

DELIVERABLE 6.1

Consumer behavior and social aspects of water consumption

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Abstract

This deliverable provides a comprehensive literature review and discussion of the factors influencing consumer behavior and water consumption, including price, psychological, socio-demographic and contextual determinants. Measures aiming to address the relevant factors and change consumer behavior are presented based on the psychological literature. This report served as a knowledge base when designing the DAIAD user trials to test its effect on consumer behavior and water consumption. Further, it will guide the data analyses to study the relevance of socio-demographic and psychological factors for behavioral changes, as well as the effects of different types of information. Finally, an empirical study is presented, which analyzes the factors influencing the willingness to adopt water monitoring & feedback devices.

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Executive Summary

This deliverable focuses on water consumption and the socio-psychological factors influencing consumption behavior and provides theoretical and empirical perspectives on consumer behavior related to water consumption. Based on the existing literature, it first presents a detailed theoretical overview of the determinants of water consumption behavior and methods to bring about behavioral change. Second, it presents empirical results regarding the willingness to adopt technological feedback devices and its determinants.

This report served as a knowledge base for designing the trials and data analyses which will be conducted in WP7 of the DAIAD project. Moreover, it can give actors from the water domain intending to implement measures to influence water consumption a broad overview of the relevant factors and feasible measures.

The document is structured as follows.

After an introduction in Section 1, Section 2 reviews the determinants of water consumption and consumer behavior. This begins with an overview of socio-demographic aspects which cannot be influenced, but should be considered when designing, analyzing or forecasting water demand, or when designing measures intended to change demand. Subsequently, the financial and psychological determinants and aspects are described in detail which can be addressed and influenced by the water utility or other actors in order to change consumption behavior. Among the psychological theories and concepts presented, we describe psychological action theories, specific determinants and concepts, and, finally, integrated frameworks.

In Section 3, we give a broad overview of types of intervention intended to change behavior. First, we discuss the basic methods to change behavior based on the determinants described in Section 2. Then we examine specific types of method of particular relevance for the DAIAD trials.

Section 4 presents an empirical study of the determinants for the willingness to adopt technological feedback devices such as DAIAD@feel. We first describe the aim and setting of the study, its theoretical background and the hypotheses. The method and results are then described in detail. The section concludes with a discussion of the results.

Finally, building on the literature review presented in Sections 2 and 3, Section 5 begins with general recommendations and implications for the design of the DAIAD trials and measures to change water demand. Based on the empirical findings presented in Section 4, we then discuss the implications for promoting the adoption of technological feedback devices.

Abbreviations and Acronyms

NAM	Norm activation model
TPB	Theory of planned behavior
PBC	Perceived behavioral control

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1. Introduction

Deliverable D6.1 presents the results from a study of water consumption behavior and the social aspects of consumption. The goal was to identify the relevant determinants of water consumption behavior in general, as well as the relevant factors influencing the adoption of DAIAD and their effect on water consumption behavior. In particular, D6.1 guides the design and analyses of the user trials (WP7), in which socio-demographic and psychological factors and the effects of different types of information will be studied.

A literature review was conducted in order to identify relevant factors as well as promising intervention approaches to study in the DAIAD trials. Due to the fact that, to the best of our knowledge, there is no psychological literature on the adoption of such water consumption feedback devices, and because the trials in WP7 focus on the effects of using such devices (as well as on influencing factors), an empirical study was also conducted to examine which factors influence the willingness to adopt such feedback devices.

The remainder of this document is structured as follows. Based on the literature review, Section 2 focuses on the determinants of water demand, including price, psychological and socio-demographic factors. Section 3 presents an overview of intervention options to bring about changes in both consumption behavior and demand. Following these results from literature research, Section 4 describes the above-mentioned empirical study of determinants for adopting feedback devices for water conservation behavior. Finally, in Section 5, the results of the literature review and the empirical study are discussed with regard to implications and directions for the DAIAD project.

2. Determinants of water demand

In order to identify the determinants of water demand, we draw on economic and psychological literature. The determinants presented in the following sections include those which *can be* addressed by a water supplier (e.g. a utility) to directly influence demand and those *which cannot*. The price of water is the most prominent factor in the first group, but there are also others that can be addressed such as psychological constructs including *awareness, attitudes and norms*. In the second group, which cannot be influenced by the water supplier, the type of *household* (*representing the typical client of a water utility*) and *geographical characteristics* are relevant factors. Knowledge about both groups of determinants is useful to manage or change water demand by addressing factors that *can be influenced* on the one hand, and to *forecast water demand* by including relevant factors into models on the other hand.

In the following, we begin with the second group of factors before dealing with those that can be directly influenced by intervention.

2.1. Socio-demographic determinants

Besides the price of water, the most influential determinants of water use quantities seem to be certain socio-demographic characteristics of water users and households. Most important from an economic perspective are *household income* and the existence of *alternative, less expensive water sources* like private wells. Other physical or structural determinants discussed in the literature include the *size* of the household, the *age* of its members and its *geographical* location. The relation to households rather than individual water users highlights a general phenomenon in the context of water use statistics: *for technical reasons,* water metering, which represents the basic data source, is usually done on the *level of buildings or households*, but very *rarely on the level of individual users*. So households are the most widespread basic entity of water use.

2.1.1. Household income

In economic terms, water is a *normal good*, which means that water demand increases with increasing income. In accordance with this, the income elasticity of water demand is positive. As Dalhuisen et al. (2001) show in their meta-study, income elasticities have a mean of 0.46 and a median of 0.28, but the range of values is considerably smaller than for price elasticities.

Similar to price elasticity, income elasticity depends on a variety of factors which are responsible for the reported variability to a large extent. One of these factors is income itself. As Agthe and Billings [AB97], Saleth and Dinar [SD00], and Schleich and Hillenbrand [SH09] find in their studies, higher income households exhibit lower income elasticity.

Other significant factors identified by Dalhuisen et al. (2001) are the time perspective and the type of tariff system. On average, long-run elasticity is smaller than short-run elasticity by 0.34, which can be explained by the habituation effect and, thus, the lower attention paid to income increases occurring over a longer

period of time. With respect to tariff systems, the mean income elasticity under decreasing block prices is approximately 1.1 higher than in increasing block and uniform price schemes.

As in the case of price elasticity, there are artifacts due to factors that do not influence the actual income responsiveness of water consumers, but the econometric estimates of the related elasticity. Specifically, the type of price variable used for the statistical analysis makes the difference. As Dalhuisen et al. (2001) discovered, income elasticities based on marginal prices are 0.27 higher than the corresponding elasticities based on average prices.

Another methodological issue discussed in this context refers to attempts to identify the wealth of a household independent of the income of one or more of its members. As discussed in [AG+03], the value of the property appears to be a good proxy for household income – with the additional advantage that it can be assessed without asking household members. Unfortunately, this relationship has not always been confirmed in other studies. While living in a one-family house increases water consumption significantly in the study of Messner and Ansmann [MA07] for the city of Leipzig, Schleich and Hillenbrand [SH09] cannot confirm this effect for the entirety of German communities. This failure to confirm may be due to the aggregate nature of the data, which tends to "dilute" all effects and thus renders them less significant. Dalhuisen et al. (2001) confirm this effect by pointing out that the aggregation of household data yields lower income elasticity.

2.1.2. Household size and age

Next to price and income, household size has been assessed in a large number of studies of the determinants of water consumption (see overviews in [KK+07][NR+10]). In all these studies, it was confirmed that the volume of water used *increases with the number of household members*, but that this increase is less than proportional. Typically, water volume is found to increase by approximately the square root of the number of family members [AV06][SH09].

In some studies, the age of water users was also assumed to influence water consumption. Typically, age structure was assessed as the share of household members above a certain age. It turned out, however, that the results were often insignificant or not consistent between different studies. While Nauges and Thomas [NT00] found younger family members use more water than older ones, Schleich and Hillenbrand [SH09] arrived at the opposite result. In the former case, it was argued that younger people might be less careful when using water and might demand more frequent laundering than older ones. In the latter case, it was speculated that older people have more time to spend on outdoor activities such as gardening, which leads to higher water demand.

2.1.3. Education of household members

Higher education in general seems to have *little influence* on water consumption. While Grafton et al. [GK+09] identify a small but significant influence, Schleich and Hillenbrand [SH09] are unable to show a significant effect. While, in the latter case, this may again be due to the use of aggregated data, the effect is expected to be low even if more disaggregated data could be used. This expectation is in line with results for environmental behavior in general (e.g. Homburg & Matthies, 2005).

2.1.4. Water-saving technologies

Water-saving technologies have been and are being employed in a significant share of households in various regions. Schleich and Hillenbrand [SH09] are convinced that this type of technical progress is the primary cause for the significant reduction in water use experienced in Germany between the 1980s and 2005. Examples of such water-saving innovations are *washing machines* which decreased their water consumption from some 150 liters in 1980 to about 40 liters per wash in 2001, and *dishwashers* with a decrease from about 50 to less than 15 liters over the same period. *Two-flush and reduced-volume flush* toilets and *more efficient shower heads* are other ways of cutting water use in two water-intense applications by up to one half [NR+10]. To determine the effect of these technologies on water demand on a large scale is not so easy, as this effect is masked by other effects such as increasing income-induced water use. Therefore, the number of studies investigating this water-saving effect is rather small. In a longitudinal study in Miami (Florida, USA), Lee et al. (2011) found water use was reduced by 11 to 15 percent after exchanging showerheads, toilets or washing machines and even larger effects when several measures were combined. Herber et al. [HW+08] found a 15 percent reduction for the low-volume flush toilets alone and another 14 percent for the use of highly water-efficient washing machines and dishwashers.

2.1.5. Existence of private wells

Private wells are an alternative source of water, which can complement the commercial water supply wherever underground water is easily accessible. They are especially common in rural areas, where they were historically the main water source and where many uses (e.g. irrigation) do not require the water quality provided by the supply network. From this perspective, it is surprising that only a few studies have included private wells as potential demand factors in their investigations. To our knowledge, only Schleich and Hillenbrand [SH09] have explicitly assessed the effect of wells on household water demand. They found a small but significant effect, with the presence of a well leading to a 1.5 percent reduction of drinking water consumption.

2.1.6. Other contextual determinants

As studies have shown for energy consumption behavior [MD+10][Ni92], water savings might also depend on the year and region. In years of crisis, energy savings were found to be lower. Crises directly affect changes in culture, politics and lifestyles. Higher energy savings have been observed in regions familiar with drought.

2.2. Price

While, in the long run, the use of water is determined by a wide variety of social, cultural and individual characteristics, the price of water seems to be the most important lever to influence the demand for water. Its importance is shown by the debate about water as a "*human right*" and the obligation (of any government) to make *a certain quantity of water accessible to every person regardless of his/her ability to pay*.

Beyond this issue of basic need, the water price can be – and has been – used to manage water demand in many cases. This leads to the question of how *responsive* water users are with respect to water price

changes. The basic economic concept for measuring this responsiveness is *price elasticity*, i.e. the percentage decrease of water demand brought about by a one percent increase in price. Price elasticity depends on a variety of factors that will be examined in detail below. Before this can be done, however, the next section specifies how a price increase comes about, how it is implemented in actual water tariffs, and how these tariffs and their changes are perceived by the clients.

2.2.1. How does price matter?

There is an enduring debate among economists as to which price is relevant for determining price elasticity in the context of water demand management (see Arbues et al. [AG+03], Klein et al. [KK+07]). In theory, the *marginal price* of a good should be relevant for a buyer's decision to buy this good or not. This presupposes, however, that the client knows exactly what *the next unit s/he intends to use will cost*. In turn, this presupposes that s/he knows *exactly* the water *tariff* and the *quantity* of water s/he has used at the moment of the buying decision. At this point, it makes sense to examine the existing types of tariffs and the challenges they may pose.

