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Rejection of innovations: 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. Examples include smart home technologies for controlling heating, lighting and appliances and domestic electricity generation with storage for co-ordinating personal consumption and peak demand.

Whilst innovation literature predominantly focuses on processes for encouraging adoption; 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 homes, energy, mobility, and food domains. Our survey captured temporal changes in adoption, personal and contextual characteristics, communication, social influences, innovation experiences and perceived attributes. We compare responses of participants who discontinued an innovation with two control groups: 1) participants who continued adoption and 2) those who remained non-adopters. We also provide a unique contribution by assessing the impacts of Covid-19 on post-adoption processes, domain behaviour and information flow.

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 for industry and policy 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.

Introduction

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 (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. It is therefore necessary to understand why diffusion is not occurring 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). 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.

Objective and overview of paper

Our aim is to improve understanding of the post-adoption processes for innovations that are digital or digitally enabled and potentially offer lower carbon alternatives to mainstream consumption. We conducted a repeated measures survey with UK consumers to capture changes in the adoption dynamics for 16 innovations, analysing the results through the lens of Rogers (2003)'s well-established theory of the Diffusion of Innovations (DoI).

Literature review

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). The majority of studies focus on the decision making process which leads to a 'positive' outcome: gaining knowledge, being persuaded, and deciding to adopt (van Oorschot et al., 2018). To a far lesser extent, researchers have focused on factors leading to non-adoption otherwise known as rejection or resistance (Huang et al., 2021; Talwar et al., 2020). In both cases, studies concentrate on the first stages of DoI decision-making.

There is a notable 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. Such literature predominantly focuses on the retention of products (e.g. van den Berge et al., 2021), and the business models of the circular economy (e.g., Jackson, 2017). Far less focus has been on 2) the post-adoption decision to discontinue. In the following sections we focus on four broad factors (the individual, innovation, communication, and context) and hypothesise which characteristics are associated with discontinuance.

Discontinuance of innovations

Individual characteristics

Within the literature, discontinuers are thought to have certain individual characteristics commonly coupled to 'laggards' – 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 have been previously 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 investigate 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 a study on IT software discontinuance, Gokhale and Narayanaswamy (2006) 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 the adopter 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

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

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 decision processes due to new circumstances e.g., negative news about the device manufacturer.

H_3 Discontinuance occurs if positive reinforcing social influence is lacking

Contextual factors

Beyond the individual, innovation, and 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).

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). 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). 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 may move to a rural area where lack of availability results in discontinuance.

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

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., transport and digital communication networks; 3) geographical availability; 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.

Covid-19

Covid-19 drastically altered daily life for most citizens, with different aspects impacted more than others. 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 with shared modes of travel 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).

Evidence suggest that nationwide confinements and social distancing caused the pandemic to impact all four factors investigated in this paper. 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 and maintenance of social networks - *communication and social influence* (Vrain et al., 2020)*;* and 4) dramatic reductions in physical mobility (Le Quéré et al., 2020) - *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

Low carbon digital products and services

Digitalisation of daily activities is rapidly increasing. 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, 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 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.

Our unique contributions are: 1) a focus on influential factors leading to discontinuance (rather than adoption) of a wide range of low carbon digital innovations across four consumption domains, 2) the collection and analysis of temporal data to gain detailed insights on change dynamics; and 3) the inclusion of empirical data capturing the impacts of Covid-19 on discontinuance processes, domain behaviour and information flow.

Method

Repeated measures survey

A repeated measures survey was conducted online with 995 UK residents during July - September 2019 (Wave 1) and November - December 2020 (Wave 2). The survey investigated 16 low carbon product and service-based innovations from across domains (mobility, food, homes, and energy), with varying attribute appeal, illustrative of the changing possibilities available to consumers as a result of digitalisation (Table 1) (Wilson et al. 2020).

The online survey was administered to a nationally representative sample by a market research company (Dynata) and took approximately 20 minutes to complete. The survey consisted of 9 blocks of questions. 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 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. Further blocks of questions captured individual characteristics such as socio-demographics, digital skills, and online use. All questions pivoted based on both the innovation and adoption status each respondent was assigned to. Questions used either single or multi-item scales based on both established precedents from the literature (with slight modifications to fit our research context) and newly developed items. 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 question wording remained the same to accurately capture changes in adoption status and influencing factors on decision processes. Respondents were allocated to the same innovation as in Wave 1. Additional questions were included in Wave 2 to capture insights on the impact of Covid-19 on various topics such as innovation use and social networks. Both survey instruments are accessible in Data Availability.

