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The discontinuance of low carbon digital products and services

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ABSTRACT

Digital consumer innovations offer low-carbon alternatives to mainstream consumption practices. We address a lack of research on the factors influencing post-adoption decisions of discontinuance for this important class of innovations. We conducted a repeat survey with UK consumers (n = 995) in 2019 and 2020 to investigate 16 digital products and services across mobility, food, homes, and energy domains. Our survey captured temporal changes in adoption, personal and contextual characteristics, social influences, innovation experiences and perceived attributes. We also provide a unique contribution by assessing the impacts of Covid-19 on post-adoption processes.

Our results indicate that discontinuance is associated with: 1) services more than products; 2) perceived functional attributes not met by experienced attributes; 3) a lack of positive social influence, including word-of-mouth; 4) a lack of social network connections to other adopters; and 5) a decline in an individual's financial situation. Covid-19 was not found to be a significant factor influencing innovation discontinuance. Findings highlight generalisable insights regarding issues that need addressing to overcome discontinuance. For example, while digital services offer low-carbon promise, continued adoption is sensitive to their strong performance attributes. There is a need for continued innovation to sustain market position relative to more familiar incumbents.

1. Introduction

International targets to reduce carbon emissions require urgent demand-side transformation and changes to daily life, in addition to the decarbonisation of energy supplies. Despite the growing recognition for action amongst governments and citizens alike, current behaviours and the scale of solutions is insufficient (IEA, 2020).

The current digital revolution offers many opportunities to harness secular trends, for example through smartphone applications, to modernise, control, improve efficiency and reduce energy demand (Statista, 2020; TWI2050, 2020). A range of digital consumer innovations already exist, and if adopted at scale, offer low-carbon alternatives to mainstream consumption practices (Wilson et al., 2020). Examples include app-based circular economy sharing platforms providing the ability to identify, track and trade materials for re-use; food apps which reduce food waste through enabling consumers to find produce that would otherwise be wasted; and digitally controlled smart home technologies allowing greater control and automation of domestic heating and lighting. Nevertheless, market shares of such products and services remain low e.g., the dominant food waste app in the UK 'Too Good To Go' has only been downloaded by 9 % of the population (Wells, 2021). To maximize benefits from these innovations, it is necessary to understand why diffusion is not occurring as expected or at the rate required to help the low carbon transition (OECD, 2018).

Diffusion research predominantly focuses on the processes leading to the adoption or non-adoption of innovations (Clausen and Fichter, 2019; Huang et al., 2021). However, an often overlooked but crucial element is the consideration of post-adoption decisions. Understanding the factors influencing innovation discontinuance - 'the decision to reject an innovation after having previously adopted it' (Rogers, 2003, p.130) - is important for informing strategies to encourage retention at the individual level. Research on discontinuance and the characteristics and behaviours of discontinuers (an adopter who decided to discontinue) can also help to identify and tackle adverse effects at the social network level such as negative messages spread by discontinuers discouraging adoption (Lehrer, 2015).

Abbreviations: DoI, Diffusion of Innovations; P2P, Peer-to-peer; WOM, Word-of-mouth.

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The aim of this paper is to improve understanding of the post-adoption processes of innovations that are digital or digitally enabled and potentially offer lower carbon alternatives to mainstream consumption practices. We use Rogers (2003)'s well-established theory of the Diffusion of Innovations (DoI) as a conceptual framework to investigate and answer the research question: Which characteristics of the decision maker, innovation, communication, and context are associated with discontinuance for low carbon digital products and services? Rogers' DoI theory offers a comprehensive philosophy regarding the process an individual goes through when deciding to adopt an innovation. The stages of this process are knowledge, persuasion, decision, implementation and confirmation (see Rogers, 2003 p.169 for greater detail of each stage). Although the theory focuses predominantly on innovation adoption, it also touches upon post-adoption decisions (Rogers, 2003 p.130) and has been applied in several other studies exploring discontinuance (e.g., Fenech, 2011; Maki and Vishwanath, 2020; Parthasarathy and Bhattacherjee, 1998).

We use a repeat sample survey methodology with consumers from the UK to capture changes in adoption dynamics for 16 different innovations. Our unique contributions are: 1) a focus on influential factors leading to discontinuance (rather than adoption) of a wide range of low carbon digital products and services across four consumption domains, 2) the collection and analysis of temporal data from 2019 and 2020 to gain detailed insights on change dynamics; and 3) the inclusion of empirical data capturing the impacts of Covid-19 on innovation adoption/discontinuance processes, domain behaviour and information flow.

We first present literature concerning the post-adoption decision process and hypothesise the key influential factors associated with discontinuance. We then provide an outline of our repeat survey methodology used to test our hypotheses, followed by the results which provide cross-innovation and cross-domain insights. Our discussion section summarises the implications of our findings, highlighting the issues needing to be addressed by industry and policy to increase innovation retention, reduce the risks of market stagnation or decline, and help accelerate the low carbon transition.

2. Literature review

2.1. Post-adoption decision processes

There is a common tendency for diffusion research to have a strong pro-innovation and success bias (Gripenberg et al., 2021; Rogers, 2003). The vast majority of studies focus on the decision making process which leads to a 'positive' outcome: gaining knowledge, being persuaded, and then deciding to adopt (van Oorschot et al., 2018). To a far lesser extent, other researchers have focused on the factors leading to non-adoption otherwise known as rejection or resistance (Huang et al., 2021; Mani and Chouk, 2018; Talwar et al., 2020). In both cases, such studies concentrate on the first stages of the DoI decision-making process before adoption.

Notably, there is a lack of research into post-adoption decisions (Ng, 2020). The latter stages of the DoI decision process focus on adopters who have reached the implementation stage, putting the innovation into practice, and then the confirmation stage which can have one of two outcomes: 1) continue and retain the innovation, recognising the benefits, integrating it into routine and promoting it to others; or 2) discontinue the use of the innovation (Rogers, 2003 p199). From a sustainability perspective, there has been a growing interest in 1) the continuance of innovations, wanting to reduce waste and avoid obsolescence (Munten et al., 2021; van den Berge et al., 2021). Such literature predominantly focuses on the retention of products (e.g. Wells and Nieuwenhuis, 2018), and the business models of the circular economy (Jackson, 2017). Far less focus has been on 2) the post-adoption decision to discontinue an innovation.

2.2. Discontinuance of innovations

Of the discontinuance literature that does exist, inconsistency of vocabulary has been an issue, with several terms commonly used interchangeably. It is important to distinguish that our use of 'discontinuance' throughout this paper is Rogers (2003)'s broad definition previously used in Section 1 and does not adhere to the narrower distinct terminology clarified by Fenech (2011), such as: 1) 'disposal' the act of disposing an object; 2) 'dispossession' the parting of people from their object at the end of the consumption cycle; and 3) 'substitution' or 'replacement' stopping use of an innovation in order to use a newer or improved innovation. The above terms are deemed inappropriate for our study as we focus on both products (objects) and services (non-objects) which are relatively new to the market and so unlikely to be substituted for a 'newer' alternative as part of an ongoing dynamic of technological substitution.

In the following sections we focus on four broad influential factors (the individual, innovation, communication, and context) and hypothesise which characteristics are associated with discontinuance.

