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ORIGINAL ARTICLE

The role of perceived control over appliances in the acceptance of electricity load-shifting programmes

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Abstract Many countries, Switzerland included, envisage an energy transition characterised by the increased production of renewables. One challenge faced by these nations is that peak household electricity demand often does not correspond with the peak production of renewables such as photovoltaics (PV) and wind. Load-shifting via the use of smart appliances provides one option to better match renewable electricity production with household electricity demand. However, load-shifting requires the adoption of smart grid and smart metering technologies, which the public often views as a form of surrender to a lack of control and data security issues. Thus, load-shifting might encounter social disapproval. This paper analyses how control over the use of appliances and data security perceptions influence the social acceptance of load-shifting programmes via a social psychological online experiment ($N = 250$) by taking the example of the dishwasher. Results suggest a significant causal influence of the level of control over appliance on the acceptance of a load-shifting programme. In situations where participants perceived a lack of control over their appliance, acceptance levels dropped significantly. Regarding data security, experimental manipulation has been unsuccessful; therefore, no valid conclusions can be drawn regarding this factor. These results indicate the presence of serious concerns regarding the control of appliances when people are asked to consider a load-shifting programme. The development of a deeper understanding of these concerns may help utilities to create more successful, socially accepted load-shifting programmes and communication strategies.

Keywords Load-shifting · Control · Data security · Social acceptance · Electricity demand of households

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Introduction

Following the accident at Japan's Fukushima nuclear power plant in 2011, the Swiss government decided to pursue a new energy strategy (Energy Strategy 2050, Swiss Federal Council 2013). The cornerstones of this new energy strategy include the phasing out of Switzerland's nuclear power generation, the reduction of per capita energy consumption and the increase in production of new renewable energy sources. In 2014, five nuclear reactors produced 38% of Switzerland's electricity, whilst hydro power accounted for 56%; only 4% of electricity was produced by the so-called new renewables (i.e. photovoltaics, wind power, biomass, geothermal, combined heat and power; Swiss Federal Office of Energy, 2015b). Thus, the phasing out of nuclear power and the promotion of renewables indicate a tremendous shift in Switzerland's electricity system in the coming decades. Compared to the current system which includes five nuclear power reactors in four sites accounting for 38% of domestic electricity production, this new system will be less centralised due to increases in wind and photovoltaics (PV) power. This is because although these two renewable electricity production technologies have the largest potential in Switzerland (Swiss Federal Council, 2013), large-scale wind or PV parks will not be feasible in Switzerland. At the same time, due to their stochastic production patterns, providing base load and meeting peak demand will be challenging.

This new electricity system will require substantial changes in both the supply and demand side. These changes will significantly affect households, which account for approximately one third of Switzerland's electricity demand (Swiss Federal Office of Energy, 2015b), for example through increased electricity prices in general, and new tariff models. In the future, households' demand is expected to remain stable according to a scenario which is in line with Switzerland's new energy strategy (Prognos, 2012). This sounds puzzling regarding the planned efficiency measures but is due to the ongoing trend toward electrification of services (e.g. heat pumps to substitute oil and gas-fuelled heating systems which currently provide around 70% of households' space heating; Swiss Federal Office of Energy, 2015a). Electricity demand for mobility is expected to rise due to increased e-mobility (Prognos, 2012).

These demand developments together with increased production of wind and PV and the phase out of nuclear power represent a challenge since peak household demand may not match the peak production period of renewables. Household demand during working days is typically characterised by a small peak in the morning hours followed by a larger peak in the evening (Godoy-Shimizu et al., 2014; Soares et al., 2014). This pattern can be observed across Switzerland, and as a recent study concludes, 'solar energy production takes place at times when demand for electricity is not necessarily high' (Perret et al., 2015, p. 3). This mismatch of demand and production presents a challenge which might be overcome through load-shifting. According to Eid et al. (2015), load-shifting provides several potential benefits for the electricity system. From an economic point of view, load-shifting can lead to a general reduction of costs of electricity supply. From an environmental perspective, load-shifting can lead to decreased energy use, increased energy efficiency and a commitment for renewable energy production. From an electricity grid perceptive, load-shifting helps to maintain grid stability and at the same time, the need to increase electricity transmission or generation capacity is reduced in the long-term. In general, two different load-shifting strategies can be distinguished for households: technical solutions and individual adaptation. Technical solutions could be storage systems such as batteries, pumped-storage hydropower or power to gas. One negative side effect of this strategy is that an expansion of Switzerland's storage infrastructure implies massive costs.

Another interesting strategy therefore is individual adaptation. Such individual adaptation could occur either through actual behavioural change (e.g. individuals operate appliances whilst the sun is shining) or due to the adoption of the so-called smart appliances. Behavioural change may be socially contested, especially when considering behaviours such as cooking and the use of information and communication technologies or if lifestyle changes are necessary in order to operate appliances during times when people are typically away from their homes.

