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NUDGING PEOPLE TO SAVE ENERGY IN SMART HOMES WITH SOCIAL NORMS AND SELF-COMMITMENT

Research in Progress

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Abstract

Despite energy efficiency measures the global demand for energy has risen in 2017 as a result of global economic growth and changes in consumer behaviour. To reduce the energy consumption and CO2 emissions, behavioural interventions have to be considered beyond technology advances. We address this by studying how the change of digital choice architectures with nudges can be used to influence the energy-saving behaviour of consumers in a smart home app. With a full factorial experiment, we test the efficacy of two nudges –'self-commitment' and 'social norm'. With the herein reported pre-study, we evaluate the research design and identify improvements for the full study. This research-in-progress paper contributes by concretising the usage of digital nudges in the field of Green IS and behaviour change in the realm of energy-saving. Hence, it can serve as a starting point for discussions on its suitability and further studies focusing on different digital interventions that help to decrease energy consumption.

Keywords: Digital Nudging, Green IS, Smart Home, Energy-saving, Sustainable HCI

1 Introduction

Due to the global warming and climate change, nations worldwide have started to set objectives to decrease the harmful greenhouse gases and energy consumption. The EU defined directives to save energy and increase efficiency, including an annual reduction of 1.5% in national energy sales (European Commission, 2019). However, in 2017 the worldwide energy demand rose by 1.9% being the fastest annual increase in this decade. This development is driven by economic growth and changes in consumer behaviour, which outpaced efficiency measures (International Energy Agency, 2018). Taking Germany as an example, the energy consumption of private households has also increased since 1990 despite all technological progress (Federal Environment Agency, 2018).

Beyond energy efficiency measures, the energy consumption behaviour is considered as one important corner stone to reduce the energy demand. Influencing the energy consumption is of particular interest since private households show a contradictory behaviour: 90% of consumers have a high energy-saving awareness, simultaneously their actual energy consumption remains notably high (Frondel, Ritter and Sommer, 2015). Particularly, the desire for comfort often outranks energy-saving even if reducing energy bills is often an important consideration to buy smart home equipment (Buchanan, Russo and Anderson, 2015). Energy efficiency gains are, hence, compensated by higher energy consumption of households, i.e. rebound-effects (Buchanan et al., 2015).

Besides traditional energy (-saving) research, the Information Systems discipline – and therein Green IS – has addressed the potentials of IS to enhance sustainability and to tackle high energy consumption (Melville, 2010; Watson, Boudreau and Chen, 2010; Kossahl and Busse, 2012). We have yet mainly focused on energy-related technologies, such as smart meters as well as their adoption and impact on energy conservation (Kranz and Picot, 2011; Corbett, 2013; Wortmann and Flüchter, 2015). Such systems offer the potential to reach customers on a large scale with tailored information, and thus could lead to better results on energy efficiency interventions and behaviour changes (Loock et al., 2012; Aman, Simmhan and Prasanna, 2013).

Since the interaction with digital interfaces that control energy consumption becomes increasingly common with the growth of smart home technologies, our research aims to contribute to the energy-saving goals by studying how cognitive flaws regarding energy consumption (e.g. deemphasising the effect of individual decisions on the global energy consumption) and inconsistent decisions (e.g. agreeing to save energy but behaving differently) can be mitigated with information systems. Therefore, we make use of digital nudging – a concept that changes digital choice architectures to make certain outcomes more likely (Meske and Potthoff, 2017). Elements similar to nudges have already been used in Green IS research to improve energy-savings (Loock, Staake and Thiesse, 2013). For example, smart metering with in-home displays and websites that provide feedback with visualisations of the consumption have been investigated as nudge to support the user in saving energy (Krishnamurti et al., 2013). However, Fan et al. (2017) highlight the low emphasis on the used system's design and that it often misses mobile applications which can strongly promote energy-savings – especially as smart home apps or in combination with smart meters.

