Challenges in evaluating intervention effects of feedback on residential energy conservation in a field setting

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Abstract

A field intervention investigated the effect of feedback on residential electricity use in households in Sweden. For a period of eight weeks differentiated energy use for daily domestic behaviors was monitored by 15 residents via an internet-based system. Feedback designed based on Relational Frame Theory was convened to enhance motivation for energy conservation and follow-up studies analysed the maintenance of change for another 3 months. Psychological factors including values, attitudes, moral judgment competence, locus of control and sense of coherence were assessed by web surveys. No significant effects of the feedback on reduction of energy use were found. The small sample size and not monitoring warm water energy use were discussed as explanatory factors.

Keywords: energy conservation, feedback, Relational Frame Theory

1. Introduction

In order to reduce CO2 emissions, changes in the energy systems, for example, a substantial increase in the use of renewable energy and reductions in the use of fossil fuels are required (EEA, 2012). In Europe a quarter (24.4 %) of household energy consumption is for housing (Eurostat, 2016). Private household electricity use in Sweden is related to 20% of the total annual consumption of electricity (Energimyndigheten, 2015). Since production of electricity often is linked to various environmental problems, as CO2 emissions with indirect effects on climate change, it seems worthwhile to seek ways to reduce electricity consumption. Despite a considerable improvement of the technical energy efficiency of appliances over the past decades, a reduction of the total energy use has not been sufficient because of the continuously increasing demand for domestic electricity (Midden, Kaiser, & McCalley, 2007). However, analyses have shown that there is a potential for substantial electricity savings in the residential sector due to measures targeting behavior change (De Almeida, Fonseca, Schlomann, & Feilberg, 2011). Reduction of energy use through conservation and efficiency has also been pointed out to be options with immediate and cost-effective effects (Alcott & Mullainathan, 2010).

Household energy conservation has been a topic of interest in applied social and environmental psychological research since the 1970s. Reviews show, however, that interventions aiming to encourage households to reduce energy consumption have had varying degrees of success. Frequently given feedback has proven to have positive effects on behavior change, whereas information tends to result in higher knowledge levels but not sufficient behavioral changes or energy savings. Rewards only have short-time effects on encouraging energy conservation (Abrahamse, Steg, Vlek, & Rothengatter, 2005). The reviews of interventions, both of household energy reduction specifically as well as promoting pro-environmental behavior in general, have identified three key conditions that ideally should be fulfilled: (a) Measuring actual behavior changes implemented in real life, instead of using self-reports; (b) examining underlying psychological determinants of behavior change, and; (c) measuring whether effects remain over a longer period of time (Abrahamse et al., 2005; Lehman, & Geller, 2004; Hines, Hungerford, & Tomera, 1986/87; Geller, 2002; Schulz, 2014; Steg, & Vlek, 2009).

The general aim of the present study is to examine how a motivation-increasing intervention affects individuals' reduction of residential energy use. In order to meet the above three conditions, this intervention study has a design that allows measuring actual changes of the residential energy use, examining underlying psychological factors, as well as studying whether reductions of energy use are maintained over time.

1.1 Review of Previous Research

There are serious limitations to the vast number of studies in recent decades investigating the effects of values and attitudes on pro-environmental behaviors (PEB). One well-documented limitation is that self-reported attitudes, values and intentions are only moderately related to actual change of behavior (Bamberg, 2003; Kaiser, & Schultz, 2009). Because of this attitude-behavior gap, the approach of attitudinal research is unlikely to contribute to any solutions of decreasing energy waste, and Lehman and Geller (2004) note an urgent need for applied behavior analysis. According to classical psychological learning theory, the identification of functional relations between manipulable environmental variables and observable behaviors in the real world will be necessary to determine the effectiveness of strategies designed to enhance PEBs (Skinner, 1953).

On the other hand, interventions to directly reduce observable energy consumption, combined with self-reported measurement of underlying determinants of energy use and energy-related behaviors, have hardly been examined. For that reason Abrahamse et al. (2005), Lehman and Geller (2004), and Newsome and Alavosius (2011) recommend that evaluations of intervention´s effectiveness should measure changes in behavioral determinants (demographic variables, attitudes, values and other psychological factors) as well as changes in energy-related behaviors. In other words, the effectiveness of interventions and possible determinants of behavior should be examined in combination in order to increase the understanding of the success or failure of intervention programs.

One of the reviews of previous interventions to influence household energy conservation indicate that antecedent strategies (i.e. commitment, goal setting, information, modeling) show increased effects when combined with consequence strategies (i.e. information feedback, rewards) (Abrahamse et al., 2005). This combination of strategies to change behavior will be more successful since commonly there are multiple barriers to pro-environmental behaviors (Gardner & Stern, 2002; Lehman & Geller, 2004; Osbaldiston & Schott, 2012; Schulz, 2014; Steg & Vlek, 2009). However, the review of Fischer (2008) reveals mixed findings and Ehrhardt-Martinez, Donnelly, and Laitner (2010) argue that there is no current consensus regarding the impact of combined interventions.

Information provision is a widely used antecedent strategy to promote behavior change. This includes general information about energy-related problems, or more specific, tailored information, designed to reach specific persons about energy-saving measures. Informational provision aims at changing knowledge, awareness, norms and attitudes with assumed effects on behavior. The research to date indicates, however, that information alone is not effective in achieving behavior change, and it is therefore essential to combine information with other strategies (Abrahamse et al., 2005; Abrahamse & Matthies, 2013; Lehman & Geller, 2004). Another antecedent strategy is goal setting, based on goal setting theory, where individual's specific behavior is considered to be goal-directed

and motivated by the anticipation of reaching an attractive goal (Abrahamse & Matthies, 2013). Goal setting is often used in combination with other interventions, such as information feedback, and is most effective when goals are specific, high, and realistic (Abrahamse et al., 2005; Abrahamse, Steg, Vlek, & Rothengatter, 2007).

