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Does perception of automation undermine pro-environmental behaviour? Findings from three everyday settings

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ABSTRACT

The global deployment of technology to aid mitigation of climate change has great potential but the realisation of much of this potential depends on behavioural response. A culturally pervasive reliance on and belief in technology raises the risk that dependence on technology will hamper human actions of mitigation. Theory suggests that 'green' behaviour may be undermined by automated technology but empirical investigation has been lacking. We examined the effect of the prospect of automation on three everyday behaviours with environmental impact. Based on evidence from observational and experimental studies, we demonstrated that the prospect of automation can undermine even simple actions for sustainability. Further, we examined the process by which automated technology influences behaviour and suggest that automation may impair personal responsibility for action.

1. Introduction

The deployment of technology to counter climate change is in many respects a paradox. Despite the increasing demands for energy due to the advances of technology, technology is also part of the solution. Global wind energy capacity has almost tripled in the past five years, with major construction programmes for wind turbines in place in India, Brazil, Mexico, South Africa and many other countries (GWEC, 2014). Germany has already succeeded in generating more than 50% of its electricity demand through solar energy in June 2014 (Vidal, 2014) and demand response based on smart metering rollout has been argued to have the potential to achieve 25–50% of the EU's 2020 target for CO_2 reduction (CapGemini, 2008).

Reliance on technology is culturally pervasive. The popular press frequently emphasises the power and potential of science and technology to save humanity, in presenting the topic of global warming and climate change. A generalised and universal faith in technology is well-documented (Hogan, 2011; Litfin, 2003; Ramakrishnan, 2002) and such discourses are perhaps inevitably drawn upon in facing the challenges of global warming. Commentators have seen a turn towards ecological modernisation in policy, in which technological innovation is expected to lead to reduced environmental impact even as environmental protection pressures (social and economic) drive technological development (Mol & Sonnenfeld, 2000). Research on responses to climate change amongst the general public has confirmed the prevalence of technological fix discourses "both as a hope and as an expectation" (Stoll-Kleemann, O'Riordan, & Jaeger, 2001). Belief in technology has been described as an ideology with "an element of the magical" that fulfils existential needs (Dickinson, 2009, p. 7). So belief in technological solutions as a panacea for climate change and energy challenges provides psychological as well as potential physical benefits, to the general public and policy makers alike.

But concerns have been raised about the consequences of such faith in technology. Voices of warning have argued that reliance on technology may undermine progress on reducing greenhouse gas emissions (Ridgwell, Freeman, & Lampitt, 2012): technology touted as a solution may divert effort from individual action to mitigate environmental impact. It is this proposition that the current research investigated, specifically, does the prospect of automated technology undermine people's pro-environmental behaviour? By pro-environmental behaviour, we mean actions which reduce adverse environmental impact, whether intentionally or not.

Why does it matter whether automation hinders people's 'green' behaviour when an automated technical solution will

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ensure sustainable outcomes? For several reasons, technology cannot achieve fully optimal solutions: technical, economic and psycho-social challenges persist. Take the case of automated lighting systems – a relatively well-understood and simple domain in which automation is being introduced to increase energy efficiency. Technical challenges remain: in-building light levels drop exponentially with distance from windows (Littlefair, 1996) so how can optimal light and energy efficiency be achieved in a multi-occupancy office for workers at the windows and those deep within the floor plan served by the same lighting circuit? Economic challenges remain: despite the potential benefit in energy reduction offered by enhanced lighting technology, the investment and payback period are perceived as barriers to deployment in offices (DECC, 2012). Psycho-social challenges remain: in the home, how can automation aimed at energy efficiency deal with switching on lights for cheer on a gloomy day, for feelings of security, for a welcome for visitors? Thus despite the enormous potential benefits which technology offers, technical, economic and psycho-social challenges limit the extent to which automation can achieve optimal pro-environmental efficiency. Human behaviour remains crucially important, alongside technological solutions, to minimise wasteful, energy-inefficient actions. In many cases, the realisation of significant mitigation depends not only on the technology but also on behavioural responses. People have to accept wind farms, buy electric vehicles, use the home heating thermostat effectively, change consumption in response to signals on the smart meter display device and enable sleep mode on appliances: "The technology itself does not change behaviour" (Faber, Schroten, Bles, Sevenster, & Markowska, 2012, p. 44). For achievement of the planned benefits of technology for climate change mitigation, behaviour is clearly important.

Much research has looked at why behaviour has not already become more environmentally friendly. Factors contributing to the status quo of limited pro-environmental action include economic and physical contexts, and lack of information as well as psychological factors, such as habits, values and social norms (Cialdini, Reno, & Kallgren, 1990; de Groot & Steg, 2010; Jackson, 2009; Strbac, 2008; Verplanken, Aarts, van Knippenberg, & Moonen, 1998). User-friendliness or appeal of particular technologies has been explored (e.g. Hargreaves, Nye, & Burgess, 2010) but there is a deeper level at which technology may be problematic. We argue that a reliance on technology may in fact hinder mitigation behaviours and may undermine motivation towards pro-environmental behaviour.

Economic studies have shown that technological improvements may have adverse effects on people's behaviour. Enhancements to energy efficiency can induce increased demand for energy services, a phenomenon termed 'rebound' (Khazzoom, 1980), and increased demand can even surpass the gains in efficiency or 'backfire' (Saunders, 1992). In transport, for example, there is evidence of a relationship between improved fuel efficiency and increasing number of kilometres driven (Hymel, Small, & Van Dener, 2010). In the domestic setting, energy abatement behaviours such as reducing the heating thermostat setting have been shown to result in an overall rebound effect of 34%, which ranged from 12% to backfire (>100%) (Druckman, Chitnis, Sorrell, & Jackson, 2011). From an economic perspective, it appears that the introduction of technical solutions may result in rebound.