2.2.1. Individual characteristics

Within the literature, discontinuers are often thought to have certain individual characteristics, most commonly coupled to 'laggards' and 'late adopters' – the last population segments to adopt innovations (Rogers, 2003). Socio-demographics such as low education and low income as well as personality traits such as resistance to change and low innovativeness have been previously shown to be associated with discontinuance (Black, 1983). However, a more recent study by York and Turcotte (2015) found no significant association between such socio-demographics and the discontinuance of Facebook.

As we are interested in digital innovations at the start of their diffusion process, we are investigating discontinuance amongst innovators and early adopters who comprise the initial 15 % market share in Rogers' stylised adopter segmentation. Such discontinuers are not expected to display 'laggard' characteristics, but rather traits which would have led them to early adoption in the first place such as openness to change and innovativeness. If we expect discontinuers to display similar socio-demographics and personality traits as continuing adopters, which individual characteristics help explain discontinuance? In Gokhale and Narayanaswamy (2006)'s study of IT software discontinuance, they state that regardless of how functionally advanced and beneficial an innovation might be, a lack of skills and competency which hinder the correct use of the innovation may lead them to underestimate the overall value and in turn lead them to discard the innovation.

H_1. Discontinuance occurs amongst individuals with a lack of competency.

2.2.2. Innovation attributes

Another factor impacting diffusion dynamics is the innovation itself and its perceived attributes (Rogers, 2003). There are five dominant functional attributes in diffusion theory shown to influence adoption rates (relative advantage, compatibility, complexity, trialability and observability). Some researchers have extended this list to encompass more specific domain attributes or symbolic attributes such as environmental or social benefits (e.g., Pettifor et al., 2020). If attributes are negatively perceived, this can contribute to slower diffusion. In relation to discontinuance, previous research has identified association with either specific attributes such as a lack of usefulness (relative advantage) and compatibility (Parthasarathy and Bhattacherjee, 1998) or broader groups of attributes such as perceived functional attributes not being met after first-hand experience (Chi et al., 2016; Gokhale and Narayanaswamy, 2006; Huang et al., 2020). Such studies focussed on IT systems and online services and are therefore highly applicable to our research.

H_{2a}. Discontinuance occurs when experiences of functional attributes

do not meet prior perceptions.

The type of innovation, be it product or service, and its associated costs have also been found to influence discontinuance. In particular, status quo bias may exert a greater influence on post-adoption decisions for product innovations with higher sunk costs (Recker, 2014). Status quo bias increases the tendency to persist with innovations once adopted. It results from the evaluation of sunk costs in comparison to transition costs. Sunk costs are the initial investments of money, time, or effort. Transition costs capture the time and effort of adapting to a new situation versus the time and effort already invested in learning to use the existing system (Recker, 2014, p. 5). Sunk costs for product innovations weigh heavily because an adopter wants to draw as much benefit as possible from the initial capital investment (Buchwald et al., 2018). In contrast, service innovations, particularly those on a pay-per-use basis, carry lower sunk costs. If transition costs in each case are similar, product innovations are less likely to be discontinued. While the initial adoption decision is very important in the case of products, post-adoption behaviour (continued adoption or discontinuance) assumes greater importance for subscription-based digital services (Parthasarathy and Bhattacherjee, 1998).

H_{2b}. Discontinuance is more likely to occur for services than products.

2.2.3. Communication and social influence

A dominant premise of DoI theory is the importance of the flow of information through communication channels and social influences impacting adoption decisions. When it comes to post-adoption decisions (Roger's 'confirmation stage'), there is conflicting evidence on the importance of such factors. Some research has shown that social influence decreases with a growing experience of a technology, i.e., post adoption (Venkatesh et al., 2003; Venkatesh and Morris, 2000). In contrast, Sanders and Hume (2019) state that individuals seek reinforcement for the innovation decision already made and may reverse this decision if exposed to conflicting messages. If social influences such as word-of-mouth (WOM) and perceived social norms (what people believe others do) are positive, this provides the reassurance that an innovation is socially acceptable to continue using it. If social influences are negative this can have the opposite effect as found by Lehrer (2015)'s study of GPS mobile apps. Buchwald et al. (2018) also argued that for vibrant and controversial new technologies, in their case self-tracking devices, social influence from an adopter's referent social group continuously occurs post-adoption and can change the direction of adoption intention due to new circumstances (e.g., negative news about the device manufacturer).

H_3. Discontinuance occurs if positive reinforcing social influence is lacking.

2.2.4. Contextual factors

Beyond the characteristics of the individual, innovation attributes, and social communication, many different contextual factors interact with and impact upon decision-making processes. Changes in contextual factors over time can alter perceptions of an innovation's appeal, encouraging or discouraging adoption and retention (Black, 1983). We distinguish two broad categories of contextual factors: 1) changes in personal context (originating, caused by, or affecting the individual, such as a new job or moving house); and 2) changes in external context (originating or caused by forces outside of the individual and affecting everyone, such as regulations or pandemics).

2.2.4.1. Personal context. Notable changes in personal circumstances such as moving home, starting a new job, or having a baby, break routine and habitual behaviours and are referred to as 'moments of change' (Verplanken et al., 2018; Verplanken and Whitmarsh, 2021). These shifts in individual life circumstances have been shown to provide ideal opportunities for individuals to try new things, such as sustainable transport modes (Thøgersen, 2012) or waste reduction measures (Verplanken and Roy, 2016). Nevertheless, the same moments of change could also impact upon perceptions of an innovations appeal, deeming it less advantageous than before. Taking the example of transport choices, an individual who previously used ride-sharing apps to commute may move to a rural area where lack of availability becomes a barrier resulting in discontinuance.

H_{4a}. Discontinuance occurs when changes in personal circumstances reduce innovation appeal.

2.2.4.2. External context. External changes include those which occur for all of society: 1) government policy and regulations e.g., rules on supply chains or international trade, as well as data management and privacy; 2) infrastructure e.g., road and rail transport networks and digital communication networks; 3) geographical availability (especially relevant for service-based innovations); and 4) market prices.

Although a wide range of external factors can shape post-adoption decisions, during our study Covid-19 was clearly the dominant change in external context impacting across our entire sample of innovations.

2.2.4.3. Covid-19. With Covid-19 declared a global pandemic, governments around the world including the UK introduced 'stay at home' orders to slow the rate of the virus spreading (Cabinet Office, 2020). Daily life drastically altered for most citizens, with different aspects of life impacted more than others (see Cruz-Cárdenas et al. (2021) for a literature review on Covid-19 and consumer behaviours). The disruption of being confined at home resulted in abstinence from previous activities such as travel (flying was down 60 % in 2020 and use of public transport including rail was down 30 %). People who continued to travel altered behaviours. Shared modes of travel were substituted by private vehicle use and active modes, particularly in cities (ITF, 2020). Beyond travel, general activity shifted from offices and retail to homes (Octopus Energy, 2020). Households learnt to adapt to new practices and ways of coordinating and organising everyday life (Boons et al., 2020). Experiences of the pandemic have also been strongly shaped by gender, class, age and ethnicity (Weill et al., 2020).