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

	Service (S) / Product (P) Innovation		Definition
Transport	S	Carsharing / car clubs	A membership-based service offering short-term rental of vehicles
	S	P2P carsharing	Networks of car owners making their vehicles available to others for short-term rental
	S	P2P ride / lift sharing	Networks connecting passengers and drivers for shared car journeys or commutes
	S	Shared ride-hailing or taxis	Vehicles with multiple passengers on similar routes, booked short notice via apps
	S	Mobility-as-a-service	App-based scheduling, booking, and payment platform for multiple transport modes
	P	Electric vehicles	Vehicles with elec. motor propulsion and a battery recharged from external sources
	P	E-bikes	Bicycles with an electric motor and battery for assisting with pedalling
Food	S	Digital hubs for local food	Buy food for delivery directly from multiple local producers
	S	Meal kits (or meal boxes)	Home deliveries of fresh produce pre-portioned for cooking specific recipes
	S	11th hour apps	Food outlets advertise surplus fresh food at reduced prices
Home	P	Smart heating systems	Monitoring, automation, adaptive learning, and control (via app) of heating
	P	Smart lighting	Customization and control (via app) of lighting
	P	Smart home appliances	Automation and control (via app) of white goods and other large appliances
Energy	P	Domestic electricity generation with storage	Electricity generated domestically stored in a battery system to maximise own-consumption
	S	P2P electricity trading	Networks of households for trading surplus electricity generated domestically.
	p	Electric vehicle-to-grid	Allowing bidirectional flows of energy between the grid and electric vehicle batteries

P2P - Peer-to-peer

Data analysis

Identification of discontinuers

Based on respondents' adoption experience of specific innovations in Wave 1 and Wave 2, we allocated each respondent to one of the following adoption statuses:

- *Discontinuers (treatment group):* adopters in Wave 1 and stopped being adopters in Wave 2 (n=168).
- *Adopters (control group 1):* adopters in Wave 1 and were still adopters in Wave 2 (n=182).
- *Non-adopters (control group 2):* non-adopters in Wave 1 and 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. As we focus on discontinuance, this sub-sample of *new adopters* are excluded from our analyses, resulting in a total sample of 973 respondents.

Hypothesis testing

To investigate influences on innovation discontinuance ($H_1 – H_{4b}$), we first developed constructs from our survey 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 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 and have more in common with non-adopters.

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 for 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 ($p<0.05$). 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. Figure 1 illustrates our hypotheses within the innovation adoption-decision process, in addition to highlighting respondents' possible allocated adoption status for our analyses.

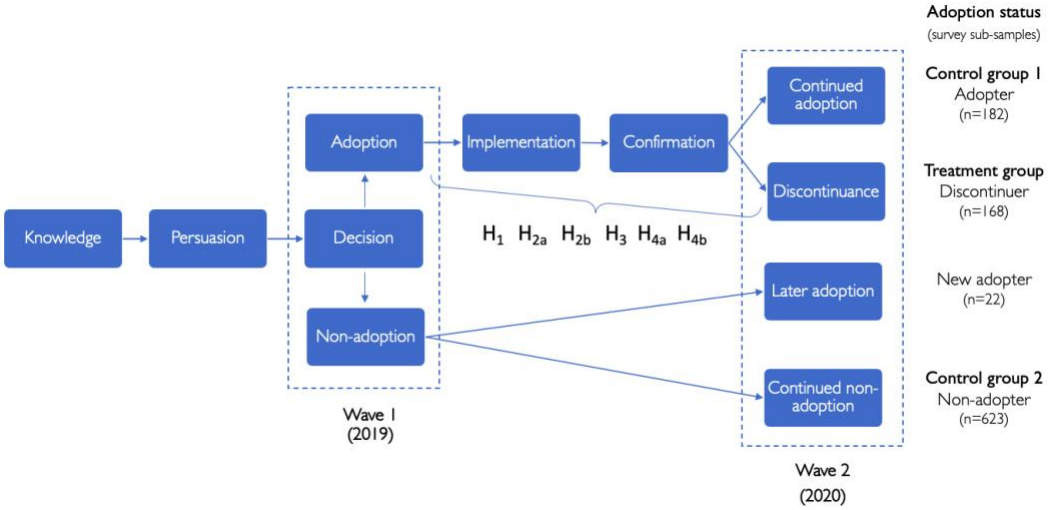

Figure 1. Hypotheses testing within the innovation adoption decision process (adapted from Rogers, 2003) showing change over time in adoption status of survey respondents between Wave 1 and Wave 2.