From a psychological perspective, the potential influence of automated systems on human behaviour has been examined in safety-critical systems (e.g. Goddard, Roudsari, & Wyatt, 2012; Mosier, Skitka, Burdick, & Heers, 1998) though such research has tended to focus on the mechanics of attention. Little research has examined the influence of automated systems on human behaviour more generally in everyday life, that is, in non-critical settings where attention may not be the salient cognitive process. Previous research in the discipline of human–computer interaction has focused on how we can use technology better: we wanted to examine the question of what pervasive automated technology does to our impulses towards pro-environmental behaviour.

We chose three domains from everyday life for study: lifts (elevators), automatic doors and lighting. We explicitly link such behaviours with environmental impact. In general, although gains in energy efficiency have resulted in each product consuming relatively less power, the pervasiveness of these and other technologies continue to drive increasing energy demands – the paradox described earlier. The domains selected for study can be seen to exemplify technologies which require relatively little energy but cumulatively, through their ubiquity, have substantial power requirements. Our primary objective was to determine if the prospect of automation undermined behaviour in these domains. Having found evidence supporting the influence of automation on behaviour, we additionally conducted an exploratory study to test a theoretically based hypothesis on the psychological process underlying the effect. We now briefly outline the theoretical background to the final study.

Two theoretical perspectives suggest that dependence on technology may indeed reduce attempts at pro-environmental behaviour. First, the norm activation model of pro-environmental behaviour (Schwartz, 1977) proposes that a feeling of moral obligation or a 'personal norm' influences environmentally-friendly intention and behaviour. A personal norm for 'green' action is in turn influenced by a sense of responsibility to act (de Groot & Steg, 2009). From this theoretical perspective, if automation reduces or removes a personal sense of responsibility, the likelihood of the outcome behaviour is undermined. Second, people tend to conserve effort – human action is purposeful rather than random and potentially wasted (Richter, 2013). If a task can be done by automated technology, individuals may simply allow the technology to complete the task in order to conserve effort. Thus the psychological processes by which automation may undermine behaviour is by weakening the responsibility to act or by triggering the drive to conserve effort or through both mechanisms.

In summary, our primary research question investigated the perception of automation on three everyday behaviours:

> In the contexts of calling a lift, exiting a door and switching off lights, is individual behaviour undermined by the prospect of automation?

Our subsidiary question, theoretically-based and aiming to explore the psychological processes involved, was:

> If so, in terms of process, does the prospect of automation influence both personal responsibility and effort?

Our research approach was in four stages. Stages I, II and III investigated the primary research question to provide empirical evidence of the influence on behaviour of the prospect of automation. The final Stage IV was an exploratory study to suggest a potential underlying process:

Stage I Conduct field studies to assess if automation undermines behaviour in real-life contexts.
Stage II Establish a robust baseline behaviour which can be manipulated under laboratory conditions.
Stage III Conduct controlled study on the baseline behaviour to assess if it is undermined by automation.
Stage IV Conduct survey studies to test if both responsibility and effort are influenced by automation.

In total, nine studies were conducted. Table 1 summarises the studies by stage, hypothesis, outcome and interpretation. Each study is described in turn below with respect to method and results. For brevity, studies are grouped where appropriate and discussion on individual studies is included only where necessary. The University Ethics Committee reviewed and approved the laboratory studies and the survey studies. Participants were assured of anonymity and confidentiality and volunteered their informed consent. The field studies observed everyday behaviour in the public domain and did not collect data on individuals and therefore did not require ethical approval.

2. Stage I the effect of automation on real-life behaviours

2.1. Study I.1: Lift (Elevator) – Field Study

Whether through undermining of personal responsibility or conservation of effort or a combination of these factors, people may be inclined to let technology take action on their behalf. To test this proposition, we sought a simple everyday behaviour with environmental impact and selected using a lift. We conducted a basic experimental manipulation to assess the effect of a sign indicating that a lift would arrive automatically. Our hypothesis was that the sign should result in people being slower to push the call button for the lift, having paused to allow it to arrive automatically, compared to the normal condition in which lift users used the button to summon the lift.

2.1.1. Method – Study I.1

Data were collected in an office building over four weekdays during the morning peak time of the lift use (8:00–9:30 am). The lift users were office workers, who chose to use the lift during observation times. After observing the neutral condition ('Push button to call lift') for two days, the test condition ('Lift arrives automatically') was then observed for a further two days. One hundred and forty lift calls were observed, with seventy cases each in the neutral and test groups. Lift users were timed by an observer with a stop-watch from the point of entering the lift lobby until pressing the lift button. The observer was positioned with a direct line of sight for observation (see Fig. 1). As the observer was visible to lift users, a sign saying 'Stairs and Lift Footfall Survey – Summer' was placed on the wall next to the observer's location to provide a credible reason for observation. The observer avoided interaction with lift users as far as possible. People who did not press the lift button or who interacted extensively with the observer (thereby potentially influencing timed behaviour) were excluded from the study. Behaviour was timed on a smartphone stopwatch and recorded on paper. Additional notes were also taken for unusual observed behaviours such as not pushing the button and taking the stairs after waiting for the lift to arrive automatically.

2.1.2. Results – Study I.1

Data from cases in which the button was not pushed were excluded (4 cases who appeared to have fully accepted the implication of automated lift arrival). Data analysis first consisted of initial screening for normality and outliers in each condition. Neither baseline nor test conditions were normally distributed, with four outliers in the baseline condition and thirteen in the test condition found by inspection of boxplots. However, the outliers were not excluded in order to not compromise the random chance and representativeness of the sample (Osborne & Overbay, 2004). The baseline mean was 2.81 (std. dev. = .81) and the test condition mean was 7.04 (std. dev. = 18.63). A Mann–Whitney U test of difference on 140 cases (70 in each condition) was chosen as appropriate for non-normal data distribution and was significant ($p < .05$), providing initial support for the hypothesis that the assumption of automation had delayed, and in some cases prevented, usual behaviour. The outliers may be considered as additionally supporting the hypothesis, with 19% of cases in the test condition as outliers at the positive side of the distribution. That is,

Table 1
Summary of studies.