In the energy domain, feedback is a frequently used consequence strategy which appears to be effective for reducing energy use. Feedback refers to the process of giving people information about their behavior with the intent to reinforce and/or modify future actions. In order to motivate behavior changes, it is essential that the consequences of the behavior becomes immediately known. The closer in time feedback is received, the greater the impact it will have on the behavior, according to psychological learning theory (Bandura, 1969; Skinner, 1953). Feedback is providing households with information about their energy consumption, and it may influence behavior if it relates specific outcomes (e.g. energy savings) to specific behaviors. Feedback is often given continuously by means of a monitor displaying electricity per hour but in some studies daily, weekly or monthly. Darby (2006a) and Grønhøj and Thøgersen (2011) found positive effects of continuous feedback on reduction of energy use. The most successful feedback approaches have resulted in household electricity savings of up to 20%, while the more common outcomes are savings from 5% to 12% (Darby, 2006a; Fischer, 2008). According to Abrahamse et al. (2005) and Fischer (2008), more frequently given feedback (daily or every hour) is more effective, as well as feedback given directly after an action and feedback given over a longer time. Karlin, Zinger, and Ford (2015), however, showed in a meta-analysis that feedback is more effective for shorter interventions (e.g., less than 3 months) or quite long interventions (e.g., longer than 1 year). It is not clear whether it makes a difference to give feedback in the form of monetary or environmental costs (Abrahamse et al., 2005). The review by Fischer (2008) identifies a combination of features for feedback to be successful as a tool for saving energy, that is feedback based on actual consumption, involving interaction and choice for households, presenting in a clear and appealing way, and using computerized and interactive tools.

From the perspective of applied behavior analysis, a successful intervention will have to establish new contingencies by altering the consequences for targeted behaviors (Cone & Hayes, 1980; Newsome & Alavosius, 2011). As mentioned above, several reviews of promoting energy-reducing behaviors (Abrahamse et al., 2005; Lehman and Geller, 2004 and Newsome and Alavosius (2011) suggest a combination of the social/environmental and the behavioral approaches. The aim is to obtain a single perspective from which the critical roles of verbal behavior and rule-governance can be understood in their relation to attitudes and contingencies of reinforcement.

The sustainable behavior of an individual involves a choice between response options that have different short- versus long-term consequences.

Knowledge about future aversive consequences (e.g. predictions about negative environmental outcomes because of global warming) does not necessarily lead to the proenvironmental choice, especially if an individual has no past reinforcing experience, the behavior is effortful and/or competes with established behavior. In addition, promoting proenvironmental choices is associated with a unique challenge in that individuals are asked to change current convenient behaviors (mostly unsustainable) of which the most harmful consequences are likely to occur in the temporally distant and uncertain future (Hirsh, Costello & Fuqua, 2015). This delay between an individual´s current unsustainable behavior and any future environmental critical consequences is a major barrier to change when considering the immediate positive consequences of the current unsustainable behavior (habits, convenience, and social norms).

This study uses an application of the Relational Frame Theory (RFT) (Törneke, 2010). The RFT allows for an application of behavior analysis referred to complex verbal and cognitive processes (see Dymond & Roche, 2013; Hayes, Barnes-Holmes & Roche, 2001; Törneke, 2010, for a more comprehensive background). Human language presents the opportunity to relate different stimuli to each other, and to derive associations verbally. These derived relations between stimuli will also affect the meaning people give to these stimuli and how they will affect them. It is taking verbal behavior (Skinner, 1957) a step forward in defining derived relational responding. As explained by Hayes et al. (2001), the basic analytic units of human verbal behavior, relational frames, may be combined into units that are more complex, e.g. energy reductions achieved by participants in an intervention are met by feedback messages where the reduction is related to the size of the reduction if all people in the country would reduce their energy in the same way. Language colors perceptions and is a part of the relation to the environment. How people describe circumstances and frame relations strongly influence how they respond to certain PEB contingencies (Newsome & Alavosius, 2015). Verbal behavior may also have the functions of rules or instructions towards future behavior and consequences that are not taking place in the present and that people have not earlier experienced (Törneke, 2010), for instance, feedback messages relating energy reductions achieved today to limited climate changes in the future of children and grandchildren.

1.2 The Present Study

The present study investigates how a feedback based on RFT, in this study named "complex feedback", may relate daily energy behaviors in the households to future consequences and in this way have a reinforcing and motivating effect on the capacity to change behavior towards energy reduction. A more detailed description of how complex feedback is applied in this study is included in the method section. As an applied strategy, the RFT behavioral analysis of language, has shown an impact on individual clinical treatments, at workplaces and in

community settings, demonstrating generalizability that may be extended to environmental issues (Newsome & Alavosius, 2011).

To examine underlying psychological determinants of behavior change, measures of values, attitudes, moral judgment competence, locus of control and sense of coherence were included. As previous research has supported a positive relationship to self-reported PEB for the value type universalism but not for benevolence, power and achievement (Hansla, Gamble, Juliusson, & Gärling, 2008a; Kaiser & Byrka, 2011), partly for the attitudes awareness of consequences (Nordlund & Garvill, 2002, 2003) and environmental concern (Bamberg, 2003; Hansla et al., 2008a) and for locus of control (Engqvist Jonsson & Nilsson, 2014), there are until now no support for a positive relationship between self-reported PEB and moral judgment competence (Lind, 2008) and sense of coherence (Antonovsky, 1988). Since previous attitude-behavior research is rarely carried out in relation to actual behavior changes implemented in real life, the relation of attitudes to actual behavior is a specific target of the present intervention.

