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Eco-Apps for Change? Evaluating mobile apps to promote and support sustainable lifestyle changes

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Abstract

Introduction: Mobile digital devices have developed from mainly voice communications to always-on internet-accessing, mini-computers used universally across the generations. As the consumption and use of smartphones and digital devices and services grow exponentially, their pervasive acceptance has coincided with an increasing demand for mobile software applications. Faced with the evidence of the deepening climate crisis, can mobile digital apps be better deployed in support of critical lifestyle and behavioural changes required to tackle the impacts of climate change? Applying a review of the existing literature on mobile apps and combining this with original data from new eco-app users affords us deeper insights into the effectiveness (or otherwise) and utility of apps in promoting lifestyle changes allowing us to better design, develop, and deploy these digital tools for environmental good.

Methods: A comprehensive review of the literature on behavioural change and its links to digital ICTs is undertaken. This is followed by an analysis of quantitative data collected from just under 100 novel eco-app users to explore what they found useful, what they found troublesome, and what forced them to reject and uninstall such apps.

Results: Findings identified an overcrowded marketplace as a barrier to success. Attrition is also an issue of concern in encouraging digital intervention lifestyle change, with some revealing they would uninstall apps if they affected the operation and running of their device, or if the services on offer were irrelevant to their needs at a particular time.

Conclusion: The study concludes by outlining recommendations and guidelines for best practices in future digital interventions for promoting sustainable behavioural change specifically using mobile digital apps.

Keywords: Eco-app; digital ICTs; smartphones; sustainable lifestyles; Climate Change.

1. Introduction

Digital Information Communication Technologies (ICTs) have profound effects on the ways we work, live, and stay connected to family and friends. As lightweight portable smartphone and mobile device consumption and use intensifies globally, their pervasive adoption has coincided with an increasing demand for mobile software applications and the emergence of an 'apps culture' [1]. The mobile phone has transformed from principally voice communications to a multi-channel device to an internet-accessing always-on mini-computer, and in response, a sizable marketplace for applications (or apps for short) has developed. An app is a digital code set designed and written to carry out a specific task other than one relating to the basic operation of the smartphone or other mobile device. With the growth of the smartphone market, mobile apps have become ubiquitous in emerging markets as well as in developed countries across the world. The global mobile internet-accessing population in 2021 stood at 4.28 billion, and mobile internet traffic as a share of total online traffic stood at 55.6 per cent [2]. The number of mobile apps available to users to install on their devices is just under 6 million[1] and the projected worldwide mobile app revenue by 2023 was set to rise to 935.2 billion USD, up from 461.7 billion USD in 2019. Adult smartphone users in the US spend nearly four hours daily on mobile internet, and 88 per cent of this is on app use rather than simple web browsing [3]. European mobile device consumers paid nearly 15 billion USD to the Apple Store and Google Play throughout 2020, representing a 31 per cent increase in gross revenue from the previous year [4]. This included spending for basic app consumption and subscriptions, both standard and premium. All signs are that this appetite for apps will continue to increase creating a crowded marketplace in the 'attention economy'. As the climate crisis becomes more evident and urgent action to address the consequences of climate change grows more apparent [5, 6], how can digital ICTs and mobile apps be utilised to promote pro-environmental behaviours and lifestyle changes? Much of the research in this area has frequently focused on the technical features and marketing of mobile apps [7, 8]. There is a growing need to focus on end-users and their experiences to determine effectiveness or otherwise. To this end, this research draws together a literature review of such applications and data from novel users of eco-apps to unearth the central features of such technologies that will potentially give them the best chance for success. The review of literature informed how the later part of the research was designed and conducted, and this

[1] The estimated figure for downloadable apps available from the Google Play Store was 3.15 million, Apple App Store 2.09 million, and Windows Store 669,000.

input from novel eco-app users is a unique aspect of this particular investigation.

There are three types of apps currently in wide use - desktop, mobile, and web. Mobile apps diverge from traditional desktop applications, designed to run on stationary home and business tower computers, and other web-based applications. Mobile apps are software that comes pre-installed on portable digital ICT devices such as smartphones, tablets, or watches, or code that can be personally downloaded and installed seamlessly on such devices through provider platforms such as Apple or Google. Apps can be generally categorised into three types: native, hybrid, and web-based. Native applications are intended explicitly to run on mobile operating systems such as iOS (iPhone) or Android devices. These can be downloaded from the App Store (in the case of iOS) or Google Play Store (for Android devices) and are available free or at a minimal charge to the end user. Web apps behave similarly to native apps but are written using HTML5 or CSS code and usually run via a regular web browser. These are not discrete apps which require downloading and installing specific code to a person's device. They are responsive websites that modify their user interface to the user's device at any given time. Hybrid apps are developed with HTML5, CSS, and JavaScript code and they operate similarly to web apps concealed in a native container. They traditionally use a home screen app icon, responsive design, quick operation, and will also work offline but are web applications disguised to look similar to the native version.