Results

Individual characteristics

We compared characteristics of individuals expected to influence post-adoption decision processes. 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 use to determine competency) (all $p \leq .01$, Table 2). Results do not support H_1 as *discontinuers* were not found to lack competency.

Although *discontinuers* were found to be different to *adopters* in some respects, these differences do not bring them in line with the *non-adopters*. Significant differences were found between *discontinuers* and *non-adopters* for most individual characteristics (Table 2). Overall, results reveal discontinuers to present typical traits of 'innovators' (young, employed, high income, open to change, innovative, digitally skilled, and active online).

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 (Table 3). Across all three groups we found a general decrease in mean attribute scores across both functional and symbolic attributes (within group analysis, Table 3).

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 3). Such findings support H_{2a}.

Comparing *discontinuers* to *non-adopters*, *discontinuers* were also found to decrease mean functional attribute 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.

Products and services

To explore whether discontinuance is more likely to occur for low-carbon services than products (H_{2b}), we analysed responses separately for each (see Table 1 for innovation classifications). Of the 168 *discontinuers*, a larger percentage (59%) had discontinued a service compared to a product (41%). In contrast, a larger percentage of the 182 *adopters* were adopters of products (61%) compared to services (39%). A χ^2 test reveals a significant association between the number of products and services and the number of *discontinuers* and *adopters* ($p \leq .01$). Consistent with H_{2b}, services were found to be 2.24 times more likely to be discontinued compared to products.

Communication and social influences

Next, we consider social influence mechanisms and whether knowing an adopter influences discontinuance. Repeat sample t-tests revealed a significant negative change in social influences among *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 3). Changes in WOM were significantly different between *discontinuers* and *adopters* ($p \leq .01$, between group analysis, Table 3). 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.

The differences found between *discontinuers* and *adopters* also map on to *non-adopters*, but with more types of social influence being significantly different (between group analysis, Table 3). 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*.

Table 2. Individual characteristics. Significant differences indicated between groups.

		Discontinuers (treatment)	Adopters (control 1)	Non-adopters (control 2)	Between group analysis treatment & control 1	treatment & control 2
Socio-demographics[a]	Gender (male, female)	62%, 38%	65%, 35%	53%, 47%		
	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 (hh) income	£30,000 - 34,999	£40,000 - £44,999	£25,000 - £29,999		
	Hh income < £25k	28%	27%	39%		**
	Employed	75%	51%	49%	**	**
	Hh with school children	25%	13%	12%	**	**
	Lives in a village or rural	23%	32%	24%	**	
Value orientation[b]	Openness to change	0.16	0.12	-0.11		**
	Self-transcendence	0.00	0.07	-0.02		
	Self enhancement	0.13	0.06	-0.09		*
	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	**	**
Innovative[b]	Revealed innovativeness	1.13	1.65	0.29	**	**
Online social media (soc. med.) use[c]	Soc. med. use (n types)	2.70	2.46	1.85		**
	Time on soc. med.	2.80	2.81	2.52		**
	Time interacting on soc. med.	2.30	2.29	2.09		**

**p ≤ .05, **p ≤.01, [a]χ2 test results, [b]Independent t-test results, [c]Mann Whitney test results*

Table 3. Innovation attributes and social influences. Within group analysis representing changes overtime (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 & control 1	treatment & 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)		
Social influences	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 ≤ .05, **p ≤.01

Contextual factors

Personal context

Analysing variables measuring individual life changes such as income, job status, family size, and moving house, χ^2 tests revealed only one significant relationship with discontinuance: a decline in financial situation ($p \leq .05$). More *discontinuers* (35%) experienced a decline of their financial situation compared to *adopters* (24%). This is consistent with our hypothesis that changes in contextual factors reducing an innovation's appeal lead to discontinuance (H_{4a}). Analysing responses from *discontinuers* and *non-adopters* revealed no association between discontinuance and a change in personal context.

External context: Covid-19

Additional questions included in our Wave 2 survey on Covid-19 provide insights on the pandemic's effect on general behaviours as well as specific innovation discontinuance. Overall, covid-19 had an equal impact across respondents: less travel, more online shopping, and the shrinking of social networks. Mobility innovations were negatively impacted with regards to usage, opinions, and likelihood to start using in the next year. The one exception was e-bikes for which prospects were less negative. Food and home innovations such as meal kits, food apps, and smart home technologies saw usage increase, although opinions and near-term growth potential remain largely unchanged.

