Philipps Universität Marburg

Feedback seeking as an active, goal-oriented behavior – a psychological reframing of energy consumption feedback

Dissertation

zur Erlangung des Doktorgrades

der Naturwissenschaften

(Dr. rer. nat.)

dem

Fachbereich Psychologie

der Philipps-Universität Marburg

vorgelegt

von

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aus Freiburg

Marburg/Lahn 2015

Feedback seeking as an active, goal-oriented behavior – a psychological reframing of energy consumption feedback

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Abstract

In the last decade the upcoming of the new digital metering technology combined with communication and information technologies caused a new wave of research on feedback and energy efficiency. In difference to earlier feedback studies, several field trials with sample sizes of several hundred up to thousands of households have been initiated in the European context in parallel. High expectations have been sowed from reviews on existing feedback research. Rather surprisingly the results in energy savings caused by feedback systems incorporating smart metering technology turned out to drag behind the high expectations.

This doctoral thesis intends to line out an existing blind spot within the energy feedback research by highlighting the notion of an active recipient pursuing own goals and develop own strategies what to do with feedback. Findings and modelling from feedback research of organizational and social psychology is transferred to energy feedback research and forms the framework of a series of studies analysing empirical data from two large one-years-trials with feedback based on smart metering technologies. Major attention is given to the general concepts introduced in the theoretical frameworks:

1) Do individuals set goals for feedback use? If they do so, how are they are linked with each other – is there empirical evidence for multiple goal profiles?
2) Are the different goals determining the feedback seeking behavior?
3) Is there any empirical evidence that individuals proactively seek feedback information in a web-based feedback system? Do goals for feedback use have any predictive power for the feedback seeking behavior?
4) What is the effect on consumption, if different feedback seeking behaviours are identified, what conclusions in relation to the theoretical framework can be made?

Re-inventing the goal-oriented individual - Transfer of theories about feedback from organizational and social psychology to current energy feedback research

1. Introduction

In the last decade the upcoming of the new digital metering technology combined with communication and information technologies caused a new wave of research on feedback and energy efficiency. In difference to earlier feedback studies, several field trials with sample sizes of several hundred up to thousands of households have been initiated in the European context in parallel. High expectations have been sowed from reviews on existing feedback research. While some of the trials collapsed due to a myriad of technical problems with the "smart" technology, some trials have been implemented successfully and achieved to manage surveys and consumption analysis. Rather surprisingly the results in energy savings caused by feedback systems incorporating smart metering technology turned out to drag behind the high expectations. Since then, a scientific discourse has started how feedback can be more successfully integrated into consumption practices – and to increase the impact of feedback on electricity consumption figures (cf. Barbu, Griffiths & Morton, 2013; Darby, 2010, Geelen, Reinders, & Keyson, 2013; Hargreaves, Nye, & Burgess, 2013).

1.1. Current state of European Smart Metering roll-out

At the moment, many parts of Europe seem particularly intent on promoting smart energy technologies as much as possible, as revealed in three primary EU Directives which have been developed since 2006 to guide this process: about energy services (2006/32/EC), the "Third Energy Package" (2009/72/EC) and about energy efficiency (2012/27/EU). Within this trio of directives, all EU member states have been mandated to conduct thorough cost-benefit analyses (CBA) by September 2012 to determine whether or not it would be cost-effective to set goals of at least 80% nationwide coverage for electricity and/or gas customers to have access to smart meters and related ICT tools (cf. table 1). At the moment sixteen countries have decided to proceed with rolling out devices for electricity nationally, and seven of those also for gas – the remainder either have found it cost-ineffective at the moment, have plans to proceed only for select groups of customers or are still in the process of deciding (EC, 2014a; EC, 2014b), despite the deadline which has already passed. In total, the commitment of these sixteen nations comes to about 195 million smart meters for electricity, or a total coverage of about 72% of all EU electricity customers, and 45 million for gas, or a total coverage of about 40% of EU gas customers (EC, 2014a; EC, 2014b).

Electricity smart meters	Gas smart meters	Countries
99% done	≥80% planned	Italy (IT)
100% done	ongoing / unknown	Finland (FI), Sweden (SE)
≥80% planned	≥80% planned	Austria (AT), France (FR), Ireland (IE), Luxembou (LU), Netherlands (NL, United Kingdom (UK)
≥80% planned	ongoing / unknown	Denmark (DK), Estonia (EE), Greece (EL), Poland (PL)
≥80% planned	not planned	Spain (ES), Malta (MT), Romania (RO)
selective groups	selective groups	Germany (DE), Latvia (LV)
selective groups	not planned	Slovakia (SK)
ongoing / unknown	ongoing / unknown	Bulgaria (BG), Croatia (HR), Hungary (HU), Slovenia (SI)
not planned	ongoing / unknown	Lithuania (LT)
ongoing /unknown	not planned	Cyprus (CY), Portugal (PT)
not planned	not planned	Belgium (BE), Czech Republic (CZ)

Table 1. *EU countries' roll-out plans for electricity and gas smart meters by 2020. Source: adapted from EC (2014a).*

1.2. Aim of the paper

This paper intends to line out an existing blind spot within the energy feedback research. Having researched since 2006 in feedback and smart metering pilots as a psychologist, the first author participated in lengthy discussions circling around issues like how to communicate data from A to B, in which colour style to design the display of feedback, whether displaying real prices or social comparisons might be more promising to meet household needs. The first author was often surprised to experience that the target for the technological innovation was not discussed in comparable extent although he cooperated in some of the pilots with other psychologists or sociologists. A strong technology-orientation was a major characteristic of the new wave of feedback research (Barbu, Griffiths & Morton, 2013, Covrig, Ardelean, Vasiljevska, Mengolini, Fulli, & Amoiralis, 2014, Gangale, Mengolini, & Onyeji, 2013). The recipients of the electricity feedback were seen as a globally reactive individual "doing something" with the feedback which would turn out the end product electricity saving (Barnsley, Blank, Elzinga, & Gourdin, 2015). While deciding that surveys would incorporate action theories like Theory of planned behaviour (Ajzen, 1991) or Norm Activation Model NAM (Schwartz & Howard, 1981) there was no explicit awareness that the target recipients would set own goals for using the feedback – despite the trial was heading for increasing electricity savings in households.

Following the notion of an active recipient pursuing own goals and develop own strategies what to do with feedback opened a huge new theoretical perspective which might be fruitful both for feedback research and the application of technologies to increase energy efficiency. This chapter briefly highlights the most relevant feedback studies of the last decade which still maintain the perspective of a reactive feedback recipient. Then a jaunt into feedback research of organizational and social psychology is illustrating their changes in feedback research since the early 1980s. Some concepts from this feedback research will be transferred to energy feedback research and discussed in the following, ending with a suggestion for a model framework and future research questions.

2. Feedback research of the last decade

2.1. Feedback definitions

In its most basic form feedback refers to the provision of information about the quantity of energy a household consumes over a given period of time (Buchanan, Russo, & Anderson, 2014). According to the systematic of environmental psychological interventions (Mosler & Tobias, 2007) feedback on energy consumption refers to the passive person-focused techniques (knowledge transfer).

From intervention research feedback can be understood as antecedent or consequence interventions (Abrahamse, Steg, Vlek, & Rothgatter, 2007): in the sense of antecedent interventions feedback on energy consumption displays information on own electricity or energy consumption. Antecedent interventions influence one or more determinants prior to the performance of behavior. Feedback on energy consumption might lead to the intention to reduce consumption and therefore motivates for energy savings.

In the case of an energy consumption feedback provided as a web-based or in-house display, consumption data is constantly available. Therefore feedback on energy consumption can be also seen as a consequence intervention as users can see the effects of their behavioural changes. Consequence intervention strategies are based on the assumption that the presence of positive or negative consequences will influence behavior.

Darby (2006) introduces the differentiation between direct and indirect feedback: Direct feedback is related to consumption information available on demand, accessible by self-meter-reading, direct displays, interactive feedback via a PC or similar solutions.

Indirect feedback typically is raw data processed by the utility and sent out to customers by bills. Indirect feedback also comprises current consumption plus historical feedback, comparative/normative feedback or disaggregated feedback.

2.2. Reviews on feedback with focus on impacts

Between 2005 and 2008 three European review summarized the various feedback approached and their effects of feedback on electricity consumption and have been the ground for all European smart metering and feedback trials. Fischer (2008) screened 26 studies on feedback from 11 countries in the years 1987 until 2007. She concentrated on studies which focused directly on feedback. According to her findings feedback led to energy savings between 5% and 12%. She also concluded that improved feedback can activate other motives conducive to electricity conservation. Depending on how it frames the problem, feedback can activate a desire for cost savings or for minimizing environmental impact. Comparative feedback can stimulate a sense of competition. To improve the incentive character even more, feedback could be combined with other instruments, like price incentives, goal setting, or a contest. Though she already expresses the idea, that feedback might activate different motives she keeps implicitly the perspective of a reactive recipient.

Darby (2006) reports energy savings between 5% and 15% for direct feedback, i.e. display of actual consumption on the meter or a screen. Between 0% und 10% savings have been attained with indirect feedback, which is processed information, mostly the electricity bill. Her conclusion puts feedback on consumption as necessity for energy savings as it is for her a learning tool - without feedback it is impossible to learn effectively. She admits that outcomes from feedback will vary according to circumstances, but might be improved by using feedback in conjunction with advice and information. Though she acknowledges potential problems of understanding, she keeps up the hypothesis, that recipient generally will react on feedback.

Abrahamse und Steg (2005) reviewed 38 papers from 1977 through 2004 with several interventions promoting energy saving in households. In the case of feedback they confirm its effectiveness, which is stronger if it is provided frequently. They criticize that most studies do not examine underlying determinants of energy use and energy-related behaviors. They recommend addressing and changing possible barriers to behavioral change by problem diagnosis for examining which behaviors and which behavioral determinants should be targeted by the intervention. Still these sounds like "find the small cog in the machine" and change it – a rather reactive concept of someone being provided with feedback.

2.3. Latest findings from research on Feedback in smart metering trials

Recent findings on effects of feedback on energy consumption and smart metering trials throughout Europe suggest that feedback rolled out all over the area of the European Union does not result in the expected significant increase of electricity conservation of 10 % or more. Findings from empirical analysis from a Danish trial indicate a reduction in energy consumption of 3% where participants received text messages and emails about household-level electricity use (Gleerup et al. 2010). In the trials run by the Irish Commission for Energy Regulation (CER, 2011) 1,5 % of savings could be achieved by different means of feedback. In a German-Austrian trial savings between 3% and 4 % were recorded (Schleich, Klobasa, Brunner, Gölz, Götz, & Sunderer, 2011; Schleich, Klobasa, Brunner, & Gölz, 2013) where households received upon their choice a monthly paper feedback information or had access to a web-based feedback portal with their household hourly consumption figures. Own unpublished analysis from a feedback trial with a web-based feedback system in the German city of Mülheim resulted in 3,2 % and from a unpublished survey in the frame of the Smart metering trial in the German city of Friedrichshafen self-estimated savings averaged in 5%.

As household surveys from the Danish (Christiansen & Kanstrup, 2009) and the German-Austrian (Sunderer, Götz, & Gölz, 2012) trials show, there is a high acceptance of energy feedback via modern information and communication technologies, and subjects seem to appreciate to have a new tool, which match with their general orientation to save energy.

2.4. Latest social science in feedback research

Recent research on energy feedback split roughly into two directions: Several studies have focused on the social impacts of feedback systems and in-house displays (IHD). Studies have put feedback on energy consumption in action context of myriad household circumstances (Wallenborn et al., 2011; and see also Grønhøj and Thøgersen 2011) and the interaction of feedback with household habits, routines and social practices and the technological configurations they involve (Darby, 2010, Pierce et al., 2010, Bartiaux, 2008; Gram-Hanssen, 2011; Strengers 2008, 2011; Hargreaves et al. 2010, 2013). The focus of social practice theorists is – in contrast to psychology- no longer on individuals' attitudes, behaviours and choices, but instead on how practices generate, how they are repeated, confirmed and adapted and finally abandonded; on how practices force practitioners to carry on with them through continued performance, and on how such practitioners may be supported to change to more sustainable practices (Warde, 2005, Hargreaves, 2011). A central assumption for all routine consumption is that it is controlled to a large extent by social norms, and is profoundly shaped by cultural and economic factors. For achieving more sustainable practices it rather needs to concentrate on the emergence and transformation of collective conventions (Shove, 2003). Though social practice theory opens up the a new perspective, conclusions and recommendations up to now are general and vague as the conclusions from Barbu, Griffiths & Morton (2013) shows: "If one chooses to focus on consumption practices and how these become instilled in society (…), then a wider range of actors should be engaged at the very start of the policy development cycle for energy efficiency."

The second direction of feedback research is addressed by individual-oriented – typically psychology-based - studies. A major issue was to study and understand behavioural changes in energy consumption. An early explanation have been formulated by Wilhite & Ling (1995) with their information-deficit-model (cf. Buchanan et al., 2014) based on following two assumptions; (1) that consumers lack information about their consumption and (2) that when provided with information consumers will respond to it in an appropriate way. Another explanation of feedback suggests that it is a learning tool (Darby, 2006).This differs from the information deficit explanation as it suggests that consumers lack understanding rather than information. A theoretical model introduced by Fischer (2008) based on Matthies'(2005) heuristic model of environmentally relevant behaviour introduces a psychological explanation. The model proposes that feedback will involve several processes, namely increased awareness of energy consumption, conscious consideration of environmental problems, realisations of the relevance of one's own behavior and an increased sense of personal control over consumption. In addition, Fischer notes that the type of feedback that is presented will influence how the environmental problem is perceived (e.g., as wasting money or energy), the motives it activates and the reasoning process that individuals engage in. Fischer (2008) does not supply any empirical data to support any of the specified processes.

Buchanan et al. (2014) used archival internet based data, namely reviews for energy monitors/meters from the online shop of Amazuon.co.uk for their qualitative data analysis to examine how consumers use and respond to energy monitors. Buchanan et al. (2014) reports that their qualitative data support some parts of the theoretical model of Fischer (2008) but also for the explanations of Wilhite & Ling (1995) and Darby (2006). They also emphasize that users had already activated certain motives to use a feedback system.

Karlin, Zinger and Ford (2015) evaluated existing studies by conducting a meta-analysis of 42 studies using the feedback intervention theory (FIT) of Kluger and DeNisi (1996). The primary argument of FIT is that behavior is regulated by comparisons made between the feedback and the preexisting or intervention-provided standards (personal goals or comparisons with past behavior or others in a social group). When behavior differs from the standard, a feedback-standard gap is created, and an individual's desire to decrease this gap mediates the effectiveness of feedback. Beth et al. hypothesize that there is a main effect of feedback on residential consumption (which they can support with their empirical outcomes). In addition they assume that a couple of mediators of the interventions (frequency, medium, measurement, combination with other intervention, comparison, granularity, and duration) have to be considered. They found that feedback is most effective when it is combined with goal-setting or external incentive interventions, when it provides goal-based comparisons, when gives feedback via a computer, and when the feedback intervention is somewhat brief (e.g., less than 3 months) or quite long (e.g., longer than 1 year). Theoretical conclusions from this paper are rather limited and the authors urge for more research into how and for whom feedback works best—and the ways in which to administer it most efficiently.

Still not empirically but by means of qualitative analysis of German smart metering and feedback systems, Nachreiner, Mack, Matthies, and Tampe-Mai (2015) elaborate how different feedback information could facilitate behavioural changes in energy consumption during the process from goal intention to behaviour. Based on the model for self-regulated behavioural change (Bamberg, 2012, 2013) they suggest strategies to design feedback being more appropriate for better impact from feedback usage to behavioural changes. Their suggestion of modelling the behavioural change as a self-regulated process in several behavioral stages explicitly introduces the assumption, that goal-orientation is crucial for the behavioural change. Despite this comprehensive and applicable contribution there is still lack of empirical analysis to support the model. According to their explanations, feedback can be used to nudge and support the self-regulation process. Still a gap remains to explain whether the use of a feedback system is seen as part of the self-regulation for changing consumption behavior.

As an intermediary conclusion, there is clear articulation for innovation in feedback research. Still, only little attempts are visible to guide a way. Such scientific narrowness is caused by following problems.

Almost all studies about feedback focus on the behaviour or practices related to electricity consumption, with the perspective to contribute academic consult for the mechanisms to enable consumption behaviour changes. Most works carry - almost unreflected – the notion that electricity consumption feedback is something, consumers absorb passively.

In addition, parts of the recent reviews and meta-analysis used material which has a sincere lack of suitable empirical data for new explanation models – evidently caused by technology-oriented study designs of recent trial surveys. Only gentle attempts are to foster in other areas of research for feedback use (e.g. FIT by Karlin et al. (2015), using internet archives by Buchanan et al., 2014).

Therefore we suggest taking a look into organizational psychology which has evolved a fruitful concept of feedback being an individual's resource (Ashford & Cummings, 1983).

3. What can we learn from organizational and educational psychology in regard to feedback?

The positive effect of feedback on task performance and motivation in organisations has been acknowledged since the 1950s (Payne & Hauty, 1955, Ammons, 1956). Feedback was seen as an instrument for organizational leaders to instruct, direct and motivate subordinates to gain performance-enhancing effects. As such, feedback was seen as a tool and forms an important resource for the organization. Accordingly, research focused on how this resource might best be used by organizational leaders. In 1983, Ashford and Cummins criticised that despite there was much knowledge about "personality and contextual variables which may constrain the performance enhancement effect of feedback, we have not moved much beyond the general statement that feedback seems to improve performance". They argued that feedback not only is a useful and important organisational resource but also a resource for individuals being a part of the organisation. Individuals typically want to perform well in their organisational context and may pursue other personal goals in their organisational lives beyond good performances. “To the extent that performance and other personally held goals are important to the individual, feedback on their behavior aimed at achieving these goals becomes a valuable informational resource” (Ashford & Cummins, 1983). They introduce the perspective that individuals actively seek for feedback (Ashford & Cummings, 1983, 1985). Feedback seeking behaviour (FSB) can be motivated by the aim to reduce uncertainty, by receive signals for the most valued goals and behaviours by the organisation, the aim to contribute to personal mastery and competence, and not last but least to protect individuals’ ego or self-esteem. Depending on the motivation to obtain personal relevant information FSB inquire into two sets of seeking strategies: the so-called monitoring strategy applies monitoring of the environment for relevant feedback cues. The inquiry strategy consists of actively request feedback among superiors and peers. According to their suggested heuristic model of the FSB process (Ashford & Cummins, 1983) feedback seeking strategies choice is determined by different costs: The effort costs are associated with the level of effort required to obtain feedback information, face loss costs are the risks involved in obtaining feedback information and inference costs which refer to the amount and type of inference required in obtaining feedback information.