As explicated by Arbues et al. [AG+03], designing a water tariff is a complex task as it seeks to reconcile such diverse objectives as *allocation efficiency, equity, sustainability and financial stability*, to mention just a few. To accommodate this set of objectives, the tariff commonly includes *fixed* and *variable* elements. The fixed elements reflect at least some part of the fixed costs of water infrastructure and make the revenues less dependent on the quantity of water actually consumed. If the fixed element covers a certain amount of water subject to use without further cost, it can also serve as a *social aspect* of the tariff.

The variable element can either be *uniform* (i.e. charging the same price for every (additional) unit of water used) or *variable* with the price for every additional volume of water increasing or decreasing continuously or stepwise after exceeding certain thresholds. The latter two are called *increasing- and decreasing-block tariffs*. Decreasing tariff schemes adequately reflect the low variable cost share of water supply and are therefore considered economically efficient. On the other hand, they tend to promote the consumption of larger quantities of water. Increasing tariffs, in contrast, promote water conservation and are considered more equitable and explicitly redistributive [MC91]. However, they may adversely affect people who, for health or other reasons, use greater amounts of water. In addition to these more common elements, tariffs can also include elements accommodating seasonal changes in water demand and supply, as well as distinguishing between peak and off-peak consumption.

Returning again to the initial questions of which are the most influential aspects with regard to affecting actual water use, what their impact on the responsiveness of water users is, and how this responsiveness can be measured, the following answers can be found in the literature.

While it is economically reasonable to consider marginal prices as relevant in the case of uniform variable prices, a complication arises under block tariffs. Earlier studies used the marginal price corresponding to the relevant block for the last unit of consumption. This simple approach has been modified since Taylor [Ta75] and Nordin [No76] introduced a "difference variable" which takes into account the difference between the water consumer's actual water bill and what s/he would have to pay if all units were charged using the marginal price. Nordin [No76] argued that this variable should represent the income effect imposed by the tariff structure. In a variety of empirical tests, however, this hypothesis could not be confirmed [AB+03]. The reactions to this finding have been twofold. Some researchers argued that this

effect was estimated *incorrectly* and that *the use of aggregated data* was the major source of this error (Schefter and David 1976). A majority of researchers concluded that the difference variable is *irrelevant* because *consumers lack the necessary detailed knowledge* about the structure of their water tariff and, in fact, the difference variable amounts to a share of household income which is too small to be relevant [NM89].[1] As a result of this debate, the average price was used in an increasing number of studies. Listing a large number of studies and their outcomes in terms of price elasticity (see also the next section), Arbues et al. [AG+03] show that, in many cases, the choice of the variable (i.e. marginal or average price) does not seem to affect the results. If a difference is stated, demand tends to be more responsive to the average price.

As will be discussed in more detail in Section 2.3, in order to save water, people need to be *aware of their own water-using behavior* and be able to *classify* it as *lower or higher consumption* in the first place. If they are not aware of their consumption patterns, they will be less motivated and hardly aware of effective ways to change their consumption. Billings and Agthe [AB80] showed that it is true that many water users *are not aware of their specific consumption* or the price they pay for water. Yet the share of these uninformed water users was found to depend on certain factors. While Klein et al. [KK+07] and Neunteufel et al. [NR+10] report that *low-income households* exhibit a significantly stronger responsiveness to the water price than *higher-income households*, Renwick and Green [RG00] are able to quantify this effect. Especially in cross-country studies, it turned out that price responsiveness depends on the share of water expenditure in total household income [NR+10]. So, responsiveness can be high despite high income if water prices are also high.

Increasing the price of water does not always lead to a change in the quantity used. A certain basic amount of the water used in households for *drinking, cooking and various aspects of personal hygiene* (including sanitation and washing clothes) is considered to be *essentially insensible* to the price of water. It represents the minimum quantity satisfying the basic human need for water, to which every person should have access. This also constitutes the human right to water (CESCR 2002). Martinez-Espineira and Nauges [MN04] approached this issue econometrically using a Stone-Geary utility function, which distinguishes between a price-sensitive and a non-price-sensitive demand component and allows quantification of both. For the city of Seville in Spain, they found a price-insensitive quantity of 2.6m^3/capita/month, which represents 40% of total consumption (6.35 m^3/capita/month). For Germany, Schleich [Sc10] calculated a similar price-insensitive volume of 3m^3/capita/month, which in this case represents 77% of average total consumption. Both studies form a basis too small to draw general conclusions, but they do give an idea of the size of this price-insensitive component.

2.2.2. Differences in price elasticity

There is a large number of studies analyzing the determinants of residential water use and almost all of them come to the conclusion that *price has a significant influence on water demand*. Regardless of the price applied, Grafton et al. [GK+09] found that the introduction of a *volumetric* water charge leads to a reduction in water consumption by 31.4%. If the price is taken into account, in almost all studies, price elasticity[2] turns out to be *negative* and *rather weak* (in economic terms: *inelastic*). This means water demand falls with

[1] In fact, water consumers not only tend to be ignorant of most details of their water bill; in most cases they actually receive such bills only once a year. This challenges the assumption that water users refer to the marginal price when deciding their consumption level.

[2] Mathematically, price elasticity is defined as the ratio of change in demand quantity (in %) over change in price (in %). For normal goods it has a negative sign, because an increasing price tends to reduce demand.

increasing price, but relatively it does not change as much as the price does. In their review, Klein et al. [KK+07] quote an average price elasticity of -0.49 [BB+02] and a range between -0.02 and -0.75 for 75% of the estimates ([EE+97]), both of which are consistent with a similar list compiled by [AG+03]. Grafton et al. (2009) [GK+09] arrived at a slightly lower value of -0.41 in their study. While this wide range of elasticities appears to reflect a certain lack of statistical reliability at first sight, the large degree of variability becomes more reasonable when understood as the *outcome of various influences*.

One factor influencing price elasticity is the *time* it takes until a *change in price translates into the respective change in demand*. It seems reasonable to assume that the effects of measures taken to reduce water consumption are more limited in the *short run* than after water users have had more time to respond. Accordingly, long-run elasticity is expected to be stronger than short-run elasticity. This is confirmed by a series of studies [DN+97][M087][NT03] showing that short-run price elasticity is in a range between -0.03 and -0.52 around an average of -0.2, whereas long-run elasticity ranges between -0.1 and -0.77 with an average of -0.5. In the study by Grafton et al. [GK+09], both short-run (-0.38) and long-run elasticity (-0.64) were found to be somewhat stronger, but the difference between them remained largely the same. The difference in level can be interpreted in terms of other factors influencing price responsiveness. Yet all the studies indicate that the *short-run elasticity is lower than the long-run elasticity by about 0.3*.

Income is another factor influencing price elasticity.[3] Klein et al. [KK+07] and Neunteufel et al. [NR+10] report that low-income households exhibit significantly stronger responsiveness to the water price than higher-income households. Quantifying this effect, Renwick and Green [RG00] show that households with an annual income of less than USD 20,000 were *five times* more responsive to a changing price than households with an income of USD 100,000 and more. There is no systematic analysis of this issue beyond this exemplary case. Additionally, it should be noted that income alone may not be decisive. Especially in cross-country studies, it was shown that price responsiveness depends on the *share of water expenditure in total household income* [NR+10]. So, responsiveness can be high despite high income if water prices are also high.

As mentioned above in the discussion about the relevance of the marginal or average price, block tariffs are more complicated because, in this case, water consumption is determined by both the marginal price and a difference variable. In the context of price elasticity, block prices again exhibit an influence related to this complication. Especially in the case of an increasing block tariff, water users do not simply respond to the price of the last unit of water consumed; they seem to calculate their *opportunity cost* and also respond to the price of the lower block and the threshold between the two. As this opportunity cost is higher in the case of increasing block tariffs (compared to uniform or decreasing block tariffs), it is not surprising it could be shown that they trigger stronger responsiveness [CH+02], yielding a price elasticity that is 0.25 higher (in absolute terms) (Dalhuisen et al. 2001).

Geographical location also seems to be an important factor. The differences in price elasticity *between countries can be significant*. Yet this does not appear to be influenced by economic development or wealth. Also, as is shown by [KK+07], substantial differences of a similar size occur within countries – between federal states or even cities – and even when controlling for household size and income. So, it remains unclear what the real explanatory factors behind these variations are.

[3] This effect is not to be confused with the direct effect of income on water consumption, which will be discussed in the next section.

Seasonality is reported to influence price elasticity in some cases. In countries where people are used to watering their gardens during the dry season, this use of water appears to be less essential than other water uses. Accordingly, the price elasticity of the outdoor demand in summer is estimated to be 5 to 10 times higher than in the winter [KK+07].

There may be artifacts due to factors that do not influence the actual price responsiveness of water consumers, but the econometric estimates of the related price elasticity. The nature of the data is responsible for the difference in this case. Accurate price elasticity can only be estimated from *individual water use data*. Even household data are not expected to make a large difference. The situation changes, however, if more aggregated data are used from communities or even larger entities. In this case individual extremes are averaged out and, as a consequence, elasticity values appear to be smaller than they actually are. According to Dalhuisen et al. (2001), this effect can make price elasticity appear 0.22 lower than it really is. A similar effect results for *aggregation* along the time axis (i.e. using yearly instead of monthly, weekly or even daily data).

2.3. Psychological determinants and concepts

In addition to the economic, socio-demographic and geographical determinants of water consumption (cf. Section 2.2 and 2.1), research has revealed that psychological factors also influence both general and environmentally-relevant behavior, such as water-consuming behavior. Most research in the field of environmental psychology has focused on *residential energy-consuming behavior and choice of transport mode*, while research in the field of water consumption is less common. In the following, we outline the psychological determinants and concepts which influence individual behavior and are relevant when studying water consumption behavior.

2.3.1. Psychological theories of action

The action theories most often applied to explain different environmental behaviors are the theory of planned behavior (TPB; [Aj91]) and the norm-activation model (NAM; [Sc77][SH82]).

2.3.1.1. Theory of Planned Behavior (TPB)

According to the *TPB*, behavior is directly influenced by an individual's intention to perform the behavior. Intention, in turn, is determined by (1) an individual's *attitude* towards the behavior, defined as an overall evaluation of its possible consequences, (2) *subjective norms*, referring to the perceived expectations of other important persons, e.g. family, peers, neighbors (we refer to *social norms* in the following), and (3) *perceived behavioral control* (PBC), defined as a person's perceived ability to perform the behavior due to non-motivational factors such as availability of opportunities and resources. The attitude towards the behavior is conceptualized by Ajzen [Aj91] (cf. also Fishbein & Ajzen, 2010) as an expectancy-value model. According to this model, the expectancy that a specific behavior results in particular consequences and their evaluation, i.e. the valence of these consequences, are assumed to determine the overall evaluation of the behavior. Figure 1 displays the variables and their relations with each other as well as to behavior.