Evidence suggest that nationwide confinements and social distancing caused the pandemic to impact all four elements of our analytical framework for discontinuance (Fig. 1). More specifically, Covid-19 impacted: 1) the use of and need to improve digital skills - *individual characteristics* (Garcia et al., 2021); 2) usefulness and useability under lockdown conditions - *innovation attributes* (Strutner, 2020); 3) restrictions on physical interaction (Giuntella et al., 2021) and maintenance of social networks - *communication and social influence* (UCL, 2020; Vrain et al., 2020); and 4) dramatic reductions in physical mobility (Le Quéré et al., 2020; Schlosser et al., 2020) except walking and cycling (Kraus and Koch, 2021) - *contextual factors*.

Understanding the magnitude and range of Covid-19's impacts on discontinuance is especially important for digital low carbon innovations to guide necessary green recovery policies fit for a digitalising world (Gerwe, 2021).

H_{4b}. Discontinuance occurs due to Covid-19 lockdowns and other restrictions.

2.3. Low carbon digital products and services

Digitalisation of daily activities is rapidly increasing. Global internet use in 2020 was up by 38 % from the previous year (ITU, 2020). The average time spent on the internet using mobile devices has increased nearly five-fold compared to ten years ago (Statista, 2021a). The number of connected devices grew by 13 % from 2019 to reach over 8.7 billion in 2020 (Statista, 2021b). Advancements in cloud computing, big data analytics, and artificial intelligence have enabled a wealth of possibilities to arise for consumers (OECD, 2019). Of the many possibilities,

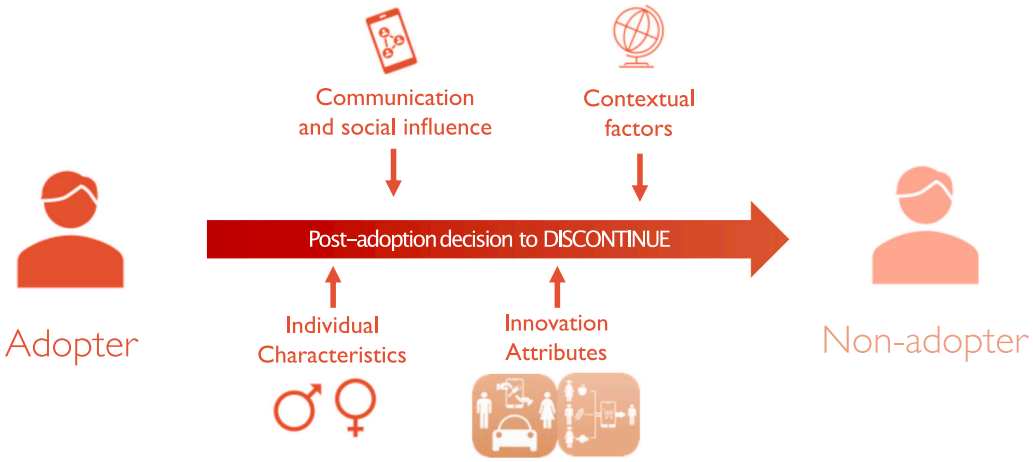

Fig. 1. Discontinuance framework.

several help reduce energy demand. For example, through real-time flow of information between connected devices, consumers can share goods and services by matching demand with supply consequently reducing overall consumption. Another example includes the ability to shift energy demand through connected devices like smart heating controls responding to weather data and energy prices (IEA, 2019).

In the digital era, many innovations are service-based rather than physical products (Libai et al., 2009). Digital services provide a unique opportunity for consumers to trial an innovation without large sunk investments in terms of time, effort, or monetary costs. However, this appealing trialability is thought to be associated with issues of low customer retention if commitment is low (Parthasarathy and Bhattacherjee, 1998). Consequently, discontinuance research has increasingly shifted from its traditional emphasis on consumer products to focus on digital services like internet banking (Laukkanen, 2016), private accommodation booking (Huang et al., 2020), fitness tracking (Buchwald et al., 2018), and social media (Ng, 2020).

To our knowledge there is still no research on the discontinuance of digital services offering clear potentials to reduce carbon emissions. Many low carbon digital services are offered as monthly subscriptions (e.g., meal kit deliveries, car club membership) or as on-demand access (e.g., ridesharing during a journey, collection of food produce that would otherwise be wasted through 11th hour apps). We investigate this important class of innovations along with digitally enabled low carbon products to test our hypotheses and validate the generalisability of our insights on factors influencing their discontinuance.

3. Method

3.1. Repeated measures survey

A repeated measures online survey was conducted in the UK, Wave 1 in 2019 and Wave 2 in 2020. The survey investigated a set of 16 consumer-facing innovations (Table 1) illustrative of the changing possibilities available to consumers as a result of digitalisation. Such possibilities include: substituting physical for digital, accessing services instead of owning goods, and integrating households into supply networks. Innovations selected were on the fringes of market share and span across multiple domains which all require significant reductions in CO2 emissions. These are mobility, food, homes, and energy. The 16 innovations consist of both products and services, are impacted by different social influences (Vrain et al., 2022) and cover a range of attribute appeal (Pettifor et al., 2020). All the innovations were pre-screened regarding their positive contribution to climate change (Wilson et al., 2020).

The survey was administered to a nationally representative sample by a market research company (Dynata) and took approximately 20 min to complete. A sample of 995 respondents completed both Wave 1 and Wave 2. Survey questions used for analysis in this paper are provided in Supplementary Data, whilst both full survey instruments and further details of the sampling method and data quality checks are accessible in Data Availability.

The online survey consisted of 9 blocks of questions (Table 2). The first block established the respondents' adoption experience of all 16 innovations (current adopter, past adopter, non-adopter but had heard of the innovation, or non-adopter and had never heard of the innovation). During Wave 1 of the survey (July–September 2019), respondents were then allocated as an adopter or non-adopter to answer standardised blocks of questions on attributes and social influences regarding one specific innovation (topics 2–6, Table 2). Although each innovation was clearly and neutrally defined, to ensure response quality, non-adopters were not allocated to an innovation they had not heard of. The quota sampling design was used to target 100 adopters and 100 non-adopters for each innovation so we could compare the distinctive characteristics of adopters (results comparing adopters and non-adopters from Wave 1 are published in Wilson et al., 2022).

Further blocks of questions captured individual characteristics such as socio-demographics, digital skills, and online use (topics 7–9, Table 2). All questions pivoted based on both the innovation and adoption status each respondent was assigned to. Questions used either single items or multi-item scales based on both newly developed items or established precedents from the literature with slight modifications to fit our research context e.g., environmental and technology activity scales used by Axsen et al. (2013), the short form of Stern's scale "brief inventory of values" (Stern et al., 1998), and domain innovativeness scale from Goldsmith and Hofacker (1991). Many questions consisted of statements with agreement or disagreement captured using a 5-point Likert scale for which 1 = strongly disagree, 5 = strongly agree.

During Wave 2 (November–December 2020) the same blocks of questions were used. Question wording remained the same to accurately capture changes in adoption status and influencing factors on the decision process. As in Wave 1, all respondents were first asked about their adoption experience of all 16 innovations. They were then allocated to blocks of more specific questions for the same innovation they were allocated in Wave 1. Additional questions in Wave 2 were included to capture insights on the impact of Covid-19 on various topics such as innovation use and social networks.