We propose that using digital nudges in smart home apps can facilitate consumers to better understand their energy consumption and to motivate them to save energy. We take up the nudges of descriptive normative social influence (e.g. "99% of your neighbours switch off the light…") and self-commitment nudges which lets people commit to their energy-saving goals (Loock et al., 2012, 2013). This research is, hence, guided by the following question: *How can social norms and self-commitment as digital nudges in a smart home app influence the energy-saving behaviour?*

In this research-in-progress paper, we introduce our research approach with a smart home app user interface and a 2x2 factorial design experiment. In section 2, we review the theoretical background on nudging and decision-making in the context of energy-saving as well as derive the hypotheses. Section 3 depicts the research design in detail to enable discussions and inform other researchers that pursue similar approaches. Section 4 reports a conducted pre-study to validate the design. Section 5 discusses the pre-study results and implications for the follow-up study. Section 6 concludes with the paper's contribution and limitations as well as our next steps.

2 Background and Hypotheses

The term nudging was coined in the context of behavioural economics by Thaler and Sunstein in 2008. Nudges are intended to promote better and predictable behaviour in decision-making situations 'without forbidding any options or significantly changing their economic incentives' (Thaler and Sunstein, 2008, p. 6). This freedom-preserving form of regulation has been distinguished from simply manipulative influences (Reisch and Sunstein, 2016) and adapted to digital environments (Weinmann, Schneider and vom Brocke, 2016; Mirsch, Lehrer and Jung, 2018). Nudges are suggested to change non-deliberative aspects of people's actions (Lehner, Mont and Heiskanen, 2016). Offering defaults, warnings, simplified information, alternative framing or priming can, thus, facilitate better decisions. Due to the large amount of information on the Internet and the resulting lower attention span of users, not all relevant details can be cognitively processed, making users more susceptible to erroneous decisions (Benartzi and Lehrer, 2015; Kroll and Stieglitz, 2019). Against this background, *digital* nudging is 'a subtle form of using design, information and interaction elements to guide user behaviour in digital environments, without restricting the individual's freedom of choice.' (Meske and Potthoff, 2017, p. 2589)

In the context of energy consumption and likewise saving, the mere provision of information is often not sufficient to bring about changes in behaviour, even if this is consistent with the person's attitude (Abrahamse, Steg, Vlek and Rothengatter, 2005). A behaviour-attitude gap is often rooted in a weakened self-control and a high cognitive load resulting in biases (Chandler and Sweller, 1991). Since energy consumption is embedded in daily routines, those activities are often driven by a habitual decision-making system leading people to use heuristics and be susceptible for bias (Kahneman, 2011). To overcome weak decisions, nudging has been proposed for sustainable consumption behaviour including energy-saving (Schleich, Klobasa, Gölz and Brunner, 2013; Harding and Hsiaw, 2014; Lehner et al., 2016). A frequently used digital nudge is consumption feedback based on smart metering data and provided to the consumer via in-home displays (IHDs), websites or increasingly mobile apps (Schultz et al., 2015). A more recent study also tested feedback nudges in a smart home app (Fan et al., 2017).

Also, a few studies from the Green IS field have started to investigate the influence of digital nudges and similar interventions on energy consumption (Albizri and Zahedi, 2012), e.g. the influence of online communities (Baeriswyl, Staake and Loock, 2011), social competitions (Yim, 2011), social norms (Loock, Staake and Landwehr, 2011), and public games (Baeriswyl, Przepiorka and Staake, 2011). However, most of the digital nudges rely on smart metering infrastructures and corresponding IHDs or web portals. Beyond that, there is little empirical evidence of nudges' efficacy in smart home apps which are increasingly used and, thus, requires closer empirical examination.

Different disciplines have applied social norms with descriptive standards to the energy-saving context (Allcott, 2011; Loock et al., 2011, 2012). In the USA, a social norm nudge has reduced electricity consumption by about 2% after Opower's customers received letters comparing their own energy consumption with that of their neighbours (Allcott, 2011). In another experiment with 560 energy consumers, Loock et al. (2012) showed a strong effect of descriptive normative feedback on the energy consumption. Particularly, they studied the importance of reference groups, e.g. geographical proximity. In the present study, we adopt previous findings to a smart home app and hypothesise the following:

> *H1: Social norm nudges in a smart home app lead to more energy-saving choices than without any digital nudge.*