In contrast, automatically operating smart appliances may be an attractive option for services that are not necessarily time-critical, such as those involving the use of a washing machine, tumble dryer or dishwasher (Perret et al., 2015). These appliances are able to receive signals from the electricity provider and therefore, start when certain conditions are fulfilled. However, one cannot conclude that smart appliances will be accepted merely because they do not require behavioural changes besides from e.g. waiting for clean dishes if the dishwasher does not start immediately. In order to successfully shift electricity loads, smart appliances require signals about the current status of the electricity system and its short-term developments due to such factors as weather conditions provided by an institution such as the electricity provider. This information can be supplied through technologies such as smart grids and smart meters. To be most effective, it is essential that these smart metering and grid technologies be accepted and utilised by the public (Sauter & Watson, 2007; e.g. Schweizer-Ries, 2008). Such acceptance will likely depend on the risks and benefits associated with these technologies (Krishnamurti et al., 2012).

The overall aim of this paper is to analyse the social acceptance of load-shifting programmes relating to smart appliances by means of a social psychological experiment. More concretely, this paper examines how different factors, such as personal control over the use of appliances and perceived data security risks, influence the social acceptance of load-shifting programmes. This paper also analyses the risks and benefits associated with a load-shifting programme of a notional utility and evaluates how these variables are linked to the social acceptance of the programme. This study takes the dishwasher as an example, as the service it provides is not too time-critical (Perret et al., 2015) and, unlike washing machines which are often shared among Swiss households, households usually have their own dishwasher. The share of households who have their own dishwasher rapidly increased over time and reached 76% in 2011 (De Haan et al., 2012).

Background

Empirical findings on social acceptance of load-shifting

In Switzerland, load-shifting to daytime appliance use is a rather new phenomenon which requires that individuals unlearn behavioural patterns which had been long-promoted and encouraged through various incentives such as lower night-time electricity tariffs. According to one Swiss study, technical potentials for load-shifting are estimated at approximately 6–8% of load (Perret et al., 2015). The authors demonstrated via experiment that financial incentives may help unlock these potentials. Whilst consumption feedback was shown to decrease overall electricity consumption, households receiving a financial incentive to shift loads decreased consumption during evening hours. In another Swiss study, participants were asked about their willingness to participate in a demand-response programme which would hand control of the operation of their dishwasher over to their utility company. Through experiments, the authors found that charging a fee for non-participation in the demand response programme resulted in participation rates similar to those seen when a reward for participation was offered (Gamma et al., 2014; Künzel et al., 2014). Internationally, utility programmes and load-shifting research approaches often focus on financial incentives to motivate people to alter their electricity use patterns or to allow their utility to directly control load (for an overview, see Newsham & Bowker, 2010). In accordance with such patterns, a meta-analysis concluded that dynamic pricing coupled with the use of automated appliances provides an effective load-shifting strategy (Davis et al., 2013). However, incentives of a non-financial nature may also be relevant. A recent real-world experiment conducted in the US state of California demonstrates the importance of social factors on the adoption of load-shifting programmes (Yoeli et al., 2013). Here, the authors demonstrated that people were more motivated to participate in a load-shifting programme when they were required to sign their name to a public list, as compared to a programme where the signing was anonymous. Thus, reputational incentives may be a powerful factor in the enhancement of participation in load-shifting programmes. In the California experiment, reputational incentives proved to be more powerful motivators of participation than financial incentives. A large-scale survey in the UK investigated participant's acceptance of different time-of-use tariffs and direct load control for the heating system (Fell et al., 2015). According to the authors, it was surprising that direct load control yielded the highest levels of acceptance as many qualitative studies emphasise concerns regarding loss of control. At the same time, the direct load control condition described in the survey allowed only small impacts on temperature and included an overriding system.

A qualitative study conducted in some UK households indicated that many held a critical view of load-shifting. This perspective likely stems from people's perception that they have little control over many electricity-demanding household activities. Examples of such activities include cooking, the operation of kettles, the operation of a fish tank, the use of a refrigerator and the consumption of electricity (such as turning up the heating) due to medical conditions (Hargreaves et al., 2010). However, Higginson et al. (2014) observed a significant flexibility involving household activities that rely on the use of electricity. Their analysis focused on laundry, in particular; study participants were shown to arrange their lives around various constraints and disruptions—for example, a washing schedule or the habit to do the washing when the sun is shining in order to facilitate outdoor line-drying. Thus, load-shifting in regard to laundry might be perceived as one constraint among many others that can be readily overcome.