We compared responses on the effect of Covid-19 on the factors hypothesised to influence discontinuance. We found no significant differences between the *discontinuers* and *adopters* for all but one item (opinion of innovation impacted by Covid-19, $p \leq 0.05$). With values close to 3 indicating Covid-19 had no effect, *adopters*' mean opinions were found to not be 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, 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}.

Discussion

Our results make an important contribution to an under explored element of DoI theory - the post-adoption decision 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, highlighting their practical implications and the necessary considerations needed for improving diffusion strategies of low carbon digital innovations.

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 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 tailored post-adoption support such as targeting incentives or positive social information online. For example, a P2P ride sharing platform could offer targeted incentives through prize draws, send notifications to members to encourage continued use and develop a sense of community to increase perceived social norms (Digital Factory, 2015).

Disenchantment of attributes

We found a greater reduction in attribute appeal amongst discontinuers compared to both adopters and non-adopters. Our analysis of longitudinal data strongly supports the notion that changes in experienced attributes influence post-adoption decision making processes leading to discontinuance. This is by no means a proof of causality, but it undoubtedly provides stronger support compared to the use of cross-sectional data analyses.

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 diffusion (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 for continued innovation to sustain market position relative to more familiar incumbents. One example of an innovation improving its appeal is digital farmers markets. Previously, 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 product choice, thus appealing to a wider market (Olsen, 2021).

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 discontinuance. A strategy relevant to both scenarios above is the need 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 visible i.e., smart home technology.

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. Furthermore, our results on Covid-19 indicate that in terms of behaviours and information flows relating to low carbon digital innovations, Covid-19 had an equal impact across respondents: 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-19 on opinions, which can be interpretated as being linked to our findings on attribute importance.

Bringing together the key findings from our analysis, we provide a summary in Figure 3 which identifies the key issues needing to be addressed for discontinuance.

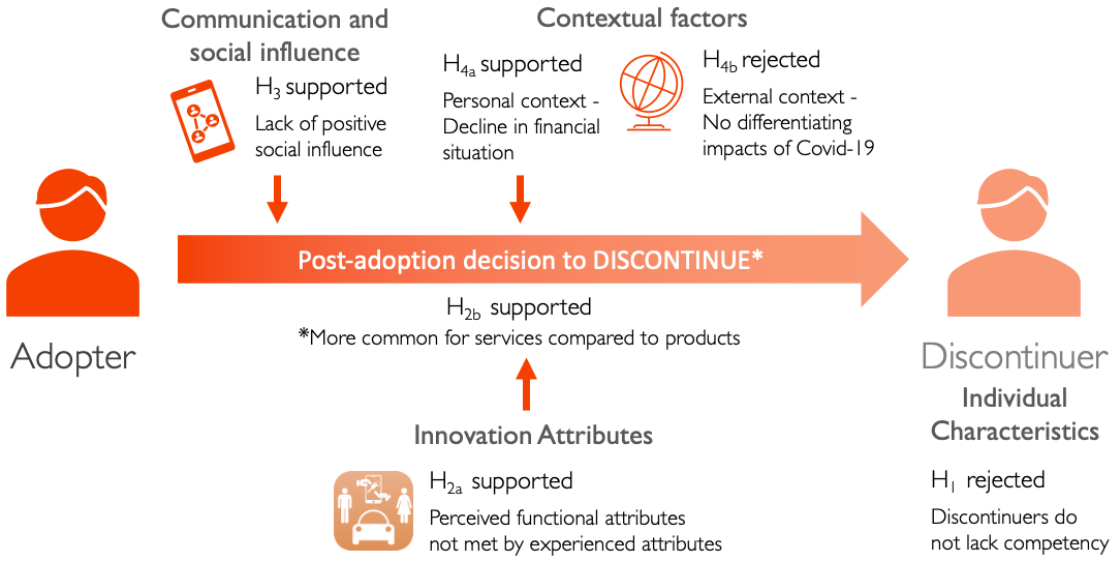

Figure 3. Summary of key findings of our discontinuance framework

Limitations and 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 is that sample sizes 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.

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 to reduce discontinuance and ensure that consumers remain adopters in the long-term.

Our findings provide insights for strategy development to help avoid discontinuance and to successfully transition to a low carbon society.