In order to develop interventions aimed to promote energy-reducing behaviors, it is important to know if the achieved behavior changes are sustained over long periods of time. A vast number of studies have not monitored the effects of interventions over longer periods, which makes it unclear whether behavioral changes are maintained or whether energy use returns to baseline levels after removal of a feedback intervention (Abrahamse et al., 2005; Hirsh et al., 2015; Lehman & Geller, 2004). Some follow-up studies have revealed that achieved energy reductions are not maintained (Abrahamse et al., 2005; Hayes & Cone, 1981). However Staats, Harland, and Wilke (2004) reported reductions of gas, water and electricity use after two years using information and individual and comparative feedback. Frazer and Leslie (2014) also found in a field study long-term effects of feedback on residential energy conservation.

A field experiment reported next examines (1) effects of complex feedback on energy savings based on actual consumption within a web-based intervention program, (2) the relations to underlying psychological factors, and (3) whether reductions of energy use are maintained over time. Our hypotheses are that (1) complex feedback preceded by goal-setting promotes energy reduction, (2) the value types benevolence and universalism, high awareness of consequences and environmental concern, high moral competence, internal locus of control and high sense of coherence are related to behavior change towards residential energy conservation, and (3) a removal of the intervention results in a decline of intervention-related savings but not in a return to baseline electricity use.

2. Method

2.1. Participants

Participants were individuals in households living in apartments which are rented out by a municipal housing company in Sweden (Gavlegårdarna in Gävle). Recruitments were made by means of a written request to participate sent out to 1,430 households from an address list provided by the housing company. Only households who had lived in their apartments for at least one year and who had the intention to stay for another six months were eligible. The request letter included information about aim and duration of the study as well as the way of collecting and handling data. With the letter followed a free-of-charge return envelope and a promise to receive two movie tickets after completion of the intervention. A reminder was sent out after three weeks. No other incentives were offered.

Consent to participate were given by 25 households, which were then randomly assigned to an experimental condition consisting of 13 participants and to a control condition consisting of 12 participants. Of the original 25 participants, 8 completed the intervention (experimental and control group) and 7 participants partly followed the intervention by completing a varying number of periods. In order to use also the information provided by these participants, a third group was created, labelled the out group. The attrition rate was 10 participants (40 %). No formal analysis of attrition was possible due to limited sample sizes. The experimental group had 3 participants, 2 men and 1 woman in the age of 36-65 years (M = 51.00), and the control group 5 participants, 2 men and 3 women in the age of 31-67 years (M = 48.00). The out group were 4 men and 3 women in the age of 25-57 years (M = 36.00). An overview of the demographic variables is given in Table 2.

Table 2. Number of participants (n), sex, age (M), education, marital status, nationality, income

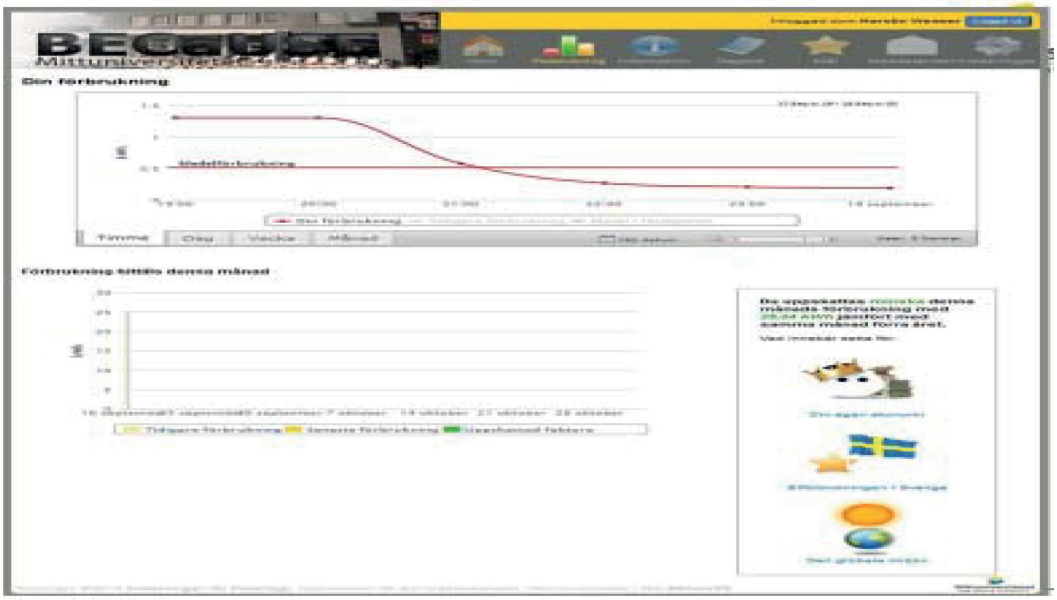
Variables	Experiment n = 3	M	Control n = 5	M	Out group n = 7	M
Sex						
Men	2		2		4	
Women	1		3		3	
Age		51.00		48.00		36.00
Education						
Without university	0		2		3	
With university	3		3		4	
Marital status						
In relationship	0		5		5	
Not in relationship	3		0		2	
Nationality						
Swedish	3		5		7	
Not Swedish	0		0		0	
Income SEK						
<235.000	0		3		5	
235.001-375.000	2		2		0	
>375.000	1		0		1	
Unclear					1	

Each participant represented a multi-person household of electricity users and all registering of electricity use apply to the household as a whole. The individual who was in contact with the researcher and gave consent to take part in the study is referred to as the "participant".