3.2. Data analysis

3.2.1. Identification of discontinuers

Based on respondents' adoption experience of specific innovations in

Table 1
Low carbon digital innovations in our study, along with their domain, type, name, definition, and an example (adapted from Wilson et al., 2020).

Domain	Type - Service (S) / Product (P)	Innovation	Definition	Example[a]
Transport	S	Carsharing (car clubs in the UK)	A membership-based service offering short-term rental of vehicles	Zipcar
	S	Peer-to-peer (P2P) carsharing	Networks of car owners making their vehicles available to others for short-term rental	Turo
	S	P2P ride-sharing (liftsharing in the UK)	Networks connecting passengers and drivers for shared car journeys or commutes	Liftshare
	S	Shared ride-hailing or taxis	Cars or minivans with multiple passengers on similar routes, booked on short notice via apps	UberPool
	S	Mobility-as-a-service	App-based scheduling, booking, and payment platform for multiple transport modes	Whim
	P	Electric vehicles	Vehicles with electric motor propulsion and a battery that is recharged from external sources	Nissan Leaf
	P	*E*-bikes	Bicycles with an electric motor and battery for assisting with pedalling up to limited speeds	Jump
Food	S	Digital hubs for local food	Buy food for delivery directly from multiple local producers	Open Food Network
	S	Meal kits (or meal boxes)	Home deliveries of fresh produce pre-portioned for cooking specific recipes	Hello Fresh
	S	11th hour apps	Food outlets advertise surplus fresh food at reduced prices	Too Good to Go
Home	P	Smart heating systems	Monitoring, automation, adaptive learning, and control (via app) of heating	Nest
	P	Smart lighting	Customization and control (via app) of lighting	Philips Hue
	P	Smart home appliances	Automation and control (via app or by utilities) of white goods and other large appliances	Samsung Smart Fridge
Energy	P	Domestic electricity generation with storage	Electricity generated domestically stored in a battery system to maximize own-consumption	Tesla Powerwall
	S	P2P electricity trading	Networks of households for trading surplus electricity generated domestically.	Brooklyn Microgrid
	p	Electric vehicle-to-grid	Allowing bidirectional flows of energy between the grid and batteries of electric vehicles	DriveElectric V2G

[a] The example column draws mainly on current US and UK markets.

Table 2
Blocks of questions included in the survey.

#	Topic	Description
1	Adoption	Current experience of 16 innovations (in the four domains)
2	Domain activity	Current behaviour in one domain (transport, food, homes, energy)
3	Domain innovativeness	Propensity to adopt innovations in one domain
4	Innovation familiarity	Familiarity with one innovation
5	Innovation attributes	Perceptions of functional and symbolic attributes of one innovation
6	Innovation information	Information-seeking and social influence on one innovation
7	Social network	Social network position and role
8	Personal characteristics	Personality, lifestyle, and values
9	Personal situation	Circumstances, living conditions, and socioeconomics

Wave 1 and Wave 2, we allocated each respondent to one of the following adoption statuses:

Discontinuers (treatment group): respondents who were adopters in Wave 1 and then stated they had stopped being adopters in Wave 2 ($n = 168$).
Adopters (control group 1): respondents who were adopters in Wave 1 and then stated they were still adopters in Wave 2 ($n = 182$).
Non-adopters (control group 2): respondents who were non-adopters in Wave 1 and then stated they were still non-adopters in Wave 2 ($n = 623$).

A smaller sub-sample of 22 respondents adopted an innovation (*new adopters*) between Wave 1 and 2. Due to our article's focus on discontinuance of digital innovations, this sub-sample of *new adopters* are excluded from our analyses, resulting in a total sample of 973 respondents. Fig. 2 illustrates our hypotheses within the innovation adoption-decision process, in addition to highlighting respondents' possible allocated adoption status for our analyses.

3.2.2. Hypothesis testing

To investigate influences on innovation discontinuance (hypotheses H_1 – H_{4b}), we first developed specific constructs from our survey (Supplementary Data) and then tested for differences between our treatment group (*discontinuers*) and control group 1 (the upper bound baseline of '*adopters*'). This established the ways in which *discontinuers* are distinctive from persistent *adopters*. This method was informed by a

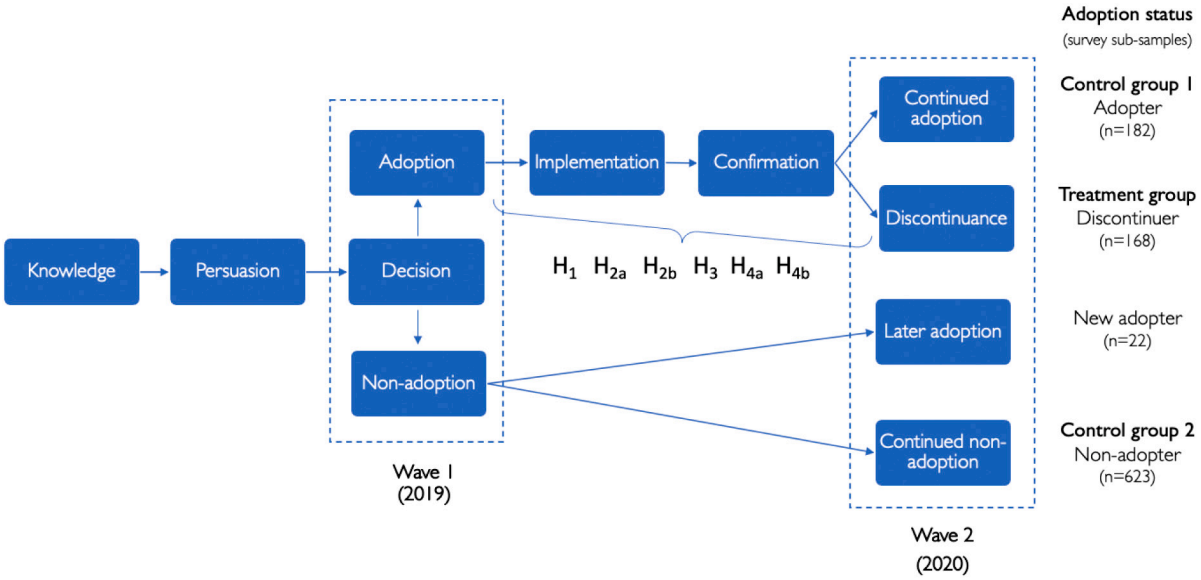

Fig. 2. Hypotheses testing within the innovation adoption decision process (adapted from Rogers, 2003) showing change over time in adoption status of survey respondents between Wave 1 and Wave 2.

similar group comparison conducted by Parthasarathy and Bhattacherjee (1998) when studying post-adoption behaviour in the context of online services.

We then conducted post-hoc tests comparing *discontinuers* with control group 2 (the lower bound baseline of '*non-adopters*') to see if *discontinuers* are uniquely distinctive or whether they were anomalous adopters in the first place in having more in common with non-adopters.