Younger research redefined the determinants of FSB strategies choice into perceived costs (self-presentation cost, ego costs, and effort costs) and perceived value (expectancy values, impression management value) (VandeWalle, 2003). Special attention was given to the finding that although accurate self-relevant information is instrumental for reducing uncertainty, attaining goals and desired outcomes, individuals still seem to prefer favorable information about themselves to maintain a positive self-view (Ashford, Blatt, & VandeWalle, 2003). With this self-enhancing motive, individuals may avoid (e.g., Ashford & Cummings, 1983), distort (e.g., Morrison & Cummings, 1992), or deemphasize the value of feedback (e.g., Roberson, Deitch, Brief, & Block, 2003) if they feel that feedback can hurt their pride and ego.

VandeWalle questioned why individuals in the same situation differentially weigh the perceived cost and value of feedback-seeking behavior. He assigned goal orientation to be the major influence on the perceived cost and value of feedback-seeking opportunities, and how these perceptions, in turn, influence feedback-seeking behavior (VandeWalle, 2003). Dweck and Leggett (1988) identified two broad classes of underlying goals that individuals can pursue: (a) a learning goal orientation to develop competence by acquiring new skills and mastering new situations, and (b) a performance goal orientation to demonstrate and validate the adequacy of one's competence by seeking favorable judgments and avoiding negative judgments about one's competence. VandeWalle (1997) has further refined a performance goal orientation into two subdimensions: (a) a proving goal orientation consisting of an individual's desire to demonstrate competence and to gain favorable judgments about it and (b) an avoiding goal orientation consisting of an individual's desire to avoid negation of one's competency and to avoid negative judgments about it. All goals are not mutually exclusive dispositions.

Still studies show that there is no consistently positive relationship relation between feedback seeking behavior and task performance (Kluger and DeNisi, 1996, Ang et al., 1993). VandeWalles (2003) multidimensional goal orientation model for feedback seeking behavior is designed to explain, that goal orientation determines the perception of feedback costs and values which consequently mediate the psychological mechanism which enhance task performance (cf. Teunissen, 2009). Psychological relevant variables for the task performance are seen in task information, self-efficacy and feedback utilization, explained briefly in the following.

Although feedback can enhance performance through a motivational effect on effort, this stimulus can be insufficient if the effort is misdirected. For such situations, feedback must also provide the information (*task information*) needed to correct errors (Kluger &DeNisi, 1996). *Self-efficacy* is the conviction that one has the capacity to organize and execute the course of action required to produce a desired outcome (Bandura, 1997). Studies conducted in diverse settings and with different methodologies have found a positive relationship between self-efficacy and task performance (cf. VandeWalle, 2003). For feedback to improve performance, the feedback must be utilized (Ilgen et al., 1979). *Feedback utilization* can be defined as the degree that feedback is used to make the changes suggested by the feedback.

While this chapter may only give a quick and incomplete overview in the feedback research of organizational psychology (for a review cf. Tayfur, 2012), the research field on feedback in Organizational and Social psychology flourished after changing marginal perspectives. This was achieved by the introduction of recipients of feedback being proactive seekers for feedback. Goal orientation as the determinant – among others –of feedback seeking behavior which boths influence the psychological processing and transferring into performance behavior offered a valuable frame to link with other psychological concepts (cf. for self-enhancement theory, self-verification the SCENT model of Anseels et al, 2007; for Self-Esteem and Self-Efficacy in Abraham, Morrison & Burnett, 2006). Since then, research on feedback-seeking behavior in social and organizational psychology has focused on aspects of feedback-seeking processes and outcomes and improved work of feedback practitioners in organizations and clinical setting (Teunissen, 2009).

4. Energy consumption feedback in the light of feedback seeking behavior and goal-orientation

The evolvement of research on goal-orientation and feedback seeking behavior is largely inspiring for the issue of energy consumption feedback in several ways.

First, if we agree with the assumption that individuals are not the passive recipients of feedback information but the active agents to seek information and use it for pursuing own goals, we have to acknowledge to focus on an earlier stage of feedback application. Up to now, almost all studies were related with the effects of feedback on consumption, and personal, feedback featuring and contextual variables influencing this impact – which is after providing feedback for some time. Under the new assumption we have to research before or at the very beginning of feedback provision to study which goals to individuals actually have if they are interested to use feedback on their energy consumption. As well it would be highly interesting to ask individuals for the motives if they are not interested to use a feedback offer. Up to now, no explicitly designed study on this issue has been published, although the need for this was raised occasionally (Hargreaves et al., 2010, Buchanan et al. 2014).

A second immediate inspiration from the insights explicated in the chapter above would be an analysis of feedback seeking behavior. As Nachreiner et al. (2015) indicated, various German feedback systems of the last few years have been designed to match with some purpose. Specific features like historical or social comparisons, games or enhancing feedback (cf. Nachreiner et al. 2015) have been integrated into feedback with the - somehow implicit – notion that individuals would make use of it. There is almost no research available on feedback usage (as an exception cf. Jain, Taylor, & Peschiera, 2014) though feedback trials of the last decade used current technologies like smart metering and internet-based feedback portals which offer the incredible valuable possibility of logfile recording (Döring, 2003) to the trace users' activities (Lancieri, 2006).

Third inspiration is the fact, that feedback is valued in relation of the goal orientation and assessed on costs and values it brings for the own goal orientation and the achieving of a certain performance. Up to now, the default task performance has been the saving impact in the individual's electricity resp. energy consumption in all studies. This has to be reflected in line with the goal orientations. Maintaining consumption – and therefore costs – on a certain level, while costs and consumptions tend to increase constantly in European households, would be a well imaginable goal for the feedback use. Though it might not be the most powerful outcome for climate protection, from an individual's perspective it would be a success in task performance.

In the last section of this paper, a theoretical psychological framework for future research is introduced to structure future research of feedback use.

4.1. An action model for goal-orientated feedback usage (Feedback seeking behavior)

In the following the concept of goals are briefly introduced. The action model (also known as the Rubicon model) from Heckhausen and Gollwitzer (Heckhausen & Gollwitzer, 1987, Gollwitzer, 1990, Heckhausen, 1991) is the most prominent theoretical framework to explain the translation of goals into behaviour and will briefly be introduced for the feedback use. Linkages between concepts from organisational feedback research will be made finally.

4.1.1. The concept of goals and goal setting

It is a central assumption that any behaviour is strongly determined by a person's intention to perform the specific behaviour (Ajzen, 1985, Fishbein, & Ajzen, 1975, Ajzen & Fishbein, 1980). According to Heckhausen (1991) the translation of a goal into actual behaviour is a complex volitional self-regulation process, especially in the case of new behavioural intentions. With their action phase model, Heckhausen and Gollwitzer (1987), Heckhausen (1991) and Gollwitzer (1990) provide a more detailed framework of motivational and volitional aspects of goal pursuit (cf. Action regulation model).

Goals are considered as internal and subjective processes and states (Bandura, 1989, Mischel, 1973) which can be differentiated from the responses performed in their execution (see the action-phase model, Gollwitzer, 1990, Heckhausen & Gollwitzer 1987). A goal "is an end state that the organism has not yet attained (and is focused towards attaining in the future) and that the organism is committed to approach or avoid" (Moscowitz, 2012). Goal-oriented responses are influenced by variations in personal dispositions (e.g. attitudes) and characteristics related to the action context (e.g. action outcome disposing an incentive). Thus, both, goals and responses can vary manifold. Goals can be assigned from outside when source variables as legitimacy and trustworthiness (Locke & Latham, 1990) facilitate the integration or redefinition of personal goals (Bargh, Gollwitzer, & Oettingen, 2010). People also set goals for themselves which have to be compatible within the individual goal hierarchy especially to “higher-order goals” (Gollwitzer & Kirchhof, 1998) and depend on the person’s attitude towards the goal (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). Social context cues as normative expectations may also influence a person’s goal selection (Aijzen, 1985). Finally, feasibility concerns whether people feel that they can make responses to attain the desired goal (Bandura, 1977, 1998).

Concerning goal assignment from outside in the frame of feedback is seen as an option in the FIT (Kluger & DeNisi, 1996), still they argue that external goals might be only relevant for any effect of feedback if it is self-relevant for the addressee. Therefore, it seems to put self-relevant goals into the focal center, as action regulation models suggest.

4.1.2. Action regulation model of Heckhausen and Gollwitzer

According to Heckhausen (1991) the translation of goals into actual behavior is a complex volitional self-regulation process, especially in the case of a new behavioral intention whose enactment is associated with considerable effort. With their action phase model, Heckhausen and Gollwitzer (1987), Heckhausen (1991) and Gollwitzer (1990) provide a more detailed proposal of how to integrate the motivational and volitional aspects of goal pursuit. The model postulates that goal pursuit consists in the chronological transit of four action phases: in the predecisional phase, a person has to solve the motivational task of setting goals between concurring wishes. In the preactional phase is characterized by the initiation of goal-directed actions; in the actional phase, the person has to bring goal directed actions to a successful result; and in the postactional phase he/she is evaluating what has been achieved as compared to what was desired. In line with the action model by Heckhausen and Gollwitzer

(1987), Heckhausen (1991) and Gollwitzer (1990) we can describe the process of feedback use as a goal-oriented action (cf. Figure 1):

1. Predecisional phase – Goal-setting for the usage feedback: the user is motivated to get access to feedback and set a goal to use the feedback. Assumable goals might be associated with ecological issues (e.g. climate protection), economic needs (e.g. saving costs), hedonism (like to discover technology, browsing around) and social purposes (e.g. being a model for others).

2. Preactional phase - access to feedback and strategy development: The individual is accessing the feedback with an idea how to use the feedback information to attain the goal set.

3. Actional phase – Use of the feedback system and actively seek feedback information: The user is acting according her selected strategies and seeks for relevant information which supports attainment of set goals. Feedback seeking can be traced according to frequency (log-in), persistence (number of clicks, minutes of search), areas of interests (specific features of the feedback system) and long-term usage (number of months of feedback usage).

4. Postactional phase - controlling the effect: The user evaluates his/her achievements with the feedback seeking. If the postactional phase leads to the assessment that the chosen strategy turns into the expected and visible seeking effect, the user eventually will run through the preactional and actional phases again for one or several times and stabilize the new feedback seeking behavior into routines. If the evaluation is negative, e. g. the individual does not find his/her achievements in line with the desired outcome, the action strategy will be refined in the preactional phase, executed in the actional phase and evaluated again. Also it is possible that negative evaluation outcomes lead to a change of the goal set (predecisional phase) or even the motivation to use the feedback losses their priority and fails in the competition of concurring wishes of the individual.

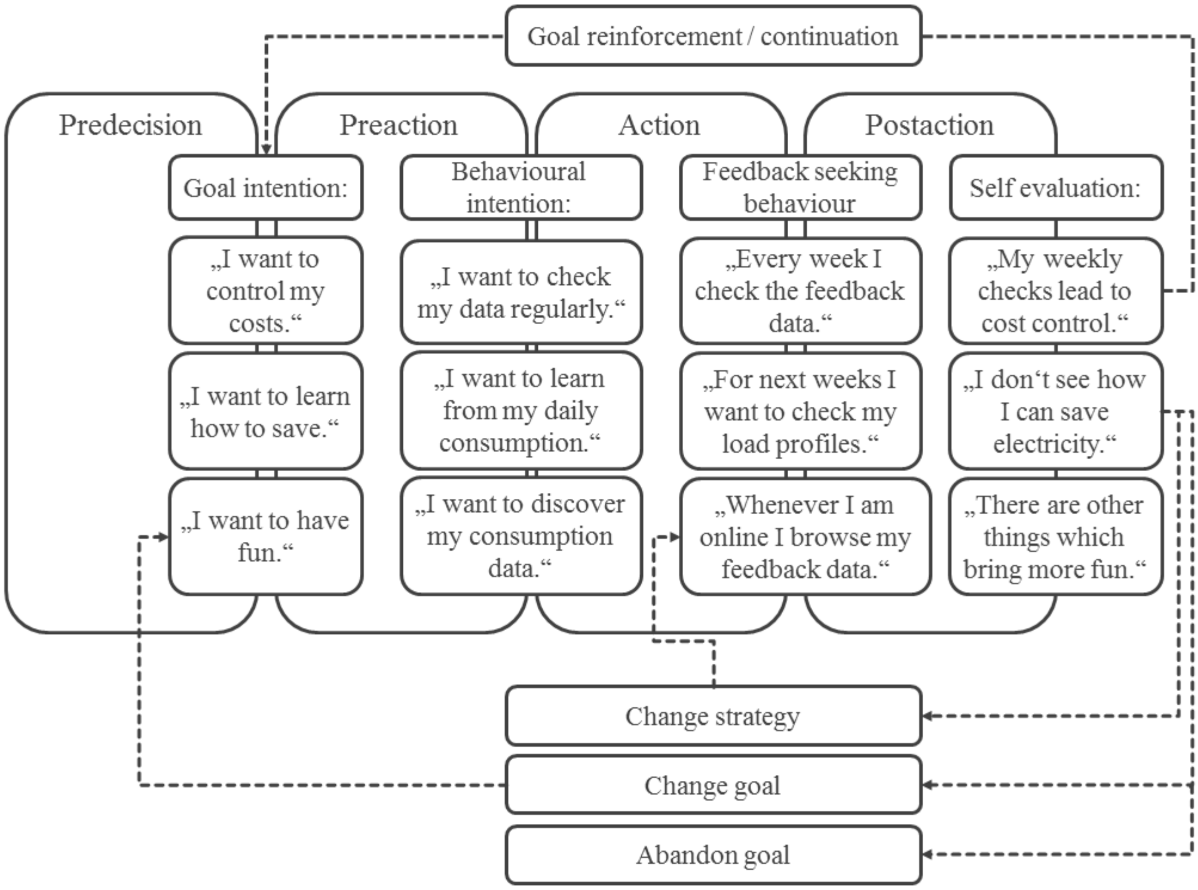

Figure 1: Adapted action model from Heckhausen and Gollwitzer for Feedback Seeking Behaviour

4.2. Relating Feedback usage and behavioural changes for energy savings

In the Feedback Information Theory FIT (Kluger & DeNisi, 1996) the existence of a goal that the individual accepts and values is seen as one of the key characteristic of feedback. Another key characteristic of FIT are standards. These standards can be personal goals or comparisons with past behavior or others in a social group (cf. Karlin et al. 2015). When behavior differs from the standard, a feedback-standard gap is created, and an individual’s desire to decrease this gap mediates the effectiveness of feedback. The last characteristic element of FIT is attention. Only feedback-standard gaps that receive attention contribute to behavior regulation. The simple presence of feedback is not enough to regulate behavior—the feedback must draw the attention of individuals’ to a feedback-standard gap that they have identified as self-relevant.

Therefore, in an integrated framework of goal-oriented feedback seeking behavior and behavioural changes in energy consumption the feedback-standard gap is the connecting link between both behaviours (Figure 2).

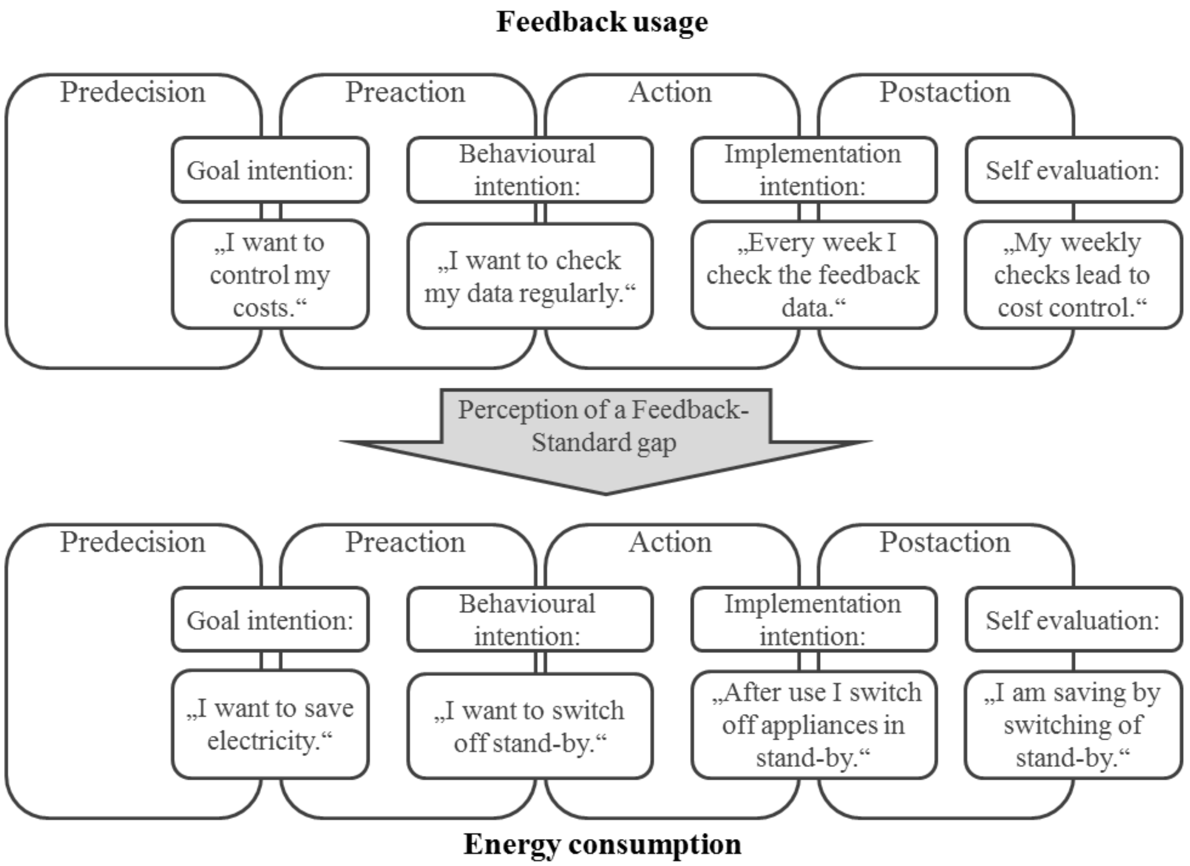

Figure 2: Integrated framework of goal-oriented feedback seeking behavior (adapted action model from Heckhausen and Gollwitzer) and behavioural changes in energy consumption (simplified model for self-regulated behavioural change, Nachreiner et al. 2105)

As explicated in the adaptation of Model of self-regulated behaviour changes for energy consumption and feedback (Nachreiner et al. 2015) it is assumed that people will set a goal intention to change consumption behaviour, if they find content from their feedback seeking behavior that may increase problem awareness and perceived personal responsibility or/and which activates supportive social norms. Argueing with the FIT characteristic of attention, problem awareness, personal responsibility or social norms are the psychological correlates that a feedback-standard gap is perceived as self-relevant.