2. Methods

This paper is broken into two key components, the first of which looks at the existing literature in the areas of mHealth and pro-environmental change brought about by such technology, and how digital ICT can be leveraged to change behaviours. The rationale for investigating mHealth apps and their potential is twofold. First, as opposed to eco-apps, there is richer literature and research available on mHealth apps and their effectiveness. In addition, mHealth apps have a specific focus on behavioural change, which is often the motivation and primary purpose of eco-apps. Then, using a novel set of collected data from new eco-app users, this research seeks to understand what apps people choose to download, their use, what users find interesting and what they find troublesome, and what coerces them to remove apps from their devices. Undergraduate students at the University of Galway, Ireland, were invited to download an eco-app of their choosing to their smartphone or mobile device and after some time operating this app – at least one week - submit a review of their experience. These were all young adults between the ages of 19 to 26 studying for the B.Sc. (Social Sciences) degree and commenced this research as part of their *Digital Citizenship* class. This review was quantitative in nature and involved the design of eight questions submitted directly to an online portal, seven closed questions and a final open question employed to illicit additional feedback and data.[2] No advice or direction as to what eco-app to download was given to the students, apart from the detail it 'should be focussed on sustainability behaviours, climate change, or environmental concerns' and to be 'frank and truthful as to the positive and negative features of the app'. This gave students autonomy to explore this pro-environmental behaviour change app environment on their terms and discover such software as they deemed to fit the criteria. An initial pilot review elicited 17 responses (included in the overall total) and prompted a revision of question 7.[3] An additional 82 reviews were gathered in two batches, the first over two weeks in October 2021 and the second in October 2022, from students undertaking the B.Sc. (Social Sciences) undergraduate programme, bringing the total reviews collected to under one hundred (n=99). The eco-apps installed and reviewed are presented chronologically in Table 1 in the appendix.[4] (Ethical approval was not deemed necessary because the review study was done with adults, over the age of 18 years, who were free to participate or withdraw at any stage of the research. So no children or vulnerable adults took part in this particular study. All participants were anonymised and the review took place as part of the normal expectation of adult university students.)

3. Technology that Supports Behavioural Change

Technology-based approaches to behaviour change interventions have some potential given the widespread adoption and acceptance of mobile digital ICT devices and technologies. They offer the mechanism and the means to track physical activity, capture critical personal data, date-stamp and time-stamp activities, and provide encouragement and useful feedback that motivates, increases confidence, and affords social and peer support to the user. Human behaviour largely denotes our corporeal and emotional manner, and behavioural theories seek to better understand the reasons why people engage, or fail to engage, in particular actions. A non-exhaustive list suggests five particular theories have likely consequences for technology-based behaviour change: *Self-Determination Theory* (SDT); *Social Cognitive Theory* (SCT); the *Health Belief Model* (HBM); the *Theory of Planned Behaviour*; and the *Transtheoretical Model* (also referred to as the stages of change model) [7]. Self-determination theory seeks to understand the motivation that underlies an individual's choice and is the framework that suggests that an individual has specific psychological needs that, when

[2] One of these questions was the student's number, which will not be included in these findings, and the questions posed are provided in the Appendix (1.a).

[3] Question 7 changed from 'would you keep this app on your smartphone and use it in the future' to 'what would make you uninstall this (or any other app) from your smartphone or mobile device?'

[4] All were free to download for users and the majority were available to iSO (iPhone) and Android Operating Systems.

satisfied, can lead to motivation, personal growth, and overall well-being [8], while Social Cognitive Theory moves away from a focus on behaviour to a focus on cognition [9]. The Health Belief Model encompasses a number of significant concepts that foretell why individuals might take specific action to avert, screen for, or regulate ill health,[5] and has been used for many decades in predicting health-related behaviours and to try and design interventions for positive behavioural change [10]. The Theory of Planned Behaviour originated as the *Theory of Reasoned Action* [11] seeking to predict an individual's intent to engage in a behaviour at a particular time and place based on the idea that a person will make logical, reasoned decisions to engage in a particular behaviour by appraising the information available to them at a given time [12]. The Transtheoretical Model of health behavioural change posits such change encompasses development through six specific phases: pre-contemplation; contemplation; preparation; action; maintenance; and termination [13]. To progress through these stages of change, individuals apply cognitive, affective, and evaluative processes, of which ten have been identified. The literature largely demonstrates that theory has merit for developing and appraising human behaviour change interventions [14], and a meta-analysis of behaviour-change interventions indicates that interventions based on such theoretical framework were more valuable in changing behaviours than non-theory-based interventions [15].

The concept of *nudging*, first presented by Thaler and Sunstein [16], advocates that our knowledge about systematic biases in decision-making can be used to assist individuals in making optimum choices. Nudges, in general, are behavioural change techniques and methods designed to influence individuals to make better choices by exploiting insights from psychological research. They are interventions in the choice architecture - the structure of the decision context - that predictably alters an individual's behaviour without ascribing substantial financial rewards or penalties to the process, with the intervention remaining 'easy and cheap to avoid' (p.6). More recent approaches to understanding the notion of *digital nudging* in exploring the efficacy of user-interface components to influence an individual's behaviour in digital choice settings have concentrated on nudging behaviours through anchoring and adjustment, omitting the important nudging mechanisms of priming and status quo bias. An anchor indicates an individual's understanding of a question for which the answer is unknown and is to be deduced. Essentially, an anchor is a starting point, a clue, a cue, or a pointer that can be attuned to help individuals approximate an answer. The anchoring and adjustment heuristic posits that individuals use a particular starting point (i.e. an anchor) and make

[5] These concepts are benefits and barriers to a behaviour, cues to action, self-efficacy, seriousness, and susceptibility.

modifications until they achieve an acceptance position over time. For priming and status quo bias, a randomised laboratory experiment of one hundred and twenty individual participants indicated that groups nudged with a status quo bias might act more pro-environmentally, while priming's ineffectiveness in motivating individuals was also noted [17]. In suggesting what designers should consider when designing new types of nudges, Caraban, Karapanos [18] outlined design considerations for twenty-three technology-mediated nudging mechanisms, grouped into six categories and using fifteen separate cognitive biases, while discussing the factors shaping nudges' effectiveness and their ethical implications.