3.2.3. Statistical analysis

For characteristics considered to be stable over time such as personal values, we used absolute values from Wave 2 data in the same manner as Siegrist and Bearth (2021). χ^2 tests were used for count variables, independent *t*-tests for continuous variables and Mann Whitney *U* tests for categorical variables. For characteristics considered to change over time, we used paired t-tests to compare change in mean difference in items between Wave 1 and Wave 2. Significance testing for change within items is based on the null hypothesis that change is not significantly different from zero ($p < .05$). We then conducted independent *t*-tests comparing the absolute differences between the treatment group and two control groups.

Assumptions for the independent t-tests were predominantly met, with no significant outliers in the data and independence of observations. Levenes test confirmed equal variance for each group and where unequal variance was found Welchs correction was used. Approximate normal distributions were verified with Shapiro-Wilks tests. Non-parametric tests were used for variables with non-normal distributions. This includes the use of $\chi 2$ tests for count data, in which cell sizes were always higher than 5 and therefore meet the requirements for approximations to be valid.

4. Results

4.1. Change in adoption status

All survey respondents were asked about their adoption of 16 digital low carbon innovations in Wave 1 and Wave 2. Overall, for each innovation, a clear majority of respondents did not change their adoption status (>90 %). Respondents who changed adoption status were more likely to discontinue rather than newly adopt, apart from meal kits and smart home technologies for which a larger number of respondents adopted rather than discontinued adoption between Wave 1 and 2.

As previously mentioned, 973 respondents were allocated to either the treatment group or one of the control groups depending upon their adoption status of their allocated innovation. Fig. 3 provides detail on the composition of the three groups regarding their distribution across the innovations.

4.2. Individual characteristics

4.2.1. Differences between discontinuers and adopters

We compare multiple characteristics of individuals expected to influence post-adoption decision processes. In line with H_1 we expected *discontinuers* to lack competency compared to *adopters*. We found *discontinuers* to be similar to *adopters* in their personal values and social media use. In contrast, significant differences were found between the two groups, with *discontinuers* more likely to be employed, have school children, and to live in urban areas. They were also found to have a lower non-stated preference score of 'revealed innovativeness' and a higher mean score for 'digital skills' (the variable we used to determine competency) (all $p \leq .01$, Table 3). Results do not support H_1 as *discontinuers* were not found to lack competency.

4.2.2. Differences between discontinuers and non-adopters

Although *discontinuers* were found to be different to *adopters* in some respects, these differences do not bring them in line with the *non-*

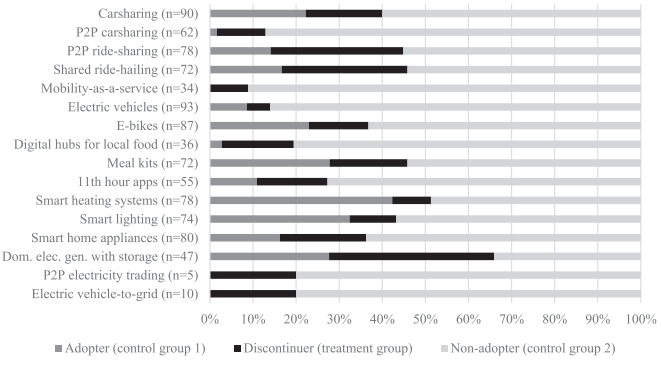

Fig. 3. Percentage change between Wave 1 and Wave 2 in adoption status for specific innovations (total $n = 973$).

Table 3
Individual characteristics using data from Wave 2. Significant differences indicated between groups.

		Discontinuers $n = 168$ (treatment)	Adopters $n = 182$ (control 1)	Non-adopters $n = 623$ (control 2)	Between group analysis	
					treatment and control 1	treatment and control 2
Socio-demographics[a]	Gender	62 % male, 38 % female	65 % male, 35 % female	53 % male, 47 % female		
	Mean age range	45–54 years	55–64 years	55–64 years		
	Over 45 years old	66 %	73 %	83 %		**
	Mean education	≥Undergrad. degree	≥Undergrad. degree	≥Undergrad. degree		
	Mean household income	£30,000 - 34,999	£40,000 - £44,999	£25,000 - £29,999		
	Household's gross income < £25,000	28 %	27 %	39 %		**
	Employed	75 %	51 %	49 %	**	**
	Household with school children	25 %	13 %	12 %	**	**
	Lives in a village or rural	23 %	32 %	24 %	**	
Value orientation[b]	Values - Openness to change	0.16	0.12	−0.11		**
	Values - Self-transcendence	0.00	0.07	−0.02		
	Values - Self enhancement	0.13	0.06	−0.09		*
	Values - Conservation	−0.08	0.04	0.04		
Activities and skills[b]	Environmental activities	0.43	0.07	−0.06		*
	Technological activities	0.13	0.27	−0.22		**
	Digital skills	0.54	0.26	−0.27	**	**
Innovativeness[b]	Revealed innovativeness	1.13	1.65	0.29	**	**
Online social media use[c]	Social media use (n of types)	2.70	2.46	1.85		**
	Time spent on social media	2.80	2.81	2.52		**
	Time spent interacting on social media	2.30	2.29	2.09		**

* $p \leq 0.05$.
** $p \leq 0.01$.
[a] $\chi 2$ test results.
[b] Independent t-test results.
[c] Mann Whitney test results.

adopters. Significant differences were found between *discontinuers* and *non-adopters* for most individual characteristics (Table 3). Overall, results reveal discontinuers to present typical traits of 'innovators' (young, employed, high income, open to change, innovative, digitally skilled, and active online). This is not consistent with certain literature's expectations of *discontinuers* being laggards, nor does it help explain why H_1 may or may not have held.

4.3. Innovation attributes

To test H_{2a}, we first examined changes over time within group responses regarding perceived innovation attributes (*non-adopters*) or experienced innovation attributes (*discontinuers and adopters*). We then compared such changes between *discontinuers* and the control groups. In line with H_{2a} we expected *discontinuers* to have a greater decline in mean

Table 4
Innovation attributes using data from Wave 1 and Wave 2. Within group analysis representing changes overtime (absolute differences, standard deviations, and paired *t*-test results) and between group analysis (independent t-test results).