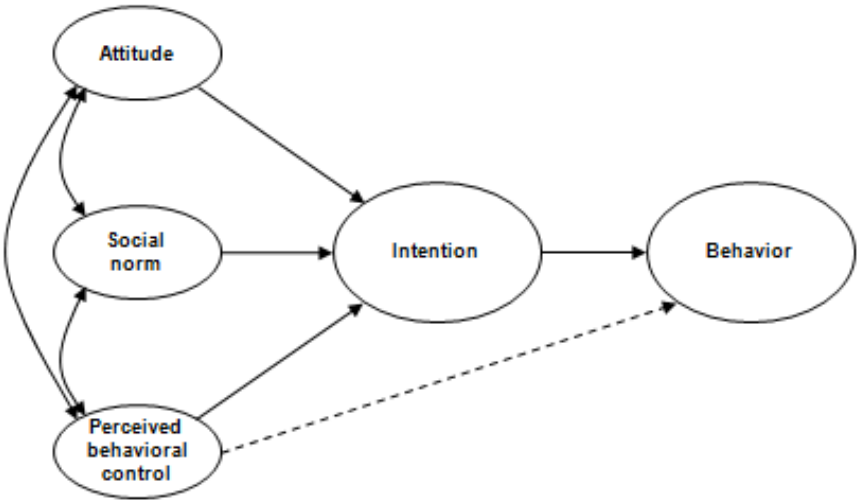


Figure 1: The theory of planned behaviour ([Aj91])

2.3.1.2. Norm-Activation Model (NAM)

Studies using the NAM explain behavior as influenced by the following variables (see Figure 2): (1) A *personal norm* to engage in the specific behavior, denoting a strong intrinsic feeling of obligation, directly influences the behavior. Prerequisites for the formation and activation of this personal norm are (2) *awareness of a related problem* that needs to be solved, (3) *awareness of the consequences of one's own behavior* and *identification of the specific behavior as an effective action* that contributes to mitigating the specific problem (we refer to *response efficacy* in the following in line with Lam and Chen [LC06]), and (4) *self-efficacy*, i.e. recognition of the personal ability to engage in these actions which is very similar to the TPB's PBC. Besides personal norms, the consideration of (5) social implications, i.e. a perceived *social norm*, as well as (6) of the *non-moral implications* of action also influence behavior. These influences are also included in the TPB in the concepts of subjective norm and the attitude concept. A further influential variable in the NAM approach is (7) the *ascription* of *responsibility* for one's own actions and their consequences.

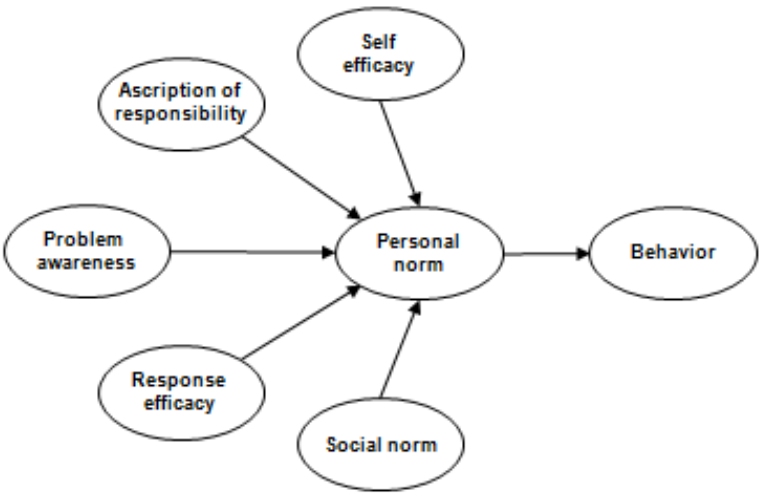


Figure 2: Paradigm of the norm-activation model (based on [Sc77] and [SH82] and previous studies that used the approach to explain environmental behaviors)

Generally, the TPB and NAM have been interpreted as reflecting two different, contrasting points of view: environmental behavior as rational and self-interested behavior vs. environmental behavior as pro-social behavior (cf. Bamberg & Möser, 2007; Homburg & Matthies, 1998). We do not want to discuss this complex topic in detail. However, the reader should keep in mind that the variables of the TPB might also be influenced by concern for other people, other species, and the environment as a whole. Bamberg and Schmidt (2003) showed that environmental concern has substantive influence on the perception and evaluation of situation-specific cognitions, conceptualized via Ajzen's TPB. Nevertheless, we agree with the above interpretation that an explicitly pro-social motivation of behavior is neglected by the TPB and that hypotheses about its interplay with the other TPB variables are not included. In order to better account for the role of the various determinants proven to influence environmental behavior and in order to understand the underlying preconditions and processes, a promising trend in the last decade is to combine both theoretical frameworks (see Section 2.3.3).

2.3.1.3. Value-belief-norm theory

Values which have also been discussed as a factor influencing environmental behavior are not an explicit determinant in these two psychological theories of action (TPB and NAM). Values represent general goals that serve as guiding principles and are central but rather distant determinants of human behavior. They influence and thus are mediated by variables such as attitudes and norms, which represent more direct and more specific determinants of behavior. The *value-belief-norm theory of environmentalism* (VBN theory; Stern, 2000) is an extension of the NAM and suggests that values and ecological world views (i.e. beliefs about relationships between humans and the environment) influence problem awareness and other variables in the causal chain.

2.3.2. Specific determinants and concepts influencing behavior

2.3.2.1. Norms

Social norms are "rules and standards that are understood by members of a group and that guide and/or constrain human behaviour without the force of laws" (Cialdini& Trost, 1998, p. 152). They are already included in the above mentioned theories of behavior (TPB: subjective norm; NAM: social norm). Ajzen (2007) differentiates between injunctive and descriptive social norms. The injunctive norm describes whether most or, at least, important others approve or disapprove of the behavior in question, whereas the descriptive norm describes whether they themselves perform this specific behavior. The perception of these norms and corresponding methods of intervention can exert significant influence on behavior, although people tend to underestimate it (Nolan et al., 2008; for methods of intervention see Section 3.2.1.4 and 3.2.1.5).

2.3.2.2. Habits

Many types of environmental behavior are deeply ingrained into our everyday routines and are influenced and controlled by automatic processes, i.e. habits. Habits are based on cognitive structures which link specific situational cues to behavioral patterns and thus, automatically determine behavior (cf. Klöckner &

Prugsamatz, 2012). Habits can support, but also inhibit environmental behavior. If people want to change their routine behavior and have pro-environmental intentions, habits are often a barrier. Thus, in case of habitual behavior, specific strategies to deactivate old habits should be applied before intervention that targets the deliberate part of decision-making can be effective.

2.3.2.3. Affective and symbolic aspects

Besides instrumental functions, the purchase and use of products also fulfills symbolic and affective functions (Dittmar, 1992). While instrumental functions relate to the functional properties of a product, symbolic functions refer to the expression of one's self and of one's social position or group membership via the purchase and use of a product. Both are related to affective functions, as instrumental and symbolic characteristics can evoke feelings such as excitement, pleasure, disappointment, pride or embarrassment.

The influence of affective and symbolic motives has been shown, for example, in transport behavior. Steg (2005) could show that commuters' car use could be better predicted by the strength of symbolic and affective motives than by purely functional motives (such as reducing costs). With regard to innovation adoption, a study by Noppers et al. (2015) on interest in and the intention to buy an electric vehicle indicates that the perception and evaluation of the symbolic attributes of electric vehicles are relevant aspects for their adoption. In other words, people who believe that electric vehicles express their personality and give them a certain status are more likely to buy them.

Thus, according to these studies, environmentally-relevant behavior is influenced not only by instrumental motives (such as saving money, water or energy in the context of a smart meter device), but also by symbolic motives (e.g. to express a green or innovative identity) and by affective motives (such as experiencing pleasure). Therefore, environmental behavior can also be promoted by enhancing its symbolic and affective value. According to Nopper et al. (2015), for the adoption of innovations (such as DAIAD@feel), it seems particularly fruitful to emphasize their positive symbolic characteristics during the early stage of innovation when there may still be "teething problems" with the product.

2.3.2.4. Theory of Cognitive Dissonance

The theory of cognitive dissonance emanates from the assumption that individuals strive for consistency between their cognitive elements, i.e. their attitudes, beliefs, knowledge components etc. (Festinger, 1957). If cognitive elements relate to each other with regard to their content, they can be consistent or dissonant, i.e. in accordance or in conflict with each other. For example, the self-perception "I am a person who engages in water saving behavior" and the knowledge "I consume more water than a person in comparable living conditions" are dissonant, i.e. inconsistent with each other. Dissonant cognitions cause the individual discomfort and motivate the individual to reduce the dissonance. This can be achieved in different ways, for example, by adding new cognitions, ignoring dissonant cognitions, or changing attitudes or behavior. The way chosen to reduce the dissonant state depends on the resistance (i.e. difficulty) of each component to change. For instance, the higher the number of cognitive elements to which a cognition is linked, the higher its resistance to change due to the fact that change could produce new dissonance.

2.3.2.5. Self-perception theory

According to the self-perception theory (Bem, 1972), people develop attitudes by observing their own behavior. For example, the ownership and use of green products such as smart meters can make people perceive themselves as citizens with pro-environmental attitudes, and could therefore strengthen or create a (more) positive attitude towards subsequent energy-saving behavior (see, e.g. McKenzie-Mohr 2011).

This topic of the positive as well as the negative side effects of induced behavioral changes is discussed more broadly in the next section.

2.3.2.6. Mechanisms and factors inducing side effects

In the context of environmental behavior, Thøgersen and Crompton (2009) discuss the likelihood of positive and negative spillovers occurring when adopting an environmental behavior in a specific area into environmental behavior in another area as well as theories to explain the respective effects.

The term *positive spillover* is used when the adoption of an environmental behavior leads to the adoption or increase of an environmental behavior in another area, while *negative spillover* denotes a decrease of an environmental behavior in another area as consequence. As an example for the latter, in a campaign providing weekly feedback on water consumption, residents lowered their water consumption (by 6.0% on average) but increased their electricity consumption (5.6%) compared to members of a control group (Tiefenbeck et al., 2013). According to Thøgersen and Crompton (2009), the empirical evidence regarding positive vs. negative spillover effects is very controversial. It indicates that a number of factors limit the occurrence of spillover.

For positive spillover, in particular, explanations are drawn from dissonance and self-perception theory as already described above. However, these mechanisms and, thus, positive spillover depend on the strength of a person's pro-environmental values and norms. Thus, sufficient strength of pro-environmental disposition seems to be a prerequisite for positive spillover (and the prevention of negative spillover) (cf. also Peters et al., 2012).

Moreover, the reasons which are drawn upon in order to motivate a behavior are crucial when campaigns aim to promote positive spillover in addition to the behavioral changes which are directly addressed (Thøgersen & Crompton, 2009). Argumentations might be based on moral (e.g. environmental) reasons for adopting a behavior, on reasons of self-interest (e.g. financial savings or symbolic value of a behavior) or a combination of both. While, in principle, it seems promising to use a variety of reasons to encourage behavioral change – in particular reasons which match a person's individual motives – appeals focused on environmental reasons are generally more likely to induce spillover into other environmental behaviors. In particular, spillover is likelier if the reasons motivating initial changes are consistent with reasons which can or should encourage subsequent changes.

In contrast to the mechanisms and factors promoting positive spillover, lack of knowledge or false estimations about the behavioral impacts may help to explain negative spillover (Peters et al., 2012). For example, in the water domain, people increased their water usage after the installation of toilet dams and aerators for faucets because they thought they would automatically save enough water (Davis, 2008; Mayer et al., 1998; Renwick & Green, 2000). Moreover, pro-environmental actions can also be used as justification

for not behaving pro-environmentally in other areas or even for reducing other environmental engagement. In general, negative side effects seem to be more likely if needs are not yet satiated.

Thus, the topic of possible side effects should be considered when designing measures intended to induce behavioral change.