Commitment strategies have been increasingly used in recent years to promote sustainable behaviour. A meta-analysis by Lokhorst et al. (2013) showed that different commitment strategies in the environmental field have proven to be effective, especially when these strategies are combined with other interventions. For example, in a study subjects were able to save 6% to 7% more energy with combined nudges, such as feedback and self-commitment (Matthies and Kastner, 2011). In the IS discipline, Loock et al. (2013) implemented a self-commitment nudge by letting users set goals in a web portal providing feedback on energy consumption. They found the goal setting to decrease electricity consumption and further showed the effect of default values for the goals. Likewise, we investigate whether a self-commitment nudge in a smart home app can increase the energy-saving behaviour and hypothesise:

> *H2: A self-commitment nudge in a smart home app leads to more energy-saving choices than without any digital nudge.*

However, single commitment strategies are less common than the combination with other intervention elements. For example, goal-setting has been combined with self-commitment in an energy consumption context (Abrahamse et al., 2005). Also, goal attainment was discussed to be dependent on the commitment (Loock et al., 2013). Generally, intervention studies for energy-saving have often combined different nudging strategies (Loock et al., 2012; Lokhorst et al., 2013; Karlin, Zinger and Ford, 2015). In our study, a mere self-commitment could be complemented with the social norm nudges which provide guidance how to attain the commitment behaviours. Hence, we hypothesise:

H3: Social norm nudges and self-commitment nudge in a smart home app jointly lead to more energy-saving choices than without any nudge.

H4: Social norm nudges and self-commitment nudge in a smart home app jointly lead to more energy-saving choices than the single self-commitment nudge.

3 Research Design

We aim to answer the research question and investigate the derived hypotheses with an experiment which is expound in detail next. The two nudges self-commitment and social norm have been suggested by prior research. As the combination of both nudges may result in a stronger effect (H3 and H4), the experiment is designed as a 2x2 full factorial between-subjects experiment. Three experimental groups (A, B, and AB) and one control group (C) are formed to isolate the effects. The study structure including the different groups is summarised at the end of this section in figure 2.

Given the introduced context of smart home apps, we operationalise the experiment with self-designed mock-ups of a smart home app in an online survey (steps described next). In general, participants are introduced to a scenario in which they use a smart home app and make decisions about specific devices. Because of the scenario, no smart home experience is required. The decisions about the devices are enriched with a context description, as explained in more detail in step 4, so that the participants can put themselves in a position to use the app.

Step 1: Selection of suitable smart home devices and energy-saving options

We require that the devices included be theoretically compatible with a smart home system, knowing that some devices are more likely to be connected than others. Following Krishnamurti et al. (2013), we selected (1) heating, (2) lights, (3) air conditioning (A/C), (4) washing machine and (5) dishwasher. For a broader scale and higher validation, the subjects were presented with five options per device as polytomous measuring points, which are disjoint and exhaustive. The options are informed by recommendations about optimal room temperatures (National Energy Foundation, 2019) as well as by studying specific machines' programmes and their stated energy consumption (washing machine: *Bauknecht WMT EcoStar 732 Di*; dishwasher: *Bauknecht OBBO Super Eco X)*. Each device or the decision, respectively, represents a discrete variable of the energy-saving degree (low to high). Table 1 presents the respective options that are displayed in the study. The first column depicts how energy-saving a certain option is. The listed durations may seem very long but reflect real programmes which could be sorted according to their energy consumption.

Degree of energy-saving	Heating: Temperature	Lights: Brightness	A/C: Temperature	Washing machine: Programme	Dishwasher: Programme
1 (low)	25°C	100%	17°C	Cooking wash 90°C and 2:35 h washing time	Intensive programme 70°C and 2:25 h flushing time
2	23°C	80%	19°C	Colour wash 60°C and 2:35 h washing time	Hygiene programme 65°C and 1:40 h flushing time
3	21°C	60%	21°C	Colour wash 40°C and 3:00 h Washing time	Auto programme 50°C and 2:10 h flushing time
4	19°C	40%	23°C	Eco cotton 40°C and 4:00 h washing time	Auto programme 50°C and 2:10 h flushing time and multizone option
5 (high)	17°C	20%	25°C	Colour wash 30°C and 3:00 h washing time	Eco programme 50°C and 3:10 h flushing time