Study	Study name	Hypothesis under test	Outcome	Interpretation
Stage I the effect of automation on real-life behaviours				
I.1	Lift (Elevator) – Field Study	A sign indicating automation delays users calling the lift	Significant difference: people slower to call lift with automation sign	People are waiting for automation instead of completing the task themselves
I.2	Automatic Door – Field Studies	A sign indicating automation delays users exiting through door	Significant difference: people slower to exit through door with automation sign	People are waiting for automation instead of completing the task themselves
I.3	Automatic Door – Field Studies	A sign indicating automation delays users exiting through door but a neutral sign does not	Significant difference for automation sign but not for neutral sign	Delay in previous door study was not attributable to the presence of sign → automation undermines behaviour
Stage II the baseline behaviour				
II.1	Lighting – Field Studies	People are more likely to switch the light off leaving a room if the light had been off when they entered	Significant difference: if the light was off on entry, people much more likely to switch it off on leaving	In real-life setting, people more likely to switch off the light when it is off to begin with
II.2	Lighting – Lab Study	Effect in Study II.1 was not due to repeat visits or individual pro-environmental motivation	Significant difference maintained: repeat visits and pro-environmental motivation did not influence the effect	In both laboratory conditions and real-life setting, a robust baseline behaviour is evident
Stage III the effect of automation on the baseline behaviour				
III.1	Lighting Automation – Lab Study	Automation undermines the baseline behaviour	No significant difference for automation condition (between light initially on or off conditions)	Automation undermined the robust baseline behaviour
III.2	Lighting Automation – Lab Study	Replication of III.1 with simpler manipulation	No significant difference for automation condition	Automation undermined the robust baseline behaviour
Stage IV process of undermining behaviour: responsibility and effort				
IV.1& IV.2	Evaluation of Home Systems	Automation influences both responsibility and effort	Automation related to abdication of responsibility but not conservation of effort	Automation may hinder behaviour through abdication of responsibility rather than conservation of effort.

in 13 cases, the individuals took much longer than most to push the button. Although a limitation of the study was the potential non-uniqueness of participants between conditions, the direction of effect, if any, was likely to be a reduction of the test effect: the participants will have seen the 'push button to call lift' instruction before the sign indicating automation.

2.2. Studies I.2 and I.3: Automatic Door – Field Studies

We sought to replicate the finding in another domain, again with environmental impact and where people may expect automation. On our university campus, all buildings have automatic doors for some but not all entrances. We hypothesised that a sign saying 'Automatic door' would result in a slower pace as people would pause to allow the door to open automatically on their behalf.

2.2.1. Method – Studies I.2 and I.3

Two busy sites on campus were selected: in the library building and in a refectory (see Figs. 2 and 3). In both sites, the researcher found inconspicuous seating close to the door, such that the pace of people exiting through the door could be timed. By using a feature in each context, a specific imaginary line marked the start of timing. The end of the timed interval was when the door was opened to the extent that the opening door cleared the door-frame, that is, the point at which the observer could first see through the door. In the baseline condition, people were timed in their normal progression to the door. In the test condition, a sign saying 'Automatic door' was placed on each door. The sign replicated the standard building information sign used extensively on the university campus and was therefore familiar to building users. Exit times were measured on a smartphone stopwatch and recorded on a laptop computer.

In the refectory, data were collected on three non-consecutive days for approximately 2 h from 11 am. Refectory users were university staff, students and campus visitors. Any occurrences where progress appeared impeded were not recorded. Three egresses by a member of refectory staff (identifiable by their uniform) were noted and not used in analysis (as refectory staff may have been aware that the door was not automated). A total of 32 cases in the control condition and 28 cases in the intervention condition (with sign) were used in analysis.

In the library, data were collected over three days, for approximately 2 h in the early afternoon. Library users were predominantly students. Any occurrences where progress appeared impeded or where the door was not fully closed at the start of timing were not recorded. Egresses by library staff (identifiable by their coloured lanyard holding staff identification cards) were not recorded. A total of 40 cases in the control condition and 40 cases in the intervention condition were used in analysis. The nature of both sites meant that multiple return visits in the observation periods were unlikely although we did not control for multiple visits by individuals.

2.2.2. Results – Studies I.2 and I.3

In both locations, a significant difference was found: people were slower to open the door when a sign saying 'Automatic door' was in place (library: No Sign mean = 2.31, std. dev. = .34; Automation Sign mean = 2.65, std. dev. = .58; $t(1, 80) = 3.19$, $p < .01$, effect size medium $r = .33$; refectory: No Sign mean = 2.12, std. dev. = .51; Automation Sign mean 2.45, std. dev. = .53; $t(1,58) = 2.45$, $p < .05$, $r = .31$, t-tests two-tailed). In two different

Fig. 1. Lift showing placement of label above lift call button.