2.2. Intervention

Apartments were technically equipped with electricity meters allowing separate measurement of energy use in every flat, which enabled monitoring of electricity use in kWh every hour. As baseline measures, data from three months before the intervention period was obtained for each household. The web system made the use of electricity visible in graphs to participants logging in to the web system, see Figure 1.

Figure 1. Energy consumption (kWh) in graphs of the web system



The electricity consumption recorded by the graphs was the total amount of electricity in the entire apartment. A breakdown of electricity into specific rooms and activities was not technically possible. An overview of the intervention, consisting of eight different periods of varying duration and contents for the two groups, is shown in Table 1.

Table 1. Overview of intervention design

Duration December 2013 – June 2015		Experiment	Control
Period	Duration	Activity	Activity
Period 0	1-2 days	Questionnaire (PRE)	Questionnaire (PRE)
Period 1	5-6 days	Information climate, lifestyle	Information climate, lifestyle
Period 2	14 days	Observation of daily use Advice on categories of behavior Diary	Observation of daily use Information of energy savings
Period 3	7 days	Goal setting Choice of behavior to change	Information of energy savings Information of energy savings
Period 4	14 days	Behavior change Complex feedback	
Period 5	14 days	Goal setting Choice of new behavior to change Behavior change Complex feedback	Energy savings info
Period 6	1 day	Survey about the intervention	Survey about the intervention
Period 7	90 days	Maintenance	Maintenance
Period 8	1 day	Questionnaire (POST)	Questionnaire (POST)

After completing a questionnaire (PRE, see Questionnaire measures below), all participants received information about climate, environment and lifestyle (period 1). The information contained facts about the impact of human lifestyle on climate change in terms of increased greenhouse gas emissions. The texts also showed possibilities for changing behavior in transport, food and energy consumption that would help to limit climate change. Both groups were encouraged to observe their daily electricity consumption given by the graphs as continuous feedback (period 2). In addition, the experimental group received advice on six categories of energy behaviors with great potential for energy savings (use of refrigerator and freezer, lighting, entertainment technology, cooking and dishes, laundry and drying of clothes and shower) and was encouraged to keep a diary about how these behaviors were visible on the graph (period 2). For example, taking a shower and preparing breakfast in the morning were to be observed as an increase of the energy consumption visible on the graph during these morning hours. These observations and self-reflections were communicated with the project manager via a message function in the program. During the next period the experimental group was offered different options of goal setting for energy reduction of two behaviors of free choice among each of the six categories of energy behaviors previously presented (period 3). For example, "Allow hot food to cool before putting it in the fridge and freezer" and "Always wash with a full loaded washing machine" constitute two options of goal setting. After a period of focusing on change of the chosen behaviors (period 4), a new process of goal setting and choice of behaviors followed (period 5). The web system provided individualized complex feedback to the participants in the experimental group each time their energy use deviated from baseline (periods 4 and 5). Feedback was given with different contents in three different ways: (1) monetary framing, (2) environmental framing (CO2), and (3) energy framing (kWh). The change of

energy use compared to baseline was put in relation to financial short-term and long-term consequences for the participant, to energy production from a local, national and international perspective and to the environmental and climate consequences of changes in CO2 emissions. For example, if a participant in the experimental group reduced the energy use with 1 kWh compared to baseline, feedback were given in three ways introduced with different symbols (see Figure 1): (1) monetary framing with the message "You have used 1 kWh less energy compared to the same time last year. This means that you pay X1 kronor less for your energy this month, 12xX kronor less after a year if you keep your reduction and you´ll pay 20x12xX kronor less for your energy after twenty years with the same low energy use". In this way, an even small behavior change is set in relation to further more complex economic consequences, relational frames, which intent to have a reinforcing and motivating effect on the capacity to change behavior. The second way of giving feedback was: (2) environmental framing in terms of greenhouse gas emissions (CO2) with the message "If all people in your town would reduce their energy use as much as you have now, 1 kWh, it would mean 95, 4 tonnes less CO2 emissions which corresponds to the same reduction of CO2 as if 43 people leave the car at home and travel by public transport to work (40 km) during one year". This verbal behavior is setting the small achieved change in relation to greater environmental consequences in order to reinforce and motivate to further behavior changes. The third way of giving feedback was: (3) energy framing (kWh) with the message "If everyone in Sweden reduced their energy consumption as much as you, 1 kWh, it would correspond to the energy that a medium-sized wind power plant in Sweden produces in two years". The achieved and rather small change of energy behavior is intended to be reinforced by this relational framing in making the energy consequences much greater. A more international perspective on relational framing can be taken with the following feedback message "If everybody in the EU did the equivalent energy reduction as you, 1 kWh, it would mean the same amount of energy that the largest Swedish hydropower plant Harsprånget produces for the time of three months".

No further activities than general information about energy savings were directed to the control group (periods 2-5).

After eight weeks of intervention activities, both groups completed a short survey about the intervention program (period 6), followed by 3 months of inactivity in order to study if the savings in energy use would be maintained (period 7). The intervention was completed by a second questionnaire (POST, see Questionnaire measures below) (period 8).