According to VandeWalle (2003) and Kluger and DeNisi (1996) the behavioral adaptation to "close" a perceived feedback-standard gap still relies on more than the self-relevance. A crucial prerequisite for an effective behavioural change in consumption feedback must provide the information (*task information*) needed to correct inadequate behaviours. In the sense of self-regulation processes (cf. Nachreiner et al., 2015) such task information has to be concretely focused on specific fields of multiple consumption actions (e. g. "Washing your laundry only with a manimum temperature help you save 5 kwh per month"). For energy consumption in a household with more than one person the implementation of behavioural changes is also a challenge of social decision making within the household – changes are only effective if all household persons admit to follow new behaviours – and an issue of practicability in the sense of social practices and routines. Therefore s*elf-efficacy* - as the conviction that one has the capacity to organize and execute the course of action required to produce a desired outcome (Bandura, 1997) – might be a strong barrier for final successful impacts.

5. A new perspective for energy consumption feedback assessment

The suggest framework and the introduction of feedback use as goal-oriented proactive behavior allows for challenging new research and a more sophisticated modelling with future empirical analysis. In the following of this doctoral thesis, empirical data from two large one-years-trials with feedback based on smart metering technologies will be analysed under the suggested framework. Major attention is given to the general concepts introduced in the theoretical frameworks:

1) Do individuals set goals for feedback use? If they do so, how are they are linked with each other – is there empirical evidence for multiple goal profiles as suggested earlier? Are the different goals determining the feedback seeking behavior?

2) Is there any empirical evidence that individuals proactively seek feedback information in a web-based feedback system? Do goals for feedback use have any predictive power for the feedback seeking behavior?

3) What is the effect on consumption, if different feedback seeking behaviours are identified, what conclusions in relation to the theoretical framework can be made?

Those questions are addressed in the following two papers.

At first, questions under 1) are addressed. Accordingly to the described findings and theoretical framework, it is hypothesized that goals regarding the usage of energy feedback systems to be manifold. In two quantitative preliminary studies and one main study, the underlying goals are examined that motivate people to make use of feedback on their own electricity consumption. Four distinct goals towards feedback usage are identified and replicated: *Having fun* when analysing energy consumption data, *learning* more about saving electricity, *controlling and reducing costs* and *avoiding inconvenience* due to perceived negative impacts on daily life. In the Main Study, a model-based cluster analysis is executed with data from a large sample from a smart meter trial in Germany to identify distinguishable goal profiles based on the four goal factors. Moreover, the predictive power of the identified multiple goal profiles on participants' actual usage of web-based energy feedback for a time span of six months in the field is analysed. The findings support the assumption that individuals carry multiple goals towards feedback usage that can be empirically clustered into distinguishable profiles. These profiles, in turn, shaped actual long-term feedback behaviour, thus serving as a valuable starting point for customer segmentation and the design of future energy feedback products.

Secondly, questions under 2) and 3) are surveyed in the next step. Accordingly a set of analysis to evaluate statistically the relation between motivations (conceptualized as goals), feedback use and energy consumption are presented. Analysis are based on log files on usage behavior of a web-based feedback system, survey data and energy consumption data from a one-year trial of smart metering systems and feedback with more than 600 consumers. Results show that feedback seeking is differentiated in several specific feedback seeking behaviours, which are associated to individual goals. Only one feedback seeking behaviour is successful for the effect of electricity saving. In the frame of introduced theoretical works it is discussed why other feedback seeking behaviours have not been effective for saving electricity.

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Manuscript #1:
What motivates people to use energy feedback systems? A multiple goal approach to predict long-term usage behaviour in daily life

What motivates people to use energy feedback systems? A multiple goal approach to predict long-term usage behaviour in daily life

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Abstract

Feedback systems on energy consumption are provided more and more worldwide. However, the success of these systems to increase energy efficiency in households is limited. We believe that this circumstance is due to the fact that present energy feedback systems primarily address individuals' financial goals, thereby neglecting that people may carry a set of multiple goals towards product usage. In a series of preliminary studies and one main study, we examined the underlying goals that motivate people to make use of web-based feedback on their own electricity consumption. We identified and replicated four distinct goals towards feedback usage: having fun, learning how to save electricity, controlling and reducing costs, and avoiding inconvenience due to perceived negative impacts of feedback usage. In the Main Study, we investigated a sample from a smart meter trial (N = 345) and applied model-based cluster analysis to identify distinguishable goal profiles based on the four goal factors. We analysed the predictive power of the identified multiple goal profiles on participants' actual usage of feedback for a time span of six months in the field. The findings support the assumption that individuals carry multiple goals towards feedback usage that can be empirically clustered into distinguishable profiles.

Keywords: Feedback usage, goals, smart metering, multiple goal profiles, model-based cluster analysis, field study

Introduction

In recent years, many European countries implemented smart metering technologies – backed up by European policies aiming at establishing the widespread provision of feedback on household electricity consumption (CEC, 2012). Moreover, the roll-out of smart metering is also proceeding in North America and Asia. The impact of the systems in terms of usage frequency and energy savings, however, is yet limited not meeting the expectations policy has set on energy feedback technology (Gleerup, Larsen, Leth-Petersen & Togeby, 2010; Schleich, Klobasa, Brunner, Gölz, Götz & Sunderer, 2011; CER 2011; Schleich, Klobasa, Brunner & Gölz, 2013). This circumstance raises the need for solutions that stimulate frequent and persistent usage of feedback systems, enabling household members to eventually change their behavioural patterns (Hargreaves, Nye, & Burgess, 2013). To develop such a solution, however, it is indispensable to understand the goals people set for making use of energy feedback. We believe that these goals are manifold going beyond a mere financial motivation. This notion is in accordance with qualitative research on energy feedback identifying the goals, among others, to save electricity for environmental or economic reasons, to discover technologies, or to have fun (Buchanan, Russo, & Anderson, 2014; Hargreaves. Nye, & Burgess, 2010).

In the present research, we aimed (1) to identify the multiple goals that determine the usage of energy feedback systems, (2) to examine whether these goals can be empirically clustered into distinguishable goal profiles, and (3) to investigate the extent to which these multiple goal profiles predict actual behaviour in daily life. To this end, we conducted three preliminary studies and one main study identifying and replicating multiple goals towards energy feedback usage. Moreover, we applied a model-based cluster analysis to examine whether these multiple goals can be clustered into distinguishable goal profiles that differ among individuals. In a longitudinal field trial (Main Study), we examined the extent to which the identified goal profiles can predict actual feedback usage in daily life. Findings contribute to research on (multiple) goal setting by assessing the impact of multiple goal profiles – statistically inferred by means of model-based cluster analysis – on actual behaviour in daily life. For practice, there is a need for target-oriented consumer segmentation to give energy businesses practical suggestions for the marketing of smart energy products (Stromback, Dromacque, & Yassin, 2011). The findings contribute to a more thorough understanding of distinct customer groups of energy feedback systems and provide a straight-forward approach to design energy feedback systems, which address the multiple goals consumers have towards energy feedback usage.

Energy Consumption Feedback

While previous research on energy consumption feedback primarily focused on general effects of feedback on energy savings (Abrahamse, Steg, Vlek & Rothengatter, 2005; Darby, 2006; Fischer, 2008), only a few studies examined why and how individuals use energy feedback systems. As an exception, Nachreiner, Mack, Matthies, and Tampe-Mai (2015) analysed German smart metering and feedback systems and depicted how different feedback information could facilitate behavioural change in terms of energy consumption during the process from goal intention to behaviour. Based on the model of self-regulated behavioural change (Bamberg, 2012, 2013), Nachreiner and colleagues suggested strategies to design feedback systems that are more effective in initiating behavioural changes. We believe that more research on actual feedback usage behaviour is necessary to identify the underlying reasons that motivate individuals to request feedback on their own energy consumption in the long-term – a prerequisite for saving energy. Although previous studies reported that people tend to appreciate feedback on electricity consumption via modern information and communication technologies (Christiansen & Kanstrup, 2009; Sunderer, Götz & Gölz, 2012), there has been little research on the multiple goals consumers set for the usage of feedback systems. Hargreaves and colleagues (2010, 2013) qualitatively approached this question and revealed four distinct motivations for taking part in a smart meter trial in UK (but not explicitly for the use of a feedback system): financial, environmental, information-based, and technological motivations. The authors concluded that the reasons which people reported for participating in the trial strongly determined their expectations and usage of the feedback systems. In the present research, we analysed actual usage behaviour objectively assessed during a smart metering field trial. Importantly, we identified individuals' specific goals for using energy feedback systems and tested the predictive power of these goals in terms of actual usage behaviour across time.

Multiple Goal Setting and Pursuit

In psychological research and practices, it is a central assumption that planned behaviour is strongly affected by a person's intentions and goals to perform the specific behaviour (Ajzen, 1985; Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980). In the present research, we focus on individuals' goals towards energy feedback usage to examine the anticipated manifold antecedents of feedback usage behaviour. Goals are considered to be internal and subjective processes and states (Bandura, 1989, Mischel, 1973), initiating cognitive and behavioural actions (Gollwitzer, 1990, Heckhausen & Gollwitzer 1987; Moscowitz, 2012). The translation of a goal into actual behaviour is a complex volitional self-regulation process, especially in the case of new behaviours. The action-phase model (Gollwitzer, 1990; Heckhausen, 1991; Heckhausen & Gollwitzer, 1987) provides a detailed framework of motivational and volitional aspects of goal pursuit. The model structures goal-driven behaviour in four phases: in the *pre-decisional phase*, in which a person must solve the motivational problem of setting goals and prioritise competing needs. The *pre-actional phase* is characterised by the initiation of goal-directed actions, which can be measured in the *action phase*. In the *post-actional* phase achievements from the actions are compared to what was desired. Depending on the assessment outcome, either the action is repeated as it was "successful" or another action trial with a new strategy will be started to reach the goal or the goal will be re-specified (e.g. less ambitious target for electricity savings) or even abandoned (saving energy based on feedback is impossible).

Goal-oriented responses are influenced by variations in personal disposition (e.g. attitudes, see SSBC-model of Bamberg, 2012, 2013) and characteristics of the action context. It happens that two goals are pursued in parallel (e.g. driving a car and speaking on a mobile phone) or two goals come into conflict with action performance (Lindenberg & Steg, 2007). Conflicts between goals are solved by revising priorities of goals, temporal arrangements, or compromises between conflicting goals (Bargh, Gollwitzer & Oettingen, 2012). From the action-phase model it appears obvious that goals set in the pre-decisional phase are the crucial angle for subsequent action phases. In accordance with this notion, we aimed to investigate the goals people set *before* using the energy systems (pre-actional phase). We expect these goals to be essential antecedents of subsequent usage behaviour.

Meta-frameworks such as the Rubicon model of action (Heckhausen & Gollwitzer, 1987; Heckhausen, 1991; Gollwitzer, 1990) emphasize the notion that multiple goals or goal profiles are the drivers of individuals' decisions and action. The multiple-goal perspective states that individuals may endorse more than one goal orientation (Pastor, Barron, Miller, & Davis, 2007). This idea has been discussed in the field of goal-orientation research for more than a decade (Barron & Harackiewics, 2000; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002; Midgley, Kaplan, & Middleton, 2001). Similarly, the idea of multiple goals has been raised in research for pro-environmental behaviour (e.g., Stern, 2000; Bamberg & Schmidt, 2003; Harland, Staats, & Wilke, 1999). The goal-framing approach of Lindenberg and Steg (2007) proposes an integrated theory that explains how multiple goals may interact in influencing behaviour. According to this theory, three goal frames are distinguished: a hedonic, a gain, and a normative goal frame. In general, multiple goals are active at any given time, which may (or may not) be compatible. Thus, the strength of the focal goal may be influenced by other peripheral goals. Furthermore, the activation of an individual's goal profile varies depending on characteristics of the situation. For example, people may adopt a hedonic goal frame when planning their holidays (using the plane), while adopting an environmental goal frame for commuting (using the bike). In terms of feedback usage, it is also likely that individuals are not solely guided by a single goal factor. Instead, we assume that multiple goals determine feedback usage behaviour. These goals can be in accordance or in conflict with each other. In the present research, we aimed to identify the multiple goals people carry in terms of energy feedback usage. We applied a model-based cluster analysis (Hicks, Markon, Patrick, Krueger, & Newman, 2004; Mun, von Eye, Bates, & Vaschillo, 2008; Pastor, Barron, Miller, & Davis, 2007) to examine whether these goals can be clustered into distinct profiles.

The Present Research

The goal of the present research was to identify distinct goals, which motivate individuals to use energy feedback systems. We conducted qualitative and quantitative preliminary studies to identify and validate feedback goals across different samples. In the Main Study, we applied model-based cluster analysis (Hicks et al., 2004; Mun, et al., 2008; Pastor, et al., 2007) to examine our expectations that feedback usage behaviour is shaped by a set of multiple goals. Model-based cluster analysis allowed clusters of feedback goals to be identified, each representing a unique profile of goal strengths. Finally, using data from a long-term field study in the Main Study, we investigated whether cluster membership (based on a specific set of goal profiles) indeed constitutes a crucial predictor of feedback usage behaviour across time.

Preliminary Studies

First we conducted a qualitative preliminary study to identify attitudes and goals reported by participants who had already used a feedback system for electricity consumption. Exploratory qualitative interviews were held with 13 participants from a smart metering pilot trial in a city in Northern Germany. The most frequently expressed goal was the aim to “be informed", followed by the goal to "derive concrete actions". Further goals were to "evaluate actions to save energy", to "use the feedback to diagnose damaged devices", to "control one's own records or billing data", to "sensitise oneself to energy consumption", to "allocate daily practices to the load profile", to "understand deviations between energy bills" and to "detect incorrect operation of household appliances".

Second, based on the results of the qualitative pre-study, we developed and initially tested scales for energy feedback goals (Quantitative Preliminary Study 1). The goals retrieved in the qualitative pre-study rephrased into questionnaire items. Based on theoretical considerations, we added items measuring *hedonic* goals and goals regarding the systems' *non-instrumental aspects* (Gölz & Biehler, 2008; Hassenzahl, 2001, 2003). Participants (N = 108) were presented a demo version of a feedback system and indicated how strongly they agreed with the presented statements regarding energy feedback goals. Data was analysed with Principal Component Analysis. A five-factor solution with Promax rotation was identified. The results of the correlation coefficient matrix, internal consistency and average extracted variance indicated the existence of five distinguishable goal factors for using electricity consumption feedback systems. For details of the first and second preliminary studies, refer to Schiller (2009).

Third, we validated the developed scale structure by means of Confirmatory Factor Analysis (CFA) using a large field sample to examine the robustness of the goal scale structure (Quantitative Preliminary Study 2). In total, 648 subjects were surveyed in the context of a large smart-metering field trial in Germany and Austria. Participants received access to a comprehensive feedback web-portal (self-selectable, individual energy consumption values between monthly and hourly frequency based on bar charts and tables, displayed in units of kWh or €). An initial CFA did not replicate the five-factor solution from the second preliminary study. A second CFA with four inter-correlated latent variables yielded satisfactory global fit-indices as well as sufficient evidence of construct validity, convergent validity and discriminant validity. Results showed evidence for four empirically-distinguishable goal factors regarding the usage of feedback: the *having fun* goal indicates that feedback is seen as a tool, which has hedonic (fun-related) characteristics. The goal to use a feedback system for *learning to save electricity* indicates that people use feedback to reduce their actual electricity consumption. Another goal was based on the economically-driven motivation to use energy feedback for *controlling and reducing costs*. The goal of *avoiding inconvenience* shows that people may have concerns about potential disadvantages of energy feedback.

Main Study: Multiple Goals and their Impact of on Behaviour

The first aim of the Main Study was to replicate the goal factors identified in the preliminary studies. The second aim was to examine whether the identified goals can be clustered into distinguishable goal profiles. Finally, we intended to investigate the impact of the identified goal profiles on actual feedback behaviour across time in daily life.

Data assessment was based on a large field trial, which took one year in total. During the trial, participants had access to a web-based feedback tool that visualised the households' electricity consumption in a temporal resolution of up to 15 minutes. Actual usage of the feedback portal was recorded by means of a web-log protocol. We measured feedback goals before participants were provided with the web-based system. For the present study, we analysed usage behaviour for the first six months of the field trial as feedback usage substantially declined after this time period.

After testing for the replication of goal factors from the second quantitative preliminary study, we applied model-based cluster analysis (Fraley, Raftery, Murphy, & Scrucca, 2012; Fraley, & Raftery, 2002) to test our expectations that feedback usage behaviour is influenced by a set of multiple goals. We expected to identify goal clusters, which represent distinct profiles of goal strength. Moreover, we hypothesised that cluster membership would be a significant determinant of actual feedback usage behaviour during the field trial.

Method

Participants

Data was collected from a large trial with smart meters and feedback systems running in the three German cities of Kiel, Offenbach and Mannheim. The local utility partners contacted around 5000 households and invited them to participate in the trial. Participants received a smart meter and a feedback system for a one-year trial, free of cost; in return, participants agreed to provide information via an online survey. In total, 345 subjects (62 female) were recruited for the trial. Subjects were between 22 – 73 years old (M = 46.2, SD = 11.3) and 71% were employed. Due to missing data, the final analyses were calculated with the data of a sub-sample for which all data (feedback usage and first survey) was available (n = 310). Further, for analyses concerning detailed log-in and click numbers, we had to exclude 50 participants from analysis as this data was not permanently tracked for the respective households due to a technical failure during the field trial.