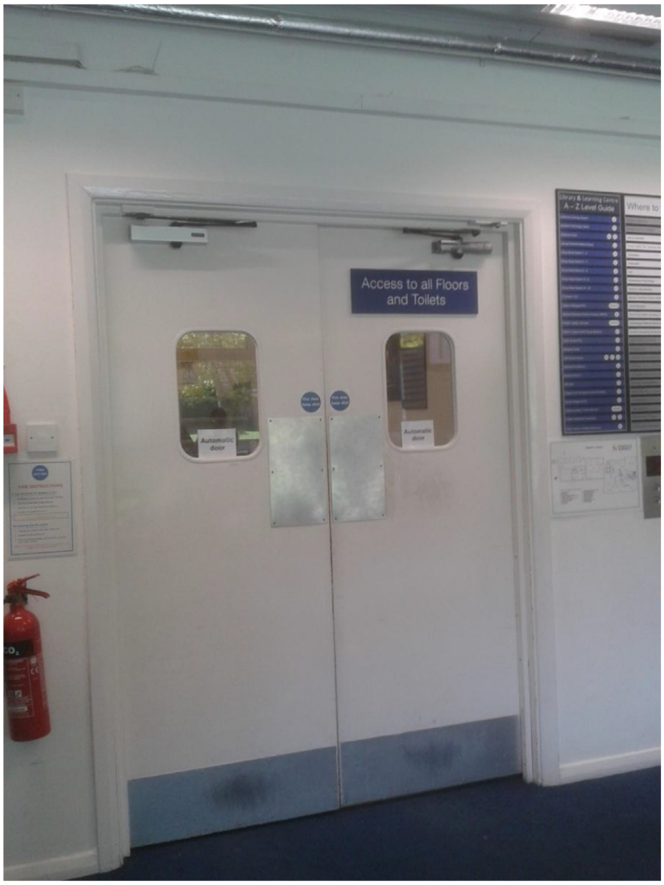

Fig. 2. Library doors with 'Automatic Door' signs in situ.

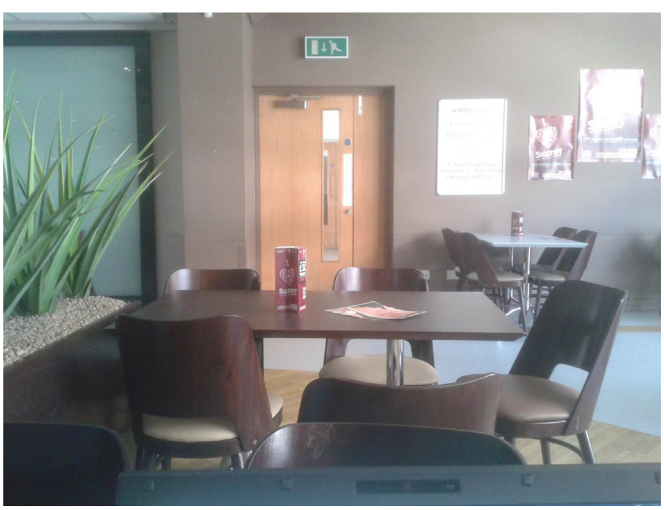

Fig. 3. Refectory door from observation site.

locations then, as predicted, people progressed more slowly when it appeared that the door was automatic. However, it is possible that the delay was caused by the time taken to read the sign, rather than the individuals waiting for the automatic system to work on their behalf. To test whether this was the case, we ran a further test in the refectory location. For an initial 79 cases, no sign was in place (control condition 1). For 60 cases, a sign saying 'Automatic door' was affixed to the vision panel (test condition) and for 65 cases, a sign saying 'Exit door' of the same size and lettering was affixed in the same position (control condition 2). Once again, the difference in time to open the door was significantly different between the automatic condition and the no sign condition ($t(1, 137) = -2.19$, $p < .05$, $r = .18$ small). The difference in mean times between the automation condition and control condition 2 ('Exit door') was also significant ($t(1, 123) = 2.66$, $p < .05$, $r = .23$ small-medium) while the difference between the two control conditions was not (no sign and sign saying 'Exit door': $t(1, 142) = .57$, $p > .1$).

2.2.3. Discussion – Studies I.1, I.2 and I.3

Because it took longer, at a statistically significant level, for refectory users to exit when a sign saying 'Automatic door' rather than 'Exit door' was in place, it might be concluded that the delay in opening the door was attributable to the indicated automation and not to the presence of the sign. The findings from both the lift studies and the automatic door studies supported the hypothesis that automation may undermine existing behaviour in real-life settings.

Having found field evidence consistent with our theoretical proposition, we then wanted to test the hypothesis that automation undermines behaviour in a controlled context. We additionally wanted to select a behaviour with greater environmental impact than lifts and doors: we chose lighting. Lighting consumes 15% of domestic energy use in the UK, a proportion that has risen continuously over the past four decades (DECC, 2013). To examine the hypothesis, we first needed to establish a robust baseline behaviour on which the effect of automation could be tested. Through casual observation, we noted that people tended to switch off a light when they left a room if it had been off when they went in so we planned a systematic observational study to test this observation. Our hypothesis was that people are more likely to switch off the light on leaving a room if the light was off when they entered. For a shared kitchen without natural lighting in a building with a manual lighting system, we observed whether people switched off the light on leaving the room and how this varied depending on whether the light was initially on or off.

3. Stage II the baseline behaviour

3.1. Study II.1: Lighting – Field Studies

3.1.1. Method – Study II.1

The kitchen was a small (2.5 m × 1.5 m), internal, windowless room, used by the office workers (university staff and researchers) on the same corridor. The observer was positioned inconspicuously in a nearby office which offered an unobstructed view of the kitchen. The observer recorded for each kitchen visit the state of the light upon arrival and departure, the time the kitchen was entered and left, whether there was someone already in the kitchen, and whether the visitor returned within five minutes. To examine individual behaviour, we included in the analysis only kitchen users who were alone when they entered and left the kitchen. A number of visitors switched on the kettle or microwave and left the kitchen but returned after a few minutes to complete their activity. These 'returners' (within 5 min) were excluded from analysis as we wanted to investigate behaviour when the visitor finally left the room.

3.1.2. Results – Study II.1

In the first study, observation took place on two days in different weeks for 6.5 h during the working day. A total of 183 visits were recorded of which 89 were used in analysis, based on exclusions for the reasons above. When the initial light state was 'on', the majority of kitchen users left the light on when they left the room (62%).