		Within group analysis Absolute difference between Wave 1 and Wave 2 (SD)			Between group analysis	
		Discontinuers -treatment	Adopters - control 1	Non-adopters -control 2	treatment and control 1	treatment and control 2
Functional attributes	Relative advantage	−0.41 (1.44)**	−0.02 (1.39)	−0.16 (1.50)**	**	*
	Profitability	−0.05 (1.51)	0.00 (1.51)	−0.09 (1.24)		
	Perc. behavioural control	−0.30 (1.53)*	−0.19 (1.56)*	−0.03 (1.52)		*
	Convenience	−0.44 (1.48)**	−0.01 (1.45)	−0.15 (1.57)**	**	**
	Perceived need	−0.41 (1.57)**	−0.15 (0.23)	−0.18 (1.45)**		*
	Choice	−0.33 (1.38)**	−0.08 (1.32)	−0.13 (1.52)**	*	
	Control	−0.31 (1.45)**	0.01 (1.44)	−0.16 (1.50)**	**	**
	Compatibility practical	−0.49 (1.59)**	−0.06 (1.51)	−0.12 (1.55)**	**	**
	Compatibility cognitive	−0.53 (1.46)**	−0.19 (1.33)**	−0.12 (1.52)**	**	*
	Ease of use	−0.28 (1.53)*	−0.06(1.58)	−0.03 (1.53)		
	Observability	−0.08 (1.55)	−0.17 (1.61)	−0.20 (1.10)**		
	Trialability	−0.03 (1.49)	−0.05 (1.64)	−0.08 (1.07)		
Symbolic attributes	Image	−0.32 (1.48)**	−0.25 (1.41)**	−0.13 (1.50)**		
	Symbolic private	−0.08 (1.51)	−0.12 (1.16)	−0.22 (1.55)**		
	Community	−0.06 (1.56)	−0.07 (1.54)	−0.10 (1.20)*		
	Symbolic public 1	−0.18 (1.52)	−0.14 (1.09)	−0.15 (1.52)**		
	Symbolic public 2	−0.09 (1.58)	−0.24 (1.57)*	−0.18 (1.55)**		
	Environment	−0.11 (1.50)	0.06 (1.10)	0.05 (1.53)		
	Climate change	−0.07 (1.54)	0.01 (1.50)	0.04 (1.56)		

* $p \leq 0.05$.
** $p \leq 0.01$.

attribute scores compared to *adopters*. Table 4 reports the results of innovation attributes, identifying both in-group (change overtime) and between group differences. Across all three groups we found a general decrease in mean attribute scores across both functional and symbolic attributes (within group analysis, Table 4).

4.3.1. Differences between discontinuers and adopters

Discontinuers significantly changed their views of more functional attributes, becoming more negative between Wave 1 and Wave 2 compared to *adopters* (between group analysis, Table 4). Consistent with H_{2a}, one interpretation is that *discontinuers'* experiences of an innovation were not favourable and did not meet prior expectations.

4.3.2. Differences between discontinuers and non-adopters

Comparing *discontinuers* to *non-adopters* to further aid interpretation, *discontinuers* were also found to decrease mean functional attributes scores significantly more than *non-adopters*. This further supports H_{2a} and provides evidence that *discontinuers* experienced functional attributes do not bring them in line with *non-adopters* and their perceived attributes.

4.3.3. Products and services

To explore whether discontinuance is more likely for low-carbon services than for products (H_{2b}) in our sample, we analysed responses separately for service innovations and product innovations (see Table 1 for product vs. service classifications of our 16 innovations). A χ^2 test reveals a significant association between continuers and discontinuers of products, and continuers and discontinuers of services ($p \leq .01$). Services were found to be 2.24 times more likely to be discontinued compared to products. These results are consistent with H_{2b}.

4.4. Communication and social influences

Next, we considered social influence mechanisms and whether knowing an adopter influences discontinuance. We expected discontinuance to occur with a lack of positive reinforcing social influence (H_3).

4.4.1. Differences between discontinuers and adopters

Repeat sample *t*-tests revealed a significant negative change in social influences between Wave 1 and Wave 2 amongst *discontinuers* (WOM $p \leq .01$, electronic WOM and neighbourhood effect $p \leq .05$). *Adopters* on the other hand expressed a slight positive change across all four mechanisms, with social norms significantly increasing ($p \leq .05$, within group analysis, Table 5). Changes in WOM were significantly different between *discontinuers* and *adopters* ($p \leq .01$, between group analysis, Table 5), thus implying *discontinuers* either received more social information deterring use of an innovation such as negative WOM or experienced a general decrease in exposure to positive reinforcing social influences.

Furthermore, independent *t*-tests showed significantly fewer *discontinuers* knew another adopter compared to *adopters (1.16, 1.32* $p \leq .01$). Combined, our findings suggest discontinuance is associated with both a lack of receiving positive social influence, especially through forms of WOM, and not knowing another adopter, thus supporting H_3.

4.4.2. Differences between discontinuers and non-adopters

The differences found between *discontinuers* and *adopters* also map on to *non-adopters,* but with more types of social influence being significantly different (WOM $p \leq .01$, electronic WOM and neighbourhood effect $p \leq .05$, between group analysis, Table 5). Differences were also found between the number of respondents knowing an adopter, although here, significantly more *discontinuers* knew an adopter compared to the number of *non-adopters* knowing one *(1.16, 1.07* $p \leq .01$). In sum, results do not suggest *discontinuers* are exposed to similar social influences as *non-adopters*.

4.5. Contextual factors

4.5.1. Personal context

To investigate H_{4a}, we analysed variables measuring individual life changes such as income, job status, family size, and moving house. Table 6 presents the percentage of each group experiencing a specific change between waves. Analysing responses from *discontinuers* and *adopters*, χ^2 tests revealed only one significant relationship with discontinuance: a decline in financial situation. More *discontinuers* experienced a decline of their financial situation compared to *adopters*. This is consistent with our hypothesis that changes in contextual factors reducing an innovation's appeal could lead to discontinuance (H_{4a}). Analysing responses from *discontinuers* and *non-adopters* revealed no association between discontinuance and a change in personal context.

4.5.2. External context: Covid-19

Additional questions included in our Wave 2 survey on Covid-19 provide insights on the pandemic's effect on innovation discontinuance. Fig. 4 provides a high-level summary from our results of Covid-19's impacts on the use, opinion, and intentions towards innovations in different domains of activity. We compared responses from *discontinuers* with the two control groups on the effect of Covid-19 on the factors hypothesised to influence discontinuance (H_1–H_{4a}). Table 7 reports the mean responses and statistical test results. Values close to 3 indicate Covid-19 had no effect.

We found no significant differences between the *discontinuers* and *adopters* for all but one item (opinion of innovation impacted by Covid-19, $p \leq 0.05$, Table 7). *Adopters'* mean opinions were not affected (2.95), whereas *discontinuers'* opinions became more negative (2.81). Such differences in opinions are not observed been *discontinuers* and *non-adopters*, with both groups stating opinions declined in a similar way (2.81, 2.79).

Other than innovation opinion, overall, we found Covid-19 to be a truly exogenous factor, impacting all respondents in a similar way. In other words, there were no differentiating impacts of Covid-19 just on discontinuers, leading us to reject H_{4b}.

Table 5
Mean scores of social influence mechanisms from Wave 1 and Wave 2. Within group differences representing changes overtime (absolute differences, standard deviations, and paired *t*-test results) and between group differences (independent t-test results).

Social influences	Within group analysis Absolute difference between Wave 1 and Wave 2 (SD)			Between group analysis	
	Discontinuers - treatment	Adopters – control 1	Non-adopters - control 2	treatment and control 1	treatment and control 2
Word of mouth (WOM)	−0.48 (1.51)**	0.08 (1.56)	0.13 (1.46)**	**	**
Electronic WOM	−0.23 (1.55)*	0.05 (1.54)	0.05 (1.39)		*
Social norms	0.01 (1.57)	0.21 (1.56)*	0.14 (1.38)**		
Neighbourhood effect	−0.24 (1.58)*	0.02 (1.64)	0.04 (1.46)*		*

* $p \leq 0.05$.
** $p \leq 0.01$.