What is more, individuals may have to become acquainted with new infrastructure and enabling technologies such as smart meters and smart grids, which are crucial in the move toward load-shifting programmes (Darby & McKenna, 2012; Newsham & Bowker, 2010). Many of these programmes require smart meters as a key technology (Spence et al., 2015), for example, to interact with household appliances. However, smart meters are a heavily contested infrastructure

(Krishnamurti et al., 2012; Mah et al., 2012). A recent survey in the UK, for example, indicated that many survey participants were ambivalent whether they supported smart meters or not (Spence et al., 2015). Research into different types of contested technologies and infrastructures has indicated that acceptance is often crucially dependent on the public's perceptions of associated risks and benefits (for example, Moser et al., 2015; Seidl et al., 2013; Siegrist, 2000; Siegrist et al., 2005). As the experiment in this study investigated a load-shifting programme which operated through a smart meter, the focus lies on perceived risks and benefits associated with smart meters. Respective empirical findings are presented in the next two chapters.

Perceived risks of smart meters

A growing body of literature is examining risk perception of smart metering with data security, and control being crucial issues (Döbelt et al., 2015; Krishnamurti et al., 2012; Mah et al., 2012). This not only concerns smart meters but also smart homes (which may include smart energy management systems): A study found that data security and control are key concerns in participants' attitudes toward smart homes in the UK (Wilson et al., 2015).

Data security is a crucial issue associated with smart metering because behavioural patterns, habits, patterns of occupancy and technology usage of residents can be inferred from real-time electricity consumption data. This information could be used or misused by utilities or other third parties for commercial purposes (e.g. targeted marketing) or even for criminal activities (Döbelt et al., 2015; Yan et al., 2012). Therefore, one key issue involves the perceived risk of consumer privacy violations and the supposed inability to protect personal customer data (Krishnamurti et al., 2012; Verbong et al., 2013).

Moreover, customers fear a loss of control over their appliances due to direct load control by utility companies and worry that utilities may act as 'big brothers' (Krishnamurti et al., 2012, p. 793; Verbong et al., 2013). Control represents a construct which has been researched in psychology since decades (Skinner, 1996). It is important to distinguish between objective control and subjective or perceived control. Both perspectives may diverge: Although a situation might be under control of someone else, an individual can still have the subjective feeling to be in control. Studies show that the level of subjective or perceived control has a more powerful influence on people's cognitions, emotions and behaviours compared to level of objective control (Skinner, 1996). Based on this finding, one could expect that not so much the actual fact that a utility has control over appliances has an impact on acceptance. More important, regarding acceptance is if people subjectively perceive a loss of control over their appliance (for an overview, see Fell et al., 2015).

In addition to data security and control, the following studies identified further perceived risks of smart meters: Krishnamurti et al. (2012) identified that customers fear higher electricity bills due to more accurate meter readings. Mah et al. (2012) illustrated that customers perceive smart meters to be associated with various health risks such as headaches and cancer. Additionally, customers may simply be disinterested or may believe that changes to their routine will be too difficult to implement (Verbong et al., 2013). On a more systemic level, Davies (2010) suggested that due to internet connectivity, large infrastructure projects such as power grids and power stations might be prone to hacker attacks.

Perceived benefits of smart meters

In addition to perceived risks, research has also identified various benefits associated with smart metering technologies (Krishnamurti et al., 2012). Such benefits include the improvement of grid efficiency, a reduced risk of blackouts and monetary savings resulting from the use of smart meters. Savings will likely stem from increased information and reduced labour costs due to automated meter reading. Moreover, participants expected benefits from smart meter-connected enabling technologies such as in-home displays providing continuous information regarding electricity consumption.

Study goals and hypotheses

This paper is based on the assumption that load-shifting of households' electricity consumption is a promising strategy to be implemented in conjunction with an investment in storage and transmission systems in order to ensure a balance between the production of renewables and household electricity demand. The literature review indicated that a key technology to enable load-shifting, namely, the smart meter is societally contested and thus, may lack public acceptance. This is because smart meters are associated with various risks and some benefits. Among perceived risks, data security and control are crucial issues. Consequently, a need exists to develop a better understanding of the relationship between these perceived risks and benefits and the widespread acceptance of load-shifting programmes.

The goal of this study is to analyse the social acceptance of load-shifting programmes by means of a social psychological experiment. This study takes dishwashers as an example. More concretely, it examines how critical issues such as control over the use of the dishwasher and data security perceptions influence the social acceptance of load-shifting programmes.

Based on the review of related literature, the following hypotheses were developed:

- Hypothesis 1: Acceptance of the load-shift programme is higher if the level of perceived control is high.
- Hypothesis 2: Acceptance of the load-shift programme is higher if the level of perceived data security is high.

Further, a more exploratory approach was taken to examine the following research question: How are risks and benefits associated with load-shifting programmes linked to programme acceptance? To this end, the hypotheses as well as the exploratory research question were tested via an online social psychological experiment.

