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Systematic Review of Household Water Conservation Interventions Using the Information–Motivation–Behavioral Skills Model

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Abstract

Increasing droughts and water shortages are intensifying the need for residential water conservation. We identify and classify 24 water conservation studies using the information–motivation–behavioral skills (IMB) model by categorizing interventions based on content and water conservation effectiveness. This synthesis revealed several insights. First, all of the interventions used information, motivation, and/or behavioral skills, suggesting that water conservation interventions can be interpreted within the IMB framework. Second, interventions with two or more IMB components led to reductions in water usage, but the average effect sizes

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between different types of interventions were similar and there was a considerable range around these averages. To the extent that intervention effectiveness is driven by populations lacking specific IMB components, more elicitation research to identify gaps in specific populations could support greater effectiveness. Designing interventions explicitly with the IMB model would facilitate comparability across studies and could support a better understanding of water conservation interventions.

Keywords
water conservation, drought, information–motivation–behavioral skills model, interventions, sustainability, review

Faced with increased droughts (Cook et al., 2015; Diffenbaugh et al., 2015) and unprecedented water shortages (Bates et al., 2008), water utilities, governments, and community-based organizations are using diverse methods, including behavioral interventions, to reduce water use. Although there is a wealth of correlational research identifying psychological factors associated with water use (for reviews, see Fielding et al., 2012; Hurlimann et al., 2009; Russell & Fielding, 2010), water conservation studies report mixed findings on the efficacy of psychological factors in reducing household water use. We propose that the information–motivation–behavioral skills (IMB) model provides a theoretical lens to explain mixed findings, identify future research directions, and design actionable intervention strategies.

Many types of interventions can reduce water demand, including pricing and use restrictions (Inman & Jeffrey, 2006). Higher prices lead to less water use (Olmstead, 2010; Olmstead & Stavins, 2009). However, pricing changes can be slow to implement, can be politically unattractive for elected water boards, and can have limited impact, especially for higher income users (De Oliver, 1999). In a recent case, a 1% water price increase only led to a 0.1% decrease in demand (Los Angeles Department of Water and Power, 2010). Formal restrictions can also be effective (Haque et al., 2014; Kenney et al., 2004; Renwick et al., 2019) and are common (Dixon et al., 1996; Palazzo et al., 2017). However, restrictions are also limited by political will (Cooper et al., 2011; Stoutenborough & Vedlitz, 2014), can be difficult to enforce (Sisser et al., 2016), and can be less effective than other means (Brennan et al., 2007; Grafton & Ward, 2008; Olmstead, 2010; Olmstead & Stavins, 2009). Moreover, heavy-handed restrictions are unlikely to persist when drought severity decreases (Knickenmeyer & Taxin, 2018). Similarly, behavioral interventions have costs and benefits. Interventions aimed at voluntary

reductions are flexible and cheap because most water districts already communicate with their users, and these interventions can lower both short- and long-term operating costs to utilities, ultimately lowering costs for customers (Chesnutt et al., 2018).[1] However, there are no prescribed best practices for implementing effective behavioral interventions targeting reductions in residential water consumption.

We use the IMB model to synthesize the similarities and differences observed across 24 behavioral intervention studies, with a specific focus on the content of messages shared with water users. The IMB model was first designed by Jeffrey and William Fisher and applied to health communications (J. D. Fisher & Fisher, 1992). These behavioral scientists created effective HIV/AIDS prevention interventions by providing specific IMB intervention components to at-risk individuals (J. D. Fisher & Fisher, 2000). Our rationale for extending the IMB model to the water conservation domain is threefold. First, the three components of the model closely mirror the approaches implicitly used in existing water conservation interventions. Much water conservation messaging includes informational components, typically in the form of drought awareness (Anderson, 2019; Syme et al., 2000). In addition, interventions often include specific attempts to motivate water users and provide them the skills to actually reduce their water use. Given this, it is possible to categorize interventions by their inclusion of information (I), motivation (M), and/or behavioral skills (B). Second, for HIV/AIDS prevention, the IMB model was effective for sustained behavior change, which is similarly required for many household water use reductions (e.g., shorter showers, running full loads of dishes and laundry). Third, the IMB model offers a prescriptive process for conducting research that encompasses elicitation, design and implementation, and evaluation that may prove useful in the varied local contexts of water use interventions.