2.3.3. Integrated frameworks

2.3.3.1. Models based on meta-analysis

Substantial empirical evidence has been collected on various behaviors, including different environmental behaviors. More recently, researchers have proposed integrating relevant concepts into one model (cf. Bamberg and Möser 2007; Matthies 2005). Bamberg and Möser (2003) and Klöckner (2013) suggested integrated models, which have been substantiated by meta-analyses based on a variety of studies of different environmental behaviors. While Bamberg and Möser (2007) included the components of TPB and NAM, Klöckner (2013) additionally included habits and values in his analyses. His study identified intentions to act, perceived behavioral control and habits as direct predictors of behavior. Intentions are directly influenced by attitudes, personal and social norms, and perceived behavioral control. Personal norms are influenced by social norms, perceived behavioral control, awareness of consequences, ascription of responsibility, an ecological world view and self-transcendence values, while they are inhibited by self-enhancement values. With regard to intervention, the model results indicate that, beside attitude campaigns, there should be a focus on de-habitualizing behavior, strengthening social support and increasing self-efficacy by providing concrete information about how to act. Intervention which addresses values only has an indirect effect on behavior.

2.3.3.2. Goal framing theory

Goal framing theory is another approach that integrates concepts and variables from different theories (Lindenberg & Steg, 2007). According to this theory, goal frames, i.e. goals which are activated, influence the way people process information and their behavior based upon it. At any given time, multiple goals are generally active. They may or may not be compatible with background goals which support or inhibit behavior according to the focal goal. Three general types of goal are distinguished: (1) the *hedonic goal* "to feel better right now," which is a priori the strongest, (2) the *gain goal* "to guard and improve one's resources," and (3) the *normative goal* "to act appropriately"[4]. With regard to environmental behavior in particular, normative goal frames imply acting pro-environmentally. Also, hedonic and gain goals may support pro-environmental actions, but only as long as it is profitable and comfortable to do so. Thus, pro-environmental behavior can be promoted by supporting normative goals, or by making environmental behavior more compatible with gain and hedonic goals.

2.3.4. Conclusion

To summarize, according to psychological studies of various environmental behaviors, psychological factors such as certain *personal attitudes* or *personal or social norms* might *increase or decrease water consumption*.

[4] These goals can be related to three theoretical approaches relevant in environmental psychology: gain goals can be related to the TPB, normative goals to the NAM and VBN theory, and hedonic goals to approaches including affective and symbolic aspects (cf. Section 2.3.2.3).

With regard to the sustainable use of water, it is necessary to be aware of the problems, i.e. the negative consequences of water consumption and link them to one's own behavior. Based on this, *consumers have to know and be aware of effective behavioral options to reduce water consumption*, so that a *personal norm* can develop and be activated in the relevant situations to perform these behavioral options. If these options are *perceived to have overall positive consequences* and if consumers *perceive their own abilities and opportunities* to conduct the specific behavior, the likelihood increases that water-saving behaviors will be implemented. These factors and ultimately behavior are also influenced by a person's relevant others, i.e. by *social norms*, values and the perceived behaviors of others. Moreover, water saving behaviors are more likely if *habits* do not represent a barrier, but do support the desired behaviors. If a person *perceives himself/herself as environmentally conscious and is aware of corresponding beliefs and attitudes*, water saving behavior is more likely according to dissonance and self-perception theory. In this context, *normative goals* which are focal at the places where water is used, support water saving behaviors. Finally, water saving behaviors are facilitated if they are *compatible with gain and hedonic goals*, i.e. if people feel good and gain something when saving water.

The various factors which were described should be considered when water conservation behavior should be promoted and specific methods to change water-consuming behavior (see next Section) have to be chosen and implemented. For the field of water-consuming behavior, more research is needed to expand and confirm the outlined relations as studies of the specific relevance and role of these factors are still rare.

3. Ways to change behavior

This chapter starts with an overview of the different approaches employed to try and change behavior (Section 3.1) and presents basic methods used to change water-consuming behavior by addressing the aforementioned water demand determinants (Section 3.2). In the subsequent section, we examine specific types of methods which seem particularly relevant for the DAIAD user trials (Section **Error! Reference source not found.**). For empirical evidence on specific approaches incorporating ICT, in particular in the water domain, we refer to DAIAD deliverable 1.1 (State of the art Report, Section 2).

3.1. Matching intervention to relevant determinants

Empirical studies of measures to change environmental behavior have been conducted mainly for energy consumption and transport behavior. In order to utilize the knowledge obtained from these studies for the field of water consumption, similarities and differences of the consumption behavior in both fields have to be taken into account. The methods of intervention studied address various factors influencing consumption, from contextual ones to individual factors.

In order to design and develop effective intervention programs, it is important to choose the appropriate techniques based on a psychological and theoretical analysis of the problem, i.e. the behavior and its relevant determinants that should be changed or promoted. Psychological theories and approaches to this step were presented in Section 2.3. The appropriate choice of technique depends on the identified determinants influencing the relevant behavior.

To help identify appropriate ways of intervention, Mosler and Tobias (2007) developed a classification system, which presents the variety of possible intervention techniques relatively comprehensively. The system includes a classification according to psychological aspects and indicates when a technique is appropriate and how different types should be combined. According to this system, all behavioral change techniques can be divided into two groups: The first group includes techniques which change individual preferences, in order to create the necessary precondition for behavioral change. Both structural and individual-focused techniques can be found in this group. The second group includes techniques which activate or encourage behavioral change when preferences already favor the behavior and actual implementation in a given situation has to be supported.

The first group includes techniques which *focus on structural conditions* and facilitate behavioral change, or make the previous behavior more difficult. Examples include change of infrastructure, change of supply and the introduction of incentives, or sanctions and prohibitions. Techniques are also included that *focus on the person and psychological variables* and alter norms, attitudes, beliefs and knowledge, i.e. by knowledge transfer, argumentative and affective persuasion, as well as requests which encourage cognitive processes.

The second group contains techniques which focus on situational characteristics in order to promote the implementation of existing behavioral dispositions. For example, these techniques point out opportunities to act by means of prompts, or activate norms via commitment strategies or other people modeling the behavior. Finally, techniques are included in this group which focus on the diffusion of a target behavior. They aim at promoting common action and social support, for example by participation, collective activities and social networks.

3.2. Basic methods

3.2.1. Starting from common determinants

3.2.1.1. Methods to change knowledge and awareness

With regard to the basic psychological determinants of behavior, such as problem awareness, realization of the consequences of one's own behavior, as well as awareness of effective behavioral alternatives (response efficacy) and sufficient competences to conduct the behavior (PBC), it is feasible to consider intervention in the form of conveying information [Ma05].

When considering and comparing the effect of providing information in different studies, it has to be taken into account that the specific content can be very different (e.g. general information about a problem vs. detailed information on how to solve a problem) and thus, information can have an effect by affecting different determinants of behavior.

With regard to a specific target behavior, information should ensure that individuals are aware of the problems related to their former behavior. However, *problem awareness* has only a moderate and indirect effect on the intention to act. Without the mediating effect of other variables, individuals will not take action. In particular, awareness raising should be quickly followed or accompanied by increased problem-solving ability and self-efficacy. It is crucial that individuals make the link between their own behavior and the perceived problem, i.e. that they are aware of the consequences of their behavioral options (*response efficacy*) and that they possess the knowledge and skills for concrete action. This indicates the need for different types of information.

Information can be provided in different ways that may be relevant for its effectiveness. When designing informational and feedback measures, psychological knowledge is useful about how humans process information. The concept of bounded rationality (Simon, 1957) describes how humans process information and make decisions in real-life conditions, i.e. with limited time and knowledge as well as a limited capacity to process information on the one hand, while receiving an excess of available information and a multitude of messages or appeals to change behavior from different sides on the other hand. As a result, they are forced to ignore or only superficially process part of the information. Information which matches their own attitudes and supports their own behavior is generally preferred. Based on this knowledge, informational messages should be enhanced by clearly structured information in an appealing format. In order not to overwhelm individuals, it seems recommendable to deliver basic information and make further information

available which can be accessed according to situational and individual needs. Further details on informational measures can be found in Section 3.3.1.

3.2.1.2. Methods to change attitudes and underlying beliefs

In order to encourage actual behavioral change, it is decisive to promote favorable attitudes towards the behavior. As presented above, attitudes are based on specific beliefs, in particular on specific expectations and assessments of the consequences associated with the behavior. Measures which address and can help to change these beliefs are, for example, information, persuasive communication (arguments) as well as direct experience with the behavior and its consequences (e.g. opportunities to test a smart meter).

Public media is influential in drawing – or not drawing – the public's attention to environmental issues and in shaping attitudes towards these issues (cf. Hervé-Bazin, 2014). Therefore, media coverage should be part of environmental campaigns. However, in order to successfully motivate behavioral change, reporting environmental issues should not focus on frightening messages or presenting impacts as something beyond human control "like scary weather". Such messages are likely to have counterproductive effects and might be "tuned out" due to people feeling helpless or that someone else such as politicians and other players are responsible for action. Instead, communication on environmental issues "should stress the possibility of effective action that can be taken quickly, framed in the context of forward-thinking, efficiency, prudence, and caring" (Patchen, 2006).

Additionally, interpersonal communication is a powerful instrument to form or change attitudes. Members of the target group who are more involved in environmental issues could be encouraged to share information with their social networks and start an exchange on the topic (cf. Hervé-Bazin et al., 2014).

3.2.1.3. Methods to influence behavioral control

Behavioral control to perform a specific behavior is a crucial determinant in effectively influencing behavior. Ajzen (1991) differentiates between actual and perceived behavioral control, as people may indeed have sufficient skills, but may not act as long as they perceive low behavioral skills. On the other hand, people with high perceived skills may not be successful in changing their behavior as long as they have insufficient actual skills (cf. Bartholomew et al., 2011). Therefore, it is often worthwhile to work on improving real and perceived skills. Examples of methods to enhance skills and perceived behavioral control include instructions and training, such as guided practice, or other people modeling the behavior.

In the context of perceived behavioral control, it also seems important to provide consumers with appropriate feedback, which allows them to assess their own environmental behavior compared to others (cf. next section). As an example, providing consumers with feedback including social comparisons that account for their living situation should increase their motivation and perceived behavioral control to take action.

3.2.1.4. Methods to change and emphasize social norms and symbolic aspects

With regard to social norms, the appropriate measures differ depending on whether favorable social norms already exist or not. If favorable social norms already exist in the target group, they can be activated by emphasizing them in a given situation, e.g. by normative messages, or feedback including social

comparisons. According to the differentiation of descriptive and injunctive norms, messages could inform individuals about what most other (similar, according to specific criteria) people do (descriptive normative message). Alternatively, they could provide the information that others approve the respective behavioral change, or imply some kind of direct assessment of the behavior, i.e. approval or disapproval (injunctive normative message). Creating opportunities for social comparison and social support (e.g. by facilitating observation, or initiating and mobilizing social networks) is another possibility to exert social influence.

However, adverse effects have to be considered and prevented regarding the use of social comparisons. For example, Schultz et al. [SN+07] showed that descriptive normative feedback (i.e. feedback including information about what others typically do) led to an increase in electricity usage among below-average consumers, whereas a combination of descriptive normative and injunctive normative feedback (i.e. feedback on what other people approve of) did not. In order to use social comparisons effectively, it seems important to ensure that upward comparison motivates and encourages the setting of more ambitious, but realistic and motivating goals. Downward comparison should act as positive reinforcement for behavioral change and should make individuals feel more self-efficacious.

If favorable social norms do not yet exist (in the context of the target group) or if they are weak, measures should be taken to change, develop, or strengthen them. The behavior should be promoted as a socially desired, popular and attractive one. For example, prominent persons could act as role-models and supporters of the behavior. Public media could feature role-model stories of desired behavioral change based on authentic cases. Moreover, for convincing and authentic communication, the institution launching the behavioral change campaign should take a leading role and perform the desired behavior themselves. In addition, members of the target group who have a key role (i.e. who are well respected and whose opinion is relevant for others) could help by approaching and convincing other members through personal communication and serving as a credible source of information and role-models. Finally, public commitment can be used in order to show broader support for a specific behavior and convince more people to join in.