Method

Experimental design

Study setting

Participants were instructed to imagine receiving an offer from their energy utility to participate in a load-shifting programme. Participants were informed that their household would be equipped with a smart meter, which would communicate with their dishwasher. Similar to the study conducted by Künzel et al. (2014), the programme focused on a direct load control of dishwashers. The rationale behind this particular choice of appliance centred on the fact that the operation of dishwashers, tumble dryers and washing machines can be load-shifted rather simply (Perret et al., 2015). However, many Swiss households do not possess independent washing machines or tumble dryers, instead sharing these particular appliances with neighbours. Such a practice often leads to the continuous daily use of washing machines and tumble dryers by different parties. In line with previous Swiss studies (Gamma et al., 2014; Künzel et al., 2014), the current research therefore focused solely on dishwashers. The proposed offer made by the utility company stated that a participant's dishwasher would only be operated if the local production of electricity exceeded local demand. If demand was not exceeded, the dishwasher would be placed on hold. In the experiment, the two variables of 'control' and 'data security' were each manipulated on two levels (high vs. low), resulting in a 2 × 2 design with the control group receiving no information about control or data security. Participants were randomly assigned to the different conditions.

Manipulated (independent) variables

Control: high vs. low

In the 'control high' condition, participants were informed that a button could be pressed at the smart meter to immediately activate the dishwasher, thus circumventing the load-shift programme. In the 'control low' condition, participants were informed that there was no opportunity to circumvent the load-shift programme.

Data security: high vs. low

In the 'data security high' condition, participants were informed that electricity consumption data was strictly protected and could only be viewed by the electricity provider. In the 'data security low' condition, participants were informed that electricity consumption data was not protected and that the electricity provider was allowed to hand the data over to third parties.

Control group

The control group received no specific information regarding control or data security.

Please see Appendix for a translated version of the presented stimuli.

Measured (dependent) variables

Risk perception

The scale measuring risk perception consisted of eight items which addressed several risks as identified in the literature analysis (Krishnamurti et al., 2012; Mah et al., 2012; Verbong et al., 2013). Participants were asked to record how strongly they associated the load-shift programme with several risks (see Table 1 for the full list of items) on a seven-point Likert scale ranging from 1 'not at all' to 7 'very strongly.' The wording of the questionnaire was based on the risk perception scale developed by Moser et al. (2015).

Benefit perception

The scale measuring benefit perception consisted of six items which addressed several benefits as identified in the literature analysis (Krishnamurti et al., 2012). An additional item was included which addressed the customer benefit of contribution to the energy transition. Participants were asked to record how strongly they associated the load-shift programme with several benefits (see Table 1 for the full list of items) on a seven-point Likert scale ranging from 1 'not at all' to 7 'very strongly.' The wording of the questionnaire was based on the benefit perception scale developed by Moser et al. (2015).

Acceptance

Acceptance of the programme was measured by evaluating responses to the following three statements: 'I can imagine very well participating in this programme', 'If my energy utility offered such a programme, I would participate' and 'I do not want to participate in such a programme' [recoded]. Participants responded to each item on a seven-point Likert scale ranging from 1 'I do not agree at all' to 7 'I do agree strongly'.

Manipulation check

To determine whether the manipulation of the 'control' and 'data security' variables had been successful, participant responses to the following two questions were evaluated: 'Because of the programme, I lose control over the use of my appliances' and 'The programme represents a risk to my personal data.' Participants responded to each item on a seven-point Likert scale ranging from 1 'I do not agree at all' to 7 'I do agree strongly'.

Procedure

The data were collected in late September and early October of 2014 in the German-speaking part of Switzerland. Participants were recruited through the online panel company Respondi, and an equal number of males and females were selected and contacted via e-mail with invitations to participate in the study. Participants were welcomed and informed that Swiss households consume approximately one third of the nation's energy. Participants were then advised that one method of more efficiently utilising renewable electricity involved the matching of electricity production with demand via a smart grid and smart metering. Participants were asked to imagine receiving an offer from their energy utility requesting their participation in a programme which would promote dishwasher use at times of peak renewable electricity production. The programme specifics differed according to that of experimental conditions or control group to which participants were randomly assigned. Perceived control and perceived data security were described as either 'high' or 'low' for the experiment groups, or no indication was given for the control group (see Appendix for translated stimuli). Following a description of the programme, participants were asked to express their spontaneous reaction in a textbox. Next, they were asked to respond to the risk and benefit perception scales. Upon completion of the acceptance items and manipulation check questions, participants were asked to provide demographic information. Completion of the entire questionnaire took approximately 10 min on average; participants received a small incentive for participation in the form of points that can be converted to different coupons online.

