Journal of Environmental Management 247 (2019) 867–876

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics

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ARTICLE INFO

Keywords:
Water conservation
Behavioural change
Persuasive technology
Social norms
Pro-environmental behaviour
Water demand management

ABSTRACT

The world faces imminent drought-related challenges that, from a tap-water supply perspective, require increasingly expensive infrastructure enhancement and energy expansion to maintain sufficient service levels. This paper argues that enhancing domestic water conservation provides a promising alternative or necessary addition to reduce costs and to stimulate pro-environmental behaviour. Although the number of field experiments on how people's behaviour can be changed with respect to their daily water consumption is growing, to date, most studies in this field have focussed either on explanatory socio-economic factors (e.g. water pricing, income, or family composition) or behavioural intentions and personal characteristics related to behavioural change. Accordingly, there is limited empirically validated knowledge about the use and effectiveness of different influencing tactics to change behaviour. This paper provides a review of the empirically oriented literature in this field and aims to provide an up-to-date assessment that identifies eight different Behavioural Influencing Tactics (BITs) that target long-term water conservation behaviour within households. Our analysis is structured around three information processing routes: the reflective route, the semi-reflective route, and the automatic route. We conclude that the current body of literature is promising and provides a useful body of evidence on the range and effectiveness of individual water conservation mechanisms, but that needs further development to deepen our understanding of how to effectively prolong and reinforce newly formed water conservation routines.

1. Introduction

In many water scarce locations around the world, water is perceived to be abundantly available and is provided at relatively low costs for domestic users. Even so, the world is projected to experience a 40% fresh water shortage by 2030 (WRG, 2009). Although global diets and consumption patterns place the most pressure on the world's diminishing freshwater resources (Hoekstra et al., 2012; Vanham et al., 2018; Gawlik et al., 2017; Koop and Van Leeuwen, 2017), households can also make a significant contribution in reducing overall water demands. For example, average domestic water consumption in litres used per person per day varies from 575 in the United States, 490 in Australia, 360 in Mexico, 322 in Japan, 131 in China to 200–300 in most European countries (UNDP, 2006). On a global scale, most domestic water consuming activities are related to hygiene purposes such as showering, bathing, toilet, and washing machines (Carragher et al., 2012; Zhang and Brown, 2005; Gato-Trinidad et al., 2011). Watering lawns and gardens is a water-demanding activity too, particularly in warm and dry conditions (Hurd, 2006). In the face of rapid urbanisation, climate change, and increasing affluence (Koop and Van Leeuwen, 2017), water crises such as Australia's struggle with the millennium droughts or Cape Town's 2018 threat of day zero, when supplies would be fully depleted, are likely to unfold more frequently, with far-reaching consequences. Furthermore, a changing climate is expected to intensify heat waves and drought events, leading to episodes with high peaks in water demand. Because of abrupt changes in pressure, such peaks occasionally result in tap water discolouration and require expensive infrastructure enhancement and entail high energy costs to treat, pump and maintain the water supply network (Beal et al., 2016; Rathnayaka et al., 2015). In parallel, supply side technologies such as waste water recycling and the use of alternative sources (e.g. rainwater harvesting and desalination) are increasingly viewed as necessary measure (e.g. European Commission, 2018; Smith et al., 2018; Steflova et al., 2018). Interestingly, and despite its potential to provide an essential part of any drought-related solution, consumers' changing water demand patterns get somewhat crowded out in this discourse (Hurlimann et al., 2009). However, a more non-traditional consumer-inclusive approach (e.g. Hegger et al., 2011) may be indispensable to create the support,

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https://doi.org/10.1016/j.jenvman.2019.06.126
Received 13 March 2019; Received in revised form 28 June 2019; Accepted 30 June 2019

commitment, and behaviour change necessary to ensure sustainable water consumption under increasingly water-scarce conditions.

Domestic water savings can be increased through economic incentives (e.g. water pricing), technical improvements (e.g. water-saving household appliances), or policy instruments and regulation. In this paper we focus specifically on behaviour influencing as a way to enhance domestic water savings. Those studies that do focus on water demand management have mainly concentrated on key social and economic characteristics that may influence domestic water use (Garcia et al., 2013). These characteristics include water pricing, levels of income and education, awareness, family composition, age, gender, culture, and religion. Volumetric charge for water and a higher average water price appear effective in enhancing water conservation (e.g. Grafton et al., 2011; Worthington and Hoffman, 2008; Syme et al., 2000). Most notably, Grafton et al. (2011) claim that although water expenditures account for less than 1% of the household's income, it is the most important variable explaining differences in domestic consumption in 10 OECD countries. Levels of income matter for water conservation: higher income correlates with higher water consumption (Xue et al., 2017; Russell and Fielding, 2010; Mondéjar-Jiménez et al., 2011; Willis et al., 2013). Although volumetric water charge and a higher average price is effective in enhancing water conservation (Grafton et al., 2011), the feasibility of increasing consumer costs may be limited when affordability issues limit access to domestic water. Although at times considered controversial (e.g. Jollands and Quinn, 2017), an important no-regret measure in this context is installing water meters (e.g. Dalhuisen et al., 2003). In addition to level of income and pricing, various scholars maintain that education is also an explanatory variable for water conservation behaviour (e.g. Syme et al., 2000; Mobley et al., 2010). However, the associated correlation is not always clear. For instance, based on a survey of 26,689 Spanish households, Mondéjar-Jiménez et al. (2011) observed that although more highly educated people tend to know more about environmental issues, their levels of income and more comfortable lifestyle generally leads them to consume more water. In fact, an overall contradictory pattern can be observed where, as compared with people with less formal education, well-educated people are generally more committed to water conservation, yet actually consume more (Gilg and Barr, 2006; Fan et al., 2014; Gregory and Di Leo, 2003; Clark and Finley, 2007; Aprile and Fiorillo, 2017). Accordingly, Fan et al. (2014) observed in their survey of water use patterns of 776 Chinese households that the gap between how much water people think they consume and what they actually consume increases with the level of education and income. Households that accurately estimate their water consumption have the best water-saving practices (Beal et al., 2013; Fan et al., 2014). Family composition matters too. Individual water consumption decreases with increasing family size (Willis et al., 2013; Gregory and Di Leo, 2003; Fielding et al., 2012). In addition, families with young children and older people are more likely to exhibit water conservation, whereas adolescents generally consume more (e.g. Davies et al., 2014; Clark and Finley, 2007). Moreover, gender appears to be a determining factor, as many observations indicate that females generally consume considerably less than males (e.g. Tong et al., 2017; Davies et al., 2014). Lastly, culture and religion have also been observed as a significant factor in water use behaviour (e.g. Tagat and Kapoor, 2018; Laurent and Lee, 2018).