Other key approaches are noted in the literature. Michie, Richardson [19] set out to advance a broad consensually agreed hierarchically organised taxonomy of behaviour change techniques (BCTs) used in interventions resulting in ninety-three BCTs clustered into sixteen different groups. Promoting such a taxonomy suggests that a well-specified intervention is critical before the evaluation of effectiveness is worth undertaking and that an understated intervention cannot be delivered with any type of reliability and, if assessed, could not be replicated. Consolvo, Klasnja [20] developed eight guidelines for designing technologies for lifestyle behaviour change arguing that technologies need to be *abstract* and *reflective*; *aesthetic*; *comprehensible to users*; *controllable*; *positive*; *public*; *unobtrusive*; and also include *historical data*. They suggest that previous research reviewed the various cognitive biases and particular implementations of nudges and they attempted to address the 'how to' of nudging, linking the why to the how. There are hosts of additional approaches to behaviour change and over the recent past, interest in theories of behaviour and models of behaviour change has intensified with contributions from psychology, economics, and sociology. Darnton [21] identified over sixty socio-psychological models and theories of behaviour, several of which have been used as the basis for proposing and executing change programmes and promotions, with varying degrees of success.

3.1 mHealth: Mobile Apps and the Potential for Better Health Outcomes

With the expansive development of digital ICTs and growth in worldwide connectivity, improvements in mobile technologies in healthcare have accelerated significantly over the previous ten years, and this has unlocked new opportunities, possibilities, and original ways to improve personal health and healthcare delivery. Mobile health (mHealth) refers to the use of mobile apps and wearable devices for health reasons [22], and these enable the delivery of health-related services through everyday mobile devices such as smartphones watches or tablet devices [23]. Designing ways to better assess such technologies is crucial to improving the standard and quality of available health apps. The aim of delivering services that are built on the pillars of evidence-based, reliable, long-term effectiveness, and user-oriented quality

[24]. Bates, Landman [25] argue that four significant policy concerns need to be addressed with medical apps. The safety of such apps must first be ascertained so that the public can be protected. In addition, a directory of evidence is required that will allow clinicians and patients to determine which particular apps are most effective. Moreover, medical apps must be able to communicate directly with electronic health records (EHRs) to allow the seamless and secure transfer of health information. Finally, the marketplace must be encouraged and persuaded to design and develop apps that primarily will improve patient care and provide real value. It is vital to understand users' sentiments if we are to design meaningful apps that will be widely installed, and used extensively.

Clinician involvement is frequently an important part of the initial design stage and content input of mHealth apps. This input includes internal drivers – for example, an understanding of illness, motivation and self-efficacy - in addition to external drivers such as user compatibility, specific illness information, and social networking, which are better at enabling behaviour change [26]. Motivation is often considered to be the most important of these factors. A further study indicated differing opinions about how the cost of mHealth apps affects their overall trustworthiness [27]. Some participants understood paid apps to signify they were of better quality, while others held a differing viewpoint. The latter group contended that the cost of an app was meaningless when it came to trustworthiness, a position borne out in findings in other studies. The considerable variation in available mobile health apps has resulted in a large but inconsistent body of literature. In their review, Milne-Ives, Lam [28] argued that mobile apps are largely ineffective when it comes to improving health outcomes and behaviours as few studies established any substantial differences between the app and control groups. Schoeppe, Alley [29] suggest that expected app design and development should pinpoint features that promote users' app engagement, be tailored to particular population groups, and be more cognisant of health behaviour theories while Neilsen [30] suggests the effective incorporation of behaviour change techniques in an app facilitates overall increased engagement and effectiveness.

3.2 Eco-apps: Promoting Pro-Environmental Lifestyle Change

As smartphones and other internet-connected mobile devices continue to grow in popularity, so too does the development of mobile applications designed to promote environmentally friendly behaviours (also known as *eco-apps*). Such persuasive apps have been identified as promising because of their ability to provide end-users with the potential for real-time and bi-directional interaction, and these can be classified as Behaviour Change Support Systems

(BCSS),[6] a term first introduced by Oinas-Kukkonen [31]. Researchers in the field of Human-Computer Interactions (HCI) posit there are new and developing opportunities for digital ICTs to encourage pro-environmental actions and attitudes by employing behavioural psychology to promote environmentally conscious behaviours in individuals. But He, Greenberg [32] cautioned against a ‘one size fits all’ approach and offering similar feedback to differently motivated individuals at various stages of readiness, willingness, and openness to change. In her analysis for improving mobile phone interventions in understanding and acting on environmental problems, Typhina [33] offers recommendations as points of discussion and exploration to reconceptualise the structural promise of eco-apps to address environmental concerns. Developers and designers should seek and encourage the participation of different stakeholders in the developmental stages of eco-apps, and this must include the end-users. They should strive to capture lived experiences and new and novel experiences through eco-app use, but attempts should also be made to enhance and support important offline relationships through the use of these eco-apps. Nkwo, Suruliraj [34] found that among the one hundred and forty-eight mobile apps they evaluated, a total of seventy-one (n=71) socially-oriented strategies from the social support category of the Persuasive System Design (PSD) framework were employed. Such findings indicate that socially-oriented strategies are effective at promoting sustainability and pro-environmental behaviours more broadly. In contrast to passive participation, Such strategies should be purposely designed to inspire and encourage the active participation of users to achieve mutual goals. Ochmann and Lehrer [35] suggest green digital interventions in the form of daily challenges should be personalised with the users’ pre-existent behaviours, goals, context, and everyday routines and habits, that challenges be set at the right level of difficulty to engage the user, users should be supported in setting goals that are both relevant and will have a significant impact, the challenges need to be modified to the user’s context and, reminders need to be part of the design process.