Sample

In total, $N = 250$ participants took part in the study. All participants lived in the German-speaking part of Switzerland and were recruited through the online panel company Respondi. The average age of participants was 44.7 years (SD = 15.9 years), with the youngest participant being 17 and the oldest being 84 years old. Forty-four percent ($n = 110$) of respondents were female and 56% were male. According to demographic information, 49% of participants had concluded vocational training, 23% had completed some form of higher education (e.g. university of applied sciences, university, PhD), 11% had completed senior high school, 11% had completed higher vocational training and 4% had completed compulsory school; 2% of participants chose not to specify their education level.

This sample is roughly representative of Switzerland's population with regard to education and age, with the national average being 41.8 years old (BFS, 2016). However, fewer sample participants had completed only compulsory school and more had completed vocational training or higher education than that of what is seen in the Swiss average where 15% of the population completed compulsory school; 44% has completed vocational training and 18% has completed higher education (BFS, 2013). Compared to Swiss population statistics, men are slightly overrepresented in the sample; in Switzerland, 49% of the population is male (BFS, 2016).

Results

Manipulation check

Control

Analysis of variance suggested that manipulation of the 'control' variable had significant influence on participant responses to the following item: 'Because of the programme, I lose control over the use of my appliances', $F(1, 245) = 15.25$, $p < .001$. Participants in the 'control low' condition agreed more strongly with this statement ($M = 4.96$, SD = 1.82) as compared to that of participants in the 'control high' condition ($M = 3.91$, SD = 2.10) or the control group ($M = 4.43$, SD = 1.44). Manipulation of the 'data security' variable and of the interaction effect did not exert significant influence on the control manipulation check item. Results indicated that the manipulation of 'control' had been successful.

Data security

Analysis of variance did not suggest that manipulation of the 'data security' variable had a significant effect on participant responses to the item: 'The programme represents a risk to my personal data', $F(1, 245) = 0.20$, $p = .66$ (data security low: $M = 4.04$, SD = 2.01; data security high: $M = 3.91$, SD = 2.01; control condition: $M = 3.61$, SD = 1.75). Also, manipulation of control and the interaction effect did not demonstrate significant influence. Thus, results indicated that the manipulation of 'data security' was unsuccessful.

Construction of scales

To construct scales, risk and benefit perception items were subjected to a principal component analysis. As many studies conceptualised risk and benefit perception as two separate scales (such as Bearth et al., 2014; Fischhoff et al., 1978; Moser et al., 2015; Seidl et al., 2013; Siegrist et al., 2000), it was expected that risk and benefit perceptions would load on two different scales. However, analysis of the Kaiser criterion and a visual inspection of the scree plot suggested a three-factor solution, which explained 56% of the total variance. Results of the principal component analysis suggested a benefit perception factor (RP), which explained 25% of variance. Items related to risk perception were separated into one general risk perception scale (RP), which explained 18% of variance. The data security item loaded on this factor. In addition, a specific factor related to a perceived lack of control (PLC) explained 13% of variance (see Table 1). Due to this study's emphasis on the issue of control, this three-factorial structure with a separate perceived lack of control scale was maintained. The calculated scales representing the respective item means all had good or acceptable reliabilities: Cronbach's α for benefit perception = .85; Cronbach's α for risk perception = .75; and Cronbach's α for perceived lack of control = .78.

The three acceptance items were aggregated on one scale with a very strong internal reliability, Cronbach's α = .90. Table 2 provides an overview of all scale descriptives for the different experimental conditions and for the total sample.

Test of hypotheses

Acceptance of the load-shift programme was expected to be higher in the 'control high' group than that in the 'control low' group. Furthermore, acceptance of the load-shift programme was expected to be higher in the 'data security high' group than that in the 'data security low' group. Study results confirmed the first hypothesis. An analysis of variance (ANOVA) revealed a significant main effect of control, $F(1, 245) = 6.85$, $p < .01$, partial $\eta^2 = .03$, representing a small to medium-sized effect. Planned contrasts revealed the expected pattern:

Table 1 Items measuring risk and benefit perception. Factors and factor loadings (after varimax rotation) and communality (h^2). Bold loadings indicate the items corresponding to the respective factor ($N = 250$)