Data Availability

The two online surveys and 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/

References

Black, W., 1983. Discontinuance and Diffusion: Examination of the Post Adoption Decision Process, in: Bagozzi, R.P., M., T.A. (Eds.), NA - Advances in Consumer Research Volume 10. The Association for Consumer Research, Ann Abor MI, pp. 356–361.

Buchwald, A., Letner, A., Urbach, N., Von Entreß-Fürsteneck, M., 2018. Insights into personal ICT use: Understanding continuance and discontinuance of wearable self-tracking devices. 26th Eur. Conf. Inf. Syst. Beyond Digit. - Facet. Socio-Technical Chang. ECIS 2018.

Chi, Y., Kang, M., Han, K., Choi, J., 2016. A Study on the Discontinuance Intention on O2O Commerce: With a Focus on the Mediating Effects of Perceived Risk and User Resistance. Int. J. u- e- Serv. Sci. Technol. 9, 207–218. https://doi.org/10.14257/ijunesst.2016.9.2.21

Clausen, J., Fichter, K., 2019. The diffusion of environmental product and service innovations: Driving and inhibiting factors. Environ. Innov. Soc. Transitions 31, 64–95. https://doi.org/10.1016/j.eist.2019.01.003

Digital Factory, 2015. Using "BlaBla" for Success - The case of BlaBlaCar.

Garcia, K.R., Rodrigues, L., Pereira, L., Busse, G., Irbe, M., Almada, M., Christensen, C., Midão, L., Dias, I., Hardy, R., Quarta, B., Poulain, M.M., Karnikowski, M., Costa, E., Irbe, M., Almada, M., Christensen, C., Midão, L., Dias, I., Heery, D., Quarta, B., Poulain, M.M., Bertram, M., Karnikowski, M., 2021. Improving the digital skills of older adults in a COVID-19 pandemic environment. Educ. Gerontol. 47, 196–206. https://doi.org/10.1080/03601277.2021.1905216

Gerwe, O., 2021. The Covid-19 pandemic and the accommodation sharing sector: Effects and prospects for recovery. Technol. Forecast. Soc. Change 167, 120733. https://doi.org/10.1016/j.techfore.2021.120733

Gokhale, R.A., Narayanaswamy, R.S., 2006. The Role of Experience in Discontinuance of IT Innovation. Proc. 2006 South. Assoc. Inf. Syst. Conf. 1–7.

Gripenberg, P., Sveiby, K., Segercrantz, B, 2021. The Prevailing Pro-Innovation Bias, in: Sveiby, K.-E., Gripenberg, Pernilla, Segercrantz, Beata (Eds.), Challenging the Innovation Paradigm. Routledge, New York, p. 12.

Huang, D., Coghlan, A., Jin, X., 2020. Understanding the drivers of Airbnb discontinuance. Ann. Tour. Res. 80, 102798. https://doi.org/10.1016/j.annals.2019.102798

Huang, D., Jin, X., Coghlan, A., 2021. Advances in consumer innovation resistance research: A review and research agenda. Technol. Forecast. Soc. Change 166, 120594.

IEA, 2019. Energy Efficiency 2019.

ITF, 2020. Re-spacing Our Cities for Resilience. Paris, France.

Jackson, T., 2017. Prosperity without growth: Foundations for the economy of tomorrow., Second edt. ed. Routledge, Abingdon, Oxfordshire.

Kahma, N., Matschoss, K., 2017. The rejection of innovations? Rethinking technology diffusion and the non-use of smart energy services in Finland. Energy Res. Soc. Sci. 34, 27–36.

Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernethy, S., Andrew, R.M., De-gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G., Friedlingstein, P., Creutzig, F., Peters, G.P., 2020. Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. Nat. Clim. Chang. 10, 647–654. https://doi.org/10.1038/s41558-020-0797-x

Lehrer, C., 2015. Examining discontinuers' Word-of-mouth behaviour in the context of mobile location-based services. 23rd Eur. Conf. Inf. Syst. ECIS 2015 2015-May, 0–20.

Libai, B., Muller, E., Peres, R., 2009. The diffusion of services. J. Mark. Res. 46, 163–175.

Ng, Y., 2018. Building an Innovation Discontinuance Model: The Case of Twitter. The University of Texas.

Ng, Y., 2020. Re-examining the innovation post-adoption process: The case of Twitter discontinuance. Comput. Human Behav. 103, 48–56.

