Real-World Impact of Information Systems: The Effect of Seemingly Small Design Choices

by

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Abstract

Information system (IS) have not only become indispensable in professional contexts, but can also serve as a platform for data-based interventions targeting issues for humanity. Providing individuals with concrete feedback on their current behavior has been shown to foster sustainable behavior. So far, research on the real-world impact and underlying mechanisms of such IS-enabled interventions is scarce. In a randomized controlled field experiment with 1,423 participants, we systematically test the effect of different intervention strategies regarding their impact on energy consumption and user experience. We find a conservation effect of over 18% for the best treatment. In particular, the results suggest that small, seemingly harmless variations of IS design choices regarding numerical, normative, or emotional feedback can considerably affect behavioral outcomes (energy use). Potential explanations of observed behavior are given based on theories from psychology. The study delivers design implications for innovative IS artifacts that highlight the importance and necessity of taking cognitive processes into account.

Introduction

Understanding the contribution of IS on work performance has been one of the core research interests of the community from its start. Today, in the ages of exponentially growing computing power and easy-to-use sensors at negligible costs, IS are also increasingly entering our private lives, in which smartphones, personal computers, or many other devices have become indispensable (Baskerville 2011; Hess et al. 2014). The role of IS and the circumstances that shape the adoption and usage of IS in these non-professional contexts are fundamentally different from organizational settings. Beyond the application of IS to fulfil economic needs, idiosyncratic and social needs of individuals gain in importance (Baskerville 2011). Aside from facilitating processes (e.g. smart thermostats, live traffic information) or providing entertainment (e.g., games, social media), privately used information systems (PIS) may serve as a platform for data-based interventions in real-time. So-called persuasive technologies – designed to support behavior change – can support the individual's capabilities and decision making (Corbett 2013), helping them to disrupt habits and supporting the pursuit of individual (e.g., physical activity, health) or societal goals (e.g., sustainability) (Hermsen et al. 2016). While IS scholars have developed theoretical frameworks that explicitly address the adoption also of PIS (e.g., Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology), research that investigates the practical impact and contribution of such technologies to societal problems is still scarce (Gholami et al. 2016). In fact, leading IS scholars increasingly stress the importance of empirical evidence and call for conducting real-world impact studies that contribute to pressing societal issues, in particular to the 17 sustainable development goals put forward by the United Nations, of which many focus on environmental sustainability (Agarwal and Dhar 2014; Agerfalk 2014; Beath et al. 2013; Gupta 2017; Rai 2017; Sawyer and Winter 2011). While the Green IS community in particular seeks to address this, recent meta-analyses point out a strong propensity to conceptualizing and analyzing studies and identify a lack of empirical design- and impact-oriented contributions (Gholami et al. 2016; Malhotra et al. 2013). In particular, studies that establish a link between the design (content, framing, representation) of an IS artifact and its actual impact on resource consumption or carbon emissions are missing. Yet research conducted in other disciplines (environmental psychology, behavioral economics) highlight how even seemingly small changes to the content or framing of behavioral interventions can have large implications on their real-world impact (Hardisty et al. 2010; Schultz et al. 2007, 2015).

With findings from a randomized controlled field experiment with 1,423 hotel guests we contribute to the current state of research in four ways: First, we roll-out a persuasive technology and quantify consumer behavior in a real-world setting. Further, we confirm the large influencing potential of data-based interventions by finding a large treatment effect on the target behavior of over 18% for the most successful treatment condition. Next, we systematically vary the content of the intervention and show that seemingly harmless variations can have a detrimental impact on resource conservation. Last, we map the results to theories from cognitive psychology to (potentially) explain the observed behavior. The results indicate the importance of carefully choosing the design based on a well-grounded development of IS and of providing a detailed artifact description.