When the light was off when a kitchen user entered, the light was off for the majority when they left (64%). Table 2 presents the distribution of scores. The influence of the initial light state on the final light state was statistically significant (χ^2 (1, 89) = 5.99, $p < .05$): based on the odds ratio (Field, 2005), the light was 3 times more likely to be off when kitchen users left the room if it was also off when they entered. In the second study, we attempted to ensure an 'Always on' condition (183 visits, 88 included in analysis) in which the observer always switched the light on in the kitchen when someone turned it off and observed the effect over two days. We then attempted to ensure an 'Always off' condition (169 visits, 83 included in analysis) in which the observer always switched it off when someone left it on, provided this could be done unobtrusively in both cases, and again observed the effect over two days for each condition. Again, the influence of the initial light state on the final light state was statistically significant (χ^2 (1, 171) = 31.65, $p < .001$). Based on the odds ratio, the light was 6.62 times more likely to be switched off in the 'Always off' condition. Thus in both conditions, an individual was more likely, at a significant level, to turn off the light when it was off on entry.

3.1.3. Discussion — Study II.1

The effect was consistent with the theory of normative influence (Cialdini et al., 1990): people are likely to act in the way they think others act. Thus without automation, people may believe that the previous person had switched the light off and they follow suit. Other research on light switching behaviour has also linked a 'light off' condition with descriptive norms (Dwyer, Maki, & Rothman, 2015; Oceja & Berenguer, 2009). The two current studies indicated a strong effect and a robust pattern of behaviour but it is possible that some aspects of study design may have affected the results. In particular, as each case in the data represented a kitchen visit, it is feasible that multiple visits by an individual could have biased the data. In addition, as the corridor housed members of the environmental psychology group amongst other disciplines, it is feasible that some kitchen users had higher levels of environmental concern, and were thus more motivated to switch off the light than a more random sample. To address these potential weaknesses, we conducted a controlled, laboratory study with volunteer participants, measuring pro-environmental motivation and with each data point representing one individual.

3.2. Study II.2: Lighting — Laboratory Study

3.2.1. Method — Study II.2

Participants were recruited through posters around the university campus and through a university database of volunteers for research. Prospective participants were invited to take part in a study entitled 'People and their Surroundings' and an incentive of £5 (approximately $8/€6) was offered for participation. Participants were brought to a small windowless laboratory with artificial lighting and a single, standard light switch beside the door. For half of the participants, the light was on when they entered, for half the light was off. The participant was asked to complete three short tasks and, on completion, to return to the researcher in the adjacent lab. Just before leaving the participant to begin the tasks, the researcher mentioned that "You're the only session in this room today. We won't be using the room after you", to lead the participant to believe that the room would be unused when they finished. The three tasks were distracter tasks (on colour in gardens, travel mode and perception of urban surroundings): the behaviour of interest was whether the participant left the light on or switched it off when they left the room. On their return to the adjacent laboratory, the participant completed an established measure of environmental motivation (MTES; Pelletier, Tuson, Green-Demers, Noels, & Beaton, 1998). Of the sample 76% (n = 79) was female, mean age was 22.42 and 59% of participants were from not from arts and human sciences disciplines. In line with Pelletier et al. (1998), MTES comprised 24 items scored from 1 to 7, anchored at 1 'Does not correspond at all', 4 'Corresponds moderately' and 7 'Corresponds exactly'. The subscales for intrinsic, integrated, identified and introjected motivation were used. We did not examine self-determined versus controlled motivation separately as we were not exploring these aspects of motivation in this study. The score was calculated as the mean of the four subscales (mean 4.06, std. dev. .67).

Table 2
Distribution of scores for Study II.1.

Pre-condition	Post-condition	
	On	Off
On	29	18
Off	15	27
'Always On'	71	17
'Always Off'	32	51

3.2.2. Results — Study II.2

The predicted pattern of behaviour was observed under laboratory conditions: if the light was on initially, it was more likely to be left on. If the light was off initially, it was more likely to be switched off (see Table 3) and the effect was strongly statistically significant (χ^2 (1, 79) = 27.56, $p < .001$). The odds ratio indicated that, if the light was off (n = 43) initially, it was 15 times more likely to be switched off than if the lights was on initially (n = 36). Logistic regressions of final light condition onto environmental motivation, age and gender were non-significant (Model χ^2 (11) = 8.95, non-sig, R^2 = .1 (Cox & Snell), .13 (Nagelkerke), B(SE) = .43 (.24) MTES, −.37 (.63) gender, −.04 (.04) age, all non-sig). The laboratory study therefore replicated the findings of the observation studies in a controlled experiment, and showed that the effect was not related to pro-environmental motivation or demographics.

3.2.3. Discussion — Study II.2

As the two leftmost columns in Fig. 4 show, across field observation studies and a study under controlled conditions, within each study when automation was not a factor, if the light was off when an individual entered a room, it was more likely to be switched off than left on when they exited. The effect of automation on this behaviour could now be investigated in an experimental context.

4. Stage III the effect of automation on the baseline behaviour

4.1. Study III.1: Lighting Automation — Laboratory Study

4.1.1. Method — Study III.1

Having established a robust everyday behaviour in Studies II.1 and II.2, we next investigated an 'automation' condition, in which participants were primed to believe that automation could take

Table 3
Distribution of scores for Study II.2.