The same measures and principles apply to symbolic aspects. In general, the respective behavior, such as the adoption and use of a smart meter, should be promoted as popular and as a means to represent individual characteristics which are attractive to the target group.

3.2.1.5. Methods to activate or change personal norms

If personal norms, i.e. a moral obligation to perform the behavior, are already established in the target group, they need to be activated in a given situation. Appropriate strategies could be cues, prompts as well as direct feedback to remind a user to take action in a given situation. For example, Kurz et al [KD+05] placed labels at particular appliances (such as showers, washing machines, dishwashers, and toilets) informing about their water and energy consumption. Although this intervention was very rudimentary, it led to 23% reduction in water consumption.

Methods using social and normative influence can also activate or change personal norms. These methods include emphasizing social descriptive norms, as well as involving role-models or members of the target group who spread the desired behavior among their networks by communicating or showing it to other members. Other techniques with normative influence are private or public commitment and goal setting. These methods are described in more detail in Section 3.3.3.

3.2.1.6. Methods to change habitual behavior

As already mentioned, trying to change habitual behavior is a particularly difficult challenge, as many of the types of intervention described such as informational strategies are likely to fail if they are not designed in a way that effectively deactivates old habits by situational changes (Klöckner & Prugsamatz, 2012; Verplanken & Wood, 2006).

One strategy to deactivate old habits is to change or avoid the triggering situation, i.e. to change or remove the situational cues to which habits are connected. In this context, research has shown that *life events* such as moving to another city, changing jobs, or becoming a parent can serve as windows of opportunity, in which old habits are weakened as they are accompanied by a change in one's way of life (Müggenburg, 2015). A prominent example of a measure to use such a window of opportunity is the city of Munich in Germany, which has given new citizens detailed information packages on all the available transport means in the city since 2007 in combination with a ticket allowing free use of public transport for a week.

However, habit deactivation alone is not sufficient to change habitual behavior; this has to be accompanied by other measures. In order to support the development of new habits, it could be combined with commitment to behavioral change, for example a written commitment to change behavior for a certain time frame (cf. Matthies et al., 2006). This commitment can also include a concrete "if-then plan" on when, where and how to perform the intended behavior, i.e. link the behavior explicitly to situational cues (*implementation intention,* cf. Klöckner & Verplanken, 2013; Schweiger, Gallo & Gollwitzer, 2007). Consistent implementation of the behavior and positive experiences during the trial period support the establishment of the new behavior. Moreover, having people choose a delayed reward far in advance (*early commitment*; see Robbins et al., 2001) can strengthen their motivation to change behavior for the time needed to develop new habits.

3.2.1.7. Methods to change structural determinants

From an economic perspective, *changing the price of water* is the primary instrument to change the demand for water. However, from a social perspective, higher water prices are often considered to contradict the "*human right to water*". According to this fundamental right, *every person should be able to afford* at least the quantity of water required to meet *basic human needs*. If this basic quantity is indeed supplied at a low price, it is still possible to comply with sustainability criteria by increasing the price of the water used beyond the amount required for basic needs. However, the resulting price scheme – increasing block prices – does not reflect the actual cost structure of water supply with its *high fixed and low marginal costs*. From an economic perspective, this price scheme is therefore considered inefficient. Besides the quantities used, price schemes can also refer to other parameters such as water availability. Seasonal price increases, for instance, could reflect the greater scarcity of water in months with low precipitation.

With regard to the effects of such price schemes, Schleich and Klobasa [SK13] evaluated the effects of residential energy prices differentiating between peak and off-peak times (with a ratio of peak to off-peak prices of 177%) in a large field experiment in Germany. The experiment with more than 1,500 households lasted six months. Results suggest this time-of-use pricing led to average percentage reductions in peak demand of 6% to 7%, while off-peak demand neither reduced nor increased. Total demand was therefore reduced as a reaction to the pricing scheme. These results are in line with findings from most time-of-use pricing experiments in other regions (mainly in North America). Differences over the duration of the

experiment (6 months) were not observed. As this time frame is rather short, the authors believe behavioral changes were responsible for the observed changes in demand, while investments in energy-saving measures might play a role in longer time frames. Thus, in the long term, the effects might even be larger if households do not return to their former habits.

The access to water can also be restricted by means of *regulation*. In this case, water use could be prohibited, e.g. for irrigation or car washing (i.e. non-essential uses). Alternatively, water supply can be limited to certain times of the day. In case of prohibition, changes of behavior depend on further factors such as whether compliance is or can be checked or violation is sanctioned, or whether the prohibition is comprehensible to the users and accepted by them. In case of limitation of water supply, users would have to adjust to these limitations and might shift at least part of their demand to times with no limitation. As shown by Michelsen et al. (1999), the net effect of such restrictions is still as intended: less water is used in total.

Finally, technological devices are included among the measures which address structural determinants. Such devices can, for instance, enhance the efficiency of water use, resulting in a reduction of the actual water used without compromising the comfort of water users. There are certain expenses when investing in such technologies which are usually covered by the water user. Nevertheless, the investment usually pays off within a relatively short period of time. In this case, it may make economic sense for the water supplier to invest in a retrofit program, e.g. providing more efficient shower heads, if this is less costly than increasing the water supplied.

3.3. Methods with specific relevance for the DAIAD trials

In this section, we examine specific types and effects of methods in more detail which seem particularly relevant for the intervention and interface design in the DAIAD trials. These include information, feedback techniques, as well as normative and persuasive methods. In this context, we also discuss possible adverse and side effects of intervention to change behavior. Finally, we present existing findings regarding the amphiro a1 as an example of feedback using ICT.

3.3.1. Information

Information is often necessary as a pre-condition for behavioral change, but it is usually not sufficient on its own to induce action. For the design of the DAIAD user trials, it should be considered which information should be given and how it could be designed best in order to support behavioral change.

With regard to the basic psychological determinants of behavior (such as awareness of the problem, of the consequences of one's own behavior, and of behavioral alternatives as well as sufficient competences to conduct the behavior), conveying information is feasible [Ma05]. When considering and comparing the effect of providing information in different studies, it has to be taken into account that the content can be very different (e.g. general information about a problem vs. detailed information on how to act to solve a problem) and can affect different determinants of behavior. Moreover, information can be provided in very different ways that can be relevant for its effectiveness.

Types of intervention that refer to a specific situation, state of knowledge, or emotion appear to yield higher savings than less specific ones [PK+11]. Abrahamse et al. [AS+07] point out that *tailored information* such as home audits conducted by energy saving experts is more effective than more general information. However, to offer such tailored intervention, one must gather and process information. This is often difficult to manage on a large scale, especially if deployed over a larger number of customers as is the case with individual energy audits. In this context, authors have stressed the potential of ICT systems to resolve this conflict and achieve cost-effective energy efficiency gains using modern data processing, personalization, and immediate feedback technologies [OH09].

Prompting is a very rudimentary form of informational intervention. Prompts consist of short written messages or signs which remind people of a specific behavior in a given situation. They may encourage a desired behavior if the basic determinants of intention already exist, such as a positive attitude towards the behavior (Abrahamse & Matthies, 2013). To be effective, prompts should be well placed, well timed and formulated politely. Prompting is a feasible technique to promote less complex behavior, e.g. turning lights off when leaving a room, and to help to change habitual behaviors.

Delmas et al. (2013) offer the most comprehensive meta-analysis of studies on information-based intervention promoting energy conservation. The electricity consumption reductions achieved by the various strategies were around 7.4% on average. However, information about monetary savings or monetary incentives (payment or rate changes) led to increased energy consumption instead of helping to reduce consumption. An explanation given by the authors is the "*licensing effect*", i.e. through such information, users may *learn that costs and/or potential savings are small, and they are entitled to use energy as they are paying for it*. These findings indicate that a strong *focus on pricing information and strategies might not be as effective* as often assumed by stakeholders and practitioners.

According to the review of Abrahamse et al. [AS+05], information led to more knowledge, but did not always lead to behavioral changes. In contrast, offering rewards caused consumers to reduce their consumption, but this was not a permanent effect. Feedback measures were effective as long as *feedback was given consistently and frequently*. Combining feedback with other measures, e.g. *comparisons with other users* and a *competition* with awards as incentives, was evaluated as especially successful by the authors.

Similarly, in a study of Abrahamse et al. [AS+07], combining goal setting with tailored information and feedback successfully reduced residential energy consumption. Comparative feedback was also used, but did not have an effect on energy consumption. Their results are mainly consistent with other studies. With regard to comparative feedback, mixed findings are reported in the literature (cf. discussion in [AS+07]). Explanations for the lack of effect of comparative feedback on energy consumption could either be the fact that it was not sent immediately following the behavior in question, or that the reference group might not be relevant for the participants. Another possible explanation is that the social norms are not very salient as there was no communication with members of the reference group. As the authors point out, more research is needed on why social influences seem relevant in some cases but not in others.

3.3.2. Different forms of feedback

As the DAIAD project focuses on the development and design of the smart meter or feedback device Amphiro b1, different forms of feedback and their effects will be considered in the following in order to guide the design of the feedback applied in the DAIAD user trials.

Regarding the effects of different forms of feedback, Darby [Da06] conducted a review of findings in the energy-related literature: *Direct feedback* refers to immediate feedback from the meter (if the meter is easily visible to the user when consuming energy), or an associated display monitor. Its effects range from 5 to 15%, according to Darby [Da06]. Findings indicate that users with high consumption are more likely to respond to direct feedback than users with low consumption. This feedback provides the consumer with adequate information on different end-uses in a simple way by showing consumption when an appliance is switched on vs. when it is not in use. Darby [Da06] points out that, ideally, every household should know its current consumption and changes in it without having to switch on other optional feedback devices.

The term *indirect feedback* denotes feedback that has been processed in some way before reaching the energy user, usually via billing. Consumption reductions induced by this type of feedback range from 0 to 10% depending on the context as well as on the frequency and quality of the given information. Accurate, frequent billing, for example, provides better insights into variations of consumption and causal factors than single billing once per year. With regard to the provision of *comparative information*, comparison with previously recorded periods of consumption appears to be more effective than comparison with other households or a target figure.

According to Darby [Da06], long-term effects of feedback are supported if the psychological determinants of water-saving behavior, the development of new habits as well as the investment in efficient appliances and technology are successfully promoted. Additional information, normative measures or advice on saving options as well as information on efficient technology seem to be useful here. Continued feedback is necessary for enduring effects. As far as incentives given within a certain time-frame in combination with feedback are concerned, the effects are likely to peter out once the incentive is no longer available.

Gölz et al. [GG+12] and Klobasa et al. [SK+12] studied the effects of feedback via smart metering on household energy consumption in Germany and Austria. Households could choose whether they wanted to receive feedback via an internet portal or a postal letter. Each option was chosen by approximately 50% of the households in both studies. Feedback was combined with advice on energy-saving measures. In both studies, the effects on energy consumption ranged around reductions of 4% on average. The feedback option (internet portal vs. postal letter) did not make a difference. In the study of [SK+12], the largest reductions were achieved in households with a medium level of consumption, while households with a very high or very low consumption hardly changed their demand. Different effects of measures on different consumer types were also suggested by the reviews of [AS+05] and [Da06]. In particular, differences were found for high and low consumers of energy, with the low consumption group increasing their energy use after receiving feedback [AS+05].

Gölz et al [GG+12] also studied the evaluation of the online and postal feedback instruments offered to the participants of their study and assessed the way the internet portal was used. Feedback was mainly evaluated as positive and as informative, useful, understandable and user-friendly. Participants of the study stated that the feedback raised their interest in the topic of energy consumption. 15% of the participants felt under pressure to reduce their consumption, while about 25% of the sample was afraid of problems regarding privacy protection. The online information portal was mainly used during the first month after implementation. The type of information most frequently consulted were consumption values for hours and days and advice on energy saving. The rate of usage then dropped drastically during the second month (on average by 50%) and continued to decline over time.