Table 1. Overview of all options for measuring the degree of energy-saving behaviour

Step 2: Formulation of stimuli for social norm nudge

With the smart home devices and options, we formulate the stimuli for the social norm nudges (table 2). We considered three aspects: First, the stimulus should set a pole among the possible options. For example, using 18°C for heating in the social norm formulation should convey that a low heating temperature is preferable. At the same time, 18°C does not prime a specific option or make them a quasi-default (there are only the options 17°C, 19°C, 21°C, 23°C and 25°C) but requires to reflect and decide. Second, the norm needs to be perceived as credible by the participants. The actual percentage uses random decimals to pretend a specific calculation which is perceived as not unrealistically high on the one hand but still being the largest group on the other hand. For example, the A/C stimulus reference is set to '35.90% chose 24°C' which is a rather inconvenient though energy-saving option. A higher percentage would carry the risk of being perceived as unlikely. Considering five options for each device, 35.90% is intended to reflect the largest group and thus sufficient for a descriptive norm. The third aspect is the relevancy of the descriptive norm for the respective user. Households can much differ in their energy consumption (e.g. family vs. single household). We use the phrase "of similar households" which is facilitated by the retrieval of the participant's type of household at the survey's beginning.

Device	Stimuli for social norm nudges in group A and AB (translated from German)
Heating	57.23% of similar households prefer a room temperature of 18°C or less in the bedroom.
Lights	71.34% of similar households dim their bedroom lights to about 30% or less in the evening.
Air conditioning	35.90% of similar households set the air conditioning to 24°C or higher.
Washing machine	52.17% of similar households wash their coloured cotton laundry at 30°C.
Dishwasher	45.96% of similar households choose the Eco program for the dishwasher.

Table 2. Overview of the social norm nudges with descriptive normative formulations

Step 3: Design of the smart home app mock-ups including the self-commitment nudge

The mock-ups resemble a native app (in German) and enable a familiar user experience (Joorabchi, Mesbah and Kruchten, 2013). Different design elements are considered which aim to suggest a real app called "LIVE SMART", e.g. tab bar, buttons, dropdowns, icons/pictograms and horizontal paging (see figure 1). We include details like the time that could distract participants when not matching the scenario explained in step 4. The study started for all participants with a welcome screen (figure 1 left).