The feedback system

The feedback system encompassed electricity metering devices in all participating households. Meters were connected via various communication technologies (narrowband PLC, GSM, broadband PLC) to data concentrators, which communicated with the back-end system of the utility via IP. The feedback web-portal ran on a server of the utility and was connected to the back-end system. Twice a day, data was uploaded from the meters to the data concentrators, from there to the back-end system and finally up onto the feedback web-portal. The web-portal allowed the participant to view and compare the household's specific electricity consumption in monthly, weekly, daily and hourly values (variable scaling), visualised as energy (kWh), power (W), costs (Euro) or CO_2 emissions (t CO_2). All data was presented as bar charts. In addition, participants had the opportunity to download their consumption data as csv files. The web-portal also included a tool displaying the estimated load for four different groups of appliances (stand-by, cooling appliances, white goods [washing machines, dishwashers] and others) and offered general information about smart metering technology, hints on saving energy, frequently asked questions and contact information. The utility designed the web-portal in cooperation with the partner research institutes.

Measurement of feedback usage

In many earlier feedback trials, feedback usage was based on participants' subjective reports from questionnaire data rather than being objectively measured. The application of interactive technologies (e.g. web-portals) – as in recent smart metering trials – now allows for reliable analysis of actual feedback usage based on objective data (Jain, Taylor, & Peschiera, 2012; Lancieri, 2006). For the present study, we assessed actual feedback usage by objective measurements based on log files (Döring, 2003; Heinecke, 2002). In the log file, every interaction between the participant and the feedback system was measured by documenting the user name (a pseudonymised ID), the index code (representing the accessed content within the web-portal) and a time stamp.

The processing of the log files allowed us to quantify feedback usage behaviour, resulting in three measures, which we applied as dependent variables. As feedback usage substantially declined after a time period of six months, we focused on this period of field trial in our analyses.

The number of months in which log-in data was available determined the behavioural measure *number of log-in months*, quantifying the duration of feedback usage. For each month within the first half year of the field trial, it was assessed whether participants visited the feedback web-portal or not. Hence, values of this dependent variable could range from 0 to 6 months. Darby (2007) expects that behavioural changes in electricity consumption need time for consumers to adapt to new routines. According to Darby's cyclic model of learning by experience, households have to observe their consumption patterns, reflect upon their possibilities to change behaviour and then increase energy efficiency. Therefore, the dependent variable number of log-in months served as a measure of continuity. Longer periods of usage should provide more time for observation and reflection and thus eventually to behavioural change.

The behavioural measure, *number of log-ins*, summed up the number of entries into the web-portal. This measure relates to the availability of feedback data, which several authors (e.g. Fischer, 2008; van Elburg, 2009; Stromback et al., 2011) expected to be crucial for its successful uptake.

After successfully logging in, users were free to browse through the web-portal to check their consumption data in their preferred display mode (units, scaling). Each click led to another index code. Addition of the index codes (except log-in, start page and log-off) resulted in the behavioural measure, *number of clicks.*

Feedback Usage Goals

In the Main Study, we included the goal factors identified in the preliminary studies. Specifically, participants rated the extent to which they agreed with the eight feedback goal items (1 - *strongly agree* to 4 - *strongly disagree*) that had been identified in the Preliminary Studies. Each of the four goal factors consisted of two items (cf. Table 1 for items).

Procedure

The field trial in Kiel, Offenbach and Mannheim began in January 2010 and ended in December 2010. Recruited subjects had to sign a participation agreement covering issues of ownership and damage to the hardware, obligations for survey participation and data privacy. The field trial was accompanied by a panel survey online, which was conducted with the household member who provided his/her e-mail contact during the initial trial registration. The first survey of the Main Study took place before the beginning of the field trial. Thus, we were able to assess the predictive power of feedback goals on future actual feedback-usage behaviour. Subjects were contacted by e-mail and received an invitation and an access code to participate in the initial online survey. The utility partners installed the smart meter and provided the feedback system after the respective participant had completed the survey. After successful installation, subjects received their access data (log-in name and password) to access the feedback web-portal. This method ensured that participants first reported the independent variables, before we measured the actual feedback usage behaviour.

Data analysis

The data analyses were based on the data of the initial survey, conducted before participants had access to the energy feedback information, as well as on the feedback-usage data from the first six months of participation.

Initially, we conducted a Confirmatory Factor Analysis (CFA) to investigate whether the identified goal factor structure (cf. Preliminary Studies) was also represented by the Main Study's sample. We specified the four latent goal variables and their respective item pairs as indicators and analysed global and local fit-indices.

Afterwards, we examined our expected multiple goal approach. To this end, we applied model-based cluster analysis using the Mclust R-package (Fraley, et al., 2012; Fraley, & Raftery, 2002) to identify clusters of observations that have similar profiles of feedback goals. Clusters were represented by a latent categorical variable with *K* numbers of categories. A given individual's value on the latent variable determined her/his goal profile. We applied mixture modelling, assuming that the covariance structures vary across clusters. The applied algorithm fits mixture models by assuming the identified subpopulations to have differing covariance characteristics. Specifically, the covariance matrices differed with respect to their geometrical properties: i.e. shapes, volumes, and orientation (for a detailed description see: Hicks, et al., 2004). The data was fit by maximum likelihood (ML) estimation applying an expectation-maximisation (EM) algorithm. We used the Bayesian information criterion (BIC, Schwartz, 1978) to identify the model, which best fit the observed data by taking model parsimony into account. This involves identifying the number of clusters, which best covers the observed data by aiming to minimise the number of model parameters.

Subsequently, we investigated the classification accuracy of the chosen cluster solution. To this end, we estimated the confidence of cluster assignment for each person by calculating posterior probabilities of individual cluster membership. Subsequently, we computed average posterior probabilities of cluster membership for each cluster and compared the highest and second-highest posterior probabilities for persons assigned to a given cluster. This additionally allowed potential similarities between identified clusters to be estimated.

Finally, we examined the predictive power of cluster membership with regard to actual feedback usage behaviour. We first applied an ANOVA including cluster membership as factor and feedback usage duration as the dependent variable. That is, we investigated whether specific profiles of feedback goals (multiple goal approach) significantly determine actual feedback behaviour during the first six-month period of feedback access. Then, we applied a multivariate analysis of variance (MANOVA) to test the predictive power of the identified multiple goal profiles on the dependent variables *number of log-in* and *number of clicks*. The MANOVA was based on a subsample due to missing data (cf. Participants).

Results and discussion

Analysing the measurement model of feedback goals

We conducted a CFA to assure the reliability and validity of the measurement model developed in the Preliminary Studies. We specified the four latent goal variables and their respective item pairs as indicators.

The CFA confirmed the four-factor goal structure identified in the Preliminary Studies. Global fit-indices (Hu & Bentler, 1995) were found to be very satisfactory ($\chi^2 = 35.8$; $df = 14$; $\chi^2/df = 2.6$; $p < .001$; $TLI = .92$, $CFI = .97$; $RMSEA = .06$; $SRMR = .046$). In addition, internal consistencies exceeded the recommended thresholds (Nunally, 1978), ranging from

.67 (*learning to save electricity*) to .79 (*having fun*). Moreover, convergent ($t > 1.96$) and discriminant validity criteria were met (cf. Table 1).

Table 1: *Reliability and convergent validity of the CFA model in the Main Study*

Construct	Indicator	Indicator reliability	AVE	Standardised factor loadings	S. E.	*t*
Having fun	The website would draw my attention to becoming more aware of my/our electricity consumption.	0.786	0.31	0.85		
	The internet display would make it fun to become aware of the electricity consumption in my / our household.			0.76	0.089	11.81
Learning to save electricity	I would mainly use the electricity consumption feedback to find out what I really can do to save electricity.	0.665	0.15	0.63		
	With the help of the website I can learn how to use electricity sensibly.			0.80	0.14	9.39
Controlling and reducing costs	I would mainly use the electricity consumption feedback to assess whether I / we have to top up on our electricity account.	0.730	0.41	0.73		
	I would mainly use the electricity consumption feedback to keep a check on the consumption data in my electricity bill.			0.80	0.125	8.10
Avoiding incon-venience	By using the web portal I feel under pressure to save electricity.	0.670	0.13	0.98		
	Constantly checking my electricity consumption online would ruin my daily life.			0.52	0.69	3.02

Identifying model-based profiles of feedback goals

The model-based cluster analysis supported our assumption that the data is determined by distinguishable profiles of goal strengths. The analysis revealed that the best fitting model involved an eight-cluster solution (Model 1, BIC = -1832.12). This model consisted of clusters with equal shapes and volumes but different orientations (ellipsoidal). The second and third best-fitting models were based on the same structure, containing nine (Model 2: BIC = -1879.53) and five (Model 3: BIC = -2201.12) clusters. We decided to choose Model 1 over Model 2 based on Model 1’s BIC value and its more parsimonious cluster structure. As the BIC substantially declined between Models 2 and 3, we excluded the latter option. That is, we chose Model 1 with an eight-cluster solution, equal shapes and volumes and varying orientations. Of the eight clusters, one cluster represented only five participants (1.5 %) and thus was excluded from analysis, resulting in a final seven-factor solution. Figure 2 depicts the number of participants allocated to each cluster as well as the clusters' mean values on the four feedback goal scales.

Next we calculated the posterior probabilities for each participant to estimate the individual likelihood of being a member of the seven clusters. The average posterior probability for participants being assigned to their respective cluster was 93.49 %, supporting the hypothesis that the model accurately classified members into the seven clusters. For 70.3 % of the participants, the model fit very well, as posterior probabilities of those individuals exceeded 0.95 with respect to their allocated cluster. The model did not fit well only for a small subsample (10 % of participants), as indicated by posterior probabilities below 0.75. Table 2 shows the average highest and second-highest posterior probabilities for each cluster. As depicted, average posterior probabilities were lowest for Cluster 2 (76.15 %) and Cluster 6 (85.35 %) but indicated an accurate model fit for the remaining clusters (>.95 %).

Table 2: *Posterior probabilities for the assigned cluster and the second best-fitting cluster in the Main Study.*

	Cluster							
	1	2	3	4	5	6	7	*M*
Posterior probability								
Assigned cluster	0.76	1.00	0.98	1.00	0.85	0.98	0.97	0.93
Second-highest cluster	0.11	0.00	0.01	0.00	0.06	0.02	0.02	0.03
Cluster number								
Second-highest cluster	5	5	5	3	2	5	1	

Description of identified goals profiles

Cluster 1 represents 30 subjects (10 %), whose main goal is to save costs. No other goal is strongly represented in this cluster, although participants of this and Cluster 3 are the only ones who slightly agree that the use of feedback would cause inconvenience.

Cluster 2 consists of 60 subjects (19 %). This goal profile is hierarchically dominated by the goals of *having fun*, *learning to save electricity* and *controlling and reducing costs.* The distribution of the goal *controlling and reducing costs* within the cluster is bimodal: one peak corresponds to slight agreement and one to disagreement.

Nineteen subjects belong to the Cluster 3 (6%). The distribution of the goal factors within this cluster shows a strong peak for all four goal factors at the mean of the scale.

Cluster 4 represents 44 subjects (14 %) and is characterised by high values of the goals *having fun* and *learning to save electricity.* The distribution for *controlling and reducing costs* shows – as in Cluster 2 – two peaks, one corresponding to slight agreement and one to disagreement.

Cluster 5 is the largest cluster, containing 76 subjects (25 %). Members' overriding goal is to *have fun* and – with less strength – to *learn to save electricity*. The distribution of the goal *controlling and reducing costs* is bimodal in this cluster.

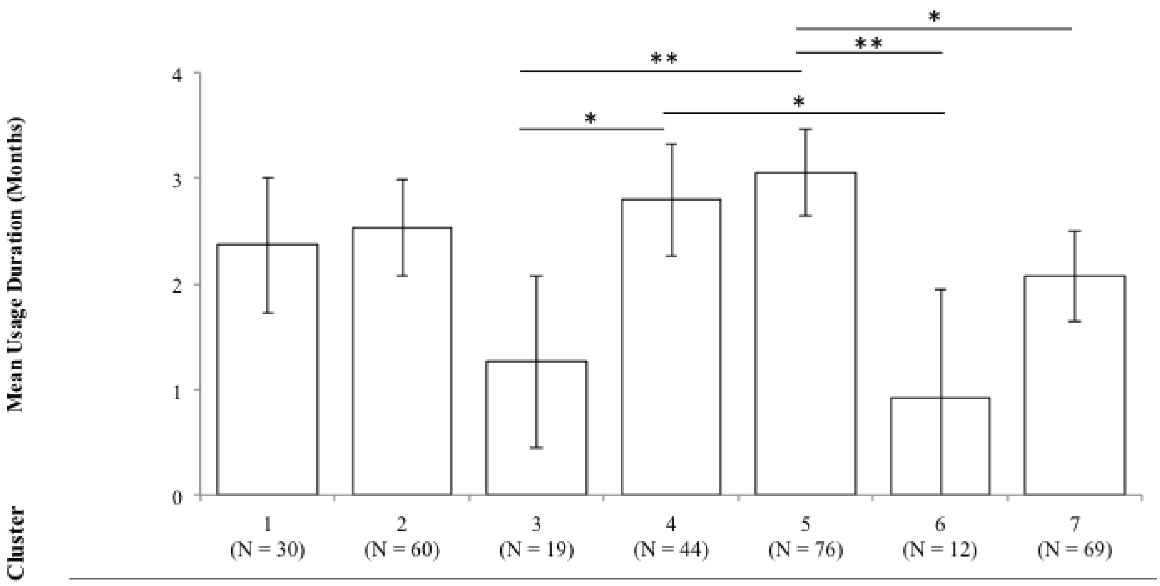
Cluster 6 contains twelve subjects (4%). Members strongly agreed that they aim to *control and reduce costs* but also to *avoid inconvenience*. They did not agree that *having fun* is an important goal, while a bimodal pattern was shown in terms of *learning to save electricity*.

Finally, Cluster 7 represents 69 subjects (22%). The cluster's goal profile is characterised by almost equal levels of slight agreement for *having fun*, *learning to save electricity* and *controlling and reducing costs*.

Testing of the predictive power of goal clusters on usage behaviour

We conducted an ANOVA with cluster membership as a factor and the duration of feedback usage as the dependent variable. Results revealed a significant effect of cluster membership on the feedback usage duration ($F(6, 303) = 5.021$, $p < .001$, $\eta^2_{par} = .09$; cf. Figure 1). Post-hoc comparison (Sidak-corrected) showed that mean usage duration was longest in Clusters 4 and 5, approaching three months, which significantly differed from the mean usage duration of members of Clusters 3 and 6 ($\Delta M_{Cl4\text{-}Cl3}$ = 1.53, p = .045; $\Delta M_{Cl4\text{-}Cl6}$ = 1.88, p = .032; $\Delta M_{Cl5\text{-}Cl3}$ = 1.79, p = .003; $\Delta M_{Cl5\text{-}Cl6}$ = 2.14, p = .004). In addition, feedback usage duration was significantly longer in Cluster 5 than in Cluster 7 ($\Delta M_{Cl5\text{-}Cl7}$ = 0.98, p = .025).

Figure 1: *Mean usage duration of the energy feedback system in the main study as a function of cluster membership (graph). Mean values of feedback goal scales depending on cluster membership (table).*



Scale	M_{Cl1}	M_{Cl2}	M_{Cl3}	M_{Cl4}	M_{Cl5}	M_{Cl6}	M_{Cl7}
Having fun	1.41	1.92	2.21	1.96	1.00	2.31	2.09
Learning to save energy	1.38	1.89	2.03	1.85	1.26	1.89	1.90
Reducing costs	1.00	2.48	2.09	2.37	1.83	1.88	2.09
Avoiding inconvenience	3.08	4.00	2.33	3.50	3.52	2.04	3.00

Subsequently, we computed a MANOVA to test the predictive power of multiple goal profiles on the two remaining behavioural measures, *number of log-ins* and *number of clicks*. Multivariate tests reached no significance (F(12, 510) = 0.846, p = .603, $\eta^2_{par} < .02$), indicating that cluster membership did not affect feedback usage behaviour in terms of the total amount of log-in and click numbers.

General Discussion

Goals on feedback usage

The present research shows that the goals, which people set for using feedback systems, are manifold and can be empirically clustered into distinct profiles of goal strength. In the Main Study, the allocation to one of the seven identified goal profiles predicted actual feedback usage behaviour in daily life. The findings indicate that energy feedback usage behaviour is shaped by a combination of pre-set goals rather than a single motivation. Hence, the present research challenges the assumption that people's motivation to use energy feedback is merely based on a financial motivation. Policy interventions aiming to increase energy efficiency by means of energy feedback should take these findings into account, thus targeting a variety of goals beyond the saving motive only.

The identified goals encompassed the goals of *having fun*, *controlling and reducing costs*, *learning to save electricity*, and *avoiding inconvenience*. These findings extend previous qualitative research by applying quantitative methods to identify and validate feedback goals across different samples (Hargreaves, et al., 2010). In line with the goal-framing theory (Lindenberg & Steg, 2007) the goal of having fun represents a hedonic goal. *Controlling and reducing* costs states a gain goal. The goal of *learning to save electricity* and the *avoiding inconvenience* goal can be defined as normative goals. Specifically, *learning to save electricity* reflects both social and personal norms. *Avoiding inconvenience* seems to be strongly linked with personal norms, constituting a steady motivation conflicting with feedback usage.

In the Main Study, we clustered the four goal factors by means of model-based cluster analysis to yield distinguishable profiles of goal strength. We identified seven goal profiles that affected actual energy feedback behaviour in terms of usage duration (in months). However, absolute log-in and click numbers did not significantly differ between goal clusters. Descriptive data of the feedback usage behaviour may provide an explanation for this finding:

usage behaviour tremendously declined during the field trial showing a peak in the first two months. Log-in and total click numbers might have been affected by explorative behaviour, in which participants engaged during the first months' of participation. Such explorative behaviour seems to be influenced by individual patterns of information search and computer skills rather than by participants' pre-set goals. In contrast, participants' pre-set goals were suitable to predict their willingness to use the feedback systems beyond the first months of participation.

In line with the descriptive finding that feedback usage tremendously declined during the first months of the field trial, on average, none of the identified goal clusters exceeded feedback usage duration of three months. Only very few individual cases were recorded which had longer usage periods; the maximum was 6 months within the one-year trial. According to the learning cycle model of Darby (2006, 2007), longer periods of usage should be accompanied by more observations and reflections, thus eventually initiating behavioural change. Our analysis of the predictive power of the identified goal profiles on actual feedback usage speaks for the empirical evidence of these concepts, although we were not able – due to the trial and research design – to investigate the impact of goal profiles on feedback usage *and* changes in energy consumption. Based on our findings and theoretical considerations, we expect that longer feedback usage duration results in stronger energy savings. This hypothesis, however, goes beyond the scope of the present research and has to be tested in future studies in more detail. This also holds for research on direct effects of goals' profiles on energy savings.