Items	Factors, explained variance and respective factor loadings			h^2
	Benefit perception (25%)	Risk perception (18%)	Perceived lack of control (13%)	
(BP) The programme will make a substantial contribution to the energy transition.	**0.84**	−0.13	−0.09	0.72
(BP) Because of the programme, less money needs to be invested in future energy infrastructure.	**0.73**	0.01	−0.10	0.54
(BP) The programme will reduce my electricity bill.	**0.71**	−0.10	−0.02	0.52
(BP) Because of the programme, I will have a better overview of my electricity consumption.	**0.75**	−0.10	−0.01	0.57
(BP) Because of the programme, there will be fewer blackouts in the future.	**0.61**	0.07	−0.13	0.40
(BP) Because of the programme, I can make a contribution to the energy transition.	**0.83**	−0.12	0.00	0.70
(RP) The programme will increase my electricity bill.	−0.14	**0.72**	0.20	0.58
(RP) Unauthorised parties could misuse my personal data.	−0.19	**0.61**	0.38	0.55
(RP) The programme will result in increased [a]electro-smog in my apartment.	0.00	**0.78**	−0.06	0.61
(RP) The programme will not make a substantial contribution to the energy transition.	−0.17	**0.38**	0.29	0.26
(RP) The programme will result in more blackouts in the future.	−0.05	**0.69**	0.07	0.49
(RP) In the future, I will have to buy new, compatible appliances.	0.17	**0.56**	0.35	0.46
(PLC) I can no longer decide myself when to use my appliances.	−0.03	0.12	**0.89**	0.80
(PLC) This programme restricts my freedom of action.	−0.17	0.32	**0.80**	0.77

Wording of the instructional question was as follows: 'How strongly do you associate the programme with these potential consequences?' Responses were given on a seven-point Likert scale ranging from 1 'not at all' to 7 'very strongly.' [a] Electro-smog refers to a non-scientific term which includes different types of electro-magnetic field around powerlines or appliances. Some people are afraid that electro-smog might have negative impacts for their health or for the environment

acceptance was higher in high control conditions ($M = 4.81$, SD = 1.77) than that in low control conditions ($M = 4.13$, SD = 1.97), $t(245) = 2.67$, $p < .01$. The highest acceptance level was found in the control group ($M = 4.88$, SD = 1.60), where the concept of having control over one's appliances was not mentioned. However, the difference was not statistically significant when compared to that of the high control condition (see Fig. 1).

Results did not support the second hypothesis. As expected, following the results of the manipulation check, the manipulation of data security did not have a significant influence on participants' acceptance of the load-shift programme, $F(1, 245) = 0.01$, $p = .91$, partial $\eta^2 = .00$. Additionally, the interaction effect between both manipulated variables did not have a significant influence on participants' acceptance, $F(2245) = .47$, $p = .5$, partial $\eta^2 = .00$ (see Fig. 1).

The relationship between risk, benefit, control perception and acceptance

The study continued with an exploration of the relationship between perceived risk, perceived benefit, perceived lack of control and acceptance via a hierarchical linear regression analysis.[1] First, perceived benefits and risks were entered as predictors. Second, perceived lack of control was entered in the regression analysis. For both models, acceptance was entered as a dependent variable. Table 3 provides an overview of the results.

[1] To account for the influences of the independent variables in the experiment, the following analysis was first carried out for the different experimental conditions separately. Patterns in all experimental groups were comparable (except for the condition 'high control, low data security' where perceived lack of control was not a significant factor). Thus, it was decided to include the whole sample in the analysis reported below.

Table 2 Descriptives for the different scales (means and standard deviations)

Experimental conditions	Benefit perception *M* (*SD*)	Risk perception *M* (*SD*)	Perceived lack of control *M* (*SD*)	Acceptance *M* (*SD*)
Control high, data security high (*n* = 46)	4.52 (1.26)	3.55 (1.26)	4.34 (1.81)	4.74 (1.96)
Control high, data security low (*n* = 45)	4.39 (1.35)	3.51 (1.22)	3.54 (1.82)	4.89 (1.57)
Control low, data security high (*n* = 55)	4.08 (1.31)	3.57 (1.38)	5.17 (1.56)	4.24 (2.09)
Control low, data security low (*n* = 55)	4.03 (1.21)	3.73 (1.01)	4.93 (1.76)	4.03 (1.85)
Control group (*n* = 49)	4.73 (1.00)	3.36 (0.88)	4.68 (1.28)	4.88 (1.60)
Total sample (*N* = 250)	4.33 (1.25)	3.55 (1.16)	4.58 (1.74)	4.53 (1.86)

Responses were given on a seven-point Likert scale ranging from 1 to 7, where 1 indicated the lowest level of perceived benefits, perceived risks, perceived lack of control and acceptance

The model revealed that both perceived benefits and perceived risks predicted acceptance; the greater the benefits and the smaller the risks perceived by a participant, the stronger their acceptance of the load-shifting programme. These two factors explained 56% of the total variance in the acceptance variable. The inclusion of the lack of control factor explained an additional significant share of the variance in acceptance. The more acutely participants perceived a lack of control over the use of their dishwasher, the more strongly they rejected the programme. These results indicate that lack of control is a significant deciding factor regarding participation in load-shift programmes.