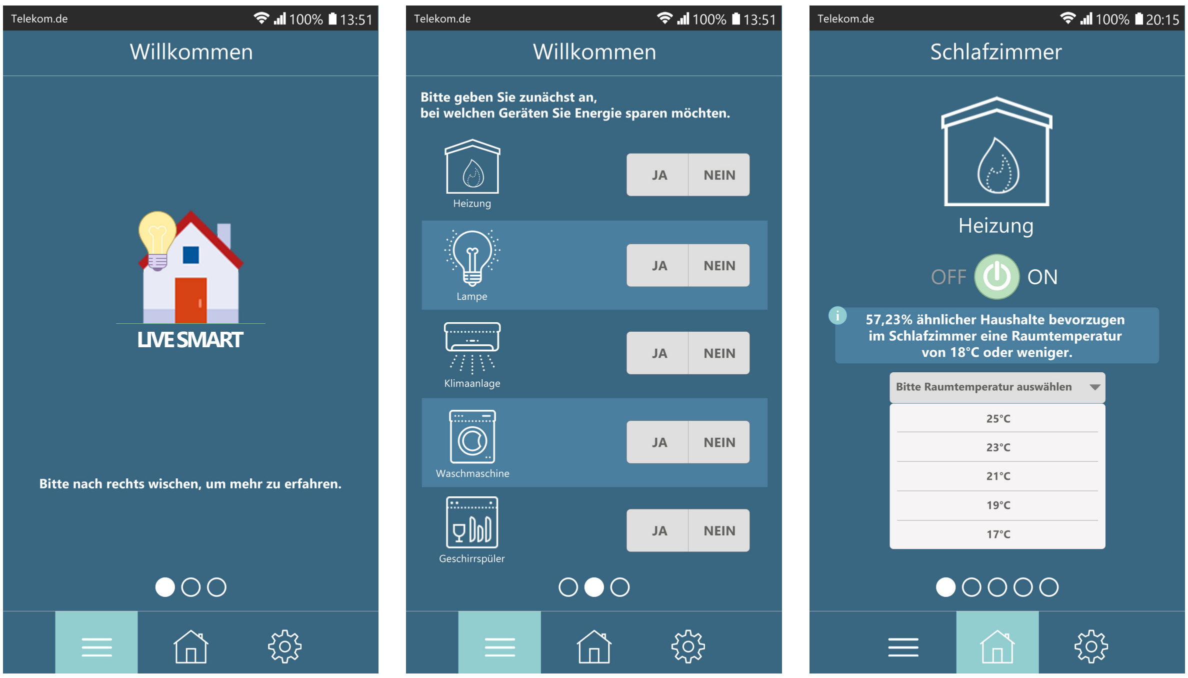

Figure 1. Mock-ups of different steps: welcome view (left), self-commitment view (centre; groups B and AB), social norm view (right; groups A and AB) (in German)

The centred screen represents the self-commitment nudge. Here, the respondents have the opportunity to set their commitments by clicking buttons (“Yes” or “No”) and specifying the devices they want to save energy for. By that, participants are confronted with simple decisions about potential energy-saving. They are motivated to question their attitude and make a decision for the smart home app. The self-commitment mock-up is accompanied by a situation description in the online experiment so that the participants do not understand the interface as a pure survey of available devices. Also, the mock-up states the instruction: *First of all, please indicate which devices you want to save energy with.* Such an initial commitment is expected to be remembered when deciding about energy-saving options later on causing a) a more reflective processing of information and b) the mitigation of choices that would be inconsistent with the commitment (Lokhorst et al., 2013).

Like explained in step 1, all participants have to decide between five options for each device (table 1). The third image in figure 1 depicts one decision screen which entails the info box with the social norm nudge above the dropdown list. The clues are slightly highlighted by a discreet, light blue colour of the information box, so that they are salient, but not too strongly emphasised and unpleasantly perceived. This measure is subject to the nudging principles of subtleness, but at the same time there is a risk that the information stimuli will not be perceived. Therefore, we include a manipulation check.

Step 4: Survey setup integrating mock-ups with usage scenarios and further measures

The survey starts with instructions about decisions in a smart home app (see figure 2 for the study structure). However, the actual focus on energy-saving is hidden to minimise priming effects. Next, demographics are asked including sex, age, education, the type of household and the number of persons living in the household. Also, the experiment conditions (groups A, B, AB or C) are calculated using a random number function without the participants’ notice. Then, the smart home app is introduced with its basic purposes and functions (e.g. connected devices, controlling and automating). Participants receiving the self-commitment nudge see the middle mock-up from figure 1 accompanied by a scenario that introduces the devices and explains that the app can support saving energy.

For the following device screens (e.g. heating) with and without the nudge, we present situations that justify using the app (e.g. *Imagine you came home at 20:15 in the evening and it seems too cold in the bedroom. You have, therefore, switched on the heating via your smart home app…*). The type of room, the distance of the participant from the room, the time component and other relevant factors are taken into account so that a direct decision about the options seems plausible. The respective decisions form the device-specific energy-saving behaviour (interval scale from 1 to 5 as explained in step 1). The overall energy-saving behaviour is the average of all five measuring points.