Participating households all started the intervention on the same day in December 2013, but as most of them showed a varying total duration of the intervention depending on inactive periods caused by illness, vacations, heavy workload and birth of child, the last participant was not completed until June 2015. Despite these variations of the total duration from start to end date, the effective

performance periods comprised a total of five months for all participants. In this way the different intervention periods were occurring over different seasons, and may not be confounded by co-occurring changes in temperature or season. The missing periods of active participation of the individuals in the out group were constructed afterwards according to the intervention program.

The researcher and participants communicated via e-mail within the web based system and via telephone.

2.3 Questionnaire measures

In addition to the questions about sociodemographics reported in Table 2, the following measures were obtained:

(1) Value orientation. A selection of 16 value items from Schwartz´s (1992) Value Inventory Scale was used to assess the value orientation. The participants were asked to indicate the degree to which each of the 16 values was a guiding principle in their lives. Each value was rated on a scale from 1 "fully disagree" to 5 "fully agree". The values social power, wealth, social recognition, authority, self-respect, ambition, influences, and capability represented self-enhancement with the value types power and achievement. The values social justice, equality, a world at peace, loyalty, forgivingness, tolerance, the welfare of others, and responsibility represented self-transcendence with the value types universalism and benevolence (see Tables 4 and 5) (Schwartz, 1992). Items were recoded as to make higher scores indicate stronger guiding principles in the lives of the respondents.

(2) Awareness-of-consequences beliefs. Participants indicated to what extent they agreed with 9 items measuring egoistic AC, altruistic AC, and biospheric AC using three items for each AC sub-scale after Stern et al. (1993) and used by Gärling et al. (2003). Respondents rated on a scale from 1 "fully disagree", and 5 "fully agree". Items were recoded as to make higher scores indicate stronger beliefs that environmental degradation adversely affects valued objects and that environmental protection benefits them;

(3) Environmental-concern evaluations. The procedure suggested by Schultz (2001) used 12 items to measure environmental concern with the question: "I am concerned about environmental problems because of the consequences for:" (abbreviated version of Schultz, 2001, p. 338). Participants were asked to indicate the degree to which they were concerned about harmful effects of environmental problems for egoistic items (ECself: me, my future, my lifestyle, and my health), altruistic items (EChum: all people, children, people in Sweden, and my children), and biospheric items (ECbio: plants, marine life, birds, and animals). Participants were asked to rate on a scale from 1 "fully disagree" to 5 "fully agree". Items were recoded as to make higher scores indicate stronger environmental concern.

(4) Moral Judgement Competence (MJC). A questionnaire was used derived

from the dual-aspect theory (Lind, 2008). The participants completed the Swedish version of the MJT questionnaire, validated and certificated by Lind (2010a). The MJT questionnaire assesses moral judgment competence by recording how a person deals with arguments, especially with arguments that oppose his or her position on a difficult problem (Lind, 2008). The main index for moral competencies, the C-score, measures the degree to which judgments about pro and con arguments is determined by moral concerns or principles rather than by non-moral opinions. Participants confront two moral dilemma stories, one about workers dealing with a law violation and a second about a doctor having to decide whether he is going to assist a dying patient to take her own life (euthanasia), and must express whether he or she approves or disapproves a string of arguments in favor or against the prescribed behavior in each story. After this the participant makes a decision about the dilemma described ("Was the behavior of the workers/doctor morally correct or incorrect?"), the participant is given six arguments in favor of the decision and six against it for each dilemma (Lind, 2009). These arguments were designed to represent each of Kohlberg´s six moral orientations (Kohlberg, 1984). Participants rated on a 9-point scale ranging from "-4" (completely disagree) to "+4" (completely agree). An example of an item in favor of workers' behavior corresponding to the developmental Stage 1 is "Because they didn´t cause much damage to the company." Another example of an item against the workers' behavior corresponding to Stage 4 is "Because we would endanger law and order in society if everyone acted as the two workers did." (Lind, 2009). The calculation of a C-score ranging from 1 to 100 followed the procedure devised by Lind (2010b).The score indicates the percentage of an individual's total response variation due to his or her concern for the moral quality of given arguments or behavior. It may be categorized as low (1-9), medium (10-29), high (30-49) and very high (> 50 points) (Cohen, 1988; Lind, 2010b).

(5) Locus of control was measured using an abbreviated version of the Rotter scale (1966). This version was developed by Andersson (1976) for use in Sweden, mainly in work settings. The scale consists of eight statements related to the construct of locus on control. For each statement participants made agreement-disagreement ratings on a 5-point scale from "agree completely" (1) to "disagree completely" (5). The summed ratings has a minimum score of eight and a maximum of 40, with a low score representing an external locus of control orientation and a high score representing an internal locus of control orientation.

(6) Sense of coherence (SOC) was measured with a 13-item short version of the original scale. It covers the three components of the SOC construct, comprehensibility, manageability and meaningfulness (Antonovsky, 1993). Participants were asked to rate on a scale from 1 to 7 with a high score representing high SOC.

2.4 Statistical analyses

The small number of households participating in each group did not permit an inferential statistical analysis in order to make meaningful comparisons of intervention effects. Analyses of the results are therefore based on individual means and observation of individual and group usage patterns.