Although the body of literature about various social and economic factors is highly relevant in explaining consumption patterns, these studies often do not focus on the more fundamental psychological factors that influence water conservation behaviour. Most literature about pro-environmental behaviour (including water conservation behaviour) focusses instead on either personal characteristics or behavioural intentions (Hurlimann et al., 2009). Until recently, a significant gap existed with respect to empirically oriented research concerning actual water-saving behaviour mechanisms, in particular for achieving long-term water savings (e.g. Hurlimann et al., 2009; Landon et al., 2018; Stewart et al., 2013). Moreover, despite the problematic relation between reported behaviour and use (i.e. up to 30% overestimation; Berk et al., 1993), many studies still rely on self-report questionnaires to test different behaviour-influencing mechanisms (Gregory and Di Leo, 2003; Berk et al., 1993; Lawrence and McManus, 2008). Accordingly, until recently there was limited empirical knowledge about how people's behaviour can be changed in relation to their daily domestic water consumption (Katz et al., 2016; Otaki et al., 2017). In response to this knowledge gap, a growing number of field experiments and data analyses have made a significant effort to examine the most recent psychological insights (e.g. Bernedo et al., 2014; Ferraro et al., 2011). This paper provides an–up-to-date overview of these empirically oriented studies that investigate how different Behaviour Influencing Tactics (BITs) can stimulate water conservation in daily water use activities at home. In doing so, we aim to provide an up-to-date assessment of the current state of knowledge in this field and to identify avenues for further research. We also intend to provide an empirical foundation that will help water suppliers, policy-makers and other practitioners, to better deal with drought-related challenges and provide them with means to achieve their sustainability ambitions.

After this brief introductory, section 2 provides an overview regarding existing notions of behavioural influencing. It also describes the methodological approach of the systematic literature review. Section 3 provides the resulting overview of empirical studies with respect to the eight key BITs for conserving water in households. A discussion of the current state of the literature and concluding reflections on key avenues for future research are offered in section 4 and section 5, respectively.

2. Conceptual framework and methods

2.1. Structuring different behavioural influencing tactics: a conceptual framework

Over the years, many scholars have attempted to understand the fundamental mechanisms that shape human behaviour from the perspective of behavioural psychology. Traditionally, the Theory of Planned Behaviour (TPB) (Ajzen, 1991) has been a leading model. This theory builds on the premise that individuals make behavioural decisions based on careful rational considerations. In this context, behaviour is considered as a primary result of *behavioural intention*, which is in turn determined by an individual's *attitude* towards a specific behaviour, the person's belief of what is expected by others (*subjective norm*), and how difficult or easy people think the behavioural change would be (*perceived behavioural control* or self-efficacy). The TPB, accordingly, assumes that personal volition or willpower is strong. Over the years, a large body of literature has expanded TPB with concepts such as belief salience, moral norms, self-identity, and affective beliefs (Conner and Armitage, 1998). At the same time, however, there is increasing recognition that behavioural intention is just one of many factors determining behaviour (e.g. Webb and Sheeran, 2006; Kahneman, 2003; Thaler and Sustein, 2008). For example, the leading work of Tversky and Kahneman (1981) showed that beyond rational choices, more unconscious processes such as loss aversion are better predictors of how we make (financial) decisions. Kahneman (2003) distinguishes two systems of information processing: system 1, which is unconscious, energy-efficient, quick, and based on intuition and emotions, and system 2, which is conscious, energy-consuming, slow, intentional, and based on cognition. Due to a lack of mental energy, time, and capacity Kahneman (2003) suggests that system 1 processes the most information.

To structure the debate on BITs for domestic water conservation, this paper distinguishes three routes of information processing, based on these key insights from the field of behavioural psychology (most notably with applications in health-related and pro-environmental behaviour): a reflective, semi-reflective, and automatic route. The reflective route appeals to the conscious processing of information

Table 1
Key Behaviour Influencing Tactics (BITs) to influence water use behaviour in households. The eight tactics are categorised according to the reflective, semi-reflective, and automatic information processing route. A full list with references to all 52 studies including size, length, and location of the studies is provided in the supplementary information.

	Tactic	Principle and effectiveness	Key references
Reflective	Knowledge transfer	Providing information to raise awareness, change attitudes, and behaviour. Information campaigns alone seem insufficient to achieve long-term water conservation. For temporary water savings, one-sided messages that target high-consuming and relatively uninformed households seem effective.	Fielding et al. (2013); Michelsen et al. (1999); Syme et al. (2000)
	Increasing self-efficacy	Enhancing people's belief that they are able to implement the intended behaviour. Field experiments suggest that providing tips, advice, and concrete examples about how people can save water enhances water conservation behaviour. In particular, short, practical, and timely advices is effective.	Clark and Finley (2007); Jugert et al. (2016); Kurz et al. (2005); Lee and Tansel (2013);
Semi-reflective	Social norms	Behavioural patterns that are semi-consciously applied to conform to social environments. Experiments indicate that normative messages are effective. Long-term water conservation can be achieved by repeating these messages. Competitive-framed peer ranks appear effective for low consumers. Neutrally framed ranks are effective for high consumers.	Bernedo et al. (2014); Ferraro et al. (2011); Jaeger and Schultz (2017); Otaki et al. (2017);
	Framing	Selecting and emphasising certain aspects to achieve a desired interpretation by using unconscious biases in information processing. Experimental research has observed that messages framed as suggestive, emphasising direct impacts, or appealing to intrinsic motivation are more persuasive.	Katz et al. (2018); Kronrod et al. (2012); Zhuang et al. (2018)
	Tailoring	Data-driven personalised messages that increase recipients' responsiveness. Showing attitude behaviour discrepancies evokes a feeling of discomfort, triggering water conservation. Real-time information prompts temporary water savings. The literature is inconclusive about longer-term conservation habits.	Boyle et al. (2013); Davies et al. (2014); Liu et al. (2017); Tom et al., 2011
Automatic	Using emotional shortcuts	Evoking emotions in order to influence people's response to (unrelated) messages. Positive emotions may invoke cooperation and trust, and the use of humour can remove people's resistance. Appeals to fear can also encourage the desired behaviour, provided that people feel high levels of self-efficacy.	Fang and Sun (2016); Novak et al. (2018); Tijs et al. (2017)
	Priming	The exposure to one stimulus – such as words or a smell – influences a response to a subsequent stimulus. Unconsciously processed cues (primes) can lead to goal-directed cognition and behaviour. The use of primes is largely unexplored for domestic water conservation.	Baek and Yoon (2017)
	Nudging	The choice architecture that alters people's behaviour in a predictable way without forbidding or limiting freedom of choice. The principle is to make the 'better' option more convenient to select. Though nudges are rarely applied to stimulate water conservation, its potential is high.	Newell and Siikamäki (2013)