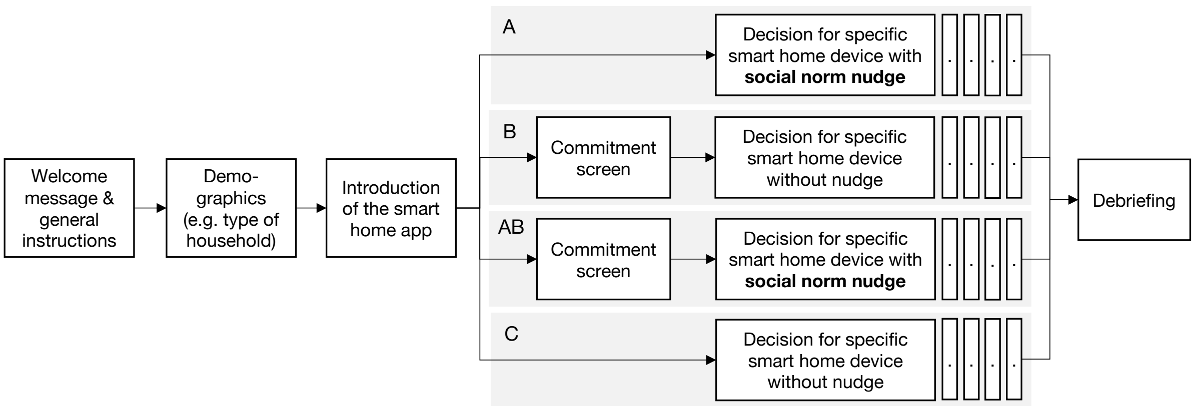

Figure 2. Flowchart of the survey; grey-coloured areas indicate parallel experiment conditions labelled with A, B, AB and C

4 Pre-study Results

We conducted a pre-study with N = 113 completed answers to validate the research design and experiment setting. We recruited the participants in lectures and seminars from the authors’ universities but also by means of directly contacting colleagues. The participants’ mean age is M = 29.02 years (SD =

8.64, range: 18-58). We had 57.5% female and 42.5% male participants. Most participants live in a rental flat (64.6%), followed by an owned house (15.9%) and an owned flat (9.7%). The mean number of persons in the participants' household are 2.36 (SD = 1.16; range: 1-5).

For the investigation of the hypotheses, a one-way ANOVA is calculated to test whether there is a group difference in energy-saving behaviour depending on the nudge condition (see table 3). The four groups (A = Social Norm, B = Self-Commitment, AB = Self-Commitment x Social Norm, C = Control Group) are compared with sizes from n = 22 to n = 34. According to the Shapiro-Wilk test, all groups have a normal distribution. This is additionally supported by the Kolmogrov-Smirnov test for groups A, AB and C and confirmed by a visual inspection for all groups. The variance homogeneity was checked with the Levene test: F(3, 109) = 0.215, p = .886. The examination of the ANOVA at a significance level of 5% shows that there is a significant statistical difference in energy-saving behaviour in the individual nudge conditions, F(3, 109) = 2.99, p = .034, η^2= 0.082 (medium effect size).

Group		Energy-saving		Levene-Test		One-way ANOVA	
	N	*M*	*SD*	*F*	*Sig.*	*F*	*Sig.*
Social Norm (A)	24	3.53	0.485	0.215	.886	2,992	.034
Self-Commitment (B)	33	3.35	0.508				
SocNorm x Self-Com (AB)	22	3.70	0.548				
Control group (C)	34	3.35	0.476				
Total	113	3.45	0.515				

Table 3. *Descriptive and inferential statistics of the groups, ANOVA*

The results of the contrast test were considered under the assumption of variance homogeneity. Though the mean values showed differences, the contrast tests did not yield significant results (see table 4).

	Contrast	A	B	AB	C	Contrast pairs		t	df	Sig.
H1	1	1	0	0	-1	Social Norm	Control group	1.393	109	.167
H2	2	0	1	0	-1	Self-Commitment	Control group	-0.013	109	.990
H3	3	0	0	1	-1	SocNorm x Self-Com	Control group	2.571	109	.011
H4	4	1	0	-1	0	Self-Commitment	SocialNorm x Self-Com	-2.567	109	.012

Table 4. *Planned contrasts between conditions according to the hypotheses*

Looking at participants that received the self-commitment nudge (n=55), 50.9% selected all five devices as goal for the energy-saving. The mean of 4.09 devices further indicates the strong commitment in the first place. For the main survey, we will consider a larger data set and better equalised group sizes.