Table 6
Percentage of each group experiencing a change in personal context between Wave 1 and Wave 2. χ^2 test results identify variables with significant association with discontinuance.

Change between Wave 1 and Wave 2[a]		Discontinuers (treatment)	Adopters (control 1)	Non-adopters (control 2)	Between group analysis: Treatment and control 1	Between group analysis: Treatment and control 2
Income	Financial situation declined	35 %	24 %	28 %	*	
	Stopped working	4 %	12 %	3 %		
	Started working	2 %	2 %	2 %		
Household	Increase in household size	10 %	6 %	5 %		
	Decrease in household size	5 %	3 %	7 %		
Change in housing		10 %	6 %	7 %		

[a] Socio-demographics re-coded into dummy variables based on median response values.
* $p \leq .05$.

Response type	Transport	Food	Communication	Social networks
Domain activities	• 67% used their cars less (all) • 25% stopped their use of public transport (domain n=594) • 9% started using bikes/e-bikes or walking (domain n=594)	• 32% shopping less at supermarkets (all) • 24% increased their frequency of food delivery (domain n=208) • 35% increased the number of meals prepared from scratch at home.(domain n=208)	• 15% used smartphone apps more (all) • 27% increased the amount of time spent on social media (all) • 25% increased the amount of time spent interacting on social media with others (all)	• 54% interacted with a smaller number of both close friends and other social contacts (all) • 55% interacted less often with both close friends and other social contacts (all).

Response type	Transport innovations	Food innovations	Home innovations
Specific innovations	• Shared transport platforms most negatively impacted e.g. 33% of ride sharing adopters (n=21) and 58% of shared taxi adopters (n = 24) stopped using the innovation • 17-35% had a more negative opinion of shared transport platforms • 12-26% would be much less likely to use them in the next year.	• All three food innovations experienced an increase in use e.g., 27% used meal kits more (n=75) • Unchanged opinions and intentions	• All smart home technologies were used more e.g., 27% used smart heating more (n=144) • Unchanged opinions and intentions

Fig. 4. Summary of impacts of Covid-19 reported by survey respondents.

5. Discussion

Our results make an important contribution to the lesser explored element of DoI theory - the post-adoption decision making process of discontinuance. By comparing discontinuers to those who continued adoption, we discovered significant differences through our repeated measures data analysis, identifying factors likely impacting discontinuance.

Additionally, by comparing discontinuers to non-adopters we found discontinuers to be distinctly different. They do not share many traits with non-adopters, thus implying that they were not anomalous adopters in the first place.

We focus the following sub-sections on each of our key findings regarding the factors influencing discontinuance. We highlight the practical implications of our results and the necessary considerations needed for improving diffusion strategies of low carbon digital innovations.

5.1. Characteristics of discontinuers

We discovered discontinuers to exhibit individual characteristics most common to those of Rogers (2003) population segments known as ‘early adopters’ and ‘innovators’. With their openness to change and willingness to originally adopt digital innovations with low uptake rates, it is clear they are prepared to take risks. Our assumptions that a lack of competency would lead to discontinuance were not supported by our findings. As such, other factors in our discontinuance framework are more likely to influence discontinuance at this early stage in the diffusion process. One trait identified as distinct to discontinuers and worth noting here is their high digital skills combined with high social media use. Considering this alongside our results of a decline in positive social influence amongst discontinuers (further discussed in Section 5.3) suggests their discontinuance may have been influenced by an increased likelihood of being exposed to negative electronic WOM. It is important for businesses to be aware of this online activity and the types of adopters most likely to discontinue. This in turn helps guide managerial decisions to provide tailored post-adoption support such as targeting incentives or positive social information online. One example

Table 7
Mean scores on the impact of Covid-19 for factors hypothesised to influence discontinuance and significant between group differences. Values below 3 mean 'less due to Covid-19', values above 3 mean 'more due to Covid-19'.

				Between group analysis	
Covid-19's impact on…	Discontinuers (treatment)	Adopters (control 1)	Non-adopters (control 2)	treatment and control 1	treatment and control 2
Individual characteristics					
Technological activities	2.98	3.02	2.89		
Environmental activities	3.06	3.08	3.02		
Digital skills / smartphone use	3.18	3.11	3.12		
Social media use	3.22	3.30	3.19		
Social media interaction	3.14	3.26	3.18		
Innovation attributes					
Opinion of innovations	2.81	2.95	2.79	*	
Communication and social influence					
Word-of-mouth	2.99	2.92	2.90		
Electronic word-of-mouth	2.89	2.94	2.90		
Social norms	2.91	2.94	2.89		
Neighbourhood effect	2.88	2.88	2.88		
Contextual factors					
Financial situation	2.85	2.83	2.85		

Mann Whitney test result = *p ≤0.05.

considered to be successful is a P2P ride sharing platform offering targeted incentives through prize draws, sending notifications to members to encourage continued use and developing a sense of community to increase perceived social norms (Digital Factory, 2015).

5.2. Disenchantment of attributes

We found a greater reduction in attribute appeal amongst discontinuers compared to both adopters and non-adopters. Our analysis and careful design of longitudinal data collection strongly supports the notion that changes in experienced attributes influence post-adoption decision making processes leading to discontinuance. This is by no means guaranteed proof that changes in experienced attributes caused the decision to discontinue, but it undoubtedly provides stronger support for such a causal mechanism compared to the use of cross-sectional data analyses which would only capture a snap-shot in time (Vander-Weele et al., 2016).

During the implementation stage, a reduction in satisfaction of an innovations' attributes is known as 'disenchantment' (Rogers, 2003 p.190). Disenchantment can be caused by lack of information and misuse of an innovation, although in previous literature this has been found to be more common amongst later adopters (Parthasarathy and Bhattacherjee, 1998). Another cause more common to early adopters is the innovation's attributes being inappropriate for the individual or not sufficiently interesting (Kahma and Matschoss, 2017; Ng, 2018). As we also found service-based innovations to be discontinued more than products, this suggests services suffer greater disenchantment discontinuance, amplified by the ability of consumers to have lower sunk costs and commitment (Recker, 2014).

An important implication of disenchantment amongst early adopters is that it creates an early stumbling block in the diffusion process (Parthasarathy and Bhattacherjee, 1998). Large scale diffusion will not occur unless disenchantment is addressed as continued adoption is sensitive to their strong performance attributes. There is a real need from digital product and service providers for continued innovation to sustain market position relative to more familiar incumbents. One example of an innovation improving its appeal is digital farmers markets. In the past, many would only provide vegetable boxes at a collection point, but lack of convenience and choice led to 're-invention'. Now they provide delivery and wider selections of produce, thus appealing to a wider market (Olsen, 2021).

5.3. Social influence

Our results show that positive social influences were reduced amongst discontinuers. Whereas those who remained adopters expressed positive influence from various sources and were more likely to know another adopter in their social circles. We interpret these results as either: causal - the innovation was not reinforced socially, and thus the individual was more inclined to discontinue; or reverse causal - another factor i.e., innovation attributes, leads the individual to discontinue and this in turn leads to the innovation becoming less salient and thus social influence is perceived to be lower.