3.3 Limitations to the Use of Digital Technology to Aid Behaviour Change

Finding ways to rebalance and enhance our relationship with nature for the well-being of all people and the biosphere is internationally echoed in responses to the United Nations Sustainable Development Goals. However, unrestrained economic growth, globalisation, and an increasing global population continue to widen the gap between humanity and nature. There is mounting evidence of the relationships between the natural environment and biodiversity, and our overall well-being [36, 37], yet access to nature is still largely an

[6] Behaviour Change Support Systems are defined as information systems which are designed and developed to create, modify or reinforce attitudes, behaviours or an act of complying without using duplicity, pressure or enticements [31].

unrecognised health benefit despite indications of improved individual welfare by enhancing connectedness to nature [38-40]. Studies have found that adults and children who spend significant amounts of time on their smartphones are also more likely to display a disconnect with nature and exhibit stronger negative behaviours and feelings towards the environment [41-44]. Excessive use of smartphones in their Unaware[7] mode has a considerable negative effect on overall quality of life [45] and consequently, people who use their smartphones excessively have less time for other activities, including less contact and connectedness with nature. Smartphone phone overuse, nature-deficit disorder, and public health are all interconnected and, therefore, must be considered collectively in future studies exploring the complicated relationships among these concerns [44].

While there is concern about digitalisation's increasingly negative environmental impacts [46], nevertheless, the role of digital ICTs has undoubtedly increased possibilities and the potential for pro-environmental behaviour change. But they have also added to the complexity of effective interventions and measures to aid real and long-term sustainable and positive change in human behaviours. To design interventions that last designers, developers, and policymakers should be concerned with factors that influence the maintenance as well as the adoption of pro-environmental behaviours [47]. Digital ICTs can create opportunities to inspire, enable, and bolster positive change. However, if we are to release its true potential there is a need to be more ambitious in what we do and not just simply digitise analogue strategies or generate additional communications mechanisms. In the recent past educational programmes, awareness campaigns, and product innovation have been disappointing, and government policy and legislation have had inadequate impact. Johnson [8] [48] maintains the potential to succeed, in terms of behavioural change, lies in digital technologies' ability to do things that no person, or nothing else, can do. Computers and related digital technologies are devised to process huge quantities of data and have the capacity to analyse, visualise, and communicate that data in an appealing fashion and at great speed. In contrast, emotion has a pivotal role in human decision-making and behaviours. Applying this understanding - what is possible and has potential in terms of the technology use and what it cannot do, at present - must be central to human behaviour change via the use of such technology. But even when we consider just one specific Design for Sustainable Behaviour (DfSB) strategy that computers do well – feedback - a study drawing on an extensive review of the literature points

[7] Unaware denotes smartphone use that is performed at the same time as other activities that need or demand our attention such as driving, watching TV, cooking, or simply talking to family or friends.

[8] Stephen Johnson is a consultant specialising in behaviour change and social innovation: see http://stejoh135.dreamhosters.com/considered/.

to limitations of this approach including the requirement for further information and comparisons, the issue with numerous users, technical matters, the downgrade to background technology, and the potential rebound effects [49].

In an interdisciplinary expert panel discussion on technology for behaviour change, Diefenbach, Kapsner [50] suggest while such digital technologies have certainly the potential to improve lives they also raise serious ethical concerns such as whether we should consider the induced changes in behaviour as manipulation. If this is so does the design of these products express sufficient respect for the autonomy, privacy and overall dignity of the end-users? Moreover, instead of making our lives trouble-free, these digital technologies for behaviour change often intentionally create friction, attempting to break habits and routines that people have grown comfortable with and accustomed to in inspiring personal reflection that is part of the process of human behaviour change [51]. Such friction might not be appropriate for all circumstances of behaviour change, especially long-term and sustainable change. An additional concern is in the design and development of mobile apps that promote and encourage personal reflection and transformation. Despite the huge number of health apps to support behaviour change, for example, very few are designed alongside public health experts or have even been assessed rigorously [52]. Mobile health apps' effectiveness has not been adequately determined, it is claimed [53, 54], and many studies do not even indicate whether or not their mobile health behaviour apps are grounded in behavioural theories, which is a crucial component of effective health-related behavioural interventions [55].

Of particular concern to mobile app designers and developers is the attrition rate - the percentage of users who install an app but then quickly uninstall it from their mobile device. The worldwide retention rate for lifestyle apps on day one after installation is 20.9 per cent, but this falls to just 4.5 per cent on day 30, while the retention rate for educational apps on day one is 18.8 per cent falling to just 2.5 per cent by day 30 [2]. Based on Quettra's data, the average app loses nearly 77 per cent of its daily users in the first 3 days after an install; over 30 days it has lost 90 per cent; within 90 days it has lost over 95 per cent of its original users [56]. The average app may lose its entire user base within a few weeks or months. In a study to explore the reasons individuals uninstall mobile apps, the role of satisfaction was deemed important, and in the case of negative disconfirmation - the application not performing as expected - eventually leads to cessation of use [57]. Consuming too many resources in terms of power, memory, and processing time were also prominent factors that led to discontinuation. In a recent survey of over 2,000 mobile app users, participants were asked what their main reason for uninstalling mobile apps would be: they no longer use the app (39.9%); limited storage space (18.7%); too much advertising (16.2%); excessive notifications

(12.6%); confusion (5.4%); technical issues (5.4%); other (1.6%) [58]. Earlier research found the most significant reason was finding it 'useless': other important factors were software crashes; high memory allocation; instability and inconsistency; poor User Interface (UI); intrusive advertisements; lack of improvement; and it was a 'boring app' [59]. Understanding the reasons behind the very large number of app uninstallations will help limit such attrition and will lead to better and more successful design and development. To this end, there is a growing need to better understand the design and development of mobile apps, from the end user's perspective. Findings from a review of previous studies focussed on mobile apps in the education sector revealed little in the way of evaluation or testing had been done on the effectiveness of such technologies [60] and this is a crucial gap in our understanding that needs to be closed.