(system 2), where attitudes are formed in light of rational arguments, relevant experiences, and knowledge. In the automatic information processing route, choices are made on the basis of an automatic response (i.e. system 1), without the intervention of cognition. Given that System 1 and System 2, by definition, do not function in isolation of each other, we acknowledge that many BITs are situated within a continuum ranging from reflective to automatic behaviour (e.g. Institute for Government, 2010), with many BITs essentially being a subtle combination of both (e.g. Kahneman, 2012; Kelly and Barker, 2016). Within this continuum, a considerable number of BITs for water conservation could be referred to as semi-reflective information processing. The semi-reflective route centres on the formation of attitudes through rules of thumb and simple heuristics. To this end, people search for peripheral stimuli, that is, simple cues indicating which choices should be made. Such simple cues include the attractiveness and/or the credibility of the source, the length of the message, the number of arguments, or how other people behave. These three information processing routes provide a frame for systematically and inductively categorising the empirically oriented literature on BITs for domestic water conservation (Table 1).

Each BIT can address both water curtailments and the adoption of water-saving technologies. Adopting water-saving technologies consists of single events, whereas water curtailment behaviour depends on people's willpower to stick to their water-saving choices time after time. Accordingly, different studies observed a higher willingness to implement technology over behaviour change (e.g. Dalhuisen et al., 2003; Kempton et al., 1992). We, however, consider both water curtailments and the adoption of water-saving technologies as necessities for domestic water conservation that should be addressed through BITs. Before we delve into these mechanisms, we will first expand on the research design of this study.

2.2. Literature review methods

In order to obtain an up-to-date insight into the empirically tested mechanisms to enhance conservation behaviour in domestic water use activities, a structured literature review was done using Scopus and Web of Science. Firstly, we used the following keywords: Household Water Conservation Behaviour (n = 309), Behavioural Change Household Water Conservation (n = 38), Feedback Household Water Conservation (n = 42), Household Water Conservation Behaviour (n = 309), and Water Saving Behaviour Change (n = 89). Secondly, for the total number of papers (n = 787), the title, keywords, and abstract were examined and only papers that were related to behaviour mechanisms and domestic water use were selected (n = 93). Thirdly, all of these 93 resulting papers were read and further evaluated for inclusion. Inclusion criteria for the full review were based on empirically tested behavioural studies regarding the reduction of domestic water consumption, leaving 39 papers that were reviewed thoroughly. Fourth, by applying the 'snowball method', we used the reference list of articles to search for other relevant empirical studies about water conservation behaviour in households. As a result, a total of 52 papers formed the basis for this review. What follows is an analysis of (the effectiveness of) the different behaviour influencing tactics in the literature that was reviewed.

3. Results

In total, 52 papers were identified that include field experiments about domestic water conservation behaviour. From these studies, eight key reflective, semi-reflective and automatic BITs proved to be pivotal. Table 1 provides an overview of key applications of BITs for water conservation.

3.1. Reflective route of behavioural influence

The reflective route appeals to the conscious processing of information, where attitudes are formed in light of rational arguments, relevant experiences, and knowledge. Key BITs that work through this reflective route of information processing are *knowledge transfer* and *increasing self-efficacy*. It should be noted that these two tactics, like all other BITs presented in this paper, are not fully mutually exclusive, and it may, at times and to some extent, be conceptually and empirically difficult to distinguish between them.

Knowledge transfer: Providing information is a frequently applied technique to raise awareness, change attitudes and enhance water conservation behaviour. The rationale behind this tactic is that the more people know about water scarcity issues and water conservation campaigns, the more likely it is that their attitude towards water conservation will be positive (Syme et al., 2000). Media campaigns have been regularly used in response to drought crises. A combination of price incentives, water use restrictions and knowledge transfer is claimed to lead to roughly 10–25% savings, in particular during drought periods and predominantly in lawns and gardens (Syme et al., 2000; Kneebone et al., 2018; Michelsen et al., 1999). In particular, the wealthier, high-consuming households show the highest temporary water savings in response to these types of measures. When these high-consuming households are not well-informed about causes, impacts, and uncertainties of drought-related- issues, Salmon and Atkin (2003) argue that one-sided messages are most effective. Unlike two-sided messages that discuss both the pros and cons of curtailments, one-sided messages focus exclusively on the benefits of water curtailments. For an informed and often smaller target group, two-sided messages seem more reliable and persuasive, and may enable long-lasting water savings: not providing the cons would evoke suspicion in the eyes of these households. Experiments indicate that increased personal involvement in drought issues increases the short-term effectiveness of knowledge transfer (Fielding et al., 2013). For example, Borisova and Useche (2013) recorded short-term behavioural change (i.e. 31% savings) related to their workshops targeting irrigation water use in Florida, United States. However, the behavioural change was short-lived, and water consumption patterns returned to pre-experiment levels after one month. For this reason, many field experiments point to the importance of more frequent information transfer and repetition (e.g. Chang, 2013; Middlestadt et al., 2001; Borisova and Useche, 2013). However, due to the temporary and reactive nature of many water conservation campaigns, Syme et al. (2000) observe that little priority is given to the evaluation of the campaign's effectiveness in the long run. In addition, various measures such as price increases and water use restrictions are often taken simultaneously, complicating the assessment of knowledge transfer as an independent strategy. As such, no definitive statements of the long-term effectiveness of large-scale knowledge transfer campaigns can be made (Syme et al., 2000; Wang et al., 1999). In fact, beyond self-report questionnaires (where people indicate what they have learned or how they behave), surveys assessing the actual increase in knowledge show generally disappointing results (Syme et al., 2000; Schultz et al., 2016; Hamilton, 1985; Berk et al., 1993). In particular, more generic knowledge about water or energy conservation has shown to provide little incentive to change habits (e.g. Abrahamse et al., 2005; Kurz et al., 2005; Landon et al., 2018). In sum, the evidence we have seen suggests that knowledge transfer is an important means to make people more receptive to water conservation (Syme et al., 2000; Stern, 1999), but is in itself insufficient to foster behavioural change in the long run.