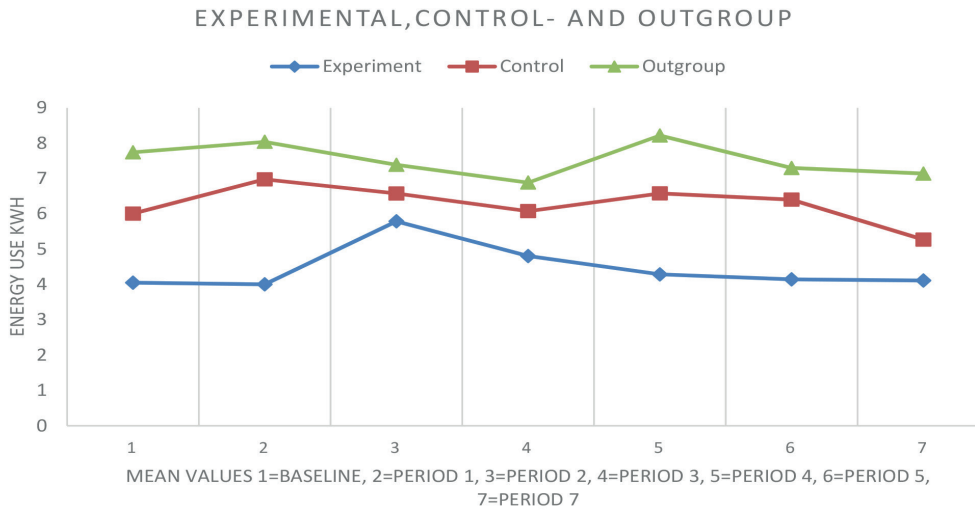
3. Results

The electricity use during the intervention was measured in kWh as the dependent variable. The mean values of energy consumption for each participant of the three groups during baseline and intervention periods are presented in Table 3 and Figure 2.

Table 3. Mean values (M) of energy consumption (kWh) for each participant during baseline and periods

Participant	baseline	period 1	period 2	period 3	period 4	period 5	period 7
Experiment							
A	4,493	5,265	8,348	5,368	4,176	4,057	3,946
B	3,777	3,083	4,083	3,887	3,994	3,502	4,275
C	3,881	3,662	4,934	5,160	4,688	4,873	4,946
Control							
D	8,778	9,904	10,037	9,213	10,070	9,596	7,943
E	6,196	7,400	7,235	6,451	6,084	5,659	4,801
F	3,242	3,620	4,466	4,659	4,063	4,053	3,178
G	7,046	9,180	6,931	7,726	7,710	7,148	7,458
H	4,769	4,772	4,206	2,329	4,961	5,550	2,975
Outgroup							
I	5,449	6,580	4,988	5,553	5,332	5,131	4,055
J	12,963	15,900	11,266	12,097	18,900	16,214	10,169
K	4,449	5,726	4,690	3,982	4,101	3,861	3,782
L	4,938	4,193	4,847	4,051	4,384	2,851	4,856
M	12,080	8,547	10,378	8,953	10,409	9,087	12,617
N	8,847	10,184	9,403	10,321	8,951	9,111	9,113
O	5,457	5,130	6,137	5,294	5,431	4,822	5,371

Figure 2. Energy consumption (kWh) as mean values for the experimental, control- and outgroup in each period during the intervention.



Period 1: information (exp and con); Period 2: exp = observation of daily use, advice on categories of behavior, diary; con = observation of daily use, information of energy savings; Period 3: exp = goal setting, choice of behavior to change; con = information of energy savings; Period 4: exp = behavior change, complex feedback; con = information of energy savings; Period 5: exp = goal setting, choice of new behavior to change, behavior change, complex feedback; con = information of energy savings; Period 7: exp and con = maintenance

As can be seen, for the experimental group there was only a slight tendency of reduced electricity use observed when the complex feedback was provided. A more detailed examination of how participants consumed energy shows that participant A used less energy during the periods with complex feedback, while participants B and C show differently raising and declining patterns of change during the same periods. As expected, no energy use reduction during the complex feedback was discernible for the control group, with the exception of participants E and F. For the out group there was an unexpected reduction of energy use during period 4, although participants of this group did not take actively part of the intervention after period 3. It was not possible to relate the found values of the psychological factors to any successful behavior change (see Tables 4 and 5).

Table 4. Values of psychological factors PRE and POST for the experiment- and control group

	Participants					
	Experiment PRE			Experiment POST		
Variables	A	B	C	A	B	C
Value types						
Power	4.5	3.0	2.5	3.0	2.5	2.25
Achievement	4.5	4.25	2.5	3.25	4.0	3.5
Benevolence	5.0	4.25	4.25	4.25	4.5	4.5
Universalism	4.75	3.75	2.25	5.0	4.25	3.0
Awareness of consequences						
For oneself (ACself)	5.0	3.67	3.67	3.33	4.0	4.0
For others (AChum)	5.0	3.67	3.67	4.33	3.67	3.6
For the biosphere (ACbio)	3.67	3.67	3.33	5.0	4.0	4.0
Environmental concern						
For oneself (ECself)	--	2.5	3.25	4.75	2.5	3.25
For others (EChum)	--	2.75	3.25	5.0	3.25	4.25
For the biosphere (ECbio)	--	3.25	4.0	4.75	4.0	5.0
Moral competence	18.5	18.8	2.4	13.0	22.4	9.7
Locus of control	29.0	15.0	24.0	32.0	15.0	23.0
Sense of coherence	56.0	36.0	53.0	43.0	26.0	61.0