Methodological Limitations

In terms of methodology, it is important to discuss the field setting of the present studies: a major asset of the present studies was the opportunity to investigate the effects of psychological variables on actual behaviour in a real-life setting. This real-life setting certainly contributes to the external validity of the data. However, research in field trials may be accompanied by some methodological issues, which should be considered. The questionnaire was completed by whichever household member provided his/her e-mail address at the initial trial registration. Each household received only one log-in code and password for the web-portal, as we assumed that mainly one person in the household would actively use the feedback system. This assumption was supported by a control question in the Quantitative Preliminary Study 2 assessing “which person in the household is mainly engaged with the feedback system”. We obtained the result that, for 97% of households, the member completing the questionnaire was also the principal user. However, we cannot exclude that, in some cases, multiple users had access to the web-portal, thus potentially reducing the impact of the identified goals on feedback usage.

The developed measurement model of feedback usage goal factors does not comply with the usual statistical convention that a factor should be measured by at least three items to ensure a reliable measurement (Hays, 1988). However, the scale structure was confirmed in multiple samples. Local and global fit-index criteria such as uni-dimensionality, internal consistency and both convergent and discriminant validity proved to be sound. Moreover, the scales are short, allowing feedback goals to be measured economically in future field trials.

Implications for Practice

Although goals are seen as an immediate and important predictor of behaviour, theories of attitude-behaviour relations and models of health-related behaviour (for reviews see: Abraham, Sheeran, & Johnston, 1998; Austin & Vancouver, 1996; Bargh, Gollwitzer, & Oettingen, 2010; Conner & Norman, 2005; Maddux, 1999) emphasise that people – even those with strong goals – frequently fail to attain their goals (Sheeran & Webb, 2012). Transferring these findings to the energy sector (or the development of energy feedback systems in particular), it is necessary to develop interventions and technologies that support the attainment of consumer goals in the long-term. To this end, it is indispensable to identify different consumer groups that differ in terms of their goals regarding system usage. A segmentation of consumers provides policy and industry with practical suggestions for the development of tailored energy feedback systems (Stromback et al. 2011).

The present studies showed the goals individuals set for using energy feedback systems can be empirically clustered into goal profiles. These profiles may serve as a base for consumer segmentation in practice. In the following, we propose three main customer segments that are built upon the identified seven goal profiles. We emphasize that each consumer segment has specific demands on the features and the design of energy feedback systems.

Segmentation of Consumer Groups

The first customer segment has a pragmatic view on feedback systems. For them an energy feedback system is a tool to save costs and to learn electricity-saving measures (see also: *information-deficit-model*; Wilhite & Ling, 1995). The pragmatic-oriented Clusters 1 and 7 can be subordinated to this segment as members are mainly aiming to reduce financial costs. To achieve their goal of *controlling and reducing costs*, they also set the goal of learning. For this segment, communication should be oriented to the saving of costs. Tailored systems should also provide support features for saving energy, in addition to a mere presentation of consumption. Cost-related products such as variable tariffs or dynamic pricing could be promising add-ons to the feedback.

The second customer segment consists of consumers who are eager to save electricity and costs, but also seek for having fun when using the systems. The hedonic-oriented Clusters 1, 4, and 5 can be subordinated to this segment due to the dominant goals of *having fun* and *learning to save electricity*. Members of this segment, on average, kept using the feedback systems for the longest duration in the Main Study. Marketing tailored to this consumer segment should in particular communicate the hedonic aspects of (long-term) system usage. As currently examined in smart grid and smart city projects (i.e. 2020energy, EnerGaware, Greenplay Project, Save Energy), a combination of online gaming aspects and real-life events could address the hedonic goals of this consumer segment.

The third consumer segment is possibly the most challenging one, as members have conflicting goals regarding feedback system usage. The doubt-oriented Clusters 3 and 6 can be subordinated to this segment. Members of this segment strive to save electricity, but also aim at keeping the systems' impact on their lives as low as possible. These conflicting goals resulted in the lowest average usage durations in the Main Study. For practice, this means that marketing tailored to this segment needs to address concerns such as perceived (or anticipated) inconvenience by providing examples on how measures to save energy could be integrated into daily life without negative impacts. Moreover, messages emphasising social norms (see Schultz, Nolan, Cialdini, Goldstein & Griskevicius, 2007) might increase usage behaviour of these members, demonstrating a strong societal acceptance of the systems.

Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spences (2013) suggested with their personas of *energy citizen* and *energy consumer* another way of consumer segmentation: the energy consumer has no desire to learn more about her/his energy consumption or ways to save energy, and thus has relatively little knowledge about energy-related issues as compared to the energy citizen persona, the more reflexive, engaged citizen with more knowledge, skills and access to technology.

To generate impact in terms of climate protection, technological solutions need to be combined with additional measures (Hargreaves et al. 2013). In line with Geelen, Reinders, & Keyson (2013), we suggest developing comprehensive business models to comply with user needs, and providing personalised approaches to initiate behavioural change. Policy measures can make use of existing social structures such as communities and neighbourhoods to integrate the technology into a social framework (Goldbach & Gölz, 2015, Heiskanen et al. 2013, 2015; Burchell, Rettie & Roberts, 2016). We believe that the present findings constitute a valuable starting point for developing consumer-adapted energy feedback technologies, as well as interventions at the community and neighbourhood level. Further longitudinal field research is needed to more deeply understand which formal (IHD; feedback system, tariffs) as well as informal measures (local energy experts, energy managers, peer-to-peer counselling) lead to increased behavioural changes and more sustainable energy practices.

Conclusions

The presented research emphasizes that individuals' feedback usage behaviour is shaped by a set of multiple goals. Correspondingly, energy feedback systems should meet this variety of goals, which go beyond a mere motivation to save energy or money. The present research applied model-based cluster analysis to identify groups of consumers with distinguishable profiles of goals towards energy feedback system usage. In practice, we propose to categorise these clusters into three core consumer segments. These segments allow policy-makers and industry to develop interventions and technology that are tailored to the goals inherent to the specific consumer segments. This approach is a valuable starting point for developing feedback systems that meet consumers' multiple goals, thus increasing usage behaviour and eventually initiating more efficient consumption behaviour.

Acknowledgements

Financial support for the preliminary quantitative studies is acknowledged from the German Federal Ministry of Education and Research under the socio-economic research funding programme "From Knowledge to Action – New Paths towards Sustainable Consumption" under the Contract 01 UV0804 (Acronym: Intelliekon). Financial support for the preliminary qualitative study and the Main study is acknowledged from the German Federal Ministry of Economics and Technology (Contract 0327448A/B Smart Metering).

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Manuscript #2:
Feedback Usage leads to Electricity Savings? Analysis of Goals for Usage, Feedback Seeking and Consumption Behaviour

Feedback Usage leads to Electricity Savings? Analysis of Goals for Usage, Feedback Seeking and Consumption Behaviour

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Abstract

Findings from smart metering trials throughout the European Union in the last five years suggest that feedback on electricity consumption does not result in the expected increase in electricity savings of 10 %; instead a reduction in electricity consumption between 1.5% and 4 % is recorded. Nevertheless, there are very few explanations concerning how feedback works to generate the change of behaviour. In this paper, the author introduces the perspective that individuals actively seek feedback as goal-oriented behaviour. Accordingly, a theoretical approach using action models (Heckhausen and Gollwitzer, 1987) is presented to explain the relation between feedback usage and behavioural changes. The modelling implicates that feedback usage can lead to a transfer of motivation and knowledge for energy consumption behaviour. Accordingly a set of analyses is presented to evaluate statistically the relation between goals, feedback-seeking behaviour and energy consumption. The analyses are based on log files on usage behaviour of a web-based feedback system, survey data and energy consumption data from a one-year trial of smart metering systems and feedback with more than 600 consumers. Results show that feedback-seeking is differentiated in several specific seeking strategies which are associated with individual goals. Only one strategy of feedback usage is successful in saving electricity, which urgently challenges the notion that feedback information directly impacts behavioural changes.

Keywords: Feedback, electricity saving, goal-oriented usage, knowledge transfer

Introduction

In the years 2005 to 2010 a number of review studies on feedback approaches and feedback effects have been published. Findings vary from increased consumption to energy savings of up to 27% (Abrahamse, Steg, Vlek & Rothengatter, 2005; Darby, 2006; Fischer, 2008, Ehrhardt-Martinez et al., 2010). All these papers conclude that provision of feedback is considered as energy-saving. Therefore, European – as well as North American - policies initiated the roll-out of Smart Metering technologies (CEC, 2006) and widespread provision of feedback on household electricity consumption (CEC, 2012).

Recent findings from smart metering trials throughout the European Union, however, suggest that feedback on electricity consumption does not result in the expected increase in electricity savings of 10 %; instead a reduction in electricity consumption between 1.5% and 4 % is recorded (Gleerup, Larsen, Leth-Petersen & Togeby, 2010; Schleich, Klobasa, Brunner, Gölz, Götz & Sunderer, 2011; CER 2011; Schleich, Klobasa, Brunner & Gölz, 2013). Other studies corroborate a high acceptance of feedback on electricity consumption via modern information and communication technologies, and subjects seem to appreciate this new tool, which corresponds to their general inclination to save energy (Christiansen & Kanstrup, 2009; Sunderer, Götz & Gölz, 2012). Meanwhile few studies have questioned how feedback might work to affect energy savings. Buchanan et al. (2014) report three existing hypothesis: the information-deficit-model (Wilhite & Ling, 1995) based on the following two assumptions; (1) that consumers lack information about their consumption and (2) that when provided with information consumers will respond to it in an appropriate way. Other explanations of feedback suggest that it is a learning tool (Darby, 2006).This differs from the information deficit explanation as it suggests that consumers lack understanding rather than information. A theoretical model introduced by Fischer (2008) based on Matthies' heuristic model of environmentally relevant behavior (2005) introduces a psychological explanation. As Buchanan et al. (2014) report, some parts of Fischer's theoretical model are supported by their data, but also other explanations. They also emphasize that users had already activated certain motives for using a feedback system. D'Oca, Corgnati, and Buso (2014) tested a combination of persuasive communication (graphical real-time and historical feedback data, and social comparisons with peer households) for the effect on electricity saving. They conclude that consumers are motivated through feedback information to save energy. The latest explanation presented by Nachreiner, Mack, Matthies and Tampe-Mai (2015) models the behavioural change as a self-regulated process in several behavioural stages.

Feedback and energy saving as two goal-oriented behaviours

In organisational psychology several decades ago, Ashford and Cummings (1983, 1985) argued that feedback is not only a useful and important organisational resource but also a resource for individuals being part of the organisation. They introduce the perspective that individuals actively seek feedback (Ashford & Cummings, 1983, 1985). This perspective was acknowledged widely in psychological research and practices, since it is a central assumption that any behaviour is strongly affected by a person's goal to perform the specific behaviour (Ajzen, 1985; Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980). The translation of a goal into actual behaviour is a complex volitional self-regulation process, especially in the case of new behavioural goals. With their action-phase model, Heckhausen and Gollwitzer (1987), Heckhausen (1991) and Gollwitzer (1990) provide a detailed framework for motivational and volitional aspects of goal pursuit, structured in four phases: In the pre-decisional phase, a person must solve the motivational problem of setting goals and prioritise competing needs. The pre-actional phase is characterised by the initiation of goal-directed actions, which are performed and can be measured in the action phase. In the post-actional phase achievements from the actions are compared to what was desired. Depending on the evaluation outcome, either the action is repeated as it was "successful" or another action trial with a new strategy will be started to reach the goal. Otherwise the goal will be re-specified (e.g. less ambitious goal for feedback use), changed or even abandoned (e. g. because of the self-evaluation "learning to save by using feedback is impossible"). Based on this action modelling, it is obviously necessary to work with two types of action if we research feedback and energy saving. The first action to be considered is the action of feedback use as a tool to achieve something. We follow the assumption that individuals pursue specific goals for the use of feedback, determining different modes of feedback- seeking behaviour. Goals for feedback use refer, amongst others, to saving electricity for environmental or economic reasons, to discovering technologies or having fun (Hargreaves, 2010; Buchanan et al., 2014, Gölz and Hahnel in preparation). For the use of feedback an example of the action phase model is depicted in Figure 1.

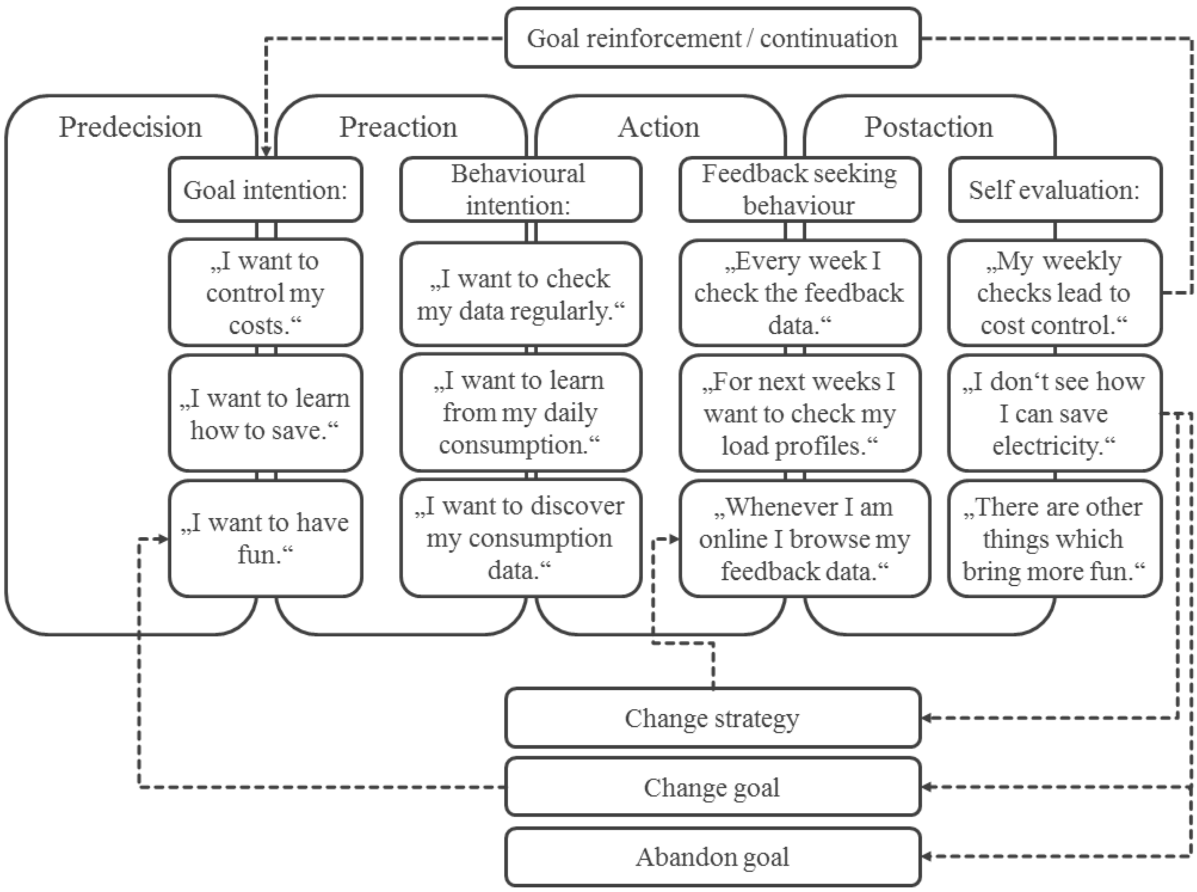

Figure 1: Explanatory Action Model for the use of feedback

The second action type refers to electricity saving, their specific goals and behaviour of curtailment and investment (Buchanan, et al. 2014, Abrahamse and Steg, 2009, Steg, 2008). A detailed multi-phase model of energy saving behaviour related to the model of "selfregulating behavioural change" (Bamberg & Schmidt, 2003; Bamberg, 2012, 2013) - incorporating the action phase model of Heckhausen and Gollwitzer (1987), Heckhausen (1991) and Gollwitzer (1990) as well as the Norm activation theory NAM (Schwartz & Howard, 1981) and the theory of planned behaviour (Ajzen, 1991) - was introduced recently (Nachreiner, Mack, Matthies, & Tampe-Mai, 2015) and almost fully complements the suggested – and simplified – "electricity consumption action model" (cf. Figure 2).