Related Work and Research Gap

In 2010, Melville called for research on the impact of different IS design choices on sustainable behavior. A recent meta-review (Gholami et al. 2016) identified a single impact-oriented study (Loock et al. 2013). While research in psychology (e.g., Schultz et al. 2007), behavioral economics (e.g., Ferraro and Price 2013), and Human-Computer-Interaction (HCI) (Froehlich et al. 2010, 2012) suggests the importance of artifact design choices on resulting consumer behavior, many IS studies (for instance on technology adoption) do not provide a detailed description of the artifact investigated (Barnett et al. 2015; Venkatesh et al. 2012). Hence, it is conceivable that results on the adoption, use, or impact of an IS artifact are strongly influenced by particular design choices that are not even mentioned in those articles.

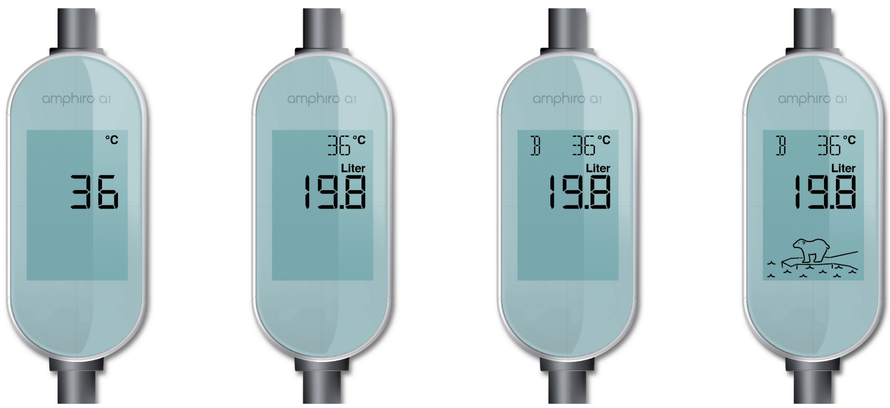
A research community that explicitly investigates such issues is HCI. Several HCI studies have evaluated user interfaces of feedback devices regarding user experience and expected outcomes; yet, a meta-study by Froehlich et al. (2010) identifies methodological flaws in HCI studies which make it challenging to draw valid conclusions: they do not measure behavioral outcomes, or lack reference data (control group or pre-intervention data). More recent studies in the HCI community are also not able to establish correlations of visualized content and outcomes in terms of energy consumption; they rely on intentions rather than studying usage (Froehlich et al. 2012), do not quantify behavior change (Hargreaves et al. 2013), or have small sample sizes that yield statistically insignificant results and do not allow for valid inference (Rettie et al. 2014). Feedback studies in behavioral economics or psychology, on the other hand, typically feature a research design that allows to gauge the impact of IS-enabled sustainability interventions. A plethora of studies investigate how websites or in-home displays with feedback on household electricity use affect conservation behavior and recent meta-studies report conservation effects of 0-5% (Delmas et al. 2013; McKerracher and Torriti 2013). Providing feedback on a single, energy-intensive activity like showering, can lead to saving effects of 22% for the target behavior which translated into 5% of the participants' household energy use (Tiefenbeck et al. forthcoming). However, the findings of all these studies are the outcome of a whole bundle of different IS design choices, with different content elements provided in parallel (e.g., energy use in kWh, financial savings, neighborhood comparisons). Thus, the influence of an individual element (e.g. energy use in kWh) on consumption behavior remains unknown. The only exception we are aware of is a recent experiment that investigated the impact of feedback on electricity use alone vs. in combination with associated costs vs. in combination with social norms (Schultz et al. 2015). Only the latter treatment yields a significant treatment effect (of 9% after 1-week and 7% after 3-months).

In short, there is a lack of studies that investigate systematically the path from information provision to engagement to actual impact on behavior. Understanding the relationship between IS design choices (feedback elements) and behavioral outcomes would be of high value for both, advancing theory and building more effective interventions in practice. In this article, we will use real-world measurement data to systematically investigate to what extent individual design choices may affect sustainable consumer behavior.