	Control PRE					Control POST				
	D	E	F	G	H	D	E	F	G	H
Value types										
Power	3.0	2.75	3.25	3.0	2.25	3.0	2.5	3.25	3.25	3.25
Achievement	3.25	4.25	4.75	3.25	4.75	3.75	4.5	4.5	3.75	4.75
Benevolence	4.5	4.75	4.5	4.0	3.25	4.75	5.0	4.25	4.25	4.25
Universalism	4.25	4.0	4.25	4.0	3.25	4.75	4.75	4.5	4.25	3.5
Awareness of consequences										
For oneself (ACself)	4.67	4.0	4.33	2.67	5.0	4.33	3.33	4.67	3.33	4.33
For others (AChum)	4.67	3.67	3.67	3.67	3.0	4.33	3.67	3.67	3.67	3.33
For the biosphere (ACbio)	4.33	4.0	4.0	3.33	4.0	4.67	5.0	4.0	4.0	3.0
Environmental concern										
For oneself (ECself)	4.0	4.5	3.5	4.5	5.0	3.75	4.0	3.75	4.0	2.5
For others (EChum)	4.0	4.5	4.0	4.5	5.0	4.0	5.0	4.0	4.0	3.0
For the biosphere (ECbio)	4.0	4.25	4.0	4.25	5.0	3.75	5.0	4.0	4.0	2.25
Moral competence	2.5	1.4	51.0	23.1	13.0	1.8	2.5	49.8	31.2	6.2
Locus of control	28.0	26.0	30.0	25.0	31.0	27.0	25.0	30.0	23.0	24.0
Sense of coherence	54.0	53.0	56.0	36.0	65.0	56.0	67.0	49.0	44.0	53.0

Table 5. Values of psychological factors PRE for the outgroup

	Participants						
	Outgroup						
Variables	I	J	K	L	M	N	O
PRE							
Value types							
Power	4.0	2.5	4.5	3.0	3.0	2.0	4.5
Achievement	4.5	2.75	5.0	4.0	3.5	3.25	4.25
Benevolence	4.25	4.0	5.0	4.75	4.5	4.25	4.25
Universalism	4.0	4.0	5.0	4.75	4.0	4.25	4.0
Awareness of consequences							
For oneself (ACself)	3.0	4.0	4.0	4.33	4.0	4.33	4.67
For others (AChum)	3.67	4.0	4.67	4.33	4.67	3.0	3.33
For the biosphere (ACbio)	3.0	3.67	4.67	4.67.	3.67	3.0	4.33
Environmental concern							
For oneself (ECself)	2.5	3.0	4.0	4.5	3.75	2.75	5.0
For others (EChum)	3.5	3.0	3.75	4.75	4.5	4.0	5.0
For the biosphere (ECbio)	3.0	3.0	5.0	5.0	4.5	3.0	5.0
Moral competence	5.3	5.1	2.8	60.7	17.3	9.5	10.8
Locus of control	22.0	20.0	24.0	24.0	23.0	25.0	28.0
Sense of coherence	43.0	43.0	68.0	54.0	33.0	36.0	56.0

During period 7, the last period of the intervention after that all active intervention strategies were removed for 3 months in order to study if reached savings in energy use would be maintained, the levels of energy use almost remained on the level from the previous period for experiment and out group. Thus, almost no decline of intervention-related savings occurred. An interesting and unexpected reduction of the energy consumption for the control group was observed during period 7.

4. Discussion

The study represents an applied behavior analysis with an experimental approach to reduce energy consumption in the real world. It matches the demand of behavioral interventions outside the lab examining actual behavior change instead of using self-reports in order to increase external validity (Abrahamse et al., 2005; Lehman & Geller, 2004).

Besides the intention to apply the results of this study in the real world, other important aims were to illustrate the effectiveness of complex feedback on household energy reduction, examining underlying psychological determinants of behavior change, and studying whether effects are maintained over a longer period of time. Results were strongly limited by the difficulties in recruiting an acceptable number of participants in a field setting. Despite a local media campaign followed by the offering of participation to 1,430 households, only 25 households gave their consent to participate. An intervention lasting for five months may challenge the participants' motivation and persistance, which may have contributed to the attrition rate of 40 %, followed by another 28 % of the participants who did not complete the intervention. The difficulties in recruiting clearly demonstrate the complications associated with studies in field settings. Regardless of an anticipated low statistical power, due to the small sample size, we considered it meaningful to carry through this planned intervention as a test of the new specifically developed web based system.

The expected effects of complex feedback on energy reduction were not found. The consumption pattern of the experimental group, however, could indicate that the participants, to a small extent, have been affected by the motivation increasing strategies during periods 4 and 5 (participant A), after which consumption increased slightly during period 7 (participants B and C) when the complex feedback was aborted. The main problem is the very small sample size, which reduced the statistical power so that the study failed to find any statistically significant effects.

The web-based program was limited in that it did not give immediate feedback after the behavior, and the frequency of the given feedback was low (Abrahamse et al., 2005; Fischer, 2008). First, the time passing between a change of an energy saving behavior and the following complex feedback given as a consequence of the program during periods 4 and 5 is widely varying. It depends on when a participant returns to the computer program after a change in the daily energy behaviors has been made and attends to the complex feedback, a time which can vary unlimited from less than one hour to several days. The closer in time a behavior is reinforced, the greater the impact this consequence will have on the behavior, according to psychological learning theory (Bandura, 1969; Skinner, 1953), which indicates that the web-based program should be modified to include a function of registering the time when the complex

feedback is given compared to the time when the participants become visually exposed to the complex feedback. This would allow a more detailed analysis of the complex feedback and its effect on energy reduction. The application of the web based intervention program on a mobile phone instead of a computer would contribute to shorten the time between behavior change and the complex feedback as reinforcement.