Increasing self-efficacy: Increasing self-efficacy involves empowering end-users in the belief that they have the ability to implement their intended behaviour. Many studies indicate that most households are motivated to save water, but fail to translate this into water conservation behaviour (e.g. Liu et al., 2015; Kollmuss and Agyeman, 2002; Randolph and Troy, 2008; Hurlimann et al., 2009). As such, Jugert et al. (2016) suggest that knowledge transfer is only meaningful when people know how they can change their behaviour and consider this feasible. Many media campaigns focus on information transfer to enhance awareness but do not target specific action (i.e. enhance self-efficacy) that would be required to convert a change in attitude into actual water conservation (March et al., 2013; Dascher et al., 2014). Based on 728 completed questionnaires collected during the 2003 summer droughts in Bulgaria, Clark and Finley (2007) found that environmental attitudes and concerns about future water shortages were significant but relatively weak determinants of water conservation behaviour. The respondents reported a lack of self-efficacy as an explanatory factor for continued water inefficiencies. Accordingly, Lee and Tansel (2013) retrofitted 271 senior or low income households with high-efficiency household appliances, which increased their sense of self-efficacy to mitigate droughts. Over 80% of the participants reported positive attitudes for the water conservation programme, and a strong correlation between this positive attitude and actual water savings was found. Kurz et al. (2005) investigated how specific behaviour can best be enhanced by increasing people's self-efficacy. In their 166 Australian household experiment, the impact of providing information through leaflets and attunement labels (labels indicating use of water by different appliances in the house) was scrutinised. The leaflets included detailed information about the importance of conserving energy and water, as well as short facts, tips, and questions about the environmental impact of the energy use and water use of various household appliances. By contrast, attunement labels were installed at specific household appliances (e.g. at the shower, lawns, and garden hose) and provided similar information as the leaflet but specified for the appliance in question. The six-month experiment revealed that information leaflets had no impact on water use, whereas the attunement labels resulted in water savings of 23%. Arguably, the attunement labels repeatedly improved peoples self-efficacy of using the particular appliance when they were about to use it.

3.2. Semi-reflective route of behavioural influence

Through the semi-reflective route, attitudes are formed by rules of thumb and heuristics. This route relates to people's search for stimuli, i.e. simple cues indicating which choices should be made. This includes, for instance, the attractiveness and/or the credibility of a source, the length of the message, and the behaviour of other people. In the literature, three key BITs that work through this semi-reflective route of information processing can be identified: *social norms, framing*, and *tailoring*.

Social norms: Social norms as a BIT refers to a variety of behavioural patterns that people apply to conform to their social environment. Research has consistently shown that when individuals are confronted with information that describes their behaviour in relation to their peers, or to peers expectations, aligned with a message concerning the appropriateness of that behaviour, they are likely to bring their behaviour into conformity (Cialdini et al., 2006; Landon et al., 2018). Many field experiments have assessed the impact of normative messages on water conservation behaviour. For example, Jaeger and Schultz (2017) ran an experiment in which 8876 Californian households under a 25% water use restriction were randomly assigned to receive door hangers with either 1) water use restriction information (i.e. *information-only*); 2) a reminder of the penalties (e.g. $500 fine) of violating the water use restrictions (i.e. *strong-warning*); 3) a *normative-message* stating that over 80% of households in their community were abiding to the water use restrictions. Both the households that received the strong-warning and the normative-message were asked to commit to the water use restrictions by giving their signature. The results show that the information-only strategy neither decreased water consumptions nor influenced commitment levels. The strong-warning strategy did lead to a great number of people committing themselves and immediately saved water (an average of 5.56%). However, within four months, consumption returned to pre-experiment levels. Remarkably, those who committed when subjected to the normative-message, initially showed a lower average water reduction (3.53%) but increased water conservation to 8% after four months, suggesting that the normative message may enable prolonged commitment to water savings. This finding is consistent with that of Ferraro et al. (2011), who also found a long-term impact for strong normative messages. In their study, 11,699 households received exclusively technical advice, i.e. information about the pros and cons of water conservation. Another 11,695 households were assigned to weak social norm treatment, and 11,699 households were subject to a strong social norm. The weak social norm group initially reduced water consumption by 2.7%, and the strong social norm group saved approximately 4.8%. Over the next two years, water savings only continued for those who had received the strong social norm (2.6%). Similarly, in a randomised experimental design with over 100,000 households, Bernedo et al. (2014) found that a one-time message combining technical information, moral suasion, and social comparisons resulted in long-lasting impacts. Water use declined nearly 50% after one year, and, peak water reduction was observed four months after the targeted period (a drought event), and impacts remained detectable six years later. In addition, in a 5565-household experiment, Landon et al. (2018) observed a significant impact for normative messages (i.e. 3% savings) and emphasised the importance of repeating normative messages over time.