3.3.3. Normative and persuasive methods

As presented above, informational strategies can be used to foster change in consumption behavior. However, in order to be effective, they should be *tailored* and designed in a way that includes or invokes *normative aspects*. For example, in order to be more effective, information can be conveyed by *role-models* or include *normative information* (based on the opinion or behavior of other consumers). Methods which can be combined with informational strategies include *goal setting, commitment, and persuasive technology* and should be considered for the design of the DAIAD user trials.

Goal setting is a feasible technique to guide an individual's actions consistently towards efforts to reach the desired outcome [SW+09]. Goals should be high, but realistic, clearly formulated and achievable in the short term (Abrahamse & Matthies, 2013). Research has shown that goal setting is more effective and its effects are longer lasting when combined with feedback (Fishbach & Finkelstein, 2010). Moreover, *implementation intentions* (cf. 3.2.1.6) can further enhance the effects of goal setting (cf. Bamberg, 2002).

In *commitment-related intervention*, participants are asked to commit themselves to change their consumption behavior. The commitment should be written and concrete and can be private or public. The mechanism which motivates the behavior can be explained using Festinger's theory of cognitive dissonance, which increases if the person does not act in accordance with his/her commitment.

3.3.4. Adverse effects

Types of intervention using feedback and comparative elements, like those which will be applied in DAIAD, have to be designed and implemented carefully as they can also have negative effects. Brandon and Lewis [BL99] showed that low energy consumers who received feedback information via ICT actually increased their energy usage. Schultz et al. [SN+07] studied this effect in more detail and reached the conclusion that descriptive normative feedback (i.e. feedback on what other people typically do) may lead to increased electricity usage among below-average consumers, whereas a combination of descriptive and injunctive normative feedback (i.e. feedback on what other people appreciate) does not.

3.3.5. Possible side effects

As already mentioned (Section 2.3.2.6), intervention inducing behavioral changes can also have positive or negative side effects in other areas (spillover).

If a person has a pro-environmental disposition of sufficient strength, communication that addresses environmental values and norms is more likely to induce positive spill-over into other environmental behaviors (Thøgersen & Crompton, 2009). In particular, the key question regarding communication aimed to induce positive spillover effects is: "Do the reasons that are given (or the values that are appealed to) in the course of encouraging a pro-environmental behavioral change affect the likelihood of promoting positive spill-over into other behaviors?" (Thøgersen & Crompton, 2009, p. 145).

In contrast, strategies to prevent negative spillover can be transferred from the discussion of rebound effects, which have some overlaps with negative spillover effects[5]. For example, de Haan et al. (2015)

[5] Rebound effects are behavioral changes which can follow the adoption of (more) efficient technology, while spillover effects can also follow other changes of environmental behavior. While spillover effects are defined as changes in areas other than the one in which the initial behavioral change took place, rebound effects can be direct (i.e. occur in the area where the efficiency improvement has taken place) or indirect (occur in other areas).

outline financial, regulatory and psychological measures depending on the reasons inducing the negative effects. With regard to the DAIAD user trials, psychological measures seem feasible that provide information about the environmental impacts of various behaviors and strengthen the norms to conserve resources in different areas (cf. also Peters et al., 2012; Tiefenbeck et al., 2013).

3.3.6. Amphiro a1 as an example of feedback using ICT

In order to assess the effect of real-time feedback on water users, *Amphiro a1* was deployed in a large field trial conducted in Switzerland covering 60 households and 160 individual users. Amphiro a1 is the predecessor of the smart meter device *b1,* which has been developed in DAIAD and will be studied in the DAIAD trials. It provides real-time water consumption feedback information via the device's LCD display (including a polar bear animation to illustrate the negative consequences of hot water consumption). In effect, using Amphiro a1 caused a decline in hot water consumption for showering by 6,400l (22%) and energy savings of 210 kWh per year and household. The decline resulted mainly from reducing total showering time. Thus, the saving effects of this point-of-use specific feedback clearly exceeded those achieved by smart meters for electricity, which are generally less specific with regard to point-of-use. The savings did not decline over time. The study also assessed participants' willingness to pay for the device, which was roughly 39 euros per meter. The reader is invited to study our Deliverable D1.1 for more information on the effects of feedback using ICT and specifically-designed web-based information portals.

The literature presented in this section indicates that a *combination* of different measures *tailored* to the needs of the target group and the behavioral context is the most effective way to induce behavioral change. General information is often necessary on the consequences of water consumption, the relevance of a person's own behavior and behavioral options, but is not sufficient to achieve this goal. However, *feedback* can enhance the effectiveness of the information provided. Clear and visible feedback seems to be a necessary component that gives users details about their water consumption and helps them to identify specific options to reduce it. Immediate direct feedback combined with frequent and detailed indirect feedback seems an effective way to provide detailed information on the effects of behavioral change.

4. Determinants of adopting technological feedback devices

This section presents an empirical study of the determinants for the willingness to adopt technological feedback devices such as DAIAD@feel and current water conservation efforts. We first describe the aim and setting of the study, its theoretical background and the hypotheses. The method and results are then described in detail. The chapter concludes with a discussion of the results.

4.1. Aim and setting

The aim of this study was to apply the NAM, one of the theories of action described above (Section 2.3.1) to explain consumers' levels of interest in adopting (i.e. buying and installing) smart shower meters. In addition, the NAM was used to assess and explain current water conservation efforts. By comparing the explanatory power of the different behavioral determinants included in the theoretical model, the study intended to provide insights for practitioners into how consumers can be motivated to adopt technological feedback devices and intensify their water conservation efforts at home.

Fraunhofer ISI and the business psychology program at Hochschule Darmstadt - University of Applied Sciences cooperated in planning and conducting the study as part of a research seminar focusing on environmental and sustainability issues. The academic supervisors were Dr. Anja Peters at Fraunhofer ISI and Professor Daniel Hanss at Hochschule Darmstadt - University of Applied Sciences.

The following sections provide a summary of the work of the student group who planned and conducted the research. This summary is based on a detailed report authored by the students and delivered to Fraunhofer ISI in February 2016. The team of students consisted of Susanna Dörr, Ralf Kaufmann, Simon Koj, Mari Schwarz, Nelli Sioud and Yohanna Weiß.

4.2. Theory

As described in Section 2.3.1, the NAM is one of the dominant theoretical models in psychological research to explain environmental behaviors. It has been applied to a wide range of pro-environmental intentions and behaviors, including conservation of energy [ZW+13] [AS09] and of hot water at home [NG02]. With regard to its predictive power for different types of environmental behaviors, the NAM has been shown to be particularly helpful in explaining behaviors involving low individual costs, such as energy conservation [AS09], rather than behaviors involving high individual costs such as car use [BS03]. Conserving warm water at home can be considered a low-cost environmental behavior, because potential downsides, such as

reduced comfort, may be partly compensated by financial savings. Similarly, buying a smart meter device may pay off over time through reduced water and energy bills. It was therefore assumed that the NAM would be well suited to the purpose of this study.

Following the paradigm of previous studies that used the NAM to explain environmental behaviors, the predictive qualities of the following psychological variables were investigated (cf. Chapter 2.3.1.2): *personal norm* (here: feeling morally obliged to conserve water), *problem awareness* (being aware of environmental problems related to water consumption), *ascription of responsibility* (feeling personally responsible for water conservation and the environmental consequences of water consumption), *response efficacy* (being aware of means to effectively monitor and reduce water consumption at home), *self-efficacy* (believing that one can personally monitor water consumption and behave in ways to effectively conserve water in one's home), and *social norm* (believing that important others such as friends and family members expect one to conserve water). In addition, the *intention to adopt smart meters* and current *water conservation* behaviors were investigated.

4.3. Hypotheses

Based upon the NAM's theoretical assumptions, the following hypotheses were formulated:

- H1a (*personal norm*): Personal norm is positively associated with water conservation/ intention to adopt smart meters.
- H1b (*personal norm*): Personal norm is a better predictor of water conservation/ intention to adopt smart meters than the other explanatory variables of the NAM.
- H1c (*personal norm*): Personal norm is positively associated with the other explanatory variables of the NAM.
- H2 (*problem awareness*): Problem awareness is positively associated with water conservation/ intention to adopt smart meters.
- H3 (*responsibility*): Ascription of responsibility is positively associated with water conservation/ intention to adopt smart meters.
- H4 (*response efficacy*): Response efficacy is positively associated with water conservation/ intention to adopt smart meters.
- H5 (*self-efficacy*): Self-efficacy is positively associated with water conservation/ intention to adopt smart meters.
- H6 (*social norm*): Social norm is positively associated with water consumption/ intention to adopt smart meters.

4.4. Method

The hypotheses were investigated in a questionnaire survey conducted from September to October 2015 among residents of Darmstadt, a medium-sized university city of roughly 150,000 inhabitants, located in the southern Rhine-Main area of Germany.

4.4.1. Participants

A total of N = 1000 residents aged 18 to 65 years were randomly selected from the city's population registry and invited to participate in the study. The invitation was sent by postal mail and included the questionnaire and instructions explaining the survey's objective, data confidentiality, and the approximate time needed to complete the questionnaire. It was additionally announced that all respondents would be entered into a raffle with the chance to win one of 10 Amphiro a1 smart shower meter devices as an incentive for participation.

166 individuals responded to the first letter. Those who had not replied within four weeks after the first letter received a reminder by postal mail including a new copy of the questionnaire. In this second round of data collection, another n = 77 individuals responded. Thus, the total sample added up to n = 243 individuals, resulting in a response rate of 25.18% after n = 35 individuals with invalid addresses had been excluded from the gross sample.

Approximately half the participants were female (48.1%) and had a college degree (46.9%). Participants were assigned to one of five age categories: 25 years or younger (19.3%), 26 to 35 years (23.9%), 36 to 45 years (11.9%), 46 to 55 years (24.7%) and older than 55 years (18.9%). The sample distribution shows that one age group (36 to 45) was somewhat underrepresented.

Half of the participants were married or in a long-term relationship (48.2%). The remaining participants were either single (40.3%), divorced or separated (7.8%), or widowed (1.2%). The most common category of monthly household income was "above € 3500" (30.5%), and the majority of respondents lived in multi-person households of two persons or more (78.9%).

4.4.2. Measurement instrument

The questionnaire consisted of separate sections, one for each of the focal variables. In addition, one section included general instructions on how to fill out the questionnaire as well as questions to assess socio-demographic information, including participants' age, gender, level of education, the household's total monthly income and size. Another section provided information on smart shower meters, their functions and how to install them. This information was presented after participants had provided their socio-demographic information and before they completed the sections measuring the NAM variables.

In order to facilitate data handling, the questionnaire was designed in EvaSys, a software tool which enables computer-assisted data entry by scanning the forms filled out by the participants. This method of data entry has been found to be very reliable in surveys with larger sample sizes [JJ+ 03].

Each of the NAM variables was measured by several questionnaire *items*, each consisting of a *statement*. Examples of such statements are provided below. Participants were asked to indicate the extent to which they thought each statement applied by marking the respective answer field of a five-point rating scale

ranging from 1 (*does not apply*) to 5 (*does apply*). An additional answer field (*don't know*) was provided, allowing participants to indicate if they were indecisive about a statement.

For each construct, a factor analysis (applying *Principal Component Analysis*, *oblique rotation* and *eigenvalues-greater-than-one*) was conducted to explore the correlational structure of the items belonging to the respective construct. Only items that had factor loadings of at least .40 and cross loadings smaller than .30 were retained for further analysis. These items were then entered into a reliability analysis (Cronbach's alpha). This was done separately for each factor if several factors were retained for a construct. Additional items were removed if Cronbach's alpha could be improved.