Octopus Energy, 2020. Energy consumption under social distancing measures.
OECD, 2019. Going Digital: Shaping Policies, Improving Lives, OECD Publishing. Paris, France.
OECD, 2018. Consumer Policy and the Smart Home, OECD Digital Economy Papers.
Olsen, B., 2021. 10 best vegetable boxes that deliver fresh produce straight to your door. Independent. https://www.independent.co.uk/extras/indybest/food-drink/subscription-boxes/best-veg-boxes-vegetables-delivery-organic-fruit-uk-local-subscription-a9597846.html (accessed 10.10.21).
Parthasarathy, M., Bhattacherjee, A., 1998. Understanding Post-Adoption Behavior in the Context of Online Services. Inf. Syst. Res. 9, 362–379. https://doi.org/10.1287/isre.9.4.362
Pettifor, H., Wilson, C., Bogelein, S., Cassar, E., Kerr, L., Wilson, M., 2020. Are low-carbon innovations appealing? A typology of functional, symbolic, private and public attributes. Energy Res. Soc. Sci. 64, 101422.
Recker, J., 2014. Towards a Theory of Individual-level Discontinuance of Information Systems Use., in: Proceedings of the Thirty Fifth International Conference on Information Systems. Auckland.
Rogers, E.M., 2003. Diffusion of Innovations, 5th ed. Free Press.
Sanders, M., Hume, S., 2019. Social Butterflies: Reclaiming the Positive Power of Social Networks. Michael O'Mara Books Limited, London, UK.
Siegrist, M., Bearth, A., 2021. Worldviews, trust , and risk perceptions shape public acceptance of COVID-19 public health measures.
Strutner, S., 2020. 12 Examples of Smart Business Adaptations Amid COVID-19. Oracle. https://www.netsuite.com/blog/12-examples-of-smart-business-adaptations-amid-covid-19 (accessed 8.5.21).
Talwar, S., Talwar, M., Kaur, P., Dhir, A., 2020. Consumers' resistance to digital innovations: A systematic review and framework development. Australas. Mark. J. 28, 286–299.
Thøgersen, J., 2012. The importance of timing for breaking commuters' car driving habits., in: Warde, A., Southerton, D. (Eds.), The Habits of Consumption. Helsinki Collegium for Advances Studies, Helsinki, pp. 130–140.
TWI2050, 2020. Innovations for Sustainability: Pathways to an efficient and post-pandemic future. https://doi.org/10.22022/TNT/07-2020.16533
van den Berge, R., Magnier, L., Mugge, R., 2021. Too good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention. Curr. Opin. Psychol. 39, 66–71.
van Oorschot, J.A.W.H., Hofman, E., Halman, J.I.M., 2018. A bibliometric review of the innovation adoption literature. Technol. Forecast. Soc. Change 134, 1–21. https://doi.org/10.1016/j.techfore.2018.04.032
Venkatesh, V., Morris, M.G., 2000. Why Don't Men Ever Stop to Ask for Directions? Gender, Social Influence, and Their Role in Technology Acceptance and Usage Behavior. MIS Q. 24, 115–139.
Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003. User Acceptance of Information Technology: Toward a Unified View. MIS Q. 27, 425–478.
Verplanken, B., Roy, D., Whitmarsh, L., 2018. Cracks in the wall: habit discontinuities as vehicles for behavior change., in: B, V. (Ed.), The Psychology of Habit. Springer.
Vrain, E., Ryan, L., Grossetti, M., 2020. Lockdown ' funnelling ': how the pandemic has changed our relationships. Conversat. URL https://theconversation.com/lockdown-funnelling-how-the-pandemic-has-changed-our-relationships-141831 (accessed 1.20.21).
Vrain, E., Wilson, C., 2021. Social Influence in the Adoption of Digital Consumer Innovations to Mitigate Climate Change, in: BEHAVE 2021 6th European Conference on Behaviour and Energy Efficiency, Virtual, 21- 23 April 2021.
Wells, L., 2021. Too Good To Go UK reaches food waste milestone. Talk. Retail. https://www.talkingretail.com/news/industry-news/too-good-to-go-uk-reaches-food-waste-milestone-25-06-2021/ (accessed 8.3.21).
Wilson, C., Kerr, L., Sprei, F., Vrain, E., Wilson, M., 2020. Potential climate benefits of digital consumer innovations. Annu. Rev. Environ. Resour. 45, 13.1-13.32.
York, C., Turcotte, J., 2015. Vacationing from Facebook: Adoption, Temporary Discontinuance, and Readoption of an Innovation. Commun. Res. Reports 32, 54–62. https://doi.org/10.1080/08824096.2014.989975

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