Research Method and Hypotheses

In a 6-months randomized controlled field trial in cooperation with a hotel in Germany, we equipped 40 hotel rooms with smart shower meters and collected data on each shower (water volume, temperature, and flowrate of each shower). We examine showering as target behavior for two reasons: First, it is a frequent and self-contained activity where the resource consumption is the outcome of an individual's daily decision-making and behavior. Second, beyond its impact on water resources, showering accounts for more than 80% of the total energy used for water heating in the residential sector (Bertrand et al. 2017), which in turn is the second largest energy end use in European and U.S. households (iea 2016). The exact amount of energy used for a shower is a product of used water and temperature; for our data analysis later on, we will use energy consumption as a dependent variable. The devices installed display feedback on the ongoing shower on a little screen located between shower hose and shower head at the user's eye level and store data on every shower taken. Guests were informed about an ongoing energy efficiency study in the hotel rooms' showers upon their arrival. At the checkout, they were asked to fill out a short survey on their user experience with the smart shower meter. For time constraints in the checkout process, the hotel management asked to limit the survey to four brief questions. Both, shower data and survey data, were collected at the room level, which allows to measure differences between the different experimental conditions. For privacy reasons, we cannot establish a link between individual guests' shower data and survey data.

To examine the effect of different display content elements, we configured four display versions of the smart shower meter (**Figure *1***). Ten hotel rooms were assigned to each study group. We used a stratified randomization process by floors (to minimize systematic differences in water pressure) and hotel room categories (economy vs. comfort) to ensure balance of the study groups.



Control group (C):
Temperature in °C

Treatment I (T1):
Temperature in °C
Water Volume in liters

Treatment II (T2):
Temperature in °C
Water Volume in liters
Energy Efficiency Class

Treatment III (T3):
Temperature in °C
Water Volume in liters
Energy Efficiency Class
Climate Animation

Figure 1: Experimental conditions

The first study group (control group) serves as a reference point for the three treatment groups and received feedback only on water temperature. The primary purpose of that element is to indicate that the device is on and measuring, without allowing users to infer cumulative water or energy use. For the three treatment groups, we additively enabled three different display elements. For the first treatment group (T1), we added feedback on the amount of water used (in liters), a numerical value that starts at 0 and counts up in 0.1 liter increments. Although (cold) water conservation is much less of an issue in central Europe than energy conservation (Amann 2012), most people can relate to liters of water much more easily than to kWh of energy (Tiefenbeck et al. forthcoming). According to feedback intervention theory (Kluger and DeNisi 1998), the provision of a pure numerical feedback without any normative evaluation or reference point (e.g., water consumption in the average shower) should not have any effect. Thus, we hypothesize:

H1 Pure numerical feedback on water consumption without a reference point or normative evaluation does not induce energy (and water) conservation.

In addition to water consumption and temperature, the second treatment group (T2) was exposed to an energy efficiency class (EEC), which rates a shower with the letters A (most efficient) to G (least efficient). Each shower starts in efficiency class A; the rating changes at equidistant kWh intervals that have been defined based on the data distribution of a pilot study (blinded for review). The element was adapted from the European Energy Efficiency scale and adds a normative evaluation to the pure numerical feedback. Hence, we conjecture that

H2 Adding a normative feedback element that rates resource consumption on an energy efficiency scale increases the conservation effect.

For the third treatment group (T3), yet another element was enabled: a drawing of a polar bear on an ice floe that shrinks at predefined kWh thresholds (and disappears if the shower exceeds twice the energy use of an average shower). Thus, the element conveys the impact of energy consumption on the environment and climate change. We hypothesize that

H3 Adding a visual element that brings to mind the impact of energy use on the environment increases the conservation effect.