Pre-condition	Post-condition	
	On	Off
On	27	9
Off	7	36

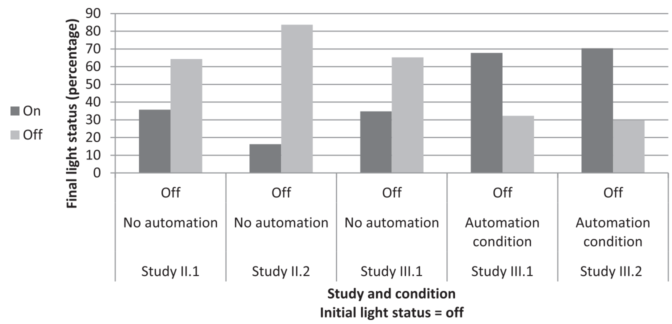

Fig. 4. Summary of Lighting Studies.

place within the setting. Using the same study protocol as Study II.2, two conditions were created. In the automation condition, the participant was led to believe that automation could occur: door signage was 'Automation Lab'; technical-looking equipment (measuring approximately 18 cm × 7 cm × 4 cm) was plugged into a wall socket but not near the light switch, and the researcher mentioned that automation testing was being conducted at times in the room, that everything would be switched off when the room was empty for an hour but that the automation was not working properly (to allow scope for participants to determine their own actions). In the control condition, indicators of automation were removed and no comment was made by the researcher. In both control and automation conditions, the light was on for half of participants entering the room, and the light was off for half. In the sample (n = 59), mean age was 23.42, 74% were female and all university faculties were approximately equally represented. Participants from Study II.2 were excluded from participation.

4.1.2. Results — Study III.1

The effect of a priori light state was again significant in the control condition: when the light was on initially, 83% of participants left it on; when the light was off initially, 64% of participants switched it off on leaving the room (χ^2 (1, 26) = 6.00, $p < .05$). The odds ratio indicated that, if the light was off initially, it was 9 times more likely to be switched off than if the light was on initially. However, the effect disappeared in the automation condition: for both initial light on and light off states, over two thirds of participants left the light on (χ^2 (1, 33) = .17, $p > .1$, non-significant). Table 4 columns 3 and 4 present the distribution of scores for the groups in Chi Square analysis.

4.1.3. Discussion — Study III.1

Having established a robust behaviour in two observation studies and the previous controlled laboratory study, that people were likely to switch off the light on leaving a room if it had been off when they entered, Laboratory Study III.1 showed that the prospect of automation undermined the effect: when participants were led to believe that the lighting in the room was automated, they no longer switched the light off themselves.

However, it is feasible that, in the automation condition, participant behaviour could have been influenced by their attention being brought to bear on the lighting by the researcher's comments. In a final replication, we conducted a third study of almost identical design but with a simpler manipulation to suggest automation.

4.2. Study III.2: Lighting Automation — Laboratory Study

4.2.1. Method — Study III.2

The study design followed that of Study III.1. The only differences were (1) on entering the target laboratory with the participant, for the automation condition (n = 30), the researcher simply said 'Oh the light is off. It's an automated system. The light goes off if the room is empty for an hour' with no other indicators of automation, and for the control condition (n = 27), the researcher said 'Oh the light is off'; (2) the light was off for all participants. Participants were recruited as before with individuals who had taken part in the earlier studies excluded from participation. Of the sample (n = 57), 74% were female, mean age was 23.81 and 47% were from disciplines other than arts and humanities.

4.2.2. Results — Study III.2

Participants were more likely to leave the light on in the automation condition (70%) compared to the control condition (47%) and the effect was significant at .07 probability (χ^2 (1, 57) = 3.28). Based on the odds ratio, participants in the automation condition were 2.7 times more likely to leave the light on than those in the control condition. Table 5 presents the distribution of scores for the groups in Chi Square analysis.

4.2.3. Discussion — Study III.2

Once again, and with a simpler manipulation than Laboratory Study III.1, the prospect of automation changed the likelihood that people would switch off the light. The rightmost two columns in Fig. 4 show that automation changed behaviour: in the automation conditions, the behaviour pattern established in the earlier studies was undermined. This answers our first research question: individual environmentally-impacting behaviour can be undermined by automation.

Having established that automation may undermine behaviour, our final study was an exploration of potential underlying mechanisms addressing the secondary research question: in terms of process, does the prospect of automation influence responsibility and effort? Our hypothesis was that automation leads to both abdication of personal responsibility for action and to conservation of effort. In two separate online studies, respondents were presented with two scenarios describing home heating or lighting systems which varied in levels of automation, and, on each, responded to measures of perception of level of automation, abdication of personal responsibility and conservation of effort.

Table 4
Distribution of scores for Study III.1.

	Post-condition	
	On	Off
Control pre-condition		
On	10	2
Off	5	9
Automation pre-condition		
On	11	4
Off	12	6

Table 5
Distribution of scores for Study III.2.

Condition (Light on in both)	Post-condition	
	On	Off
Control	14	16
Automation	19	8

5. Stage IV process of undermining behaviour: responsibility and effort

5.1. Studies IV.1 and IV.2: Evaluating a Home System – Survey Studies

5.1.1. Method – Studies IV.1 and IV.2

Participants completed a short online survey, entitled Technology at Home. The survey was identical in both studies. The initial page described the survey as concerning different types of home management systems for heating and lighting. Four scenarios describing heating and lighting systems, with an accompanying image, had been prepared: two described heating, two described lighting. One of each type presented a system similar to current or older technology and the other presented a more ‘high-tech’ system to provide a range of responses. Each participant was presented randomly with two systems from the four possible and, on each, responded to measures of perception of level of automation, personal responsibility and conservation of effort.

5.1.1.1. Study IV.1. Participants were recruited through a university database for research volunteers. Of the sample (n = 84), 71% were female, mean age was 23.9, 82% were in rented accommodation.

5.1.1.2. Study IV.2. Participants were recruited to ensure gender and age balance from existing national panels by a UK-based commercial research organisation. Ages ranged from 23 to 85, with 14–30% in each 10-year age band from 30 to 70 years old, with 6% under 30 and 6% over 70 (mean 51.52, std. dev. 12.61). Of the sample (n = 419), 55% were women, 61% owned their own home and 38% were in rented accommodation.

