased by establishing internal triggers (e.g., a sense of need or an urge to engage with the CFR; 'point of engagement/ trigger'), leading to positive engagement (e.g., feeling interested and empowered when looking at the CFR; 'engagement/ routine'), and followed by positive feelings of enjoyment, satisfaction, or relief of the initial urge (reward) resulting in subsequent disengagement, until the user experiences another trigger (point of engagement/ trigger) causing them to reengage (re-engagement/ routine). This approach aligns with literature on app engagement (71) and research on driving intentions to adopt carbon footprint tracking apps (82), suggesting that user engagement increases when an app makes users feel positive and they find the experience intrinsically enjoyable. Particularly in the initial stages of adopting a new app, the enjoyment of engaging with it is essential (83).

Lastly, our results reveal that participants report experiencing high fear and low hope regarding climate change. We did not observe a significant association with intended engagement; however, previous literature emphasises that this combination discourages pro-environmental behaviour (24, 84).

Opportunity – Physical Opportunity

Participants' frequency of engagement with their banking app was a moderately significant predictor of intended engagement with the CFR. Our results suggest that around 92% of participants use their banking app for less than 5 minutes per occasion, and 77% use it daily or every few days. Previous research on feedback and behaviour change, as well as specifically on personalised information in the context of pro-environmental behaviour change, suggests that feedback is most effective when provided frequently (30, 70, 80). However, some studies show that sustaining engagement with CFCs can be challenging (45, 70). Research on the visual design of digital feedback emphasises that an aesthetically pleasing interface can facilitate long-term engagement (85). Additionally, previous research suggests actively reminding users to engage with features through external triggers, such as push notifications, text messages, emails or in-app prompts (70, 86). Nevertheless, excessive or "interruptive reminders can lead to disengagement" by decreasing users' sense of autonomy and intrinsic motivation (86).

Opportunity - Social Opportunity

Contrary to expectations, our results did not find any items categorised under social opportunity significantly related to intended engagement with the CFR. One potential explanation might be that participants did not perceive their banking apps as interactive or social. This is consistent with Wijland, Hansen (87) that mobile banking is seen as a private affair. However, this might

be a changing trend with new services, such as PayMe by HSBC, focusing more on personal networks. As this shift in society develops, these results should be re-examined.

Recommendations and implications for practice

Users' understanding of the CFR and carbon footprints can be enhanced by designing a clear interface and following the principles of progressive disclosure (88). This can be achieved by simplifying the main interface and including timely, short, and simple explanations to facilitate understanding. To aid users' understanding of carbon footprints specifically, including a benchmark, such as the UK average, contextualising the environmental cost in Euros or GBP, as well as visual elements, such as bar graphs, clear labels, and colour coding, can be beneficial (64, 89-91). Moreover, when educating users on climate change, the CFR should inform them about the known causes and emphasise existing, practical, and achievable solutions. Also, when providing personalised feedback, the report should give easy and feasible suggestions on how a user can reduce their carbon footprint (70).

Importantly, users' motivation to engage with the CFR frequently can be increased by framing messages to reflect what the target audience values. Thus, messages can be more motivating and more successful at impacting behaviour and decision-making (92, 93). Most participants in our study scored highest on the hedonic and altruistic value orientations. Thus, for this audience, we recommend utilising a hedonic framing, focusing on users' pleasure and comfort (e.g., "These small eco-friendly changes can boost your comfort and joy every day") and an altruistic framing, emphasising how their engagement contributes to "the welfare and fair treatment of other" people (e.g., "Through your choices you can take a step toward fairness and care for others.") (49). Ultimately, messages should be tailored to the individual user's value orientation to be the most impactful. We would also suggest highlighting the personalised

nature of the report to increase perceived personal relevance and a sense of agency to guide user attention most effectively (70). For example, through messaging campaigns that emphasise how everyday choices made by individuals can significantly impact the environment. This may be achieved by triggering motivational processes stemming "from the anticipation of a future delight", for instance, through goal setting (94, 95). Giving users the ability to set realistic and achievable reduction goals and subsequently triggering their commitment and interest in progressing towards this self-determined goal may increase positive engagement and self-efficacy. According to the goal gradient effect, creating a clear sense of progression towards their goal may further bolster motivation (96). Additionally, the CFR should reward behaviours and particularly the achievement of milestones by leveraging the hedonic processes stemming "from the enjoyment and savouring of that delight" (95) or by providing sustainable shopping offers. Gamification may be a strategy to increase positive user engagement through reward seeking while minimising the chance of failure and punishment (82, 97).

Third, users can be supported in developing new engagement habits with their banking app, including the CFR. We recommend exploring notifications, such as reminding users to engage with features through external triggers, such as in-app prompts, push notifications, text messages or emails. When framed in an autonomy-affirming way, i.e. not excessively, these notifications can create new habits in banking app usage and draw attention to the CFR in a contextually relevant manner. Therefore, we recommend using in-app prompts over push notifications to maintain a user's sense of intrinsic motivation and autonomy.