This procedure was repeated until all the remaining items had satisfactory factor loadings (>= .40) and cross loadings (< .30), and the Cronbach's alpha values were .70 or higher. Finally, an index variable was computed for each factor by averaging respondents' answers to the items belonging to the factor. Negatively phrased items were recoded (i.e. data were inverted) before calculating the index variables.

The items to measure personal norm and social norm were analyzed together in a single factor analysis. This was done to investigate whether the distinction between personal and social norms would appear empirically in the correlational structure of the items. Three factors were identified; one representing personal norm and two representing social norm (see below). A separate index variable was computed for each factor following the procedure described above.

Three items were included in the survey to measure the intention to adopt smart meters. An example item is: "I intend to buy a smart meter device for my household." All three items initially included in the questionnaire were retained after the factor and reliability analyses. One index variable was computed, hereinafter referred to as "*intention*" (M = 2.34, SD = 1.21).

Water conservation was measured by four items. An example item is: "When showering, I pay attention to how much water I am using." After factor and reliability analyses, three items were retained and combined into one index variable, named "*water conservation*" (M = 3.68, SD = 1.10).

Five items were used to measure personal norm. An example item is: "I feel personally obliged to save water." One index variable, named "*personal norm*", was computed by combining the three items that were retained after factor and reliability analyses (M = 4.33, SD = 0.79).

Problem awareness was initially measured by eight items. An example item is: "Warm water consumption in private households contributes substantially to climate change." Five items were retained and combined into an index variable, named "*problem awareness*" (M = 3.46, SD = 0.86).

Eight items measured ascription of responsibility, an example item being: "I hold myself responsible for water conservation." Three items were retained and combined into an index variable, named "*responsibility*" (M = 4.24, SD = 0.86).

Response efficacy was measured by six items. An example item is: "Using a smart meter device helps to reduce household energy costs." One index variable, named "*response efficacy*", was computed by combining the two items that were retained after factor and reliability analyses (M = 4.04, SD = 1.00).

Five items were used to measure self-efficacy. An example item is: "I find it easy to keep track of my warm water consumption at home." Three items were retained and combined into an index variable, named "*self-efficacy*" (M = 3.41, SD = 1.02).

Social norm was measured by 10 items. An example item is: "When it comes to my water usage in the shower, it is important to me that others think of me as an environmentally conscious person". Two index variables were computed to combine the five items that were retained after the factor and reliability analyses. One index variable combined three items measuring how important it was to participants that other people recognized their water-saving efforts. This was named "*social recognition*" (*M* = 3.25, *SD* = 1.40) (denoting a need for social recognition). The other index variable combined two items dealing with expected effects of feedback allowing to compare one's own warm water consumption with the consumption levels of others (e.g. on social media). This index variable was named "*social comparison*" (*M* = 2.61, *SD* = 1.35) (denoting a susceptibility for social comparison).

4.4.3. Data analysis

Data analysis was conducted in four steps using the statistical software *IBM SPSS Statistics, Version 23*. During the first step, the correlational structures of the measures were investigated using factor and reliability analyses (see Section 4.4.2). The second step included the computation of descriptive statistics for the index variables resulting from the previous step (see mean values and standard deviations in Section 4.4.2). During the third step, bivariate associations between the index variables were analyzed by means of Pearson correlations. Finally, during the fourth step, the relative importance of the explanatory variables was investigated by means of multiple linear regression analyses after meeting the required statistical preconditions. Separate regression models were calculated in order to explain both the intention to adopt smart meters and current water conservation behavior. Steps one and two served as preliminary analyses. The results of steps three and four served to test the hypotheses presented in Section 4.3.

4.5. Results

4.5.1. Bivariate correlations

The results of the bivariate correlations are displayed in Table 1. All statistically significant associations were in the expected direction. Personal norm, problem awareness, and responsibility were positively correlated with the intention to adopt smart meters and water conservation, providing support for hypotheses H1a, H2, and H3.

Table 1

Pearson correlations (*r*) of index variables

Index variable	1	2	3	4	5	6	7	8
1 Adoption intention								
2 Water conservation	.153*							
3 Personal norm	.254**	.532**						
4 Problem awareness	.178*	.197**	.315**					
5 Responsibility	.199**	.261**	.619**	.536**				
6 Response efficacy	.338**	.046	.192*	.256**	.275**			
7 Self-efficacy	-.028	.495**	.367**	.011	.069	-.159*		
8 Social recognition	.405**	.216**	.324**	.237**	.338**	.220**	.048	
9 Social comparison	.454**	.031	.170*	.284**	.315**	.311**	-.144	.407**

Note. *$p < .05$. **$p < .01$; missing data were deleted list-wise; correlations varied in strength, corresponding to small ($r = .1$), medium ($r = .3$), and large ($r = .5$) effect sizes (Cohen, 1988).

With regard to social norm, only one of the two factors, social recognition, was associated with both adoption intention and water conservation. The other factor, social comparison, was associated with adoption intention only. Taken together, these findings provided only partial support for hypothesis H6.

Response efficacy was correlated with adoption intention but not with water conservation, and the contrary was found for self-efficacy. Thus, hypothesis H4 was supported for adoption intention, and hypothesis H5 was supported for water conservation.

In addition, personal norm was found to correlate positively with the other explanatory variables, supporting hypothesis H1c.

Most of the other associations were weak, with the exception of the correlations between problem awareness and responsibility, and between social recognition and social comparison.

4.5.2. Regression analyses

Two separate linear regression analyses were conducted to investigate the relative importance of the explanatory variables for adoption intention and water conservation. The results are displayed in Table 2 (for adoption intention) and Table 3 (for water conservation).

The regression model for adoption intention was significant, $F(7, 167) = 11.121$, $p < .001$, explaining approximately 29% of the observed variance. Four of the explanatory variables showed significant positive

associations with intention: personal norm, response efficacy, social recognition, and social comparison. Social comparison turned out to be the strongest predictor (cf. *ß*-values in Table 2).

Table 2

Multiple linear regression of the explanatory variables on adoption intention

	Criterion variable: adoption intention			
	B	*ß*	lower 95% CI	Upper 95% CI
Constant	-0.178		-1.231	0.875
Personal norm	0.283	.188*	.013	.554
Problem awareness	0.009	.007	-.190	.209
Responsibility	-0.202	-.147	-.458	.055
Response efficacy	0.223	.190**	.060	.386
Self-efficacy	-0.026	-.022	-.194	.142
Social recognition	0.191	.224**	.067	.314
Social comparison	0.290	.313***	.153	.426
R^2	.318			
adjusted R^2	.289			

Note. *p < .05; **p < .01; ***p < .001; CI = confidence interval; missing data were deleted list-wise.

The regression model for water conservation was significant, $F(7, 179) = 17.266$, $p < .001$, and explained 38% of the observed variance. In this model, only two explanatory variables were significant: personal norm and self-efficacy. Both associations were positive. Personal norm had the highest *ß*-value (cf. Table 3) and can thus be considered the best predictor of water conservation in the model.

Table 3

Multiple linear regression of the explanatory variables on water conservation

	Criterion variable: water conservation			
	B	*ß*	lower 95% CI	Upper 95% CI
Constant	-0.268		-1.172	0.636
Personal norm	0.608	.435**	.386	.829
Problem awareness	0.096	.077	-.073	.265
Responsibility	-0.101	-.077	-.317	.116
Response efficacy	0.010	.010	-.127	.148
Self-efficacy	0.356	.321**	.213	.498
Social recognition	0.065	.081	-.041	.170
Social comparison	-0.016	-.019	-.130	.098
R^2	.403			
adjusted R^2	.380			

Note. *p < .01; **p < .001; CI = confidence interval; missing data were deleted list-wise.

Taken together, the results of the regression analyses provided mixed support for the hypotheses. Only one hypothesis, H1a (personal norm), was supported for both adoption intention and water conservation. In addition, three hypotheses were supported for one of the outcome variables: H4 (response efficacy) and H6 (social norm) were supported in connection with intention; and H5 (self-efficacy) was supported in connection with water conservation.

Hypothesis H1b stated that personal norm would be a better predictor for adoption intention and water conservation than the other explanatory variables. This hypothesis was supported for water conservation only.

Table 4 sums up the conclusions from the correlation and regression analyses with regard to the hypotheses concerning adoption intention and water consumption.

Table 4

Support for hypotheses concerning adoption intention and water conservation

	Type of analyses			
	Bivariate correlations		Regression analyses	
	Intention	Water conservation	Intention	Water conservation
H1a (personal norm)	supported	supported	supported	supported
H1b (personal norm)	*tested with results of regression analyses only*		not supported	supported
H2 (problem awareness)	supported	supported	not supported	not supported
H3 (responsibility)	supported	supported	not supported	not supported
H4 (response efficacy)	supported	not supported	supported	not supported
H5 (self-efficacy)	not supported	supported	not supported -	supported
H6 (social norm)	supported (social recognition, social comparison)	supported (social recognition)	supported (social recognition, social comparison)	not supported

4.6. Discussion

This study investigated the explanatory power of different psychological variables concerning people's intention to adopt smart shower meters and their current water conservation behaviors. The explanatory variables were derived from the NAM, a theoretical model widely used in psychological research to explain environmental behavior, which has been found to be particularly useful for predicting behavior in situations involving low individual costs (cf. Section 4.2).

A general finding of this study is that all of the explanatory variables were positively associated with at least one of the outcome variables: adoption intention or water conservation. This finding underlines the applicability of the NAM to environmentally-relevant behaviors in general, and warm water conservation in particular.

However, according to the results of the bivariate and the multivariate analyses, the relative importance of the explanatory variables differed depending on the outcome variable. In connection with the intention to adopt *smart meters*, *social norm showed the strongest association*, followed by *response efficacy and personal norm*. In connection with *water conservation behaviors, personal norm* showed the strongest association, followed by *self-efficacy*.

A main assumption of the NAM is that personal norm is the strongest predictor of behavior among the explanatory variables included in the model. This study supported this assumption for water conservation behaviors, but not for the intention to adopt a smart meter. A possible explanation for this finding is that everyday water conservation behaviors are motivated by moral considerations to a larger extent than the decision to adopt a smart meter. For example, it has been argued that intrinsic motivations may be less influential when adopting smart metering technology than extrinsic motivations such as financial incentives [WV+12]. Others have emphasized the importance of availability in decisions to adopt energy-efficient technologies [St08]. Not knowing where to purchase such a device or high acquisition costs may be factors that reduce the technology's *perceived* and *actual* availability. Empirical support for the notion that perceived barriers, such as limited availability, play an important role in the adoption of smart shower meters comes from studies showing that *perceived behavioral control* is an important predictor of the intention to adopt smart metering technology [WV+12].

The present study highlights two other factors that may impact decisions to adopt smart metering technology: a) considerations of the *technology's effectiveness* and b) considerations regarding *social acceptance and influence*. With regard to perceived effectiveness, it was found that *response efficacy* was positively associated with the intention to adopt a smart meter. This explanatory variable was composed of two items measuring how strongly participants believed smart meters could facilitate the conservation of warm water and energy at home. One obvious way of support by smart meters is their direct feedback on the amounts of energy and water consumed in a household. Another, perhaps less obvious, way is by increasing the social visibility of consumption levels, for example by allowing consumers to compare their own warm water consumption with that of neighbors on an internet platform (an actual feature of DAIAD). If one's own consumption levels are visible to others, one may be particularly eager to meet other people's expectations concerning water and energy conservation. Empirical support for this form of social influence comes from the finding that *social comparison* (i.e. one of the social norm factors) turned out to be an important predictor of the intention to adopt smart meters in this study. In addition, it was found that people who thought it was important that others regarded them as environmentally conscious consumers of water and energy (i.e. higher scores on *social recognition*, the other social norm factor) had a stronger intention to adopt smart meters.