5.1.2. Measures – Studies IV.1 and IV.2

5.1.2.1. Abdication of personal responsibility. Two items were used to assess abdication of personal responsibility, anchored at 1 Strongly disagree and 7 Strongly Agree: “With System X, I would not need to be responsible for controlling the lighting (heating)”; “With System X, the system would take responsibility for switching lights on and off (heating the rooms and water)”. With two scenarios presented per person and two items in each, the mean of all four was calculated to measure abdication of personal responsibility (mean 4.66, std. dev. 1.32). Internal reliability was adequate to good (inter-item correlation .56, p < .001).

5.1.2.2. Conservation of effort. Two items were used to assess conservation of effort, anchored at 1 Strongly disagree and 7 Strongly Agree: “With System X, I would not have to go to the trouble of turning lights on and off (room or water heating on and off)”; “With System X, I would not need to make the effort to control the lighting (room and water heating)”. With two scenarios presented per person and two items in each, the mean of all four was calculated to measure conservation of effort (mean 4.5, std. dev. 1.45). Internal reliabilities were good (inter-item correlation .78, $p < .001$).

5.1.2.3. Values. A measure of hedonistic values (sample item: ‘An exciting life – stimulating experiences’) from the established value orientations scale (de Groot & Steg, 2008) was collected as a ‘marker’ variable to test for common-method variance (α .77, mean 4.81, std. dev. 1.18). The measure for hedonistic values comprised the mean of four items, anchored at −1 ‘Opposed to my values’, 0 ‘Not important’ and 7 ‘Extremely important’, as specified by the scale authors (de Groot & Steg, 2008).

5.1.3. Results – Studies IV.1 and IV.2

Table 6 presents correlations of the main variables. Correlation between abdication of personal responsibility and conservation of effort was particularly high in Study IV.2 so tests for multicollinearity were conducted in the regressions on these data. Multicollinearity was not detected (tolerance > .31 (Menard, 1995); average VIF 1.05 (Bowerman & O'Connell, 1990)), residuals were not strongly correlated (Durbin–Watson statistic 1.47) and the two variables performed differently in the regression analyses with different dependent variables.

A linear regression was conducted, in which perception of automation was regressed onto abdication of personal responsibility and conservation of effort, entered simultaneously. In contrast to our hypothesis, the regressions showed that abdication of responsibility but not conservation of effort was significantly related to the perceived level of automation (Study IV.1: Adj. $R^2 = .17$; $F(2, 81) = 9.62$, $p < .001$; abdication of responsibility $\beta = .43$, $p < .05$; conservation of effort $\beta = .01$, $p > .1$; Study IV.2: Adj. $R^2 = .18$; $F(2, 416) = 46.23$, $p < .001$; abdication of responsibility $\beta = .39$, $p < .001$; conservation of effort $\beta = .04$, $p > .1$). That is, the pattern of relationships was the same in both the first study with 84 students, and the second with a national UK sample of 419 adults: automation appeared to influence responsibility but not effort. Regressions of heating and lighting systems separately showed the same pattern of relationship, with abdication of personal responsibility related with statistical significance to perception of automation and conservation of effort non-significant (heating Adj. $R^2 = .17$, $F(2, 351) = 37.13$, $p < .001$, abdication of personal responsibility $\beta = .43$, $p < .001$, conservation of effort $\beta = -.02$, $p > .1$; lighting Adj. $R^2 = .16$, $F(2, 342) = 32.82$, $p < .001$, abdication of personal responsibility $\beta = .30$, $p < .001$, conservation of effort $\beta = .12$, $p > .1$).

Additionally, in both survey studies, age, gender and ethnicity were controlled for by entering these variables simultaneously with abdication of personal responsibility and conservation of effort. None of the three demographic variables was significant and the pattern of significance described above remained unchanged. To test for mediation effects of the vignettes presented, conditions were dummy coded and included in regression analysis. No consistent mediation effect was in evidence and the pattern of significance of the two variables of interest was maintained.

Additional tests were conducted for common-method variance which can bias results from data collected in the same manner from the same participants. A recommended method of testing whether this has affected results is to include a ‘marker’ variable, that is, a variable which is conceptually unrelated to the variables under examination but collected in the same way (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). This was an appropriate test in the current case as the most likely sources of common-method bias were related to item characteristics and item and measurement context. When hedonistic values were controlled for as a marker variable by entering all three predictors simultaneously, abdication of personal

Table 6
Correlation of main variables for Studies IV.1 and IV.2.

	Abdication of personal responsibility	Conservation of effort
Study 1		
Conservation of effort	.74**	
Automation	.44**	.33**
Study 2		
Conservation of effort	.83**	
Automation	.43**	.36**

**$p < .01$.

responsibility remained significant ($\beta = .38$, $p < .01$) while conservation of effort ($\beta = .04$, $p > .1$) and the marker variable ($\beta = .06$, $p > .1$; Adj. $R^2 = .18$, $F(3, 418) = 31.42$, $p < .001$) did not, supporting the case that the results were not attributable to common-method variance.

5.1.4. Discussion – Studies IV.1 and IV.2

Based on the theoretical perspectives outlined above, we had suggested that automation may undermine behaviour because it takes away a sense of responsibility and it also allows people to conserve effort. If this is true, we would expect a relationship between the perceived level of automation of an energy management system and both abdication of responsibility ('I would not need to be responsible for controlling the lighting') and conservation of effort ('I would not need to make the effort to control the lighting'). However, we found that only abdication of responsibility was related to the perceived level of automation. The finding is consistent with a recent study on lighting behaviour (published while the current paper was in preparation): although the paper in question investigated descriptive norms rather than automation, it argued that personal responsibility contributes to environmental behaviour such as switching off a light (Dwyer et al., 2015).