Discussion and conclusions

Summary and discussion of the findings

The aim of this study was to analyse how perceived control over appliance use (in this case: dishwashers) and perceived data security issues may influence social acceptance of load-shifting programmes. Furthermore, the study examined the relationship between the perceived risks and benefits of load-shifting and overall acceptance of the programme. An online experiment yielded the following results: First, perceived control over appliance use influenced the acceptance of a load-shifting programme. This is reflected in the fact that the independent variable of lack of control resulted in lower participant acceptance ratings. Conversely, perceived lack of control also emerged as a separate factor in the principal component analysis of risk and benefit perception items. In conjunction with general perceived risks and benefits, perceived lack of control explained a significant share of the variance in acceptance of the load-shifting programme. Both results indicated that the perception of control over appliance use played an important role when an individual moved to form an opinion about a load-shifting programme. Thus, this study confirmed the significance of control as demonstrated in a previous mental model study (Krishnamurti

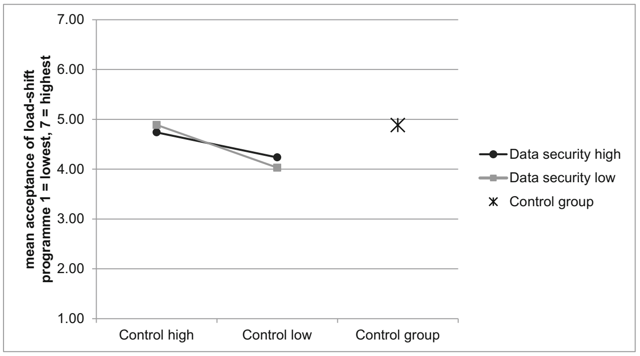

Fig. 1 Mean acceptance across experimental conditions and control group. Acceptance scale from 1 (lowest) to 7 (highest), *N* = 250

Table 3 Hierarchical linear regression model for acceptance of a load-shift programme. $N = 250$

Predictors	*B*	SE *B*	β
Step 1 (corrected $R^2 = .56$)			
Constant	2.41	.43	
Benefit perception	.90	.07	.61***
Risk perception	−.50	.07	−.31***
Step 2 ($\Delta R^2 = .05$ ***)			
Constant	3.27	.43	
Benefit perception	.85	.06	.57***
Risk perception	−.32	.07	−.20***
Perceived lack of control	−.28	.05	−.26***

Corrected $R^2 = .56$ for step 1 ($p < .001$), $\Delta R^2 = .05$ for step 2 ($p < .001$). *** $p < .001$

et al., 2012) and further extended these findings by demonstrating the causal impact of control on the acceptance of a load-shifting programme in an experimental setting. Whilst the study revealed that control is a significant factor in the formation of participant opinion regarding load-shifting programmes, researchers can only speculate as to why control is so important in this particular study. Literature suggests various reasons for this (Mert et al., 2008): People may want to be at home when their dishwasher is running, to avoid damage in case of accident. Another option is that people do not want their utility to interfere in their private sphere or they do not trust their utility or the technical system to correctly operate the dishwasher and regularly provide them with fresh dishes. People could also be afraid that they will be forced to invest in new appliances that are able to communicate with smart grid technologies. Though inconclusive, these conjectures suggest that individuals may wish to remain in control of their appliances for varying reasons, ranging from concerns over how to manage daily routines, to fears about intrusion into the private sphere and to anxiety regarding the trustworthiness of technical systems and institutions. Prior to the initiation of demand-response programmes, researchers and utility representatives must develop a better understanding of how these programmes can be successfully integrated into people's daily routines and how people's concerns can be addressed. To mitigate concerns regarding the management of daily routines, the inclusion of a button to overrule the programme might be helpful (see also the study by Fell et al., 2015). However, such a button is unlikely to resolve trust-related issues. Therefore, utilities must engage in an open dialogue with different customer groups to develop a better understanding of their needs and to better tailor their load-shifting programmes and communication strategies.

Furthermore, this study analysed the impact of perceived data security on the acceptance of load-shifting programmes. However, the manipulation check indicated that the manipulation of the perceived data security condition was unsuccessful; this was likely due to a too-narrow or insufficient operationalisation of data security in the experiment. It could also be that participants were not aware how information provided by their household may be used or misused by third parties and therefore were not able to judge whether data security actually poses a risk in this situation. When interpreting the non-significant impact of data security on acceptance in the experiment, one needs to be careful. From the data, it cannot be concluded that perceived data security plays no role in the formation of an opinion about a load-shifting campaign. Indeed, scientific literature suggests the opposite effect (e.g. Döbelt et al. 2015; Krishnamurti et al. 2012; Verbong et al. 2013). To draw a valid conclusion regarding the causal influence of perceived data security on the acceptance of load-shift programmes, the experiment should be repeated with a stronger manipulation of the respective independent variable.