Second, as more frequently given feedback is more effective, according to Abrahamse et al. (2005), and Fischer (2008), it seems clear that the program is limited by the fact that time and frequency of the complex feedback given is not registered. The web-system provided an individual complex feedback to the participants of the experiment group during periods 4 and 5 each time their energy use deviated from baseline. It was however not possible to observe when and with what frequency this feedback was given to each participant. In order to evaluate the effects of the used feedback, the intervention program can be developed in making the frequency of the complex feedback visible for the researcher.

Due to the paucity of expected effects of complex feedback on energy reduction, the possibility of relating the psychological factors to behavioral change was not possible. From a behavioral theory perspective one would argue that if actual consequences of real-life behavior changes had been found directly related to some of the psychological factors investigated, this had contributed to a better understanding of PEB and had highlighted important motivational factors (Cone & Hayes, 1980; Grønhøj & Thøgersen (2011).

The level of energy use in the experimental group demonstrated behavioral maintenance during period 7, as the energy level almost remained at the level of the previous period. On the one hand, this is noteworthy because a slight decline of intervention-related energy savings is expected to occur when the feedback periods end (Abrahamse et al., 2005). On the other hand, an unchanged level of energy consumption across the feedback periods (periods 4 and 5) and the period of maintenance (period 7) could be seen as a delayed effect of the complex feedback even if periods 4 and 5 remained unaffected. Frazer and Leslie (2014) also found maintenance (effects could not be statistically validated due to a very small sample size) of the energy use during no feedback periods using a reversal design of two months of feedback (continuously by means of a monitor displaying electricity use) followed by two months of no feedback for a total of 10 months.

The tendency of energy reduction observed for the control group during period 7 is worth noting. There may be reasons to assume that the intervention itself, without any motivation-increasing strategies, could have motivated a behavior change with reduced energy use after a longer time. The energy levels of the out group across the periods are mainly following the changes of levels of the control group, with the exception of a reduction of energy use during period 4 from a higher level at the end of period 3, and without the energy reduction

during period 7. The increase in energy use after period 3 for the out group may be an effect of that most of the participants in this group stopped their intervention activities during the same period of time.

Considering some of the demographical data, it is notable that the out group had a lower mean age, all participants in the experimental group were not living in a relationship, had a higher level of education and had a higher income than the participants of the other two groups. One may guess that an older age could be a factor positively influencing the tendency to complete an intervention of this type as the mean age among the out group is lower than that of the two groups of participants who completed the intervention. Some studies support this assumption in reporting a generally stronger environmental concern among older people than among younger people (Gifford, 2014).

The missing effects in this study may partly be explained by the fact that no hot water use could be registered within the scope of the intervention. At the beginning of the study only registration of household electric appliances remained available, which meant that each behavior change was likely to have a rather small impact on the total electricity consumption. This is inconsistent with Abrahamse et al.'s (2005) advice to identify target behaviors that have relatively large energy-saving potential.

Another factor that may contribute to the explanation of the missing effects in this study is the fact that continuous feedback was given to all groups through the entire intervention. As previously found in several studies, continuous feedback alone, using a monitor or a display, give significant reduction of energy use (Darby, 2006a; Grønhøj & Thøgersen, 2011), which raise the question of whether the use of continuous feedback in all groups across all periods in this study may have hidden any effects of the complex feedback for the experimental group. On the other hand, Nilsson et al. (2014) found no effects on electricity consumption using continuously visual feedback.

Considering the design and empirical assessment of this field study, a number of limitations can be identified. First of all, the extremely small sample size of the three groups does not allow for either providing reliable data for significance testing and conclusions based on this, nor for generalizing these results. With larger sample sizes, this study had been able to take advantage of that field experiments typically have high external validity, that is, the results and conclusions of field experiments are often more easily generalized to the population at large than results from lab studies. Even though field research limits inferences about cause and effect because of lack of internal validity and rigorous control of confounding variables, there is a need of assessment of real behaviors as stated by Frazer and Leslie (2014, p. 22), "it is also true that all the theoretical knowledge in the world is of no use to society if we do not explore the ecological validity of our theories by testing them in the real world with social relevance".

In some cases, it is difficult to make generalizations based on the results, for

samples consisting of highly motivated participants. In other cases participators are taking part in an intervention as a consequence of their own interest, either as having certain economical interest when living in private homes or as having specific interest in energy issues. This study investigated households in rental apartments who may be less actively seeking to participate and in that respect may be more comparable to a normal population. On the other hand, apartments have a lower general electricity consumption which may lead to a lower motivation of energy conservation among these households, as found by Nilsson et al. (2014). Another reason for confounding of effects could be that due to the use of combinations of intervention strategies, it is difficult to establish the contribution of each strategy separately to the overall effect.

Regarding motivational barriers to behavior change experienced by the participants during the intervention, further studies should include indepth interviews after completed interventions. It is important to understand people´s motives when searching for new and more effective ways of designing feedback interventions. This may be especially informative if the results show small or no effects.

In conclusion, the difficulty to recruit participants to this intervention study clearly demonstrates the challenges in evaluating studies in field settings. Nevertheless, it is important to continue doing field studies which provide results with a high external validity that can help solve society's environmental problems. As observed by Newsome and Alavosious (2011), interventions based on reward systems are resource demanding in practical settings in terms of costs and time. The intervention described in this study is different from other studies in the use of a problem-oriented methodology, which should be tested and replicated in the future. With increased recruiting for a more large-scale project, as well as the registration of hot water consumption, this new form of complex feedback used in this study based on Relational Frame Theory (RFT) (Törneke, 2010) may be found to motivate the desired behavioral changes that lead to reduced energy use in households.

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