Below, we identify 24 experimental and quasi-experimental studies that use messaging to try to change water use in noncommercial settings and then classify these studies using the IMB model. We compare the effect sizes of different intervention components on water conservation. These findings emphasize the importance of the combined effects of IMB in promoting household water conservation. Elicitation research can help to identify deficiencies that can be rectified with interventions tailored to diverse field settings. We conclude with a discussion of how the IMB model can inform future water conservation efforts.

The IMB Model

The IMB model posits that individuals must have the requisite information, motivation, and behavioral skills to engage in and maintain behavior change

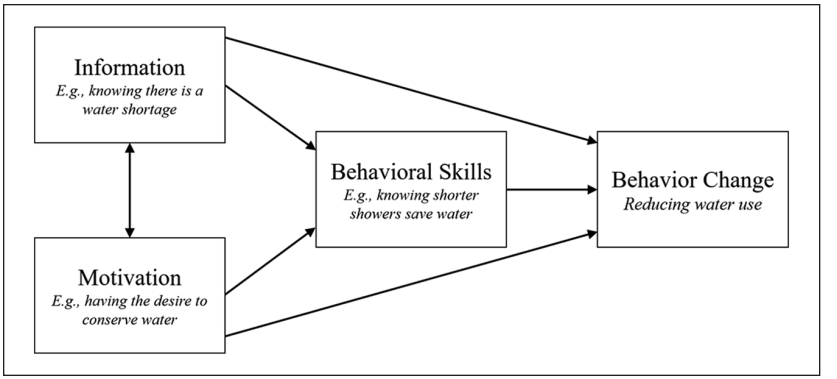

Figure 1. The information–motivation–behavioral skills model with water conservation examples in italics.

(W. A. Fisher et al., 2014). In other words, when individuals are informed about a problem, motivated to act, and have the skills to act, they will be most likely to change their behavior. Targeting low levels of one or more of these factors can support behavior change (see Figure 1). The IMB model further distinguishes itself from other behavior change models (e.g., the theory of reasoned action, Fishbein & Ajzen, 1975; transtheoretical model, Prochaska et al., 1992) by outlining a three-step approach to designing interventions that are tailored to a specific population: elicitation, design and implementation, and evaluation. Thus, the IMB model provides a theoretical understanding of behavior change and a guide for designing theory-informed interventions.

The IMB model has been used successfully in multiple health domains (for a review, see W. A. Fisher et al., 2014) and is increasingly used in other fields, including conservation (Seacat & Northrup, 2010). A meta-analysis of sexual risk-reduction interventions including more than 174 studies and 116,000 participants found that, compared with other theory-informed interventions, approaches that included informational, motivational, and behavioral skills components led to greater behavior change (Smoak et al., 2006; see also, W. A. Fisher et al., 2014).

I: Information (About the Problem)

Behavior change is more likely when individuals have accurate knowledge of a problem and its consequences. Not understanding how a behavior is related to negative outcomes can interfere with changing the target behavior (e.g., not knowing that household water use leads to reductions in finite water

supplies; W. A. Fisher et al., 2006). In line with the IMB model, we define water conservation information as individuals' knowledge about the problem—here, that water supplies are low. This conceptualization of information differentiates the concept of problem awareness from information about solutions to the problem or information about the actions of others. Here, we limit information to refer narrowly to problem awareness, following the IMB definition.

There is a general lack of problem awareness in the area of household water use. Many water consumers do not understand the water supply (Attari et al., 2017). Because of low knowledge, water conservation campaigns often focus on information about water scarcity and the consequences of failures to reduce water use (Syme et al., 2000). In correlational studies, more knowledge is associated with more conservation intentions (Trumbo & Keefe, 2005) and self-reported behaviors (Moore et al., 1994; Murphy et al., 1991). However, information campaigns alone are frequently insufficient for behavior change (Seyranian et al., 2015), may not be cost-effective (Bruvold, 1979), and may not promote enduring change (Syme et al., 2000).

M: Motivation

The IMB model posits that behavioral change is more likely when individuals are motivated. We define motivation as the activation of internal drives or concerns (e.g., goals) that direct and energize an individual to engage in a behavior (Pittman, 1998). Multiple theories provide insights regarding motivational interventions (e.g., theory of planned behavior, Ajzen, 1991; social norms theory, Cialdini et al., 1990; self-determination theory, Ryan & Deci, 2000; value-belief-norm theory, Stern, 2000). In contrast, the IMB model does not identify which motivation tools to use in interventions but does recognize the importance of motivation. Combining the IMB model with the above theories informs the design of the motivational components in interventions, including using such tools as social norms or identity appeals to increase motivation and thereby change household water use.