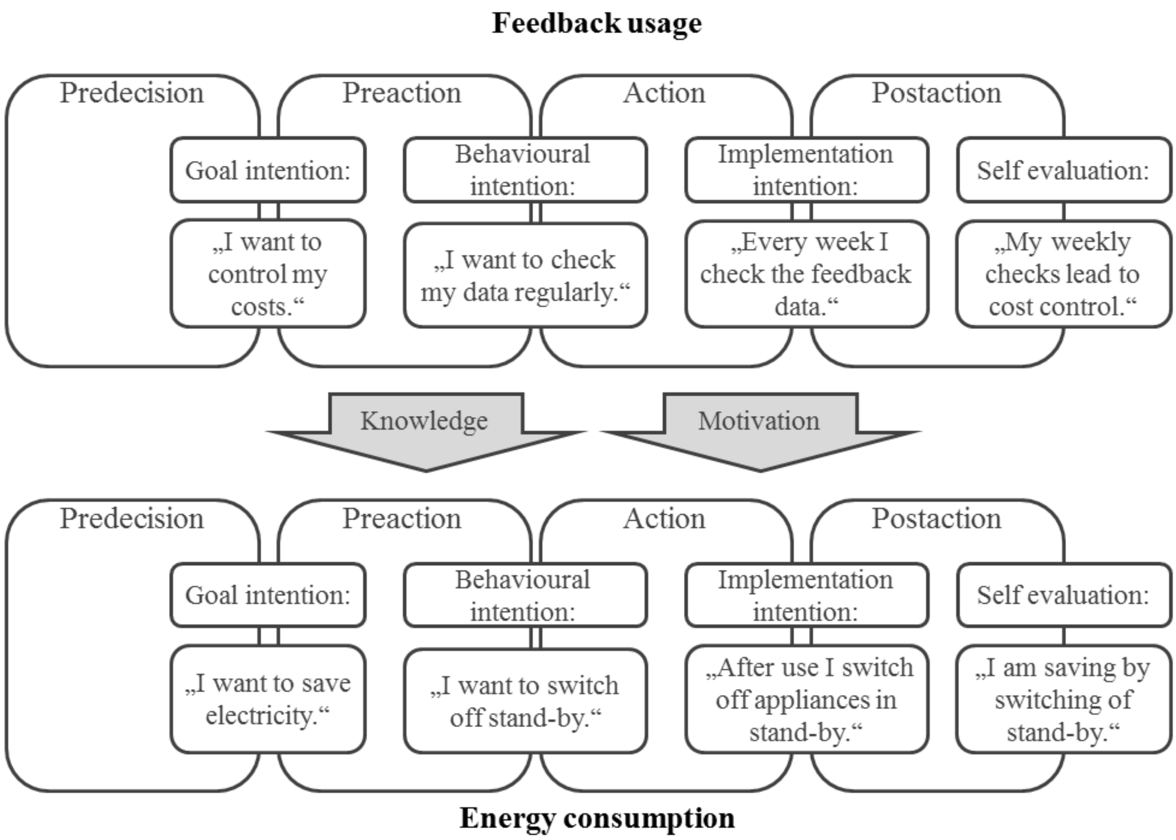

Figure 2: Action models for the use of feedback and electricity saving and their relations

The implicit notion within most explanations concerning how feedback works is that the feedback usage also enables the user to develop behavioural strategies, although it is widely acknowledged that energy is invisible and its consumption mostly determined by routinized social practices. According to this approach one precondition for energy saving is that goals both for feedback use and electricity saving have to match. In addition, we hypothesize that both behaviours are linked by transfer relations. Firstly, it is expected that depending on the motivation to obtain personal relevant information, feedback-seeking behaviour (FSB) enquires into different sets of seeking strategies: the "end product" of feedback-seeking can increase knowledge which is commonly seen as an influencing factor for behavioural changes (Steg, 2008, Steg & Vlek, 2009). Consumers can get information from feedback on real consumption figures which help to overcome existing simple heuristics like thinking that energy use is related to the size of appliances (Baird and Brier, 1981; Schuitema and Steg, 2005). Secondly, it is assumed that motivation is gained through the active seeking of feedback information to adapt behaviour. Motivation gains can be caused by normative and environmental concerns, hedonic or cost reasons (Steg, 2008). Depending on the design and information of a feedback system, one or several motivations can be activated (D'Oca, Corgnati, and Buso, 2014, Nachreiner, Mack, Matthies, & Tampe-Mai, 2015).

Relating behaviour leads to the following research questions: (1) what are consumers' goals while using feedback? (2) do consumers transfer information about their energy consumption into their knowledge for behavioural changes? The same applies for motivation – do consumers gain motivation from using feedback for saving electricity? (3) And finally, crucially, can we measure impacts from any of the two transfers by means of a decrease in electricity consumption?

The present research

In this paper log files on the usage of a web-based feedback system are used to analyse whether consumers seek feedback information specifically in a provided feedback system to develop behaviour strategies towards energy conservation. Using a questionnaire the goals of individuals towards feedback use have been surveyed. Electricity consumption data from all surveyed households and a control group can be used for impact analysis on consumption behaviour. These quantitative data sources permit testing for the following questions:

1. Are there any patterns in the use of the feedback system which could be seen as feedback-seeking strategies to elaborate behavioural strategies for electricity saving? (Study Part 1)

2. Do goals for feedback use relate to any use patterns in the feedback system? (Study Part 2)

3. Which of the use patterns successfully impact the electricity consumption? (Study 3 Part)

Answers to these questions might help to evaluate existing explanations on ‘how feedback works’ and will lead to conclusions in research and practice for future feedback applications.

Design of the field trial

Participants were recruited from eight German towns and one Austrian town where a large trial with smart meters and feedback systems had been implemented[1]. For the recruitment, local utility partners provided lists of all households which had a smart meter installed by the time the trial started. Participants were drawn primarily from this sample. The selection of households who received a smart meter was mostly based on technical considerations (meters were installed in certain streets or quarters). In total, 10,400 households with smart metering systems were selected. Afterwards, potential participants were contacted by mail and phone to request their participation. In total, 2,821 households agreed to take part in the study. For the data analysis, 2,488 households were finally included. Households had the opportunity to choose either web-based or paper-based feedback. In the final sample, 649 households opted for the web portal and 677 households opted for paper-based feedback. The remaining 1,162 households formed a blind control group, which was recruited to evaluate energy-saving effects (see Schleich et al., 2011). Each household received an incentive voucher to the value of about 20 € for participation.

[1] The trial was implemented in the German towns of Celle, Hassfurt, Kaiserslautern, Krefeld, Münster, Oelde, Schwerte and Ulm and in the Austrian town of Linz.

All studies in this paper have been calculated using data from the sub sample who decided to get access to electricity consumption feedback through the web portal (N = 649). Participants of this sub sample were 22 – 81 years old (*M* = 45.71, *SD* = 12.15). 26.4% of the subjects were female, 78.5% were working. All studies presented in this paper consider only those households from the pilot group who opted for the feedback accessed through a web portal.

Web-based Feedback

All subjects had access to web-based feedback, which was developed explicitly for the field trial. A specific study within the project was carried out before feedback design to better understand the needs and expectations of households (Gölz & Götz, 2009). The web portal gave users the opportunity to view and compare their electricity consumption using monthly, weekly, daily, and hourly values. Additionally, the web portal allowed the data to be displayed as either bar charts or tables, either in units of energy usage (kWh) or cost (Euros). All representations of the data included an estimate of base load, i.e. the consumption of standby and cooling equipment, calculated as a proportion of the overall consumption within a given time period. The portal also offered practical recommendations on saving energy, links to energy-related information and a download function for the electricity consumption data. Participants accessed their household consumption data in the web portal via a log-in code with a personal password.

Recruitment of Participants

To prepare the recruitment of households, local utility partners listed all households who had a smart meter installed by the time the trial started. This sample were the potential participants, their selection was mostly based on technical considerations (meters had been implemented in certain streets or quarters). The recruitment of the participating households for the field trial took place in three steps. In a first step, an initial pool of potential participants was identified by the utility and these were then randomly assigned to a pilot group and a control group. In a second step, written invitations and information about the experiment were sent out to the pilot group households. Control group households also received a written invitation to take part in a study about energy consumption, but were not informed that they were part of a feedback experiment. In the third step, all the households were contacted once again by phone to invite them to take part and to record their binding participation and acceptance of a privacy agreement. The households were free to choose either the web-based or the paper-based feedback.

Study Part 1

In many existing feedback trials of the last decades, the measurement of behaviour concerning the use of feedback was almost not feasible as feedback systems were neither digitally based nor interactive. By now, the application of interactive technologies (e.g. web portals) - as in recent smart meter trials - permits the reliable analysis of the traces of users' activity (Jain, Taylor, & Peschiera, 2012, Lancieri, 2006). Logfile recording is a valuable means for the evaluation of the use of information systems (Döring, 2003). In Study Part 1 it was hypothesized that users would develop different feedback-seeking strategies while using the feedback system. It was assumed that strategies would focus on different information displayed by the feedback system like “monthly electricity consumption”, “weekly electricity consumption”, “daily electricity consumption” and “hourly electricity consumption”. Also the additional features of the feedback system like the energy-saving hints, the energy saving game and the download function were expected to belong to individual strategies. An initial analysis summarized the usage data for the complete sample. A detailed analysis applied cluster analysis to find suitable user types within the sample. To assure the reliability of the cluster analysis a discriminant analysis was computed afterwards.

Method

Materials

For this study the evaluation of user-activity traces by log files on the level of a web-server was applied. Measurement was based on a log file assessing every interaction between the participant and the feedback system — including the user name (a pseudonymised ID number of the user), the index code (representing the accessed content within the web portal) and a time stamp. The log file data was transformed as follows: the first step was to create individual scores for each month of use. For this the date of the first login of a user was taken as a reference and all log file data for the following 30 days were scored up as month 1, the data of the next 30 days created the score for month 2 and so on. In a second step individual scores were calculated which included all relevant clicks for one feature of the web portal for each month (feature groups). As an example all clicks for hourly electricity consumption – either displayed as chart bar or table or in kwh or Euro – were summed up to create the score "hourly electricity consumption" (see Table 1).

Feature groups	Explanation
Hourly electricity consumption	All clicks on information concerning hourly electricity consumption either displayed as chart bar or table or in kwh or Euro
Daily electricity consumption	All clicks on information concerning daily electricity consumption either displayed as chart bar or table or in kwh or Euro
Weekly electricity consumption	All clicks on information concerning weekly electricity consumption either displayed as chart bar or table or in kwh or Euro
Monthly electricity consumption	All clicks on information concerning monthly electricity consumption either displayed as chart bar or table or in kwh or Euro
Energy-saving hints	All clicks on information concerning energy saving hints either displayed as chart bar or table or in kwh or Euro

Table 1: Feature groups of feedback use

For the cluster analysis a quotient variable was introduced as a last step. This variable represents individually for each month the percentage of clicks on a specific feature group in relation to the number of total clicks in the specific month (quotient feature group scores). For a comprehensive understanding of user behaviour individual scores with the total number of clicks per month, the total number of logins per month and an average time being logged in per month were calculated as well.

Early descriptive data analysis revealed that usage of the feedback system declined steeply after the second month. Therefore, as major dynamics in the usage activities seemed to take place in the first 3 months, for practical reasons the cluster analysis was limited to data of the first 5 months. It was expected that potential dynamics of usage would be covered sufficiently with this selection.

Procedures

In an initial analysis overall means and standard deviation for all scores of the usage data of the first 6 months for the entire sample were computed.

In a second step detailed analysis applied cluster analyses to find suitable user types within the sample. The main criteria for the selection of the number of clusters was a) reasonable allocation of individuals in each cluster (each cluster N> 30), b) a reasonable characterization of each cluster by the scores of number of logins, login time (in sec.), and all feature groups. K-means procedure was selected to run cluster analysis. Input data were all quotient feature group scores from month 1 to 5 (quotient of all clicks related to one feature group to total monthly clicks). Several cluster analyses with three to seven clusters were run. For each run the means and standard deviations were calculated for the characterizations variables. Due to the quality of characterization finally the solution with six clusters has been accepted.

For reasons of quality assurance a descriptive discriminant analysis was run to confirm the validity of the cluster analysis. The discriminant analysis allows a detailed analysis of the contribution of each dependent variable (from the cluster analysis) towards the differentiation of the groups (defined as factors or independent variables). For the analysis the six user clusters from the cluster analysis were set as dependent variables, dependent variables were all quotient feature group scores from month 1 to 5.

Results and Discussion

Overall means and standard deviation

Major outcomes of overall means and standard deviation revealed that in the first month average users logged in five times to the feedback systems, spending on average about 20 minutes with the system and used all provided features accordingly except the download function. One of the most impressive results is the steep decline of usage in the second month, with a remaining trend in the later months. Depending on the usage parameters usage declines between 50 and 75% and mostly fades out completely after month 3. The second major outcome can be seen in the extreme standard deviation of all scores. It indicates the extensive variance within each score and therefore justifies by far the detailed analysis by cluster analysis.

Feedback-seeking clusters

Applying the reasonable characterization of each cluster by the usage scores, six clusters of different sample size have been identified. Table 2 displays the means of each cluster on the relevant feature groups and characterization variables.

Discriminant analysis

The six feedback-seeking clusters from the cluster analysis were set as a group variable, independent variables were all quotient feature group scores from month 1 to 5. Five discriminant functions explain the full variance within the groups. Function 1 showed an Eigenwert λ_1 = 3,857 with a canonical correlation RC_1 = ,891 (Wilks- Lambda Λ_1 = .012, χ^2 (125) = 2406,08, $p > .01$). The most relevant predictors for the differentiation of the clusters can be seen in the standardized discriminant weights: for discriminant function 1 the standardized canonical discriminant function coefficient of the feature group “daily electricity consumption” of month 2 = .435, for the feature group “hourly electricity consumption” of month 2 = ,419. Therefore, with the canonical correlation and standardized canonical discriminant function coefficients we can show that the feature group variables are well-suited for distinguishing between the clusters and further studies can be based on the clusters.

Discussion

The analysis is a powerful support that individuals actively develop feedback-seeking behaviour (FSB). The clusters can be divided into two types of FSB: The first type can be mainly distinguished by their frequency and duration in months of feedback-seeking (Cluster 1-3). While Cluster 1 shows a moderate usage both in log-in and duration in the first two months, cluster 2’s main characteristic is only one log-in with quite a long duration and no more usage in the following months. Cluster 3 is the opposite to cluster 2. It is the smallest cluster but shows the most activities by far. Throughout four months almost all users log in more than 10 times a month. In the first month they spent more than an hour with the feedback system and also in month four they are more than 40 minutes online in the system. In none of these clusters was specific information obviously sought.

The second type of seeking behaviour is related to specific information from feedback; all clusters seem to follow a clear seeking strategy (Cluster 4 -6): Users in cluster 4 show a clear preference for the feature group “hourly electricity consumption” – which is daily load profiles with hourly data (40 clicks and app. 20 minutes in the first month). Cluster 5 also evidently shows a usage strategy: users in this cluster are mainly interested in the energy-saving hints and almost no interest in consumption data exists. Users of cluster 5 log in once and stay on average 15 minutes in the feedback system in the first month. Finally, cluster 6 shows another usage strategy which seems to be a combination of the strategy of clusters 4 and 5: users focus on the hourly and daily electricity consumption information and in addition frequently consult the energy-saving hints.

	Cluster 1				Cluster 2				Cluster 3			
Month	1	2	3	4	1	2	3	4	1	2	3	4
N of active user	69	68	28	18	202	19	24	25	30	26	28	27
Login time (in sec.)	1391	808	496	439	786	317	387	1099	3971	2658	1926	2493
Number of logins	2,8	2,7	3,0	3,1	1,1	1,9	1,3	1,4	12,6	14,8	10,8	12,6
Hourly electricity consumption (clicks)	14,3	17,5	18,0	6,7	6,0	0,5	2,2	5,0	62,3	58,2	41,8	44,7
Daily electricity consumption (clicks)	17,4	10,0	7,3	8,5	7,6	1,5	2,9	4,6	48,6	46,3	33,4	33,3
Weekly electricity consumption (clicks)	5,1	3,6	2,6	1,1	2,9	1,5	1,9	1,5	14,8	14,3	11,4	14,2
Monthly electricity consumption (clicks)	4,8	2,7	2,2	2,1	3,1	1,8	2,1	4,0	10,9	10,8	8,3	12,0
Energy-saving hints (clicks)	11,7	6,1	1,7	5,0	6,4	1,7	2,3	10,6	16,8	8,2	7,3	10,5
Download (clicks)	0,5	0,2	0,0	0,1	0,3	0,3	0,4	0,2	0,8	0,8	0,4	0,2

	Cluster 4				Cluster 5				Cluster 6			
Month	1	2	3	4	1	2	3	4	1	2	3	4
N of active user	77	23	9	3	134	19	13	9	53	48	40	42
Login time (in sec.)	1050	647	839	469	929	410	634	236	1985	810	656	654
Number of logins	1,4	1,7	2,3	1,0	1,0	1,6	1,5	1,1	5,3	4,7	5,2	3,8
Hourly electricity consumption (clicks)	39,0	5,6	28,7	7,0	4,3	3,3	23,6	2,9	16,2	5,4	5,9	5,1
Daily electricity consumption (clicks)	9,8	6,6	14,0	2,0	3,7	4,2	3,2	3,4	18,9	10,4	10,4	8,1
Weekly electricity consumption (clicks)	3,1	2,6	4,9	1,3	2,0	2,2	1,7	1,0	6,5	3,3	3,9	3,6
Monthly electricity consumption (clicks)	2,7	2,4	3,2	1,7	2,3	2,0	2,3	1,3	6,6	3,1	3,4	3,4
Energy-saving hints (clicks)	6,6	5,5	6,8	5,3	23,4	5,0	5,0	4,8	17,4	9,3	3,4	4,6
Download (clicks)	0,4	0,1	0,1	0,3	0,2	0,4	0,1	0,0	0,5	0,2	0,1	0,1

Table 2: Means for identified user cluster on major scores of feedback system usage in the first four months

The cluster activities are dynamic within the first two months; users log in about 5 times a month and spend more than 30 minutes (in the first month) with the feedback system.

Study Part 2

Part 2 analyses which goals individuals set for using the feedback service and whether feedback-seeking clusters found in Part 1 differ in their goals. Analysis was performed by Multivariate Variance Analysis (MANOVA) and Variance Analysis (ANOVA).

Method

Materials

In qualitative and quantitative studies items have been developed and validated which measure the goals pursued by the users of the feedback system (Gölz and Hahnel, in preparation). Identified goals covered the aspects like *having fun*, *learning how to save electricity, controlling costs* and others. In addition some items expressed that people have concerns about energy feedback negatively influencing their daily life and conflicting with their own moral attitudes (e.g. being socially stressed to care about electricity consumption). Some items therefore represent *avoiding inconvenience*. Subjects responded to the 17 feedback goal items taken from Gölz and Hahnel (in preparation). The goals for feedback were formated as 4-point Likert scales ranging from 1 (*strongly agree*) to 4 (*strongly disagree*). All subjects had access to web-based feedback, which was developed explicitly for the field trial (cf. *Web-based feedback*). Subjects were surveyed about six to eight weeks after being given access to the feedback system. The survey was only performed with participants if they had accessed the feedback system at least once.

Procedures

In a first step means and standard deviation for all items have been calculated; afterwards a Multivariate Variance Analysis (MANOVA) was performed to analyze all variables which differentiate between the clusters. MANOVA was selected as it avoids the accumulation of α error from several t-tests and controls the correlation between dependent variables. Dependent variables were 17 items for the goals for feedback usage. Independent variables were the cluster numbers.

In a second step for those dependent variables which showed evidence of significantly differing within the groups, univariate variance analyses (ANOVA) have been computed. Dependent variables have been the specific variable for goals feedback usage. Independent variables were the cluster numbers.