The effect of normative comparisons, such as peer ranks, appear to differ for low-consuming and high-consuming households. For example, in a 3896-household experiment, Bhanot (2017) found that neutrally framed peer-ranks, such as a neighbourhood average water consumption, resulted in an undesirable increase in water use for low-consuming households. By contrast, a competitive peer-rank (i.e. a message communicating a household's water use as a rank of all households in the neighbourhood) did lead to further water savings in low-consuming households. However, competitive peer-ranks also led to an undesirable increase in water use in high-consuming households. Other studies also suggest that competitive peer-ranks are more effective for low water consumers, whereas neutrally framed ranks seem more effective for high consumers (Schultz et al., 2016; Landon et al., 2018). In harmony with these studies, Otaki et al. (2017) observed that high consumers conserved water in response to emoticons, whereas low water consumers saved water when they saw improvement in their water saving results. Importantly, when the average water use is communicated to people with a below-average consumption, these people tend to use more water. In this case, the average water use is in fact a social norm, and people tend to bring their behaviour into conformity with such a social norm. In order to anticipate this, it is suggested that normative messages such as a smiley face can be used (Schultz et al., 2007, 2016; Perren et al., 2016). In a 100,000-household experiment, Ferraro and Price (2013) observed that social comparison messages had a greater influence than information transfer. In particular, the highest water-consuming households temporarily reduced water consumption.

Interestingly, some authors suggest that personal experiences with drought issues may weaken the impact of normative messages, since these individuals already feel a moral obligation to conserve water (e.g. Göckeritz et al., 2010; Schultz et al., 2007, 2014). For example, through a 12-month experiment with 221 households Fielding et al. (2013) observed that the impact of 1) only water saving information, 2) information plus a descriptive norm, and 3) information plus tailored end user feedback, all had similar impacts on water savings. The authors suggest that high personal involvement may be the explanatory factor, since water supplies were almost depleted just before the experiment started. However, not all studies are confirmative. For example, in a 166 Australian household experiment, Kurz et al. (2005) did not observe a water savings in response to socially comparative feedback.

Framing: Framing as a BIT refers to selecting and emphasising certain aspects of a message in order to achieve a desired interpretation or perspective. It has been noted in the literature that response to the same request differs greatly depending on how it is framed. The framing often includes the use of unconscious biases. Useful biases in this light are the tendency to prefer avoiding losses to acquiring equivalent gains (loss aversion), the fact that direct impacts are perceived as more important than impacts further ahead (i.e. hyperbolic discounting), the preference for the current state of affairs (i.e. status quo), and the tendency to search for, favour, and interpret information that confirms one's existing attitudes (i.e. confirmation bias; Kahneman, 2003). For example, Mankad and Tapsuwan (2011) observed that when people feel a high risk is involved (i.e. the prospect of loss), people are more willing to abandon the status quo by adopting alternative water systems. Although the role of gain loss framing has been widely investigated in social and cognitive psychology, its applications in the field of pro-environmental behaviour is sparse, especially for water conservation (e.g. Pelletier and Sharp, 2009; Rothman et al., 1999). For promoting pro-environmental behaviour and water conservation, experimental research focussed on the impact of framing messages as 1) direct impacts or future impacts (i.e. hyperbolic discounting), 2) assertive or suggestive formulations, and 3) appeal to intrinsic or extrinsic motivations. The framing in direct or future impacts of water conservation was tested in an experiment with 133 participants from China and the United States (Zhuang et al., 2018). The results indicated that present-framed messages lead to more positive attitudes toward water conservation than future-framed messages. In a longitudinal experiment including 1500 households, Katz et al. (2018) analysed the effectiveness of assertive messages (e.g. you must conserve water) versus suggestive messages (e.g. please consider conserving water). They observed that suggestive messages result in more water conservation behaviour in households. Accordingly, Kronrod et al. (2012) showed that suggestive appeals are more effective when recipients lack strong initial conviction, which might be the case for domestic water conservation. In addition, Katz et al. (2018) suggest that people might perceive water as a basic need, which may reduce the appropriateness of an assertive tone. In a one-week experiment including 97 households, Tijs et al. (2017) found that intrinsically motivating environmental appeals were most effective in decreasing participants' shower frequency. In fact, different studies have made it plausible that intrinsic goal-framing (e.g. saving water for a sustainable future), relative to extrinsic goal-framing (e.g. saving water to reduce costs), results in more engagement and a more profound processing of the information related to an activity (Vansteenkiste et al., 2006; Pelletier and Sharp, 2009).

Tailoring: Tailoring refers to a variety of methods to communicate individualised messages in order to increase the effects of such communications. For domestic water conservation, there has been much emphasis on providing near real-time information on water use through *smart meters* (e.g. Anda et al., 2013). By confronting people with their actual water use, people may experience a cognitive dissonance between this feedback information and how they consider themselves, or how they want others to view. Cialdini et al. (2006) suggest that such a feeling of discomfort may prompt water conservation behaviour. In comparison with more conventional face-to-face contact, tailoring through the use of smart meters is advantageous because it saves time and costs (Jaeger and Schultz, 2017). Both Walther et al. (2011) and Tom et al. (2011) indicate that online commitment produces effects similar to an in-person commitment. Combining ICT software with smart meters or other devices can therefore be considered as effective for both temporary and long-term water conservation behaviour. Various water use feedback trials, including paper-based messages and online communication portals, resulted in temporary water saving (e.g. Schultz et al., 2016; Boyle et al., 2013; Liu et al., 2017). Notably, through tailored leakage communication, including leakage feedback from 803 households that had detected leaks, Britton et al. (2013) observed an 89% reduction in leakages. Tom et al. (2011) experimented with two types of tailoring. The first group (of 50 households) received a detailed report on the water use for each individual household application based on one-week smart meter measurements as well as tips and advice for water savings. 84% of these households reduced water consumption, with an average of 39.05%. The second group of 50 households received a 1-h visit from a trained water efficiency professional, followed 5–10 days thereafter with a written report providing the findings and water saving recommendations. In this group, 62% of the households reduced water consumption, with an average of 20.48%. The longer and more detailed feedback through smart meters therefore seemed more effective, at least for the shorter term. Davies et al. (2014) observed long-term water savings triggered by tailored feedback. Based on a long trial with smart meter In-Home Displays (IHDs) that included 1923 people residing in 630 households, a water saving of 6.8% was observed over the duration of the two-year experiment. In fact, even three years after the experiment had ended and the IHDs were removed, savings were still 6.4%. The IHD proved to be most effective if it was placed in a high-traffic position within the household. In the same vein, studies suggest that personalised feedback can result in substantial savings in kitchen sinks (Rehman et al., 2018) and showers (Stewart et al., 2013). Showering volumes before and after the introduction of a visual display monitor resulted in a significant immediate water savings of 15.40 L (27%). However, shower volumes eventually reverted back to their pre-intervention level after four months. Other studies also indicate that salient real-time information about water use in itself may not provide enough motivation for achieving long-term water savings (Nguyen et al., 2018; Boyle et al., 2013). The length of feedback exposure, the location, display and timing are highly relevant for its effectiveness. In addition, it may be hypothesised that the activity itself may be of influence. For example, showering may be a form of relaxation, which is more difficult to change than saving water in kitchen sinks or watering lawns and gardens.