Results

The main objective of this study is to quantify the impact of the individual content elements on energy consumption. We complement the results from those measurement data with the hotel guests' ratings of the four shower meter variants in the questionnaire. During the 6-month study, 1,423 individuals (782 unique bookings) stayed as guests in one of the rooms with a smart shower meter. Overall, we collected 8,448 data points from 35 hotel rooms; 5 of the 40 installed devices did not deliver usable data (4 defective devices, 1 room could not be accessed for data read out) (N=241). First, we filtered out water extractions by housekeeping (cleaning of showers), which are easy to identify by their low temperatures and small water volume (N=1,463). Next, we filtered out extreme outliers (e.g. showers with a mean temperature of 47°C and above) using the same filter criteria as in (blinded for review) (N=65). As we found a high variance of flowrates within the hotel building from the 19th century, we dropped observations from rooms with mean flowrates above (N=180) resp. below (N=546) the 90% confidence interval around the mean flowrate (9.5 l/min). A subgroup analysis by room types revealed that guests in the ten economy rooms took significantly shorter and colder showers than guests in the comfort room category ($p<0.001$) despite comparable flowrates. For estimating the treatment effects, we focus on the large fraction of our sample, i.e. the 22 comfort rooms (N=4,159) and include the economy rooms later on as a robustness check. **Figure *2*** visualizes the treatment effect (in %) and standard errors by groups.

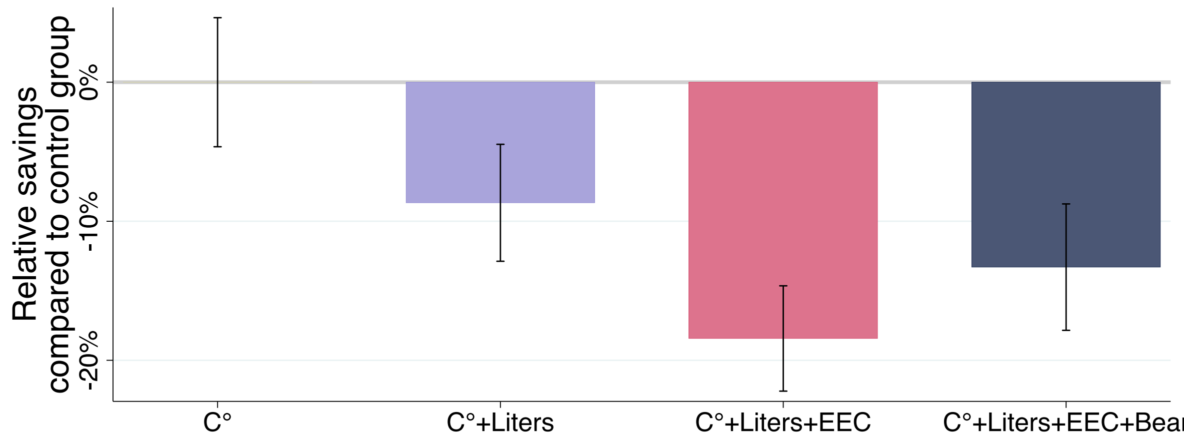


Figure 2: Treatment effect on energy use by experimental group

The control group's mean energy consumption of 1.94 kWh per shower serves as a reference point to calculate the treatment effects. Regression estimation (without controlling for flowrate) reveals a significant treatment effect of 8.7% for T1 ($p=.008$), 18.4% for T2 ($p<.001$), and 13.3% for T3 ($p=.001$). When adding flowrate as a control variable, the regression model yields similar, slightly smaller effect sizes of 8.3% for T1 ($p=.005$), 16.3% for T2 ($p<.001$), and 10.6% for T3 ($p<.001$), respectively. In order to derive the influence of the individual display elements, we conduct pairwise comparisons between the groups. T1 serves as reference group to gauge the effect for T2 (with vs. without EEC), while T2 serves a reference group for T3 (with vs. without polar bear). The results of the regression analysis (with flowrate as control variable) suggest that displaying real-time water consumption alone reduces the energy use per shower by 8.3% ($p=.011$); the isolated effect of adding EEC (relative to T1) is 9.0% ($p=.006$). Surprisingly, enabling the polar bear seems to increase energy consumption by 6.8% compared to T2, yet the result is at the margin of statistical significance ($p=.061$). Estimating the model with water volume or shower time as dependent variables corroborates the polar bear's negative influence at $p<.05$. As indicated above, we use the full sample (economy rooms included) to perform robustness checks. Whereas the effect of displaying real-time water consumption and EEC remain robust, the effect of the polar bear (difference between T2 and T3) is now far from being statistically significant (p=.77).