Lastly, it is essential to foster trust in the CFR. Allowing users to delve deeper into the methodology at their own pace to improve their perceptions of transparency can increase trust in the CFR. Another strategy may be leveraging the transmitter effect to give the CFR a more human touch. Highlighting that the CFR was created and reviewed by people who users deem

trustworthy and reliable may increase trust and decrease scepticism. According to previous research, consumer and expert endorsements can improve people's attitudes towards a product (98). Most participants' trust in science and their bank is high, so financial experts from the users' bank or renowned scientists may be particularly effective transmitters.

Strengths and Limitations

This study used a behavioural science approach to examine the factors that can increase engagement with environmentally friendly initiatives, such as using transaction data to compile carbon footprint bank reports. This approach allows for a more nuanced understanding of human behaviour and decision-making, offering valuable insights for designing effective interventions. However, this study also has some limitations. Data collection was conducted during the COVID-19 pandemic when health concerns took precedence over environmental issues in the news and the public discourse. This might have influenced participants' responses regarding priorities or their interest in the topic.

One additional limitation concerns the internal consistency of the 'Automatic Motivation' and 'Physical Opportunity' factors, as reflected by their Cronbach's alpha values, which were below 0.6. While we acknowledge this statistical limitation, we have chosen to retain the items in these factors due to their theoretical importance and relevance to the constructs. In the case of 'Automatic Motivation,' removing certain items would result in a factor with only a few items, leading to a moderate alpha of 0.68. For the 'Physical Opportunity' factor, separating the items into individual variables would compromise the conceptual coherence of the factor, as the items measure different aspects that are better grouped within a single factor. However, these reliability concerns necessitate caution when interpreting the findings.

Finally, this study used one specific data display design. So, different data visualisation methods (e.g., different features, visual elements, and layouts) may offer better data display. Future research could address this.

Conclusion

Achieving net-zero emissions can prevent global warming from causing irreversible and catastrophic consequences (3, 4). Banks have a responsibility and ability to help accelerate the shift towards net zero emissions due to their influence on capital allocation. Banks can influence and motivate individual pro-environmental actions by leveraging their unique position. One central barrier inhibiting individual, pro-environmental behaviour change is the inability to quantify the link between personal consumption choices and GHG emissions (29). This paper introduced a novel type of CFC that directly ties individuals' consumption behaviour to GHG emissions using transaction data. By embracing technological advances, such as the growing uptake of mobile banking and Open Banking, and providing personalised and relevant feedback, this CFC may more effectively inspire long-term user engagement and ultimately pro-environmental behaviour change while holding companies accountable. This study identified the most significant barriers and facilitators to intended engagement with the CFR using a behavioural science model, the COM-B model, thus contributing to the growing body of pro-environmental behaviour change literature using technology.

To get to a zero-carbon society, joint action from the bottom up and from the top-down will be necessary. Digital feedback technologies, like the presented CFC, have the potential to increase people's capability, motivation, and opportunity to engage with climate change and behave more pro-environmentally (34, 42, 45). Importantly, however, this CFC should be understood within a broader effort of interventions aimed at increasing sustainable behaviour. Rather than expecting behaviour change on an individual level to be the silver bullet, it is worth considering

how other stakeholders could use this CFC simultaneously to facilitate a simultaneous bottom-up and top-down effort towards a climate-friendly future.

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Appendix

Table 1. Comparison of limitations and advantages of the present software offers

Limitations	Advantages
Recruitment of users can be challenging (Salo et al., 2019).	The present software is embedded within consumers banking apps, which users already interact with.
CFCs focusing on direct energy use cannot capture an individual's unique carbon footprint (Turner, 2014).	The present software calculates users carbon footprint based on their transaction data.
"Limited number and diversity of participants" (Salo et al., 2019, p. 659). Many CFCs are mainly targeted at people who are already interested in sustainability (Hunter et al., 2006).	The present software overcomes this barrier by being embedded in consumers banking apps, thereby, being available to a more diverse audience.
"The quality of self-reported data" (Salo et al., 2019, p. 659).	The present software overcomes this barrier as the calculation of the report is automatic and does not rely on self-reported data.
Time burden of calculating a carbon footprint or having to initiate the generation of the carbon footprint report decreases engagement (Aichholzer et al., 2012; Hunter et al., 2006).	The present software overcomes this barrier as the calculation and delivery of the report are automatic.
West et al. (2016) highlight the trade-off between accuracy and consistency of results. Using a household-level CFC, the authors explain that out-of-date questions can breed mistrust,	Not applicable since users do not have to answer any questions.

whereas constant updates make results inconsistent (West et al., 2016).	
Studies on effective feedback provision show that general information is ineffective as it does not account for contextual differences causing cognitive overload and disengagement since the information is largely irrelevant to users (Büchs et al., 2018). Providing personalised information requires more time and resources (Büchs et al., 2018).	The software used for this research overcomes these barriers by being embedded within individual consumers' banking apps. Thereby, the feedback is completely individualised and relevant to the user. Simultaneously, it does not require more time and resources since the calculation is automatised.
The underestimation of one's individual contribution to climate change and the simultaneous overestimation of one's support in solving it are important barriers (West et al., 2016).	The present software holds the potential of countering these misconceptions by revealing people's actual impact and contribution.
Young people are still in the process of forming their identity, therefore, experience the need for individualism (Wijland et al., 2016).	This barrier is addressed by the present software, since every user is provided with a personalised carbon footprint report.

Source: Table created by authors