Item	Mean	Standard deviation
I mainly use the electricity consumption feedback to….		
.. receive concrete ideas for electricity saving.	2,17	,965
.. show others in my household how much electricity we do in fact consume.	2,23	1,151
.. be able to react immediately, if my electricity bill goes up too much.	2,46	1,073
.. see the effect of purchasing a more efficient appliance.	2,13	1,010
.. identify whether I do in fact save by changing my behaviour.	1,77	,833
.. see how electricity consumption develops over weeks and months.	1,48	,705
.. keep a check on the consumption data in my electricity bill.	**2,27**	1,116
.. assess whether I / we have to top up on our electricity account.	2,54	1,143
.. see if any appliance is not working properly	2,80	1,115
.. find out what I really can do to save electricity.	2,02	,913
With the help of the website I can learn how to use electricity sensibly.	1,97	,846
The website draws my attention to becoming more aware of my / our electricity consumption.	1,84	,808
The internet display makes it fun to become aware of the electricity consumption in my / our household.	**2,02**	,861
Constantly checking my electricity consumption online would ruin my daily life.	3,62	,742
I consider using the web portal a waste of time.	3,58	,759
By using the web portal I feel under pressure to save electricity.	3,69	,621
I am concerned about my privacy when using the web portal.	3,19	,936

Table 3: Means and standard deviations for the goals of feedback use (in bold items relevant for ANOVA)

Results and Discussion

Means and standard deviation

For goals to use feedback the strongest agreement was associated with "seeing the development of the consumption over weeks and months". The second strongest agreement was expressed for the goal to "identify whether I do in fact save by changing my behaviour". The strongest disagreement was expressed for the items related to rejecting the usage of feedback (cf. Table 3).

MANOVA

The test resulted with satisfactory criteria achieving a Wilks $\Lambda = .785$, F (85, 2445) = 1.48, p > .01. Relevant items for further ANOVA were "I mainly use the electricity consumption feedback to keep a check on the consumption data in my electricity bill." with F (5, 527) = 2.51, p > .05, and "The internet display make it fun to become aware of the electricity consumption in my / our household" with F (5, 527) = 3.71, p > .01 were considered for further ANOVA.

ANOVA

We conducted two ANOVA with cluster membership as a factor and the goals as the dependent variables. Results revealed that a significant effect of cluster membership and for post-hoc comparison for one item have been found: the item "The internet display makes it fun to become aware of the electricity consumption in my / our household" resulted in the ANOVA with F (5, 554) = 3.61, p > .01, $\eta^2_{par} = .023$ and post-hoc comparison (Sidak) revealed that the item was significantly more agreed on in Cluster 6 than in Cluster 5 ($\Delta M_{Cl3-Cl6} = 0.45$, p = .020). (cf. Figure 3). For the agreement with the items "I mainly use the electricity consumption feedback to keep a check on the consumption data in my electricity bill" (F (5, 555) = 2.76, p > .05, $\eta^2_{par} = .011$) no significant differences were found in post-hoc comparison.

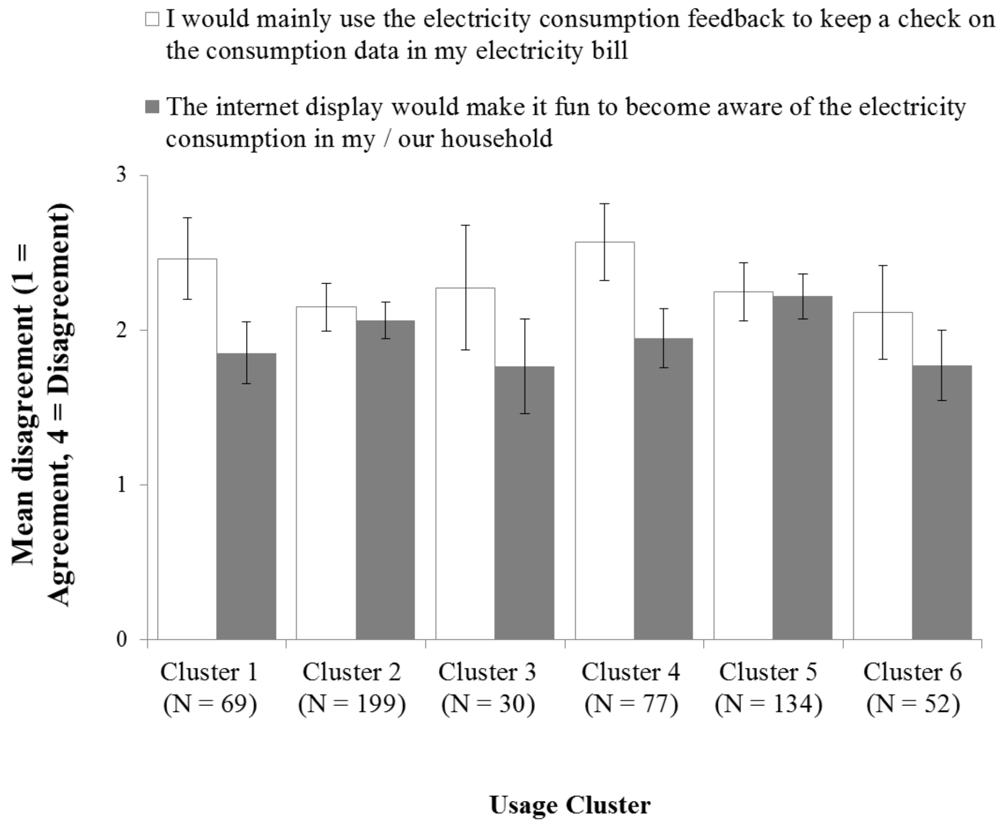

Figure 3: Mean goal agreement for feedback use in the study part 2 as a function of cluster membership.

Discussion

From descriptive results of this part of the study it can be seen that on average consumers want to understand their consumption over longer periods of time and that they are motivated in their use by identifying impacts of their behaviour changes. Other goals like learning to save electricity and controlling costs are considerably strong as well. In this study two goals for feedback use have predictive power for the way consumers seek feedback in the system (*control of electricity costs* and *having fun becoming aware of their own consumption*). Differences in the usage clusters can be explained to a limited extent regarding whether consumers are motivated by having fun using the feedback.

Study Part 3

Finally, after having found that users of the feedback system develop their own strategies to seek the data which seems relevant for them and that this FSB happens – to some extent - in relation to their goals, the exciting issue remaining is about their behaviour concerning their energy consumption. Study 3 therefore analyses whether any of the clusters saved electricity due to their FSB and if so, which of the clusters are the most successful savers. To answer this question multivariate regressions have been calculated, using socio-demographic and energy consumption data from the cluster groups and the control group from the field trial.

Method

Participants

Participants of Study Part 1 and Part 2 have been used for this study again. In addition participants who were initially randomly assigned to the control group in the field trial have been considered in the study as well.

Materials

Data on the household cumulative electricity consumption was measured since the start of the feedback trial in daily frequencies. Therefore, the electricity consumed on any given day can be calculated by simply subtracting the cumulative consumption of one day from the previous day. Accordingly, consumption data for any given day allowed reconstruction of missing data – which occurred due to temporary system failures - by interpolation. During the trial the smart metering feedback started at different points in time, however, all pilot households received feedback for more than one year.

To obtain data on socio-economic and technical characteristics, which are used in the multivariate regression, a survey at the beginning of the field phase was run with all participating households. The survey was run with participants from pilot and control groups. Eventually, after correcting the data for households which relocated during the time of the field phase or which encountered insurmountable technical problems or missing data in the socio-economic and technical characteristics, data was available for 1,055 households, of which 441 were pilot group households with the web-based feedback system and 614 control group households. The significant loss of sample size for this study compared to the sample size of the field trial (see the relevant chapter) is caused by manifold data being missing. For example, more than 150 households failed to report information on income. To abstract from "unreasonable" consumption levels, annual electricity consumption was restricted to the range of 700 to 8000 kWh. As a result, 2 observations were excluded. Substantial losses of sample size are due also to missing or irregular metering data for electricity consumption, which could not be reconstructed with the above described measures.

Procedures

Since data on electricity consumption before the field trial is not sufficiently available, a difference-in-difference approach for assessing the effects of feedback on electricity consumption as applied in Gleerup et al. (2010) is not feasible. Instead, as the study design included a control group, our analysis is based on cross-sectional data.

Six regression models using equation (1) have been performed, each estimating the electricity consumption, respectively savings, for each of the six cluster of feedback usage.

Observed household electricity consumption may be expressed as:

$$Y = X\beta + I_P\delta + \varepsilon, \quad (1)$$

where X is a row vector of variables influencing household electricity consumption, β is a vector of parameters to be estimated, and ε is an error component. The dummy variable I_P indicates whether a household belongs to a cluster of the pilot group. Least squares estimation (OLS regression) involves estimating the conditional mean of electricity consumption by using equation (1), typically relying on normality of the underlying conditional distribution. Also, OLS implies that parameters are constant across consumption levels.

The dependent variable used in the regression analysis is annual household electricity consumption.

To estimate the electricity consumption equation, the dependent variable electricity is regressed on a set of explanatory variables characterizing the household, the appliance stock and the residence. To allow comparisons, the selection of explanatory variables has been fully oriented to the analysis which was performed to assess the total electricity savings within the field trial (Schleich, Klobasa , Brunner, Gölz, Götz and Sunderer, 2011).

A couple of variables reflected household characteristics such as income, education level, and number of persons in the household (grouped into the following six age groups: 0-5, 6-17, 18-30, 31-45, 46-60, > 60). Household income groups were categorized in three groups. The variable income takes on the values of 1, 2, and 3 if household disposable monthly income (incl. transfer payments) is below 1,500 €, between 1,500 € and 2,500 € and above 2,500 €, respectively. Education level is also represented by a dummy variable which takes on the value of 1 if the survey respondent is assigned to a medium or high level of education and zero otherwise. High education refers to A-levels or above (incl. university degrees); medium level refers to secondary school (10 years of education). Floor size is included in levels and squared terms to allow for linear and nonlinear impacts of the size of the residence on electricity consumption.

Another important set of explanatory variables are the technical characteristics of the households. The following electrical appliances (in numbers) indicate the stock of household appliances in the household: refrigerator, dryer, freezer, dishwasher, boiler, computer, and TVs. In addition, a variable which sums up the number of other appliances in the household such as microwaves, play stations, or espresso machines is included.

As the trial was run in several German and Austrian cities, dummy variables were included for the municipalities to capture municipality-specific effects on household electricity consumption. To prevent singularity of the regressor matrix, no dummy was included for Celle.

Last but not least, a dummy titled “cluster” is supposed to capture the effect of the different feedback usage. Cluster takes on the value of 1 if the household belongs to the specific feedback-seeking cluster, 0 is given to participants of the control group. Participants who used the feedback but belong to other groups outside the analyzed cluster were set as missing.

Results and Discussion

To test for unobserved heterogeneity for the full sample, the joint distribution of a Probit model capturing selection in the pilot group and the electricity consumption equation via maximum likelihood methods was estimated (Schleich, Klobasa , Brunner, Gölz, Götz and Sunderer, 2011). Results, however, do not imply a selection bias from unobserved heterogeneity. Therefore, estimating the electricity consumption equation individually via OLS is appropriate (e.g. Imbens 2004). Table 4 presents the parameter estimates from OLS regressions together with robust standard errors (in brackets).

The (corrected) R2 between 50% and 53% suggest that all models explain a fairly large share of the variation in household electricity consumption. The explained variation of household electricity consumption in this study is even higher than for the total sample (46.66%, see Schleich et al., 2011). The parameter estimates associated with cluster is only significant at $p>0.05$ in cluster 2. The respective parameter estimates for cluster 4 shows a probability of error of $p = 0.115$ which is beyond the conventionally agreed levels of significance but still relevant enough to be reported.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Cluster (0/1 Dummy)	50.74 (226.35)	-289.73** (112.92)	-230.83 (275.68)	-294.19 [1] (186.60)	-67.52 (115.08)	-94.80 (212.64)
Age 0-5 (number)	94.30 (95.83)	50.07 (91.14)	67.24 (95.64)	81.47 (91.65)	93.92 (90.25)	61.36 (93.32)
Age 6-17 (number)	286.55*** (73.68)	265.87*** (67.42)	302.77*** (74.86)	295.28*** (71.25)	332.22*** (71.99)	297.76*** (75.60)
Age 18-30 (number)	269.03*** (91.246)	316.95*** (86.58)	301.03** (95.41)	342.31*** (91.96)	315.08*** (85.82)	291.57** (94.65)
Age 31-45 (number)	494.31*** 98.63	522.48*** (92.18)	478.49*** (100.54)	512.26*** (101.55)	459.15*** (91.10)	483.18*** (98.00)
Age 46-60 (number)	472.89*** (95.87)	495.16*** (89.68)	485.57*** (97.99)	565.20*** (101.07)	473.16*** (89.64)	481.51*** (94.49)
Age 60 plus (number)	547.79*** (96.91)	554.54*** (89.56)	522.70*** (97.60)	579.50*** (99.64)	518.92*** (90.17)	544.08*** (93.91)
Floor size (m2)	7.95*** (1.64)	7.48*** (1.42)	7.39*** (1.68)	6.56*** (1.82)	7.03*** (1.52)	7.47*** (1.67)
Income (1/2/3 Dummy)	64.27 (66.16)	45.25 (59.51)	74.23 (65.90)	63.03 (66.66)	93.84 (60.03)	96.80 (65.29)
Education (0/1 Dummy)	-50.41 (96.33)	-104.23 (90.01)	-18.23 (97.25)	-19.27 (95.12)	-56.65 (90.48)	-72.36 (97.32)
Fridge (number)+A13	430.81*** (120.09)	312.13** (119.24)	403.63*** (124.42)	349.14*** (132.98)	458.42*** 113.1483	401.51*** (124.66)
Dryer (number)	490.69*** (99.84)	454.44*** (92.62)	496.57*** (100.18)	491.87*** (99.91)	457.89*** (91.94)	468.78*** (96.78)
Freezer (number)	270.77*** (85.40)	263.23*** (78.26)	252.65** (84.55)	287.83*** (85.30)	272.02*** (80.06)	239.53** (83.97)
Dishwasher (number)	-71.52 (120.31)	4.41* (110.45)	-42.39 123.32	34.68 (133.91)	-47.81 (117.03)	-34.83 (121.89)
Boiler (number)	285.57*** (83.99)	326.15*** (78.79)	305.56*** (84.33)	345.08*** (85.20)	316.66*** (76.14)	344.27*** (83.17)
TV (number)	115.54 (66.30)	141.57* (59.49)	145.80* (66.96)	110.84 (65.94)	146.29* (61.47)	130.51* (65.09)
Computer (number)	156.93** (59.46)	152.56** (55.30)	158.93** (60.65)	193.04*** (59.58)	140.62* (59.07)	155.00* (60.85)
Appliances (number)	74.41** (23.72)	79.24*** (20.66)	76.16** (24.08)	63.31* (25.43)	78.87*** (22.85)	81.10*** (23.32)
Hassfurt (0/1 Dummy)	255.15 (649.60)	-145.00 (506.79)	-547.61 500.53	-746.56 (423.15)	-731.60* (323.95)	-1138.18 (705.31)
Schwerte (0/1 Dummy)	869.26 (690.83)	587.84 (551.18)	64.31 (574.18)	-236.92 (510.86)		-403.34 (762.00)
Oelde (0/1 Dummy)	817.99 (1102.42)	791.62 (701.23)	1251.53* (529.62)	956.64 (446.62)	429.73 (549.28)	-54.69 (868.08)
Ulm (0/1 Dummy)	302.55 (665.92)	-128.37 (519.96)	-552.25 (530.62)	-838.97 (454.86)	-705.49* (351.84)	-1118.83 (722.41)
Kaiserslautern (0/1 Dummy)	753.40 (654.04)	201.48 (515.75)	-110.39 (518.52)	-362.60 (430.26)	-265.29 (325.05)	-683.26 (711.49)
Münster (0/1 Dummy)	187.59 (657.11)	-139.53 (510.18)	-689.61 (511.12)	-808.71* (407.69)	-841.39** (316.74)	-1257.82 (716.54)
Krefeld (0/1 Dummy)	910.58 (661.74)	359.19 (523.73)	22.34 (520.27)	-242.59 (448.50)	-146.35 (360.79)	-560.41 (718.13)
Linz (0/1 Dummy)	649.81 634.25	170.52 (481.66)	-221.45 (496.90)	-511.49 (402.23)	-383.86 (286.15)	-807.17 (689.10)
Constant	-964.08 (643.68)	-370.05 (525.75)	-116.24 (526.12)	200.10 (446.84)	2.05 (334.06)	431.94 (710.24)
R2	0.52	0.50	0.53	0.52	0.53	0.53
Sample size	670	757	642	677	716	663

No. of clusters	56	143	28	63	102	49
Cluster in % of consumption	-1,5%	9,6%*	7,5%	9,7%	2,1%	2,9%

Note: * indicates significance at p > 0.05 in an individual two-tailed t-test, ** indicates significance at p > 0.01 in an individual two-tailed t-test, *** indicates significance at p > 0.001 in an individual two-tailed t-test.
[1] The significance for this parameter was p = 0.115.

Table 4: Parameter estimates in kWh/year from OLS regressions (with robust standard errors in brackets)

Both point estimates suggest that the feedback usage in cluster 2 and cluster 4 results in electricity savings of around 290 kWh and 294 kwh, which translates into average percentage savings of about 9.6% and 9,7% total average electricity consumption of cluster 1 and cluster 4.

General discussion

In this section the initial research questions "Are there any patterns in the use of the feedback system which could be seen as feedback-seeking strategies to elaborate behavioural strategies for electricity saving?", "Do goals for feedback use relate to any use patterns in the feedback system?" and "Which of the use patterns successfully impact the electricity consumption?" will be discussed integrative.

Goals, Feedback-seeking Behaviour and Savings

A significant saving impact is recorded in the subsample which has used the feedback system once over the whole period of trial. This subsample shows an average motivation for feedback on all measured parameters. On the other hand, cluster 3 - which is strongly motivated by a hedonic goal for feedback use - is spending several months significant share of time with the feedback system without any impact. Cluster 4's strategy can be seen as an analytical approach to gain knowledge from consumption data as individuals in this cluster focus on the daily load profile data, which at least tends to be successful if the probability of error with 0.115 might indicate (cf. Methodology issues) The fact that the other clusters, who have elaborated a specific feedback usage strategy, also fail to show saving results reveals the potential existing challenge of feedback as a tool for electricity saving: Cluster 5 is searching for knowledge from practical hints concerning how to save electricity – and does not consider consumption by itself. The transfer of knowledge from FSB into saving electricity obviously fails. Individuals in cluster 6 - which combines both strategies for knowledge gain – in addition also struggle with their motivation to be successful. From additional analyses (not presented in this paper) on motivation for energy savings, individuals in this cluster rather doubt the sense of saving as an individual.