Intervention tools that increase motivation to engage in pro-environmental action are associated with water conservation. Some interventions seek to provide motivation by highlighting the behavior of others (i.e., communicating social norms). These social norm interventions have been effectively applied to individual behaviors including energy conservation, littering, recycling, alcohol consumption, payment of tax debts, and gambling (Allcott, 2009; Hallsworth et al., 2017; Larimer & Neighbors, 2003; Perkins, 2002; Reno et al., 1993; Schultz, 1999). Given the success of the social norms approach, researchers have also used social norms to reduce water use

(Richetin et al., 2016; Sparkman & Walton, 2017). Although social norms are a commonly used and successful behavior change tool, there are many other tools and techniques available to change behavior (e.g., implementation intentions, commitments, social role models; see Michie et al., 2008; Steg & Vlek, 2009) that can be incorporated into an IMB intervention as appropriate to the context.

B: Behavioral Skills

The third component of the IMB model is behavioral skills, which is individuals' objective and perceived ability to engage in a target behavior. Although information (problem awareness) and motivation may have direct effects on behavior when the target action does not require complex skills (J. D. Fisher & Fisher, 2000), the IMB model proposes that information and motivation often indirectly influence actions via behavioral skills (see Figure 1), consistent with the reasoned action model (Fishbein & Ajzen, 1975). That is, higher levels of information and motivation lead individuals to *believe they can* engage in and/or *objectively be able to* engage in the target behavior, moving them to acquire the skills necessary to undertake the behavior (J. D. Fisher & Fisher, 1992).

Behavioral skills are also associated with water conservation. Research most often measures behavioral skills by asking about an individual's self-efficacy (i.e., one's perceived and objective abilities to engage in a given behavior). In one study that included three different communities, individuals' efficacy beliefs (i.e., that they could engage in actions to save water) were associated with a range of water conservation behaviors (e.g., installing low-flow shower heads, repairing leaks), even when accounting for environmental identity, past actions, norms, and demographics (Trumbo & O'Keefe, 2001). Self-efficacy beliefs are also a predictor of increased intentions to save water when controlling for attitudes, norms, demographics, environmental attitudes, and levels of climate change knowledge (Clark & Finley, 2007; see also, Harland et al., 1999; Lam, 1999). Importantly, individuals often report they lack behavioral skills for water conservation (Walton & Hume, 2011) and they vastly underestimate the water use of household appliances (Attari, 2014). Other domain-general theories of behavior change also recognize the importance of perceptions of abilities (e.g., perceived behavioral control in the theory of planned behavior, Ajzen, 1991). Although self-efficacy is commonly what is measured (by asking about perceptions of individuals' skills and abilities), interventions to increase behavioral skills often provide "how-to" guides or tip sheets (e.g., take a 5-min shower; Kurz et al., 2005). In other

words, behavioral skills are commonly measured with self-efficacy scales and manipulated with how-to tips.

Designing Effective IMB Interventions

Based on the IMB model, one way to increase the effectiveness of the intervention is to conduct elicitation research (see W. A. Fisher et al., 2018, for discussion) via qualitative research methods, such as focus groups with target users, or quantitative methods, such as surveys. Population-specific characteristics can then be used to tailor the intervention design to provide exactly what the population requires to change their behavior. Not accounting for preexisting levels of IMB components can lead to confusing results. For example, consider an intervention that did not work and was based on a motivation component. This null effect may be because the manipulation failed or because a population was already highly motivated. Without accounting for baseline motivation with elicitation research, it is harder to interpret the null effect and make recommendations for other populations like those with less motivation. In short, elicitation research can identify intervention targets based on which IMB components are low. After interventions, researchers can conduct additional evaluations to determine whether the intervention had the intended effect on those components. These outcomes further inform which future interventions might be most effective. This process of elicitation research is common in other fields as well, such as user-centered design (Kramer et al., 2000) and risk communication (Fischhoff & Scheufele, 2014).

Method

Current Study

We applied the IMB model to water conservation as a framework to understand how and why water conservation interventions influence behavior change. We first conducted a systematic review of water use interventions and coded whether the intervention conditions contained informational, motivational, and/or behavioral skills components. We then assessed which combination of IMB intervention components had the greatest impact on water conservation. The review followed the PRISMA guidelines as far as feasible to provide a transparent and standardized methodological approach (Moher et al., 2009). This included providing a publicly available search protocol, full search results, data extraction procedures, and discussion of possible biases. The complete review data are available at https://osf.io/mf2cg/?view_only=28b82da86d1143c0af193b541cc29e1e and complete protocol details are provided in the Supplemental Material.