6. General discussion

Despite the importance of behaviour in realising the major benefits of technology in climate change mitigation, and theoretical understanding that automation may weaken sustainable behaviour, to our knowledge there has been little or no empirical investigation of the effect of automation on behaviour. The current set of studies aimed to address this gap. We investigated two research questions. To answer the primary question (Is individual environmentally-impacting behaviour undermined by the prospect of automation?), we examined the effect of automation on three behaviours with environmental impact: calling a lift, opening a door and switching off the light. When people were led to believe that functions were automated when using a lift or exiting a door, they appeared to change their behaviour to allow the automation to take action on their behalf. We then established a robust pattern of behaviour which could also be manipulated in experimental conditions: we demonstrated that people were more likely to switch the light off on leaving a room if the light had been off when they entered. In a series of controlled, experimental studies on this baseline behaviour, we led participants to believe that the lighting system was automated. We found that the prospect of automation meant that participants were no longer likely to switch off the light themselves. Our studies therefore demonstrated that the prospect of automation does indeed undermine environmentally impacting behaviour. To answer the secondary, exploratory research question (in terms of process, does the prospect of automation influence responsibility and effort?), in two online surveys we tested whether automation influences both personal responsibility and effort. In both survey studies, with a student sample and with a large national sample, we found that perception of automation was associated with abdication of personal responsibility for action but not with conservation of effort. We conclude that automation may change behaviour by diminishing the sense of personal responsibility.

The research provides empirical evidence at the level of the individual that is consonant with the economic effects described as rebound (Khazzoom, 1980) and backfire (Saunders, 1992), the first such evidence for the effects of automated technology to our knowledge. More generally, the findings suggest a basis in individual behaviour for the cultural dependence on technology described in the Introduction above: if individuals let technology take action on their behalf, then it follows that, at societal level, our cultural norms may lead to reliance on technology to solve our problems for us.

Our final, exploratory study on underlying mechanism suggested that the prospect of automation may undermine personal responsibility for action. From a theoretical perspective, this finding has particularly serious implications. By eroding personal responsibility, automation may undermine higher-level motivations.

Action identity theory (Vallacher & Wegner, 1987) leads us to understand that in the absence of an intended higher-level motivation, behaviour can become less consistent across contexts. This means that when it comes to sustainable behaviour, if personal responsibility is weakened for one behaviour or domain, pro-environmental actions may be less likely elsewhere. Taking an example from technology-dependent policy, if electricity smart meters with enhanced automation to support real-time pricing are perceived to improve the energy efficiency of domestic consumption, fewer householders may make efforts to reduce their energy usage at home and they may make less effort to reduce their energy consumption more generally. Recent evidence has begun to question the extent to which people transfer behaviours from one setting to another. Littleford, Ryley, and Firth (2014) found that work and home behaviours demonstrated domain-based dimensionality, implying only a weak relationship between behaviours in both domains. The finding here that automation appeared to influence personal responsibility suggests that abdication of personal responsibility may be a factor which differentiates behaviour in the workplace from that in the home. This suggests that interventions to encourage pro-environmental behaviour at work could usefully emphasise a message of personal responsibility.

The value-belief-norm theory of environmentalism (Stern, 2000) holds that values, mediated by personal responsibility (along with other variables), may influence behaviour. A strong argument has been made that values must be considered if individual behaviour is to be influenced towards sustainability for the longer term (Crompton & Kasser, 2010). Thus the finding that automation may adversely impact the causal chain from values to behaviour suggests particular risks to pro-environmental behaviour posed by technological automation. Automated technology may weaken the moral argument for individual action in the face of climate change. If individuals feel that technology will carry out actions on their behalf, personal and moral responsibility is removed and there is less likelihood of engagement in actions that are pro-environmental. Moreover, it seems to us that any strategies that reduce people's sense of responsibility for the environment are heading in the wrong direction: we want individuals to take more responsibility for their environmental actions wherever possible, because only by so doing are people likely to act sustainably in a variety of environmental settings, and across different activity domains.

Taken together, the implications point to the risk that, unless the impact of automation on behaviour is addressed, technological solutions will not achieve optimal benefits and their effect may be severely attenuated. However, having suggested a potential mechanism by which automation may influence behaviour, initiatives to alleviate the effect can be proposed. First, an emphasis on personal responsibility is important in campaigning and policy. This is not to suggest that political and structural changes are unnecessary: the stress on personal responsibility should emphasise the importance of individual action *in support of* technological improvement, structural change and political initiatives. Second, we need to encourage not simply environmental behaviour change but the creation of a pro-environmental culture, analogous to safety cultures which have become widespread in high-risk industries such as construction (Choudhry, Fang, & Mohamed, 2007). The environmental crisis we face warrants no less a significant investment. Finally, campaigns could usefully address the issue directly and aim to raise awareness that technology cannot deliver if people fail to use it in the most effective way.

Limitations in the current studies should be acknowledged. Of the many uses of automated technology in everyday life, we examined only three. We hope that future research will examine a broader set – for example, technology which automatically sets appliances into 'sleep' mode would be an important additional focus, given the energy impacts of device standby (Firth, Lomas, Wright, & Wall, 2008). Our final study was exploratory and compared two potential mechanisms. Other possibilities exist which may have influenced the outcome: level of pro-environmental concern, demographics such as income and education, and attitudes to technology are further factors to be investigated alongside abdication of personal responsibility. The measures above represent a first attempt to evaluate conservation of effort and abdication of personal responsibility. Future research is needed to develop psychometrically robust measures with a wider range of items.

Our conclusion is that the prospect of automated technology can undermine pro-environmental behaviours, even the most simple. The studies showed the effect of automation on actions as minor as opening a door, calling a lift and switching off a light. The findings support the voices arguing that over-reliance on technology risks undermining human action. The message is clear for policy makers, campaigners, engineers, and science and technology communicators. In order to achieve the enormous benefits which technology can offer in efforts to mitigate climate change, human action is equally essential for success and individual responsibility must not be replaced by a blind faith in technology.

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