Taken together, the findings regarding social comparison and social recognition emphasize the importance of *social norms* in the decision to adopt smart meter technologies. This conclusion is in line with other studies suggesting that social norm is an important determinant of people's intention to reduce energy consumption. For example, in one study, households in California received either information about the energy conservation efforts of their neighbors (i.e. a social norm message) or other information such as messages about the environmental or monetary benefits of saving energy. The *social norm message was more effective in promoting the intention to save energy than all the other message types* [NS+08; Study 2]. Interestingly, people seemed to be unaware of the powerful effect of social norms on their intentions. When

asked how important various aspects were in their decisions towards conservation, the majority rated environmental protection the highest, followed by societal benefits and monetary savings; other people conserving energy received the lowest rating (Study 1).

In addition to personal norm, an explanatory variable that stood out as an important predictor of current water conservation behavior was *self-efficacy*. The index variable representing self-efficacy was composed of three items measuring the perceived ability to monitor and influence warm water consumption at home. This operationalization comprises two facets of self-efficacy: the perceived ability to *control the target behavior* (e.g. monitoring one's water consumption) and the perceived ability to *achieve the target outcome* (e.g. reducing one's water consumption). Both facets of self-efficacy have already been investigated and found to predict environmental intentions and behaviors in different domains [cf. HB+16 for an overview].

The perceived ease of purchasing and installing smart meters was not explicitly addressed in the items to measure self-efficacy. This may explain why self-efficacy turned out to be less important for predicting the intention to adopt a smart meter in this study.

Problem awareness and *ascription of responsibility* were positively associated with both the intention to adopt a smart meter and current water conservation behaviors in the bivariate correlation analyses. However, when adjusting for common variance in the multivariate regression analyses, these explanatory variables did not turn out to be significant predictors. This latter finding is in accordance with studies suggesting that the NAM can be interpreted in terms of a mediation model describing a causal chain of behavior influence [GS09]. According to this interpretation of the NAM, problem awareness is the main determinant of ascription of responsibility, which in turn is the main determinant of personal norm. Some support for this interpretation of the NAM comes from the finding that personal norm was more strongly associated with ascription of responsibility than with problem awareness. In addition, ascription of responsibility was strongly associated with problem awareness (cf. bivariate correlation analyses). More research is needed to corroborate this interpretation of the NAM.

4.6.1. Conclusions for promoting adoption of water saving behavior

Efforts to promote the adoption of smart shower meters and the conservation of warm water should target those variables that turned out to be closely related to the outcome variables in the present study.

In connection with the intention to adopt smart meters, social norm, response efficacy, and personal norm showed the strongest associations. Among these variables, social norm had the lowest mean values (cf. Section 4.4.2), suggesting that initiatives to strengthen social norms should have strong potential to change consumers' intention to adopt smart meters. One way to increase social norms is by informing consumers about other people's interest in adopting smart meters or actual adoption of such devices (i.e. a descriptive social norm). Similar strategies have been shown to effectively promote energy conservation [NS+08]. When applying descriptive norm messages, the reference group used in the message may be decisive for the strength of the effects on the targeted behavior. Empirical findings suggest that using reference groups that are similar (e.g. geographically close) to the group targeted by the intervention may be particularly effective in changing behavior [RL+14].

Response efficacy could be strengthened by communicating the results of empirical studies that illustrate the effects of smart meters (or other feedback strategies) on household water and energy conservation.

Knowing about such empirical findings should increase consumers' confidence in the effectiveness of feedback and smart metering technologies for reducing consumption levels.

In connection with water conservation behaviors, personal norm and self-efficacy showed the strongest associations. Self-efficacy had a lower mean value than personal norm, suggesting that initiatives to enhance these types of belief should have strong potential to reduce water consumption. One way how self-efficacy could be strengthened is by improving the public's knowledge of smart metering technologies and how these can help to monitor daily water and energy consumption.

Personal norm was a good predictor of both outcome variables but had a relatively high mean value in the sample. Therefore, it can be concluded that there may only be a limited potential to further strengthen personal norm, at least in the sample and underlying population under study. Campaigns aimed at strengthening personal norms could target problem awareness (e.g. through information about unsustainable levels of water consumption) or ascription of responsibility (e.g. through prompts or commitment strategies) given that both of these variables were found to be closely related to personal norm in this study.

4.6.2. Limitations

This study is among the first to investigate consumers' interest in adopting smart shower meters and allows valuable conclusions on how this technology can best be promoted to facilitate water and energy conservation. However, it also had limitations that should be addressed in future studies.

Some of the measurement instruments were developed specifically for this study because existing instruments to measure the NAM constructs had not been tailored to the adoption of smart meters. Although these instruments showed satisfactory psychometric qualities, they could be improved (e.g. by adding items to some of the instruments) and further validated in future studies.

Another limitation is that psychological variables that may be important for explaining water conservation and interest in adopting smart metering technology were not included in the present study. For example, it has been argued that perceived privacy risks may be decisive for consumers' willingness to adopt smart metering technology [WV+12]. Other researchers have proposed that perceived self-efficacy with regard to influencing the behavior of other people plays an important role in sustainable consumption [HB10]. If sustainable behavior, such as individual efforts to conserve water and energy, is socially visible, it should be more likely that this encourages other people to do the same (e.g. by constituting a descriptive social norm). Given that sustainable development goals can only be met if many individuals play their part, those convinced that individual contributions have a social impact may be more willing to actually take action and contribute their share. The above variables could be included in future studies to explore whether they further improve the explanatory power of statistical models.

The sample size of the present study was relatively small, and all the participants were residents of a medium-sized city in central Germany. Future studies should aim for larger and more diverse samples, encompassing rural and urban regions, as well as for samples from other countries. This would increase the representativeness of the findings for the general population.

Finally, the data collected in this study were correlational and, therefore, no conclusions can be drawn with regard to causality and directionality in the associations found. Longitudinal and experimental study designs are needed to shed light on these issues.

5. Guidelines for DAIAD

In this section we emphasize guidelines both for the design of the DAIAD user trials (based on the literature review presented in Sections 2 and 3) and for the promotion of smart meter adoption and water conservation (based on our empirical findings presented in Section 4).

5.1. DAIAD user trials design

5.1.1. Combining types of intervention based on theory and problem analysis

The literature on behavioral determinants (cf. Section 2) and types of intervention to change behavior (cf. Section 3) indicates that a *combination* of different measures is usually *the most effective*. These measures should be *tailored* to the determinants which are relevant for the specific behavior of the target group. Types of intervention to address different determinants have been presented that include both structural and psychological aspects. Each method has specific advantages and disadvantages, which also suggests that combining methods is the most effective.

General information such as information about a problem (e.g. consequences of water consumption), the relevance of one's own behavior and behavioral options is often necessary but is not sufficient to change behavior. *Feedback* can enhance the effectiveness of the information provided. Clear and visible feedback seems to be a necessary component in order to inform the users, in a detailed manner, about their consumption and help them identify specific options to reduce it. It seems effective to combine immediate direct feedback with frequent indirect feedback that provides detailed information on the effects of behavioral change. It should be noted that continuous feedback always poses the risk of user fatigue [CL+12] so that it should be designed with elements that vary over time and are tailored to user needs in order to keep their attention over time.

Social feedback in the form of peer comparisons has also proven effective, but should also be tailored to the individual's living situation [LS+13][SB04][AS+07]. Adverse effects on low consumers who are already using less than their peers could be prevented by adding *injunctive normative messages*. Regarding high consumers, social comparative feedback poses the risk that the gap to other households may be perceived *as too large for a motivational effect*. In such cases, commitment to *less ambitious goals* should be encouraged. Moreover, the effectiveness of different behavioral changes should be pointed out carefully, allowing consumers to perceive effective behavioral options to change their consumption. In this way, they can decide to begin with the options which they perceive as more realistic to be implemented in their daily life.

5.1.2. Avoid reactance

As far as people's engagement in behavioral change is concerned (i.e. a reduction of their water consumption), it is crucial that measures to influence behavior are not perceived as unjustified constraints on their freedom, which can induce reactance, i.e. the person behaving contrary to the desired behavior. There is an especially high risk of reactance for types of intervention focusing on norms or applying

prohibitions and penalties (Homburg & Matthies, 1998). Thus, it is important that people already have positive attitudes towards a specific behavior and therefore are more likely to embrace the respective measures applied to influence their behavior.

5.1.3. Promotion and preservation of intrinsic motivation

Studies of behavioral change often discuss intrinsic and extrinsic motivation with regard to the effects, as well as the advantages and disadvantages of intervention promoting the respective type of motivation. Extrinsic motivation describes the influence of external factors on behavior, e.g. *incentives and rewards, or prohibitions and punishments.* In contrast, intrinsic motivation is based on internal factors such as *personal values, norms and attitudes*.

Studies have shown that intrinsic motivation leads to stronger behavioral reaction or interest. For example, in an experiment with college students asked to solve a puzzle, it was observed that students who did not receive any payment for solving it also attempted to solve it during their "free time" and showed greater interest in the task than students offered a reward. Other experiments revealed that non-rewarded individuals demonstrated better compliance in the long run, despite the fact that externally motivated individuals were more engaged at the beginning [BT06].

Giving someone a task without offering a large reward also expresses confidence in their ability to finish the task. This may lead to a better result. Intrinsic motivation is about self-esteem and confidence: people tend to perform particular tasks better if these attributes are enhanced.

5.1.4. Consideration of possible side effects

Although the DAIAD trials focus on water consumption while showering, possible side effects in other areas of water or energy use should be considered when evaluating the short- and long-term effects of feedback and further intervention. Negative side effects (i.e. increased water or energy consumption in other areas) should be contained – and positive side effects (i.e. decreased water or energy consumption in other areas) supported by carefully designing the intervention measures.

To fulfil this objective, it is vital that intervention measures help people to understand the impact of different behaviors on water and energy consumption and prevent them overestimating the positive impact of their pro-environmental actions (cf. Tiefenbeck et al., 2013). Generally, environmental campaigns should focus on actions with significant impact so that individuals' time and efforts are not wasted on low-impact activities which might prevent them taking other environmental action with a bigger impact.

Positive effects could be supported by strengthening environmental norms and making environmental behavior an aspect of individuals' identity (cf. Peters et al., 2012; Tiefenbeck et al., 2013). Moreover, it should be ensured that campaigns strengthen intrinsic motivation by promoting positive attitudes towards environmental behavior. Last, but not least, it should be checked that the reasons given during the course of a campaign for motivating behavioral change also increase the likelihood of positive spillover into other behaviors (cf. Thøgersen & Crompton, 2009).

5.2. Implications for promoting smart meter adoption and water conservation behaviors

In connection with the intention to adopt smart meters, social norm, response efficacy, and personal norm showed the strongest associations. In relation to water conservation behaviors, personal norm and self-efficacy showed the strongest associations.

Regarding adoption, one way to enhance social norms is by informing consumers about other people's interest in adopting smart meters or their actual adoption of such devices (i.e. a descriptive social norm). When applying such descriptive norm messages, the reference group used in the message should be similar (e.g. geographically close) to the respective individuals targeted by the intervention. Response efficacy may be strengthened by communicating the results of empirical studies that illustrate the effects of smart meters (or other feedback strategies) on household water and energy conservation.

With regard to water conservation, one way to strengthen self-efficacy is by improving the public's knowledge of smart metering technologies and how these can help to monitor daily water and energy consumption.

Campaigns aiming to strengthen personal norms with regard to both warm water conservation and the adoption of smart meters could target problem awareness (e.g. via information about unsustainable levels of water consumption), or ascription of responsibility (e.g. via prompts or commitment strategies).

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