Intervention Study Selection Procedure

Six keyword searches were conducted in the Google Scholar, PsycINFO, and EconLit databases using search terms intended to identify experimental or quasi-experimental studies of water conservation.[2] The keyword searches returned a total of 2,286 publications between January 1980 and June 2018. As Google Scholar returned more than 1 million results with the keywords, we only included the first 400 search results in the initial sample. For all searches, titles and abstracts were reviewed.

Four additional criteria were used to select papers for formal review within the IMB framework: (a) contained communication or messaging intended to reduce water use (i.e., not just infrastructure or pricing); (b) used an experimental or quasi-experimental design to test for causal relationships; (c) measured a behavioral outcome directly related to household water usage (e.g., shower length or water metering), and (d) conducted with residential households, apartments, or hotel rooms (i.e., not agricultural or commercial water users). The title and abstract for each result were reviewed to assess these four criteria. The methods sections in the papers were then reviewed. This resulted in 16 remaining papers. Next, we completed a forward and backward reference search (Webster & Watson, 2016), identifying an additional five papers. Thanks to anonymous reviewers, an additional four papers were identified that met the inclusion criteria. Three of the papers identified referenced the same data, leaving 23 papers with unique samples. One paper reported on two independent studies, resulting in a total of 24 studies. All but six papers were peer-reviewed.[3]

Coding Procedure

We coded each article for whether the intervention contained information, motivation, and/or behavioral skills, whether pre-intervention research was conducted, intervention context (whether the study was conducted in an urban or suburban context and in drought conditions), sample size, dwelling type, and intervention delivery method (e.g., hand-delivered postcard, 2-hr workshop). The key outcome, if available, was the difference between treatment and control groups in the percentage change of water use pre- and posttreatment.

Content Coding

A primary goal of the content coding was to determine which aspects of the IMB model were included in a given intervention, how they were

operationalized, and prominent contextual factors that should be considered in evaluating each intervention. One author and one graduate student independently coded each treatment and control study condition. Discrepancies were resolved through negotiated agreement. If any disagreements persisted, they were discussed and resolved by a third coder (another author).

All coding was based solely on the published paper. For example, we did not conduct independent research to identify drought status or other contextual factors. All coders used the definition of IMB from the introduction and used a coding manual (see Supplemental Material). The 24 studies in the summary effects table (Table 1) each included at least one intervention condition with information, motivation, and/or behavioral skills, even though this was not a criterion for inclusion. There were 100 total experimental conditions including controls.

Outcome Coding

In addition to coding for intervention content, we calculated intervention effect sizes where possible. These calculations were not possible in studies with a control group that received an information, motivation, and/or behavioral intervention (three studies) or studies that did not report between-subjects statistics (eight studies).[4] The remaining sample contained 13 studies, yielding 38 quantitative comparisons of water use change between an intervention and control condition. For each of these comparisons, we calculated the percent change in the intervention condition minus the control condition for the first outcome time point (complete details of effect size calculations are provided in the Supplemental Material):

$$\text{Effect size} = \frac{T_1\text{Mean}_{\text{treatment}} - T_0\text{Mean}_{\text{treatment}}}{T_0\text{Mean}_{\text{treatment}}} - \frac{T_1\text{Mean}_{\text{control}} - T_0\text{Mean}_{\text{control}}}{T_0\text{Mean}_{\text{control}}}$$

Effects were averaged across studies without adjustment for sample size or experimental rigor. A meta-analysis was not conducted because of the heterogeneous sample of studies. Given the heterogeneity of study methods, applying a meta-analytic framework would require a very high degree of abstraction to make sense of the combination of studies (Borenstein et al., 2009). The estimated effect sizes are to highlight variability between studies and should not be used to make strong conclusions about the relative strength of different IMB intervention components.

Table 1. Characteristics of the 24 Studies Included in Qualitative Analysis.