To further examine the effectiveness of the display elements, we analyze the 444 valid questionnaires (65% answer rate, users exposed to defective devices excluded, C: 23%, T1:26%, T2: 26%, T3: 25%). **Figure *3*** visualizes users' perception of the artifact regarding the four items understandability of content, motivation with respect to energy conservation, satisfaction of using the artifact, and continuous usage intention.

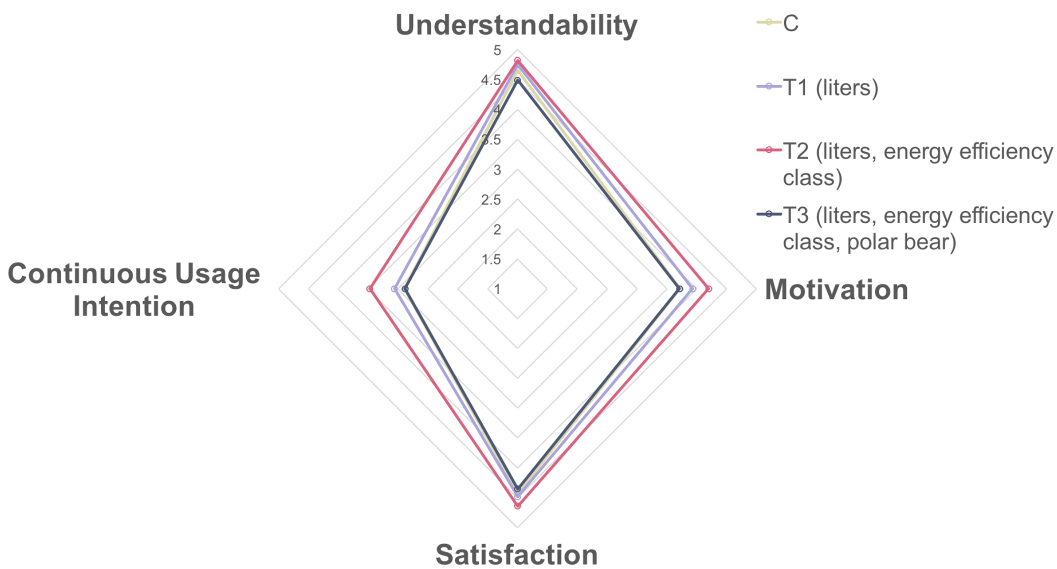


Figure 3: Survey results on the perception of the artifact

All four variables are based on a 5-point Likert scale, with 5 representing the highest level of agreement. With mean scores around 4, we generally find a positive user experience with the artifact. The only exception is continuous usage intention ("I would like to own this smart shower meter at home.") with a mean score of 2.5: A positive user experience does not necessarily create a desire to own such the device. Between the three treatment groups, we find the same pattern on all four dimensions: The display with liters and EEC (T2) is rated more positively than the liters-only display (T1) and the version with the complete set of information (T3). T3 even fails to achieve better ratings than the control group display. Independent sample t-tests show that differences between T2 and T3 are significant at $p<.05$ on all four dimensions. In other words, the polar bear has a negative impact on the user perception of the feedback technology.