4. Result

A Review of Current Pro-Environmental Behavioural Apps

The more popular eco-apps included Ecosia (n=8), a search engine whose profits, generated from user searches, go towards planting trees in areas of the world worst affected by deforestation. Treeapp (n=8) operates in a somewhat similar fashion in that the value accrued from the user's completion of a survey or for taking part in a specific marketing promotion is transferred to planting trees to combat deforestation. GoGreen assists people with their recycling by informing them which items to recycle and which are waste, and Recycle Coach informs the user how to recycle correctly. NoWaste (n=4) encourages a reduction in food waste for private households by updating the user on the length of time available until the foods' expiry date, while Evocco (n=2) gives each food item a rating in terms of its carbon footprint. Happy Cow helps users find vegan, vegetarian, and gluten-free friendly restaurants, shops, and businesses worldwide, and Depop (n=4) promotes sustainable fashion and encourages individuals to shop more ethically.

Several eco-apps focus on information on products sold to consumers. Good on you (n=5) establishes how ethically responsible each brand is, and EcoReportCard has a similar goal. CodeCheck scans the barcodes of food and cosmetics to check if they contain allergens, unhealthy ingredients, or environmentally damaging ingredients, Giki Badges has a similar function by scanning grocery products, and Ailuna (n=2) allows users to set 'green' goals through dares that result in both a lower amount of waste and a reduced carbon footprint. Environment Challenge provides current news and information about a user's local environment and creates minor daily challenges for users to accomplish to reduce their environmental impacts. Brightly (n=3) allows its community of users to read and share articles about sustainability and sustainable lifestyles, while JouleBug (n=10) tracks a person's positive environmental impacts and helps them to make everyday practices more sustainable. Earth Hero (n=5) provides tools and ideas to empower individuals to reduce emissions, Oroeco (n=2) tracks and outlines the impacts of one's behaviours and Eco-Tracker aims to do a similar job: both hope to nudge users into making more pro-environmental decisions in their lives. Refill (n=4) provides users with locations for refilling water, coffee, and food, while TooGoodToGo (n=13) offers individuals the option to buy produce and food from restaurants and supermarkets that otherwise would be thrown away. Olio (n=6) is a food-sharing app which connects communities and aims to reduce waste. Nviro is a UK-based travel app which aims to raise awareness about climate change, Tradera is a Swedish app for buying and selling second-hand and used goods, and Spinlister is a bicycle-sharing platform. Idle EcoClicker: Green Planet is a gaming app that helps children become more aware of the environment and seeks to change attitudes towards littering and purchasing items that cannot be recycled.

When asked what they found interesting or good about their eco-app, for many it was a source of information that, potentially, could be used for making positive lifestyle behavioural changes. Participants indicated this in the following ways:

> I found it interesting to have a focus on all my behaviour in buying products, food, and travel modes. It definitely encouraged awareness of taking stock of personal choices and the effects (Participant # 4).

> It made me realize how simple it is to swap my choices for more sustainable products and the impact every change makes. It helps me so much on my product choice and living as healthily and sustainable as possible (Participant # 8).

> My favourite part of the app however was that on the home page, they provide articles to read on food sustainability so you can educate yourself on the topic (participant # 92).

For others, it was a source of motivation that inspired them to make changes:

> It focuses on individual action and collectively presents the data (of all members) as a community. Actions such as turning the tap off whilst brushing teeth, switching a light off when you leave a room, washing clothes at a lower temperature, or eating a plant-based meal all accumulate points which transfer to the amount of Carbon (kg), water (L) and electricity (kWH) that have been saved. In the last 3 days, I have saved 60kg of CO2. I like that I can see how my sustainable efforts are helping (Participant # 71).

> This was an effective motivator for me as it gave me clear goals to work towards but also showed me that my score could have been worse. I think the app is productive as a tool in that it never shames the user for their score, it only offers improvements (Participant # 86).

The gamification of sustainability behaviours and practices appealed to some, as did the concept of building communities around efforts towards sustainability:

> Another bonus of this app is also being able to communicate [with] individuals and groups to discuss topics and to share this learning experience with others of the same interest (Participant # 25).

> I find it good that you can have 'friends' on the group, if someone was to have people they know as 'friends' on this app which would make the dares more competitive resulting in more 'green' habits being developed (Participant # 50).

> I found it interesting how you can compete with other people to see who is more sustainable. You can add friends on the app so it adds a fun element to play against people you know in real life. I really liked the fact it informs you in an entertaining way how much energy or water you are saving, for example, it compares refilling a reusable water bottle instead of buying a single-use plastic one to watching 90 hours of TV or keeping your refrigerator cold for 5 days (Participant # 82).

But it was important to many the eco-app they installed was visually appealing and simple to navigate and use, as well as functioning and performing well:

> I found the basic concept to be both useful and necessary. The app functions well and though it is reliant on people coming on board with the concept, it performed the basic functions well (Participant # 19).

> The app is aesthetically pleasing. The graphics and icons are modern and follow a general colour and theme. The concept of the app made me more conscious of things like packaging even before I used the app as I knew it was going to be judged. I enjoyed the progress feature on the app. This feature would compare your different shopping receipts and compile the data and represent it in bar charts. It gave a chart on the average star rating of your shopping trips every month and also what food groups took up the most CO_2 monthly (Participant # 41).