3.3. Automatic route of behavioural influence

In the automatic route of information processing, choices are made on the basis of an automatic response (i.e. system 1), without the intervention of cognition. Key BITs that work through this automatic route include *using emotional shortcuts, priming* and *nudging*.

Using emotional shortcuts: Using emotional shortcuts refers to the process of evoking emotions in order to influence people's response to often unrelated messages. Many studies have shown that promoting conservation behaviour with information transfer, such as simple statistics, is not inspiring enough (e.g. Fang and Sun, 2016; Norman, 2005). In contrast, animated videos or images can have the potential to evoke positive or negative emotions that help people learn and make more eco-friendly decisions (Norman, 2005). Positive emotions invoke more incentive to adopt a cooperative and trusting approach (Niedenthal, 2003), whereas negative emotions appeal to a person's moral conviction. In an experiment with 93 participants, Fang and Sun (2016) tested three interface formats that ranged from abstract to figurative and from emotionally neutral to evoking affection. The three interfaces were: 1) numeric, 2) a water droplet, and 3) a visualisation of water use impact in the form of a swimming fish, an animated image that could evolve into the death of a fish if water use increased (i.e. a negative emotion). The intrinsic motivation to reduce water proved to be significantly higher for the swimming fish visualisation. In a two-week experiment, Tijs et al. (2017) tested the impact of monetary versus environmental appeals on the showering frequency of 97 households. To this end, a booklet was used which included information and tasks about the environmental impact of showering (e.g. potential CO_2-reduction or monetary savings). The participating households were encouraged to make a blue-coloured plastic door hanger in the shape of a droplet with, write their water saving goal on it, and place it on the shower door. Even though the participants reported that the monetary appeals had a larger impact on them, this study showed that it was these environmental appeals that actually led to a larger reduction in showering frequency. The authors suggest that the environmental appeal activated already existing environmental values and that a feeling of hypocrite was activated when showering frequencies were not reduced. In addition to environmental versus monetary appeals, the use of humour has been widely investigated in the field of advertising (Liang et al., 2018). Humour increases a receiver's attention to information and reduces initial resistance to the message that receivers may have (Kahneman, 2003). As such, humour alone generally does not lead to increased persuasive effects but is often coupled with other BITs to elicit a favourable response from receivers (Liang et al., 2018). Gamification is another approach involving game-type elements to influence people's emotions. For domestic water conservation, the physical digital card game called *Drop!* is an example of a gamified nudge. The game is about a little girl who wants to save water and a clumsy monster who keeps spilling water. Because the game associates water saving with achievement, players have an entertaining type of normative incentive to conserve water (Novak et al., 2018).

Priming: Priming refers to use of unconsciously processed cues in the environment (i.e. primes), such as words or a smell. Research suggests that well-designed primes can lead to goal-directed cognition and behaviour and can reinforce behaviour that is in line with an individual's long-term goals (Papies, 2016). In an interdisciplinary literature review, Weingarten et al. (2016) observed that exposure to goal-related words can reliably trigger goal-directed behaviour, in particular if the primed outcome is valued by the individuals. Such primes may be completely unrelated to the topic of water. Prime tactics may be applied by water utilities to activate water-saving choices through, for example, communication in their water bills, websites, or engagement programmes (Tate et al., 2014). An appealing example of primes for water conservation is provided by Baek and Yoon (2017). They investigated the impact of positive and negative primes in the framing of messages to conserve water in an experiment with 275 students. Through text messages they primed either guilt or shame in relation to sexually transmitted diseases (STDs), based on the insight that feelings of guilt invoke an approach behaviour (which is reinforced by gain-framed messages) and shame evokes avoidance behaviour (that is reinforced by loss-framed messages) (e.g. Schmader and Lickel, 2006). Accordingly, students who were primed to feel guilty about STDs, expressed a stronger intention to conserve water in response to a gain-framed message (i.e. *Saving water means saving money, reducing water pollution, and protecting the environment*). In contrast, students who felt ashamed showed a higher conservation intention in response to a loss-framed message (i.e. *Failure to save water means wasting money, increasing water pollution, and hurting the environment*). The diverse use of primes is largely unexplored for domestic water conservation applications.

Nudging: Nudging refers to the choice architecture that alters people's behaviour in a predictable way without forbidding any options or limiting the freedom of choice (e.g. Thaler and Sustein, 2008). Nudging goes one step further than messages framing by altering the choice architecture in order to make the 'better' option more convenient or salient. The choice architecture therefore includes different BITs. Nudges are well-known in marketing psychology. For example, Ariely (2008) evaluated with how people's choices were influenced by provision of different options. Participants were asked if they wanted to subscribe to a $59 digital journal or the same journal in digital plus printed version for $125. Only 32% of the participants went for the expensive choice. However, by adding a 'decoy' option to pay $125 for only a printed version, resulted in 84% of the participants choosing for the $125 digital plus printed version (i.e. a 52% increase). The nudging principle of adding a third option which is close, or in this case equal, to the highest price but with a significantly lower quality is known as the *decoy effect*. Accordingly, providing people with an initial figure (e.g. a price or shower duration) serves as a cognitive anchor that strongly steers people's behaviour (i.e. *anchoring*). Energy efficiency labels form an interesting application of nudging that can also be applied to domestic water conservation. For example, Newell and Siikamäki (2013) observed that energy labels that provided a suggestive grade (i.e. the EU-style or Energy Star label) and emphasised certain bits of information, resulted in more energy conservation behaviour. Despite its potential, nudging appliances for domestic water conservation largely remain unexplored. In this context, nudges might be useful with respect to the water supplier's customer communication, water use labels, and in the way water-efficient household appliances options are presented.