Discussion

Participants of our experiment were exposed to different display elements representing resource consumption in the shower. Based on the shower data recorded, we find that pure numeric feedback on water consumption (in liters) already results in a treatment effect of 8.3% - hence, we reject H1. The results further indicate that providing individuals with a normative rating, in our example EEC, increases energy savings by 9.0% (compared to T1), translating into a total conservation effect of 16.3% (compared to C). Thus, H2 can be confirmed. The findings are in line with literature that finds external reference points generally helpful (Tversky and Kahneman 1991). Interestingly, adding the polar bear animation that visualizes the environmental consequences of one's energy consumption, results in a marginally significant ($p=0.061$) *increase* of energy consumption by 6.8% (compared to T2) and decreases the overall conservation effect to 10.6%. While the effect did not prove to be stable in the robustness checks with all rooms, the questionnaire data corroborate adverse effects of the polar bear: the experimental condition with the polar bear rated the user experience with the device in all four dimension significantly lower than the two other treatment groups. Different mechanisms are conceivable: Individuals may perceive the illustration of the bear's natural environment melting away as too far-fetched. Or, in line with the persuasion knowledge model (Friestad and Wright 1994), hotel guests might sense a persuasion attempt regarding their behavior, perceive this as a threat to their personal freedom in decision making and respond by resorting to adverse reactions (e.g. taking longer showers). Alluring to environmental consequences on a global level may also alter information processing strategies (Ahluwalia 2000): While water consumption and efficiency class rating describe concrete outcomes of the individual's current activity, the polar bear may induce a shift the to a high-level perspective where this individual perceives her own abilities to protect the environment as limited (Gutsell and Inzlicht 2012) and insignificant. The effect might also be due to curiosity ("Can I drown the polar bear?"). In order to draw conclusions with greater certainty on the effect of the polar bear on energy consumption (H3), we currently plan another round of data collection with two conditions only (T2 vs. T3).

Contribution, Implications, and Limitations

The present work follows recent research calls within the IS community for developing IS that target issues for humanity (Gholami et al. 2016; Rai 2017), or more precisely information-based decision models for energy consumption management (Gupta 2017). We empirically quantify the impact of an IS artifact on consumer behavior, which several scholars have been calling for (Beath et al. 2013; Sawyer and Winter 2011). The results of our use case provide evidence that IS-enabled feedback interventions in non-professional contexts can induce considerable behavior change, with an 18% conservation effect in the most successful condition. In particular, the findings show that seemingly small display content variations may considerably affect the impact of the intervention; we further provide possible explanations for the differences from psychology. Our work is a *knowledge contribution* which "embodies design ideas and theories yet to be articulated, formalized, and fully understood" (Gregor and Hevner 2013, p. 341). At the same time our work is an *empirical contribution* according to Agerfalk (2014) on which new theories might be settled on in the future. While our design-oriented work aims at deriving design implications for new innovative IS by conceptualizing the artifact, it also is a behaviorism-based approach that discovers IS phenomena in the real world (Baskerville et al. 2011; Gregor and Hevner 2013).

The current work is subject to situational, contextual and methodological limitations. First, we only tested three different display elements. While it might be interesting to test the impact of additional feedback elements (e.g., emoticons conveying (dis)approval), we were limited to the possibilities of the existing smart shower meter. From a research perspective, compared to prototype devices, the adaptation of an existing product for empirical research has the advantage that the technology is more reliable and offers the large benefit that studies with large samples can be implemented. On the downside, compared to designing a technology from scratch, that setup reduces the freedom in the design of the feedback to what is possible with the existing hardware. Second, the experiment was run in a hotel with real-world customers, which limit survey questions and data matching possibilities. In particular, we do not track the subjects' shower behavior over longer periods of time, as related studies with residential samples did (blinded for review). On the other hand, running the experiment in a hotel setting offers three key advantages: It is possible a) to collect data on a large number of subjects, b) to run the study with an opt-out design, which minimizes self-selection biases and increases the external validity of the findings, and c) to rule out financial motives driving the guests' conservation efforts, as the cost of resource use is included in the hotel price. Whether the findings can be transferred to a more general consumer context still remains an open question. Finally, after filtering our sample size is room-wise quite small (n=6 for T2, n=5 for T3). This might cause the marginally significant effect of the polar bear. Therefore, we plan another round of data collection on a larger sample in the near future.

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