But neither does cluster 2's success favour the conclusion that the transfer of knowledge from the feedback usage into the electricity saving has been successful. Moreover, we hypothesize that this subsample can barely synthesize knowledge from single feedback use - their existing knowledge on electricity saving is, however, activated by the feedback use. Under this hypothesis, the transfer of motivation impacts strongly on the saving behaviour – resulting in electricity savings of almost 10 %. Knowledge transfer can be hypothesized for Cluster 4, bearing in mind that saving results hold a critical probability of error.

Interpreting these findings, feedback does not seem to feature one of the major objectives satisfactorily – facilitating and supporting consumers' knowledge in their actions of electricity savings. Feedback matches the consumers increasing knowledge of their own consumption data, of being engaged with their own consumption for the fun in it and of gaining motivation at least in one subsample of the trial. Results show that individuals actively seek information within the system. But acquired information from the feedback systems does not lead easily to coherent saving action. These results might help us to understand the limited saving impacts of recent European feedback trials. Unfortunately the data does not allow any longitudinal analysis so it is not yet possible to give reliable answers for the non-saving clusters regarding whether their feedback use was insufficient to build up knowledge or whether the knowledge gained was not implemented in behavioural changes. Similarly it has to be acknowledged that our data does not reveal whether goals for feedback use have changed after feedback usage in the few first weeks. During the time before feedback was accessible and after initial use a change of goals for feedback and accordingly changes or giving up feedback use might have occurred. A study with data of two measuring points within the trial period does not detect any major changes within the acceptance and goals for feedback (Sunder, Gölz & Götz, 2011) but such changes might have occurred already after the first time of feedback use.

Modelling behaviour of feedback use and electricity savings

Results from the studies presented indicate that the twin action modelling of feedback and electricity consumption behaviour provide a valuable research frame for detecting the psychological and behavioural gaps in the area of electricity consumption feedback. Still, considering the latest research on feedback and smart energy systems from a social practice perspective (Wallenborn et al., 2011; Darby, 2010, Pierce et al., 2010, Bartiaux, 2008; Gram-Hanssen, 2011; Strengers 2008, 2011) and psychology (Buchanan et al. 2014, D'Oca et al. 2014, Nachreiner et al. 2015), for future research a more comprehensive modelling elaboration of the individual personal and situational variables is needed to better understand gaps and supportive interventions. The theoretical framework can be used to allocate relations between both behaviours within the different stages of behaviour. Both reinforcing as well as weakening relations might exist between different stages, e.g. a negative self-evaluation in the feedback use might weaken goal intentions for saving electricity. Practical recommendations can be derived from such stage-oriented analysis – both for more supportive design of feedback systems and supportive interventions for energy consumption changes.

Methodology issues

All studies are based on measurements from an ambitious field trial with nine utility partners. Though external validity of data is therefore of high quality, many typical limitations had to be overcome in the studies.

A major problem was the availability of measurement data for electricity consumption. Though initially more than 3,000 metering systems have been installed for the trial many technical problems with metering devices, communication lines and plausibility of data occurred. As reported, some of these problems could be solved thanks to the cumulative consumption data measuring. Nevertheless, many participants had to be excluded from analysis due to missing consumption data. Technical problems were in some cases directly linked with insufficient data provision in the feedback system and led to the exclusion of all cases where inadequate usage data was received. Last but not least, it also occurred that participants had the technical infrastructure operating without problems but could not be reached to participate in the survey. As a result, the overlap of data from survey, consumption and feedback usage decreased substantially as seen in Study 3. Sample sizes in the clusters lost were between 7% and 29 % for the OLS regression. This fact has to be seen as a critical constraint for the findings of Study 3. Nevertheless, findings are promising enough to encourage future research with similar designs.

Conclusion

Research has be focused on the mechanisms of feedback resulting in behaviour for energy saving. Specifically it would be necessary to study which knowledge consumers can transfer from FSB in feedback systems directly and which knowledge has to be pre-existing or learned from other sources. In this sense, it is also necessary to start new research and field studies on supportive measures – apart from and in combination with technical infrastructures – like energy experts, informal interactions and anchor projects as suggested by Heiskanen, Johnson and Vadovics (2013), Goldbach & Gölz (2015) and Burchell (2016) to finally facilitate an increase of energy efficiency.

To understand the interaction of different behaviours which are related to each other, longitudinal studies have to be based on the ground of solid modelling. Academic work of the last five years has provided excellent insights and has enhanced the latest behaviour models for feedback use and electricity saving. Policy should therefore acknowledge the benefits and progress from the last decade's research programmes and design future programmes with a view to continuing promising and highly relevant research in order to gain progress in more sustainable consumption patterns.

Acknowledgements

The author thanks Konrad Götz and Georg Sunderer from the Institut für sozial-ökologische Forschung (ISOE) for supporting this work through their collaboration and execution of the survey. The author thanks Joachim Schleich from Fraunhofer ISI and Marc Brunner from University of Stuttgart for their suggestions and discussions on the OLS modelling from Study Part 3. Financial support is acknowledged from the German Federal Ministry of Education and Research under the socio-economic research funding programme "From Knowledge to Action – New Paths towards Sustainable Consumption" under the Contract 01 UV0804 (Acronym: Intelliekon).

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Zusammenfassung

Die Forschung zum Feedback des eigenen Energieverbrauchs hat in den letzten 10 Jahren eine Welle neuer Arbeiten hervorgebracht, angestoßen durch die Verbreitung einer technischen Innovation – den sogenannten intelligenten Stromzählern (engl. Smart meter). Diese Zähler ermöglichen bei einer Anbindung an Kommunikationstechnologie die permanente Darstellung der Verbrauchsdaten. Ebenso lassen sich Verbräuche innerhalb definierter Zeitintervall exakt darstellen. Diese technische Neuerung zog hohe Erwartungen zur Veränderung des Verbrauchsverhaltens in europäischen Haushalten nach sich. Wesentlich war dabei die Erwartung, dass die neue und flächendeckend implementierbare Form der Verbrauchsrückmeldung zu deutlichen Stromeinsparungen führen würde und damit ein wichtiges Instrument zur Erreichung europäischer Klimaschutzziele darstellen sollte (CEC, 2006).

Nach der Durchführung zahlreicher Pilotimplementierungen zeigte sich jedoch, dass die erhofften Einsparungen nicht erreicht wurden (Gleerup, Larsen, Leth-Petersen & Togeby, 2010; Schleich, Klobasa, Brunner, Gölz, Götz & Sunderer, 2011; CER 2011; Schleich, Klobasa, Brunner & Gölz, 2013). Dennoch zeigten Studien, dass die Akzeptanz und die wahrgenommene Sinnhaftigkeit dieser Technologie von den teilnehmenden Haushalten sehr ausgeprägt waren (Christiansen & Kanstrup, 2009; Sunderer, Götz & Gölz, 2012). Verschiedenen Veröffentlichungen diskutieren inzwischen, dass zwar wissenschaftliche Evidenz existiert, dass Feedback zu Verbrauchseinsparungen führt, aber wenig dazu bekannt ist, wie dieser Zusammenhang eigentlich entsteht (Buchanan, Russo, & Anderson, 2014; Hargreaves, Nye, & Burgess, 2010).

Im Rahmen dieser Dissertation wird - übertragen von der Feedback-Forschung aus der Organisations- und Sozialpsychologie – die Perspektive eingenommen, dass Individuen Energieverbrauchsfeedback mit einer spezifischen Motivation benutzen (Ashford &

Cummings, 1983, 1985). Es wird angenommen, dass diese Motive nicht nur dem politisch normativen Wunsch nach Stromsparen zuzuordnen sind.

Zum einen konnte in der Dissertation gezeigt werden, dass Teilnehmende an Feedback-Versuchen in Deutschland und Österreich tatsächlich Ziele verfolgen, die in vier Faktoren aufgeschlüsselt werden: Ein Ziel besteht darin, sich mit den Verbrauchsdaten zu beschäftigen, weil es Spaß macht. Ein weiteres Ziel ist, dass Teilnehmende lernen wollen, wie sie Strom sparen können; und ein drittes Ziel besteht darin, Kosten des Stromverbrauchs zu kontrollieren und gegebenenfalls zu reduzieren. Ein vierter Zielfaktor wird mit der Vermeidung von Unbequemlichkeit benannt. Dieser Faktor umfasst die ablehnende Haltung, das Feedback zu nutzen aus Sorge, dass das Wissen über den Verbrauch den Alltag stört und die Person unter Stress setzen würde.

Mittels einer modell-basierten Clusteranalyse konnte gezeigt werden, dass es insgesamt sieben Untergruppen gibt, in denen die vier Zielfaktoren sich zu „multi-goal“ Profilen kombinieren. Diese sieben Untergruppen lassen sich in drei Segmente einteilen:

Zum einen finden sich zwei Untergruppen, die pragmatisch an die Nutzung von Stromverbrauchsfeedback herangehen, da sie primär die Ziele Sparen lernen und Kosten kontrollieren verfolgen.

Das zweite Segment umfasst drei Untergruppen, in denen jeweils das stärkste Motiv der Spaß bei der Beschäftigung mit dem eigenen Stromverbrauch steht. In diesem Segment besteht auch das Ziel, Sparen zu lernen und Kosten zu begrenzen, allerdings nicht in der gleichen Ausprägung wie das hedonistische Motiv.

Die zwei verbleibenden Untergruppen fallen durch ihre Widersprüchlichkeit der Motive auf. Einerseits wird die Ziele des Sparens und der Kostenkontrolle verfolgt, gleichzeitig besteht aber auch eine starke Ausprägung bei dem Faktor „Ablehnung von Unbequemlichkeit“.

Die identifizierten spezifischen Motivstrukturen ermöglichen eine Zielgruppen-spezifische Ausgestaltung von Feedback-Angeboten, indem beispielsweise bestimmte Informationen (Darstellung von Kosten und vermiedener Stromkosten) oder Kommunikationsstrategien („Stromsparen und Komfortverlust“) in den Fokus gerückt werden. Zudem wird deutlich, dass Feedback mit zusätzlichen Instrumenten wie Variablen Tarifen oder peer-to-peer Beratung kombiniert werden können und damit die dauerhafte Nutzung und verstärkte Wirkung erreichen können.

Des Weiteren wird der Frage nachgegangen, inwieweit die aus der Organisations- und Sozialpsychologie formulierte Annahme, dass Individuen aktiv nach Feedback Informationen suchen, auch für Stromverbrauchsfeedback zutrifft und in welchem Zusammenhang diese aktive Suche mit den individuellen Zielen und dem Verbrauchsverhalten steht. Zu diesem Zweck wurden log-file Daten zur Benutzung eines internet-basierten Feedbacksystems über insgesamt 5 Monate analysiert. Auch hier wurden durch eine Clusteranalyse insgesamt sechs verschiedene Feedback-Suchstrategien identifiziert. Dabei beziehen sich drei Strategien auf die zeitliche Ausprägung (nur einmal, über die ersten beiden Monate oder über alle fünf Beobachtungsmonate) ohne weitere Präferenzen hinsichtlich der dargebotenen Informationen.

Drei weitere Suchstrategien zeigen die spezifische Suche nach Informationen, wobei eine Gruppe primär Stundenverbrauchswerte aufsucht (Tagesverbrauchsprofile), eine Gruppe fast ausschließlich die angebotenen Energiespartipps rezipiert und die dritte beide Informationen anschaut. Die Strategien sind – wie eine Varianzanalyse zeigt – kaum durch die Benutzungsziele erklärbar, nur hinsichtlich des Ziels „Spaß haben“ unterscheiden sich zwei der Strategien signifikant.

Die Frage, welche der Feedback-Suchstrategien auch zu Stromeinsparungen führt, wird durch die Auswertung der Verbrauchsdaten in Kombination mit Befragungsdaten durch sechs multivariate Regressionen bearbeitet. Dabei zeigt sich, dass nur die Feedback-

Suchstrategie erfolgreich zu Stromeinsparungen führt, bei der sich die Teilnehmenden nur einmal in das Webportal einloggen und Informationen anschauen. Dieser Befund ist überraschend und wirft neue Fragen für künftige Forschung auf. Denn offensichtlich kann über eine einmalige Nutzung des Feedbacks kaum neues Wissen zur Stromeinsparung entstehen. Vielmehr ist es denkbar, dass die Information über den tatsächlichen Verbrauch und die damit verbundenen Kosten motivational wirken und bereits vorhandenes Wissen zum Stromsparen aktiviert und in entsprechendes Verhalten umgesetzt wird.

Unklar bleibt bei allen Suchstrategien, ob die Informationen, die das Feedback bietet, nicht ausreichend ist, um Verhaltensänderungen zu bewirken, oder ob die Informationen an sich Wirkung zeigen könnten, aber die „Aufgabe“, Strom zu sparen für die Individuen zu wenig selbst-relevant ist, um verhaltenswirksam zu werden. Oder ob gar die fehlende Selbstwirksamkeit (bspw. in Mehrpersonen-Haushalten) für die geringe Einsparwirkung verantwortlich ist.

Diese Fragen konnten durch die neue theoretische Perspektive des aktiven, nach Feedback-Informationen suchenden Individuums herausgearbeitet werden. Die vorgestellten Ergebnisse können im Kontext des theoretischen Rahmens sowohl wissenschaftlich als auch in der praktischen Anwendung zu Produkten im Energiesektor bzw. bei umweltpsychologischen Interventionen nutzbringend weitergeführt werden.

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Danksagung

Mein besonderer Dank gilt meinem Anleiter Prof. Dr. Andreas Homburg, der mir die Möglichkeit gab, diese Arbeit zu verfassen, und auf dessen Unterstützung ich mich die gesamte Zeit verlassen konnte. Trotz der Entfernung hatte er immer ein offenes Ohr für meine Anliegen und Probleme und meist innerhalb kurzer Zeit auch hilfreiche Antworten und Lösungen parat hatte.

Weiter möchte ich Prof. Dr. Uli Wagner für die Bereitschaft meine Arbeit zu begutachten danken, und dass er mir die Möglichkeit gab, meine Arbeit im Doktorandenkolloquium der AG Sozialpsychologie der Uni Marburg vorzustellen und zu diskutieren – und mich somit zumindest ein wenig mit den anderen Doktorandinnen und Doktoranden bekannt zu machen.

Außerdem möchte ich Prof. Dr. Otto und Prof. Dr. Schmidt-Atzert für die Teilnahme an der Prüfungskommission danken.

Ein sehr großer Dank geht an die Fördermittelgeber BMWi und BMBF sowie meine Projektpartner im BMWi Projekt Smart Metering sowie im BMBF Projekt Intelliekon. Das gemeinsame Zustandebringen der Feldtests hat diese Arbeit überhaupt erst möglich gemacht. Mein Dank für die Projekt- und wissenschaftliche Zusammenarbeit gilt insbesondere Britta Buchholz, Christian Schäfer, Annette Roser, Edelgard Gruber, Dorika Fleissner, Markus Büttner, Konrad Götz, Barbara Birzle-Harder, Georg Sunderer, Marian Klobasa, Joachim Schleich, Marc Brunner, Björn deWever, Heike Schiller, Dominik Noeren, Harald Schäffler und allen Beteiligten der Stadtwerke im Intelliekon Projekt.

Ebenso möchte ich mich bei Prof. Dr. Christof Wittwer bedanken, der mich trotz meiner Teamleiter-Aufgaben am Fraunhofer ISE darin unterstützt hat, diese Promotion fertigzustellen. Ein großer Dank geht auch an das Team Nutzerverhalten und Akzeptanz am Fraunhofer ISE für den Zuspruch, den ein oder anderen fachlichen Rat sowie das Erdulden meiner Bibliotheksaufenthalte und die damit verbundene knapperen Zeitfenster für Besprechungen und andere gemeinsame Arbeiten.

Danken möchte ich meinem Ko-Autor Ulf Hahnel danken, der mir in vielerlei Hinsicht geholfen hat, diese Promotion fertigzustellen – sowohl durch die gemeinsame paper-Erstellung, aber auch mit vielen wissenschaftlichen Überlegungen, Ideen und dem ein oder anderen Motivationsschub.

Ein letzter großer Dank geht an meine Familie, insbesondere an meine Frau Tanja, die mir immer wieder half, trotz Rückschlägen weiterzumachen und die mich insbesondere im letzten Jahr immer wieder liebevoll ermunterte, mich auf das wesentliche der Dissertation zu konzentrieren und keine unnötige Zeit mit inhaltlichen Abschweifungen zu vergeuden.

Erklärung

Ich versichere, dass ich meine Dissertation „Feedback seeking as an active, goal-oriented behavior – a psychological reframing of energy consumption feedback“ selbstständig, ohne unerlaubte Hilfeangefertigt habe und mich dabei keiner anderen als der von mir ausdrücklich bezeichneten Quellen und Hilfen bedient habe.

Die Dissertation wurde in der jetzigen oder einer ähnlichen Form noch bei keiner anderen Hochschule eingereicht und hat noch keinen Prüfungszwecken gedient.

(Ort / Datum) Sebastian Gölz

Teile dieser Dissertation werden in folgenden Fachzeitschriften publiziert:

Gölz, S. (in press). Feedback Usage leads to Electricity Savings? Analysis of Goals for Usage, Feedback Seeking and Consumption Behaviour. *Energy Efficiency Journal*

Gölz, S., & Hahnel, U., J., J.. (in press). What motivates people to use energy feedback systems? A multiple goal approach to predict long-term actual usage behaviour in daily life. *Energy Research & Social Science*

Arbeitsanteil des Ko-Autors:

Der Anteil des Ko-Autor Ulf J. J. Hahnel bei der Erstellung des papers für *Energy Research & Social Science* beträgt 30% des Aufwands.

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Gölz, S. (2016). Was hat Stromverbrauchsfeedback mit Schwimmen zu tun - Die Erfahrungen aus dem Forschungsverbund Intelliekon. In: Rico Defila, Antonietta Di Giulio (Hg.): *Transdisziplinär forschen - zwischen Ideal und gelebter Praxis. Hotspots, Geschichten, Wirkungen* (pp. 105 - 143), Frankfurt: Campus

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