> My favourite feature of the app was how accessible and easy to use it was. They had the categories organized very well and easy to find. When you complete a task/challenge; you are rewarded with points, badges and medals. I found this a very fun and addicting to earn as many points as possible (Participant # 57).

Reviewers were asked for reasons why they would uninstall this, or any other app, from their smartphone or device and a mixed response was received. Concern over the effects on the phone's battery and storage, the app running slowly or crashing, disinterest in the topic, or the app not living up to expectations all figured highly in the responses. A significant number indicated 'other' but an interesting feature here was the number who indicated that they would consider uninstalling if the app offered nothing of value in their local area. The results from this question are provided in Figure 1 below.

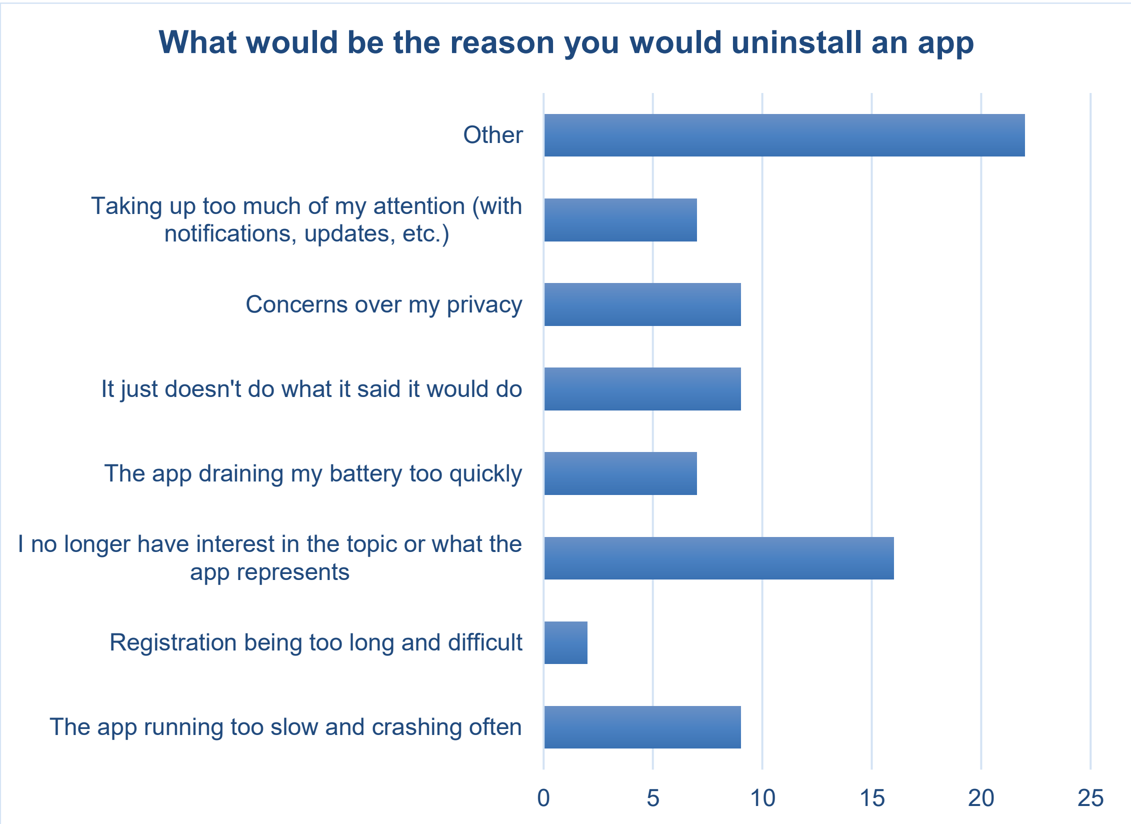

Figure 1 – Reason for Un-installing or Deleting Apps

Delving deeper into the issues participants found frustrating or poor about the eco-app they had installed on their device, one of the leading reasons stated was that the app did not perform as promised or that it did not live up to the expectation of the user. In a significant number of cases, the services on offer were not available in their local areas:

> The application is not fully functional around the world. Depending on your location you may only have some, or even none of the features. The application relies on participation from a user's city government, so if the location you are in does not have any involvement then you will not be able to use the application (Participant # 35).

> The only frustration I ran into was that it's not available in Galway, or really anywhere but highly populated cities. Its use is determined by the demand in certain areas, so this makes sense, but my experience was limited to browsing stores in Dublin (Participant # 43).

> I found it frustrating the selection of restaurants didn't extend outside the Cayman Islands as I believe this app could help people all around the world, from struggling families to college students. I also found it frustrating the limited number of restaurants available as it simply makes sense to offer this service and it has little cost to the restaurants themselves it would actually save them money as it prevents waste (Participant # 46).

Others were frustrated with the functionality of the app and the distraction of time-consuming advertisements and other such interruptions:

> The first thing I noticed about the app which I found was poor was the lack of an introduction into how users would use the app correctly. As soon as I had it downloaded and opened the app it brought me straight to a camera, which I assume is where you take a pic of the product you want to throw away and it would tell you where it goes. I also found that it took a long time then for the app to load and tell me which bin it should be put into (Participant # 28).

> I found that watching the ads was time consuming and uninteresting. The app also froze a handful of times while I was using it which slightly bothered me (Participant # 47).

For other reviewers, issues such as data privacy and the integrity of the services and content offered by the app creators generated some concerns:

> Also for the services to be added to the app the location must make themselves known to the app themselves. As the app is reliant on location users must have their location services turned on their mobile devices and some users may not feel comfortable with this (Participant # 11).