Whilst it is difficult to determine from our data whether such interaction is causal or reverse causal, a key implication of our findings is that social influences are an important element of the discontinuance framework. One strategy relevant to both scenarios outlined above is the need for industry to support the use of communication channels to spread positive messages and increase visibility and salience of an innovation (Vrain and Wilson, 2021). For example, encouraging continuing adopters to create trusted high quality online content about attributes through carefully structured review systems and feedback forms. This example of harnessing eWOM would be especially useful for innovations less traditionally visible i.e., smart technology within the home.

Although our data focusses on the impact of social influence on discontinuance, another related factor is the consequences of discontinuance on social influence. Here, we refer to the pertinent concept of 'negative interaction effect', the idea that influence of curtailing adoption by those who discontinue may be greater than the influence of promoting adoption by those who continue (Leuthold, 1967). A danger of discontinuance being unaddressed is the potential negative ripple effect of influence amongst social networks, hindering innovation adoption. Thus, reinforcing the need to act.

5.4. Context

We detected contextual changes amongst respondents at the personal level, however, only a decline in financial situation was found to have a relationship with discontinuance.

The external contextual factor we investigated was Covid-19. Despite the huge disruptions to daily life and the reporting of its unequal distribution of negative consequences (Giuntella et al., 2021; Weill et al.,

2020), our results indicate that in terms of behaviours and information flows relating to low carbon digital innovations, overall, Covid-19 had an equal impact. These include less travel, more online shopping and the shrinking of social networks. When it came to influencing the decision process to discontinue an innovation, our results suggest Covid-19 wasn't a significant direct factor. However, we did find significant negative influence of Covid on opinions, which can be interpretated as being linked to our findings on attribute importance.

Bringing together the key findings from our hypothesis testing, we provide a summary in Fig. 5 which identifies the key issues needing to be addressed from our discontinuance framework.

5.5. Further research

This paper focusses on a wide range of both: 1) factors potentially influencing discontinuance; and 2) digital low carbon innovations. This broad approach provides valuable generalisable insights, however a limitation of our research is that sample sizes for analysis at the innovation level are too small to provide robust findings for a specific innovation.

Building upon our repeat survey methodology, we recommend further research to collect panel survey data to provide longer time series to help determine whether discontinuance is likely to be temporary or permanent. Such a distinction in the factors causing the different types of discontinuance is necessary, as strategies to overcome permanent discontinuance would need to differ from those which are only temporary (Ng, 2020). Additional time series will also provide insights on the long-term impacts caused by Covid-19 as the world continues to tackle the pandemic. Future studies could also explore the possibility of testing the relationships between constructs using structural equation modelling as well as the indirect relationships to provide further insights.

Another recommendation for further research is to expand our investigation of external factors to include government regulations, incentives and other governance mechanisms which may impact upon post-adoption decision making.

6. Conclusion

A range of low carbon digital consumer innovations exist which provide an opportunity to improve both end-use and system energy efficiency, however, low rates of adoption hinder their potential. Research often focuses on the adoption process to inform scalable behavioural interventions, disregarding the post-adoption decision process of confirmation and whether discontinuance occurs.

Through focusing on the discontinuance of a diverse set of low carbon digital products and services, we find that experience of an innovation and its attributes are important determinants of post-adoption decisions. Notably, we find discontinuance of services more likely than products, highlighting the vulnerability of service-based innovation providers and the need for them to focus efforts on customer retention strategies. We also discover the importance of a range of social influences and the exposure to other adopters to provide reinforcing societal messages encouraging retention and continued adoption of an innovation. Covid-19 was found to have an overall negative impact on transport domain innovations especially the shared mobility platforms, however differences were not found between discontinuers and adopters in the magnitude of covid's impact, implying that covid was not an influencing factor in the decision-making process to discontinue.

In addition to accelerating the diffusion of low carbon digital innovations, it is crucial digital product and service providers prioritise to reduce discontinuance and ensure that consumers remain adopters in the long-term. Our findings provide insights for industry strategy development to help avoid discontinuance and to successfully transition to a low carbon society.

CRediT authorship contribution statement

Emilie Vrain: Writing- original draft and editing, Methodology, Formal analysis, Investigation. Charlie Wilson: Supervision, Conceptualization, Methodology, Funding acquisition, Writing - review & editing. Barnaby Andrew: Methodology, Formal analysis, Investigation.

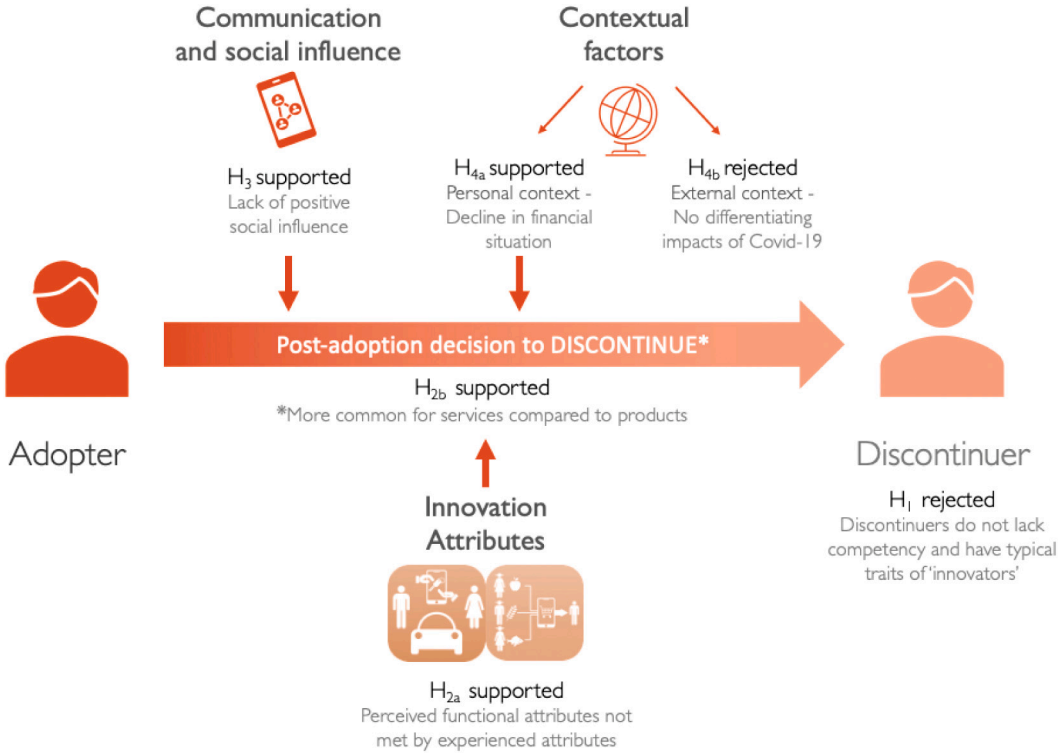

Fig. 5. Summary of key findings of our discontinuance framework.

Data availability

The two online survey datasets related to this article are available at ReShare (part of the UK Data Archive). Wave 1 is available at: https://reshare.ukdataservice.ac.uk/854723/, and Wave 2 is available at: https://reshare.ukdataservice.ac.uk/855005/

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2022.122051.

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