5 Discussion

Against the backdrop of climate change with growing energy demand worldwide, nudging appears to be a promising approach to decrease the energy consumption of consumers. With the technological advances and the diffusion of smart meters and smart home systems in private households, digital nudges can be implemented in interfaces and apps offering options for more individualised and contextualised energy information, e.g. feedback on device level (Watson et al., 2010). Building on a smart home environment and focusing on the interaction with a smart home app, this study investigates the effect of two digital nudges on the energy-saving behaviour in a full factorial experiment as called by Karlin et al. (2015). So far, we have presented our research design and conducted a pre-study with N=113. The mock-ups and the included nudges were designed on the basis of existing literature and presented here in detail. In particular, we considered details that may have an influence on the perception and processing of users (Karlin et al., 2015). As noted by Froehlich et al. (2010), previous studies have focused primarily on the intervention rather than the context and artefact as a whole. The general research approach seems appropriate to answer the research question. Nevertheless, we also identified possible modifications for the follow-up study.

The first hypothesis proposes that we can influence the energy-saving behaviour by using social descriptive norms as an additional information and orientation when deciding for the specific options. The effectiveness of such nudges has been demonstrated before (e.g. Loock et al., 2012), even though the pre-study does not support the hypothesis. As the energy-saving degree differed slightly between the groups, we need to include more participants in the follow-up study and should care for equal group sizes. Karlin et al. (2015), however, reported social comparisons as less effective on energy-saving. Another explanation could be the perception that for the A/C 35.90% of similar households is not a norm since 64.10% took other options (spread over four options). There is a trade-off between using lower values that may be perceived as more credible but not as a real norm and higher values that reflect a large majority but are less credible. The extent to which the respondents regard the social incentives as credible norm was not part of the study but needs much more attention. Although research has studied the broader idea of social influence in different applications (Loock et al., 2011; Mirsch et al., 2018), there seems to be a gap in how effective social norms can be formulated and used in digital nudging. Consequently, we need to pre-test the percentages used in the follow-up study to ensure their effect.

The assertion of the H2 refers to the positive influence of self-commitment on the energy-saving behaviour. In fact, commitments are easier made than the actual decisions. However, the commitment is usually remembered when actually deciding which should enable consistent decisions. The pre-study shows no difference in the energy-saving behaviour although the majority of the participants agreed that they wanted to save energy with all five devices. Still, the average number of about four devices to save energy with, indicates that the participants did not simply select all devices, as one might assume with such a question. It is possible that a few participants are committed to a no-saving behaviour for specific devices which we might control in a future study. Since we did not want to reduce the pre-study dataset, we have not yet performed analyses with a filter on high commitment. The current self-commitment nudge seems not to motivate participants sufficiently to save energy though.

We also hypothesised that the group with the nudge combination consisting of social norm and self-commitment led to more energy-saving behaviour than the control group (H3) and the mere self-commitment group (H4). The potential commitment to a no-saving behaviour is also present in these comparisons which we need address later on. However, the energy-saving degree of the group receiving both nudges is the highest among all groups. Prior studies have also suggested that the combination of different nudges like self-commitment and reminder/feedback are more effective (Loock et al., 2012; Karlin et al., 2015).

6 Conclusion and Next Steps

This paper entails the use of digital nudges in a smart home app to promote energy-saving behaviour. Our study contributes by suggesting and designing specific mobile app interfaces that involve the digital nudges social norm and self-commitment. It, thereby, continues the tradition of Green IS research (Watson et al., 2010) by providing starting points for further research on digital nudging to influence the energy consumption in smart home apps. This study also contributes to the emerging body of research on digital nudging that has suggested nudging to the field of Green IS (Weinmann et al., 2016). We believe that the application of digital nudging in smart home apps can contribute to behaviour change, which is essential to preserve efficiency gains and to lower rebound-effects.

The pre-study reveals some challenges that we have started to address for a follow-up study. For example, the self-commitment nudge requires further attention so that a commitment to not save energy does not offset the analyses. Also, the normative formulations need further evaluations for credibility and norm perception. As suggested by a reviewer, another limitation is the lack of real consequences of the taken options, e.g. freezing in a cold room due to the most energy-saving option.

Based on the initial findings, we are going to revise the approach including stimuli, recruiting and the experiment environment. We plan to also capture factors that may influence the efficacy of the digital nudges like the attitude towards energy consumption. An a-priori power analysis indicates a required sample size of 300-400 given a medium effect size. Hence, we need to further evaluate whether Prolific or similar study recruitment platforms will be consulted.

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