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Aitken et al. (1994)	(1) Feedback	IM	Attitudes, habits, and values survey	Melbourne, Victoria, Australia	No	226	Households	Hand-delivered postcard	+0.56
	(2) Feedback + dissonance	IM							–5.25
	(3) Control condition	None							
Borisova and Useche (2013)	(1) Educational irrigation workshop	IB	None	Oscelo, Florida, USA	NA	100	Households	2-hr workshop with Q&A session and hands-on-exercise	
	(2) Control condition	None							
Brent et al. (2017)	(1) Tips sheet	IB	None	Reno, Nevada, USA	Yes	42,703	Households	Mailed	0.00
	(2) Tips + water use history	IB							–0.90
	(3) Tips + water use history + rate information	IMB							–1.60
	(4) Tips + water use history +social norms + financial	IMB							–1.46
	(5) Tips + history + social norms + financial	IMB							–1.59
	(6) Control condition	None							
Brent et al. (2015)	(1) Utility A: Mailed WaterSmart report	MB	None	North Bay Area, California, USA	NA	1,889	Households	Mailed	–5.11
	(2) Utility A: Control condition	None	None						
	(3) Utility B: Mailed WaterSmart report	MB	None	Bay Area, California, USA	NA	3,092		Mailed	–4.90
	(4) Utility B: Control condition	None	None						
	(5) Utility C: Emailed WaterSmart	MB	None	South Bay Area, CA, USA	NA	2,380		Emailed	–1.33
	(6) Utility C: Control condition	None	None						

(continued)

Table 1. (continued)

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Datta et al. (2015)	(1) Descriptive norm-neighborhood	IMB	Focus groups	Belen, Costa Rica	No	5,626	Households	Included with water bill	–4.50
	(2) Descriptive norm-city	IMB							–2.49
	(3) Plan-making	IB							–4.37
	(4) Control group	None							
Dickerson et al. (1992)	(1) Mindful-only	B	None	Santa Cruz, California, USA	Yes	80	University Rec Center/Other	Direct contact with subjects	
	(2) Commitment-only	MB							
	(3) Hypocrisy	MB							
	(4) Control condition	None							
Ferraro and Miranda (2013), Ferraro et al. (2011) and Ferraro and Price (2013)	(1) Technical advice/tip sheet	IB	None	Atlanta, Georgia, USA	Yes	106,669	Households	Mailed	–0.58
	(2) Weak social norm + tip sheet	IMB							–2.25
	(3) Strong social norm + weak social norm + tip sheet	IMB							–4.18
	(4) Control condition	None							
Fielding et al. (2013)	(1) Information	IB	None	Brisbane and Ipswich Regions, South East Queensland, Australia	Yes	221	Households	Mailed	–12.87
	(2) Information + descriptive norm	IMB							–8.21
	(3) Information + water end use	IB							–7.26
	(4) Control condition	None							

(continued)

Table 1. (continued)

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Geller et al. (1983)	(1) Device	IB	Attitude survey	Blacksburg, Virginia, USA	NA	129	Households/ Townhouses	Hand-delivered packet	−6.04
	(2) Device and education	IB							−3.50
	(3) Device and feedback	IMB							−4.31
	(4) Device and education and feedback	IMB							−5.56
	(5) Education only	I							+2.69
	(6) Feedback only	IM							+4.77
	(7) Education and feedback	IM							−0.91
	(8) Control condition	None							
Goldstein et al. (2008), Study 1	(1) Environmental message	IB	None	Arizona, USA	NA	190	Hotel rooms	Messages on washroom signs	
	(2) Descriptive norms	IMB							
Goldstein et al. (2008), Study 2	(1) Environmental message	IB	None	Arizona, USA	NA	190	Hotel rooms	Messages on washroom signs	
	(2) Descriptive norms: guest	IMB							
	(3) Descriptive norms: provincial	IMB							
	(4) Descriptive norms: citizen	IMB							
	(5) Descriptive norms: gender	IMB							
Hahn et al. (2016)	(1) Loss framed letter	M	None	San Antonio, Texas, USA	NA	23,282	Households	Mailed	
	(2) Social norm comparison	M							
	(3) Loss framed letter and social comparisons	M							
	(4) Informative letter (gain-framing, considered control)	M							
Jessoe et al. (2017)	(1) Social norms, information, and skills	IMB	None	Burbank, California, USA	Yes	7,341	Households	Email and mailed	−2.90
	(2) Control condition	None							

(continued)

Table 1. (continued)