> While I think that the concept of the app is good, all the information may not be 100% true. The app creators state that "brand ratings are prepared in good faith based on information available from independent sources and information published by the brand themselves." Obviously, this is not the fault of the creators, but companies may alter their information in order to increase sales to those that are eco-conscious, thus affecting the integrity of the app (Participant # 39).

The emphasis on personal behavioural change implicit in the use of many of these eco-apps was somewhat of an irritation for some as they allow producers to abdicate much of their responsibility towards sustainability and the climate crisis:

> The only other problem I had was that I feel this system puts too much emphasis on the individual to reduce their carbon emissions when it is proven that corporations and governments have a much larger effect on carbon emissions (Participant # 86).

> I find the message that it sends to the public to be problematic. I agree that it is of paramount importance to live as sustainably as possible and that we all have a responsibility to this planet. However, this app solely focuses on the role of the consumer and in turn shifts the blame onto the average person. When in reality, it is the big companies and governments of the world who are the real decision makers and need to be held accountable for the damage they are causing, which is on a much greater scale than anything an individual person can create. That is the reason why I find apps like this one to be frustrating and overall unhelpful (Participant # 99).

5. Discussion

When evaluating from a behavioural change perspective, there continues to be considerable concern about the assumption that digital technology development and use, on its own, will routinely lead to positive change, and there is little evidence that such digital behaviour change interventions work or not [28, 61, 62]. That is not to say that digital interventions lack promise [63], but they need to be part of an overall strategy that is thoughtful and considers prevailing individual and community knowledge, experience, and understanding. This particular research set about linking existing knowledge in this area of mobile apps with collected data from new eco-app users to determine the central characteristics and features of such technology that will lead it to be more effective in terms of behavioural change stragegies. As noted in the literature, interventions grounded in robust theoretical frameworks are often more promising and successful in long-term behavioural change strategies, and must be a critical consideration in the overall design and development of digital technologies and applications seeking to promote and support pro-environmental behaviours. Thus, **behavioural change theory need to be embedded in the design and developmental stages of eco-apps**. Moreover, we need to caution against a 'one size fits all' approach that provides similar services and stimuli to a myriad of motivated individuals and groups at different stages of openness to change. Pro-environmental digital interventions in the form of daily challenges, for example, should be personalised with the user's existing goals and everyday routines and context in mind, and set at the right level of difficulty to engage and challenge the user. **Eco-**

apps should be targeted at the specific needs and motivation of the user, the capacity of their attention, and the precise interventions that will promote and support long-term pro-environmental behaviours rather than the design and development of the software or application itself. Indeed, **for eco-apps to be effective and meaningful, end-user involvement in the design and import of such interventions is crucial, and it must include opportunities to promote and support offline relationships and help build and maintain non-digital, real-world communities**. As noted in the literature, such socially-oriented approaches are frequently more successful at stimulating sustainability and pro-environmental behaviours.

The oversaturation of the app market is of significant concern, as evident in this research. **Findings from this study are reflective of the overall crowded and chaotic nature of the mobile app marketplace and environment**, and developers should proceed with caution. Although the study reviews are limited in terms of scale and penetration, several of the available eco-apps to reviewers were country or region-specific and did not offer a relevant service to other users, for example. **Offering a service that is appropriate to a user is crucial**, and this issue can be opaque or neglected in developer discussions on the code, operation, and functionality of an app. The app's overall operation was also a concern with some users declaring they had intended to uninstalled the app because of issues with storage space, the functionality of the app interfering with the device's normal utility, and privacy concerns. **The design and development of these digital interventions must demonstrate sufficient respect for the autonomy and privacy of the users**, and the use of digital nudges to promote and support change also brings forth some important ethical concerns. A more concise understanding of the reasons underlying the sizable number of app uninstallations will help limit such attrition and will lead to better and more effective outcomes.

6. Conclusions

This paper pursues a deeper understanding of how digital ICTs, in particular smartphone and mobile device apps, can be leveraged to promote and support pro-environmental lifestyle changes. Following a review of the literature on mHealth and eco-apps, a brief overview of a unique data set collected from young adult reviewers of the pro-environmental eco-app landscape was provided. Based on the review of eco-apps outlined, this paper concludes by challenging assumptions that digital technology development and use alone will lead to significant behavioural change. A lack of coordination, coherence, and deference to market ideologies is leading to a free-for-all 'wild west' eco-app landscape that may well be undermining serious attempts to better understand and use such digital technologies to promote pro-environmental behavioural changes. These findings offer relevant insights for other similar projects, as well as researchers studying and assessing the efficacy and impact of different eco-apps targeting behaviour and lifestyle change. More rigorous and thoughtful intention and assessment efforts will provide the results needed to ensure such apps are better designed and fit for purpose, and additional longitudinal research is needed on these issues.

There are no magical powers to digital ICTs. The ability to change our behaviours and daily practices lies in our innate capacity for reasoning, often triggered by motivation, emotion, and the need to adhere to social norms. That such mobile device apps can be used to nudge, promote, and support pro-environmental behavioural change is interesting and merits further study, particularly given its capacity for large, real-time data sets and behaviour monitoring. However, such interventions must be grounded in strong theoretical understanding, considered hypotheses, and open to objective empirical testing. To design digital services that promote and support sustainable behavioural change, we need to visualise the positive impacts such choices will have and design the eco-app accordingly. In addition, many behavioural choices are guided by practices and routines that vary according to personal preferences and circumstances. A clearer understanding of what motivates an individual to make changes in their everyday life is a crucial initial step in the development of more effective digital technologies in this domain. The inclusion of all stakeholders, including the end-user, in the design and development of an eco-app provides an opportunity to recognise such motivations and present an array of local and regional knowledge and understanding that can address current challenges for end-users of such eco-apps. Faced with the evidential growing climate emergency, we need to start getting these digital interventions correct and not simply add to unnecessary device and app consumption.