4. Discussion

4.1. Current state of the literature on water conservation behaviour

Many places around the world already experience seasonal or permanent water stress (WRG, 2009). Despite this alarming development, water is often perceived to be abundantly available and is provided at low costs for domestic users. At the same time, domestic water use in wealthier countries is high, ranging from 200 to 600 L per person per day. In this context, BITs provide both a highly necessary and attractive alternative for enhancing water conservation behaviour. Different literature reviews have been provided about the influence of specific BITs in the area of health decisions (e.g. Aarts, 2007), energy conservation (e.g. Abrahamse et al., 2005) and pro-environmental behaviour (e.g. Steg and Vlek, 2009). Empirically oriented research in the field of water conservation is, however, much more limited. Moreover, and unlike reviews focussing on one specific behaviour intervention, such as social norms (Schultz et al., 2007) or word priming (Weingarten et al., 2016), integrated reviews of different BITs with respect to a specific applicable context are sparse. This review provides a comprehensive overview of the literature on a variety of behavioural influencing tactics strategies to conserve water at the household level.

With respect to the location, it becomes apparent that of these 52 studies, the majority were undertaken in developed countries experiencing water stress, whereas water stress is clearly paramount in many other parts of the world too. Second, with respect to the year of publication, knowledge transfer and increasing self-efficacy, i.e. BITs related to the reflective route, have been the focus in the earliest studies, whereas studies about social norms, framing, and tailoring, i.e. BITs related to the semi-reflective route, are more recent. Studies about the use of primes, emotions and nudges, i.e. BITs related to the automatic route, are still sparse in the field of domestic water conservation, but they seem to have been increasing in recent years (Supplementary materials 1 and 2). Various studies report experiments with a combination of BITs, and suggest that smart integration of different BITs can increase the effectiveness of behaviour influencing (e.g. Fielding et al., 2013; Reddy et al., 2017; Jaeger and Schultz, 2017).

Although this literature has provided various important clues on the effectiveness of the different BITs, based on the current progress in empirically oriented studies reviewed in this paper, it is too early to draw definitive overall conclusions. Firstly, this relates to the fact that most experimental research about BITs are susceptible for the so-called 'Hawthorne effect', meaning that participants behave differently because they know that they are being observed. In particular studies about commitment-making are susceptible because commitment requests often are preceded by a request to participate in the study (Jaeger and Schultz, 2017; Katzev and Johnson, 1983). To limit the Hawthorne effect, it is advised that both the number of participants and the experiment's duration be increased (Darby, 2006). Secondly, most large-scale water conservation media campaigns tend to be a rather reactive response to droughts events. A combined package of water

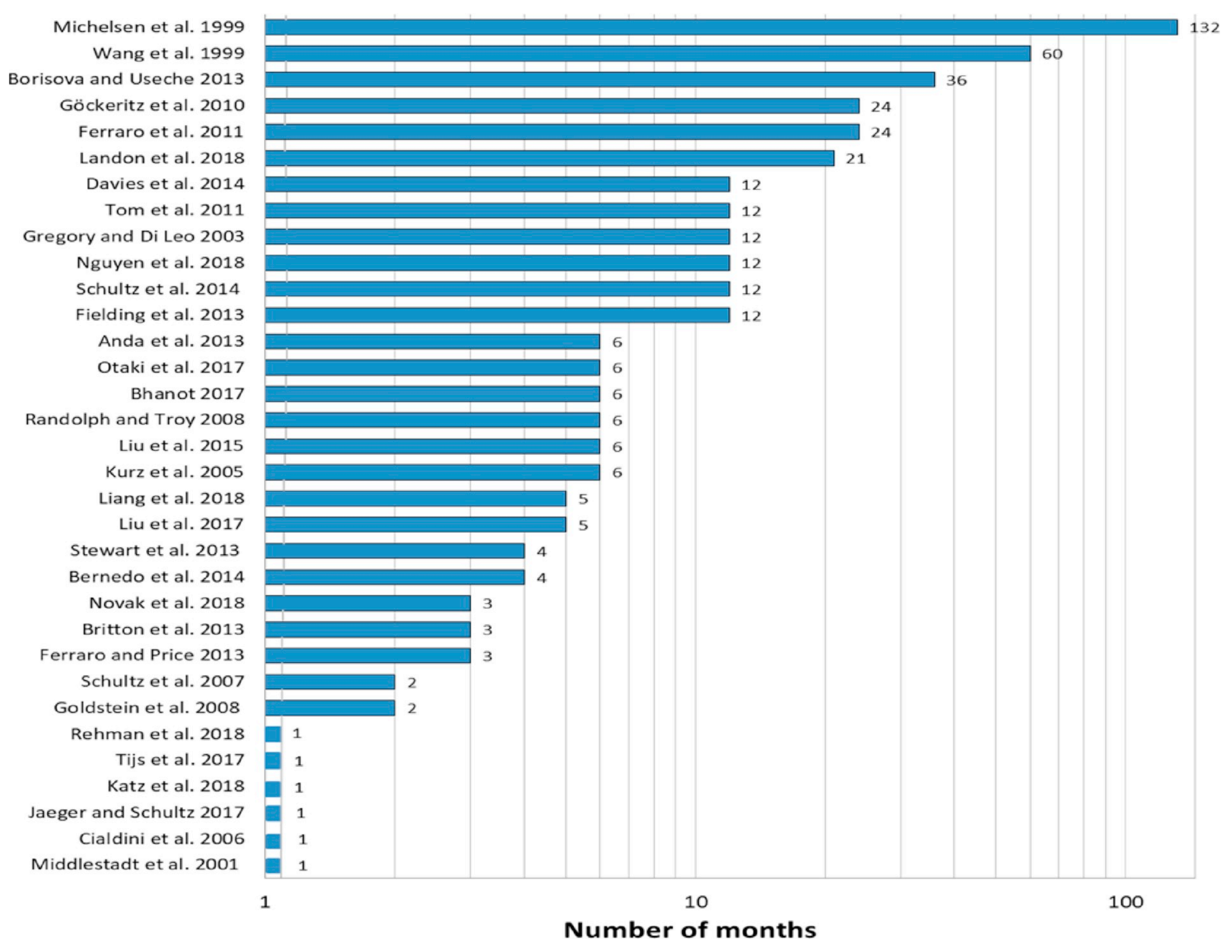

Fig. 1. Intervention periods in months of field experiments. Of a total of 52 studies, only 12 studies have an intervention period of a year or longer, 21 studies have an intervention of 1–6 months, and 19 studies have no intervention period or intervention period is not specified (not shown in figure).