Interestingly, acceptance levels in the control group, where data security and control over one's appliance were not mentioned, were comparable to levels seen in conditions with high levels of control. Mentioning risky issues such as control or data security could raise participants' awareness about potential risks which may lead to lower levels of acceptance. Thus, one could conclude that the preferred option is to refrain from communicating the risks associated with a load-shifting programme. This is, however, a strategy that could easily backfire: It should be noted that people may process information differently in a real-world context as compared to an experimental setting. Under such conditions, individuals might scrutinise information more analytically and recognise the failure to communicate potential risks. Furthermore, reflections upon the issue of control—which include issues of trust in utilities—indicate that such a communication strategy is likely to fail or even backfire and may result in low acceptance and even social protest and serious damage to a utility's public image.

Limitations of the study and suggestions for further research

Whilst the study offers interesting insights into the influence of control on the acceptance of a load-shift programme, this research possesses several limitations.

The manipulation check yielded that manipulation of the data security condition had been unsuccessful. Thus, no valid conclusions regarding the influence of perceived data security on the acceptance of a load-shifting programme can be drawn from this experiment. The manipulation of the data security condition likely lacked strength, possibly due to a resemblance to general business terms—terms that participants were conditioned to view approvingly, such as when engaging in online shopping. For future research, this manipulation should be strengthened, perhaps by pointing out the potential negative consequences of a poor data security policy to participants. Another option is to use different scenarios where data provided by households is used or misused by different third parties with varying consequences for households.

Another limitation of this study involves the experimental setting. The study was conducted online, and participants were asked to imagine that their energy utility had offered them a new programme. This represents a rather artificial setting, because though communication with a utility company can occur online, a legitimate offer would likely include the name and logo of a specific utility. In Switzerland, there are roughly 800 utilities (Blumer et al., 2014); as such, targeting the letter to the participant's local community was not feasible. Despite its artificial setting, the study offers interesting insights as to the role of control in the acceptance of a load-shifting programme. To further strengthen these insights and to facilitate application, a field experiment should be carried out, ideally in collaboration with an interested utility.

Furthermore, the study only focuses on dishwashers as one example of an appliance. For future research, it might be interesting to consider the influence of perceived control on load-shifting in other appliances, for example freezers, fridges or heat pumps. Experiences from the UK indicate that direct load control seems rather contested for these types of appliances (Spence et al. 2015). Future studies may shed light on the rationalities behind that.

Future studies could also explore in more details the reasons why control is important for peoples' acceptance of load-shifting programmes. This could be done either by means of another set of experiments systematically varying different reasons and examining their effects on acceptance or also in a more qualitative setting.

Conclusions

The study at hand demonstrates that control over one's appliances is a key concern when an individual decides to take part in a load-shifting programme. This result provides significant insight into the design of respective load-shifting programmes offered by utilities. Such programmes may contribute to Switzerland's new energy strategy by reducing investment costs in transmission and storage systems and may help to balance domestic electricity demand with the production of renewables. Moreover, such programmes may increase households' understanding of how electricity demand is linked to the production of renewables and may lead the public to understand that they, too, can contribute to the energy transition by making some adjustments to their daily electricity use.

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Appendix: materials used in the experiment

Introduction (seen by all participants):

"Swiss households consume approximately one third of the nation's energy. One method of more efficiently utilising electricity involves the matching of electricity production and households' demand.

This could mean, for example, that households use electricity (e.g. operating dishwasher) when it is windy and wind turbines produce abundant electricity. If only little electricity is produced, households are encouraged to demand only little electricity.

Thanks to such a link, Switzerland may have to build fewer power plants to meet peak demand (e.g. gas-fired power plants). An important prerequisite for this is that energy users (e.g. households), energy producers and possibly services such as the weather forecast are linked and exchange data."

Description of programme (experimental manipulation, brackets indicate the experimental groups):

[All groups incl. control group] "Please imagine the following situation: Your energy provider offers a new programme:

- [all groups incl. control group] A smart meter will be installed in your household, this is an apparatus that measures your current electricity demand and directly communicates to your energy provider.
- [all groups incl. control group] Your dishwasher will only be operated as usual if the local production of electricity exceeded local demand. If demand is not exceeded, the dishwasher will be placed on hold.
- [control high] You can circumvent this mechanism by pushing a button at your smart meter and immediately activate the dishwasher.
- [control low] There is no opportunity to circumvent this mechanism.
- [data security high] Your electricity consumption data is strictly protected and can only be viewed by the electricity provider.
- [data security low] Your electricity consumption data is not protected and the electricity provider is allowed to hand the data over to third parties.

[All groups incl. control group] By participating in this programme, you are making an important contribution to Switzerland's energy transition. You will receive a discount of 10% on your next electricity bill.

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