AUTHOR CONTRIBUTION

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

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Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information is available within the article.

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The authors declare no conflict of interest financial or otherwise.

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8. Appendix

11.1 Reviewed Eco-Apps

Eco-App Name	*Reviews*	*Website*	
Ailuna	2	https://ailuna.com/	
AWorld	1	https://aworld.org/	
Brightly	3	https://brightly.eco/	
CodeCheck	1	https://codecheck-app.com/ratings/climatescore/	
Depop	4	https://www.depop.com/	
Earth Hero	5	https://www.earthhero.org/	
Eco Cat	1	https://www.ecotradegroup.com/en/scrap-catalytic-converters-catalogue	
EcoReportCard	1	https://ecoreportcard.org/	
EcoHero	1	https://ecohero.app/	
Ecosia	8	https://www.ecosia.org/	
Eco-Tracker	1	https://eco-tracker.com/	
Environment Challenge	1		no website
Evocco	2	https://www.evocco.com/	website is no longer available
Flora: Green	1	https://flora.appfinca.com/	
Giki Badges	1	https://giki.earth/	
GoGreen	1		no website
Good on you	5	https://goodonyou.eco/	
GreenChoice	1	https://www.greenchoicenow.com/	
GreenDay	1	https://www.greendayapp.com/	website is no longer available
Greens are good for you	1	https://www.greensaregoodforyou.com/	
Happy Cow	1	https://www.happycow.net/	
Idle EcoClicker: Green Planet	1		no website
Impact Score	1	https://www.impactscore.app/	
JouleBug	10	https://www.joulebug.com/	
Karma	1	https://save.karma.life/	
NoWaste	4	https://www.nowasteapp.com/	
Nviro	1	https://nviro.co.uk/	
Olio	6	https://olioapp.com/	
Oroeco	2	https://www.oroeco.org/	
Recycle Coach	1	https://recyclecoach.com/	
Refill	4	https://www.refill.org.uk/	
Spinlister	1	https://www.spinlister.com/	

The Planet App	1	https://theplanetapp.com/
ToGoodToGo	13	https://www.toogoodtogo.com/
Tradera	1	https://www.tradera.com/
Treeapp	8	https://www.thetreeapp.org/
Total	98	

Table 1 - The List of Reviewed Eco-Apps

11.2 Review Instructions and Questions

The direction and questions for the eco-app review were as follows:

The app should be focussed on sustainability behaviours, climate change or environmental concerns, and please be as frank and truthful as possible about the positive and negative aspects of the app. The questions you will be asked are:

1. What is the name of the app you downloaded for review?
2. How much does the app cost to download?
3. Can it be downloaded to an iPhone (ISO) and/or an Android phone?
4. What exactly does the app claim to do or what service does it provide? (two or three sentences)
5. What did you find good or interesting about the app? (two or three sentences)
6. What did you find frustrating or what was poor about the app? (two or three sentences)
7. a. Would you keep this app on your smartphone and use it in the future? (yes/no/undecided)

b. What would make you uninstall this (or any other app) from your smartphone or mobile device?

8. Your student number.

9.3 What would be the reason you would uninstall an app? (other option selected)

Some of the reasoning given by review participants who selected ‘other’ were as follows:

1. No accessible locations for me to use
2. There are very few users in close proximity to my location, the distance for collection would be too far to travel
3. Lost interest

4. I might use the service at some stage, but due to the infrequency of use I would uninstall to save on phone memory. More likely, I would end up using the web interface over the app
5. Using up my storage
6. I can honestly say the only reason I would and am deleting the app is because I can't use it in my area
7. It has very little use to me due to my location
8. Using up too much storage
9. My phone ran out of storage and I needed to delete something
10. Nothing was particularly concerning about this app that would make me want to uninstall. However, generally speaking, if it were to drain my battery, take up too much storage or pop-up advertisements I would definitely have to reconsider
11. I am personally not vegan, vegetarian or gluten free. Although I like the concept of the app it is just not great for my location
12. I wouldn't as it fits into my day to day just like google or any other site browser would, so it actually makes a real world difference as its not intrusive and is a non profit, collectively speaking, I'm not saving the climate solo but with over 2 million downloads they have at the time of writing planted 159,408,969 trees
13. forget I have the app and eventually uninstall it
14. My storage becoming full as I would prioritise other apps
15. Lack of use/forgetfulness/non-complete stated goals
16. Storage space
17. Lack of daily use and lack of tangible benefit would be the main reason I would uninstall this app. Although it promotes good behaviours and offers some creative eco alternatives in everyday life, even the most dedicated user of this app would not experience any direct benefit (eg. Discounts, physical rewards like a t shirt, clothing etc.) from everyday use
18. I would not uninstall this app
19. The main reason I would uninstall the app is the cost. The app is free to download, however, it is a subscription app, therefore you must pay a monthly fee of €5.49 or a yearly fee of €32.99. It is not that beneficial for me to consider paying over €5 a month
20. Takes up a good bit of storage on my phone
21. Since I'm not able to use many of the apps features in Ireland it's not as useful to me
22. The app is too expensive for something you could do yourself for free
23. It does not used in every country. Example in Italy is not being used, even if it is a European application, being Italian this would be an issue for me as I would not be able to take advantage of it

24. Nowadays there are so many apps for almost everything, this app could happen to be forgotten about in this fast-paced nature of smartphone culture.