curtailment measures that includes price incentives, water use restrictions, and information campaigns is initiated and often achieves temporary water savings. However, consumption patterns typically return to pre-crisis levels when the drought has ended. In this case, the role of reflective routes of information processing have been poorly evaluated, and when they are evaluated, results tend to be disappointing. A final limitation in determining the effectiveness of the different BITs relates to the fact that most studies related to semi-reflective or automatic BITs focus on the impact of (a few) individual BITs introduced in relatively short intervention period or in a one-time message. This papers examined 19 experimental studies with intervention periods of less than a month, 21 studies with an intervention of 1–6 months, and only 12 long-term interventions varying from 12 up to 132 months (n = 12; Fig. 1). Nonetheless, this time component is quite relevant in interpreting the intervention's effectiveness (Fielding et al., 2013). Most studies observe relative high water-saving impacts of BITs in 1–3 months after the intervention period has started. However, many studies with intervention periods lasting more than three months observe water savings that return to pre-intervention levels. Indeed, it seems that those BITs that have initiated water conservation behaviour may not be the most applicable to effectively prolong and reinforce these newly formed habits. In order to effectively continue water conservation behaviour, more empirically oriented studies are needed that test the water-saving impact of different BITs over a prolonged intervention time.

4.2. Towards integrated strategies to reduce domestic water use

The review presented suggests that the conjunctive use of BITs is more effective. For instance, we have observed that knowledge transfer is only meaningful when people know how they can change their behaviour and consider this feasible. Likewise, it appears that real-time water use feedback provided through smart meters results in long-term savings only when such tailored feedback is reinforced by repetition, social norms, and message framing incentives. In turn, the water conservation impact of social norms or message framing appear to be short-lived if not supported by tailored feedback or information on the importance of saving water. On the other hand, we have seen that the use of emotions and primes, which work through the automatic route of information processing, prompt momentary water-saving responses, especially if incorporated in a choice architecture together with different BITs (i.e. *nudging*). In short, the empirical data suggests that in order to achieve long-term water saving habits, the well-aligned conjunctive use of reflective, semi-reflective, and automatic BITs is crucial. A particularly promising application of such an integrative approach is the use of persuasive technology (Hamari et al., 2014). One example in this regard is the ISS-EWATUS tool, which monitors water consumption for individual household appliances (e.g. shower or washing machine), communicated through a near real-time feedback mobile application that includes specific tips and advice on saving water. In doing so, Perren et al. (2016) integrated multiple BITs. In order to enhances people's perception that the system is able to help them achieve their water saving goals, messages were *tailored* and based on the household's recent and historical water use patterns; feedback was provided based on a specific water use classifications system, whereby each class had a different *message-framing,* including the use of normative emoji (i.e. *social norms*). In addition, the messages were framed to highlight inconsistencies between people's values and their actual water use (i.e. cognitive dissonance). For example: '*You are a high tech/high use consumer. High tech households like yours save water and energy by adopting efficient technology*☺*. However, although you are very concerned about the environment, your everyday routines use a lot of water and energy*☹.' Gain-framed messages were *primed* by displaying them in green, and loss-framed messages in red. Moreover, in order to increase the system's perceived credibility and feeling of trust, many tips demonstrating expertise were included (i.e. *information transfer* and *increasing self-efficacy*). The effectiveness of the conjunctive use of different BITs to save water resonates with other fields of research, such as public engagement around water reuse, where the limitations of 'standard' single BITs such as information provision have been flagged. More comprehensive approaches with a wide range of activities, appealing to both rational and emotional processes, seem to be more effective in a broader shift towards societal legitimisation of, for instance, water reuse (Smith et al., 2018) or water conservation (Hegger et al., 2011).

5. Conclusion

This paper provides an overview of the current state of the literature on influencing domestic water conservation behaviour. In doing so, we have inductively identified eight BITs that constitute foci in this area of study. We conclude that the current body of literature is promising and provides a useful body of evidence on the range and effectiveness of individual water conservation mechanisms, especially how to initiate specific water-saving habits. However, beyond individual tactics, the literature suggests that a conjunctive use of a variety of BITs into overall strategy is required. In order to develop a framework that supports policy makers and water managers designing behaviour change strategies, future research is called for to extend these findings, as well as to deepen our understanding of the causal mechanisms. Such a framework needs to be comprehensive and coherent, and it should adhere to an overarching model of behaviour (Michie et al., 2011). Future research is also needed to further examine the effectiveness and applicability of the BITs in the automatic route, given that, at present, studies based on this route of enhancing water conservation is rather underrepresented in literature. Finally, in view of the relative limited number of multi-year studies, we believe that work remains to be done towards elucidating how to effectively prolong and reinforce newly formed water conservation routines. In view of this, we strongly encourage field experiments that focus on the conjunctive use and alignment of different behaviour influencing tactics. Especially the role of repetitive messages, primes, and nudges that reinforce previously introduced normative messages, tailored feedback, or knowledge, seem to be promising approaches to sustaining water conservation behaviour in the long run.

Acknowledgements

The authors would like to thank Kees van Leeuwen, Jos Frijns, and three anonymous reviewers for their constructive comments on the early versions of the manuscript. This paper was based on research financed by the joint research programme that KWR carries out for the Dutch drinking water companies and De Watergroep, Flanders.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2019.06.126.

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