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Joo et al. (2018)	(1) Goal setting	M	None	Gyeongju, South Korea	No	306	Hotel rooms	Sign in bathroom; signed commitment at check in	−13.27
	(2) Social norms + commitment	M							−19.25
	(3) Social norms + social goal	M							−9.52
	(4) Control condition	None							
Katz et al. (2016)	(1) Conservation message	M	None	Petach Tikya, Israel	Yes	934	Households	Mailed	
	(2) Second mailing	M							
	(3) Third mailing	M							
	(4) Control condition	None							
Kurz et al. (2005)	(1) Information	IB	Attitude survey	Perth, Western Australia, Australia	Yes	166	Households	Mailed	
	(2) Information + labels	IB							
	(3) Information + labels + social norms	IMB							
	(4) Social norms	M							
	(5) Labels	IB							
	(6) Labels + social norms	IMB							
	(7) Information + social norms	IMB							
	(8) Control group	None							
Mallett and Melchiori (2016)	(1) Identity-building campaign	M	None	Chicago, Illinois, USA	No	303	Apartments	Posters and stickers	−35.20
	(2) Retrofits	None							−30.40
	(3) Identity-building campaign + retrofits	M							+9.54
	(4) Control condition	None							
Reese et al. (2014)	(1) Environmental message	MB	None	Central European alpine resorts, Switzerland and Austria	NA	132	Hotel rooms	Messages on washroom signs	
	(2) Global social norm	MB							
	(3) Room social norm	MB							

(continued)

Table 1. (continued)

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Schultz et al. (2016)	(1) Information (online)	B	Attitude and behavior survey	San Diego, California, USA	NA	301	Households	Web condition: mailed letter with survey URL. Postal mail conditions: mailed a report	
	(2) Information (mailed)	B							
	(3) Information + descriptive norms	MB							
	(4) Information + descriptive norms	MB							
	(5) Information + descriptive norms + aligned norms	MB							
	(6) Information + descriptive norms + aligned norms (mailed)	MB							
	(7) Control condition	None							
Seyranian et al. (2015)	(1) Information/tips	B	None	Los Angeles, California, USA	Yes	374	Households	Mailed	
	(2) Social norms + information/tips	MB							
	(3) Social identity + information/tips	IMB							
	(4) Personal identity + information/tips	IMB							

(continued)

Table 1. (continued)

Authors	Intervention	Intervention focus	Pre-intervention research	Location	Drought conditions	Sample size (*N*)	Dwelling	Intervention medium	Water use (%)
Sparkman and Walton (2018), Study 5	(1) Dynamic norms	M	None	Stanford Campus, California, USA	Yes	30	Laundry machines	Signs	–26.00
	(2) Static norms	M							–7.23
	(3) Control condition	None							
Thompson and Stoutemyer (1991)	(1) Commons education group	IMB	None	Southern California, USA	NA	171	Households	Mailed	–10.85
	(2) Economic interest education	IMB							–12.28
	(3) Participation control condition	IB							–10.31
	(4) Control condition	None							
Tiefenbeck et al. (2013)	(1) Feedback	IMB	None	Lynfield, Massachusetts, USA	NA	154	Apartments	Hand-delivered flyer	–6.00
	(2) Control condition	None							
Tijs et al. (2017)	(1) Environmental message	MB	None	Several towns and villages, The Netherlands	No	224 (97 households)	Households	Hand-delivered booklet	
	(2) Financial message	MB							
	(3) Control condition	None							

Note. I = Information, M = Motivation, B = Behavioral skills.

Results

The studies represented diverse contexts: 16 were conducted in the United States, most often in California (7; other U.S. states: 9). Of these, 46% of participants were urban and 33% were suburban. Of the total, 67% were households, 17% hotel rooms, 8% apartments, and 8% were university buildings. Ten studies were conducted during a drought, five were conducted when there was no drought, and nine did not specify drought conditions. The median study sample size was 264 (range: 30–106,669). Most studies were underpowered given the expected small effects found among similar studies in the energy domain (about a 2% reduction; Allcott, 2009). No studies reported conducting formal elicitation research, but five studies included surveys of attitudes, values, or behaviors before the intervention. These pre-surveys were largely used to collect potential covariates and moderators and did not inform the intervention design as suggested for elicitation research.

Information, Motivation, and Behavioral Skills in Interventions

Every study included at least one information, motivation, and/or behavioral skills intervention condition: 56% of the 79 non-control intervention conditions contained an informational component (problem awareness), 73% a motivational component, and 73% a behavioral skills component. Among the motivational messages, the most common were social normative feedback (45%), identity appeals (31%), and financial appeals (22%).[5] Twenty-four interventions (30%) included all IMB components. Most included more than one component, and information alone was the least common condition.

Efficacy of IMB Components

The main objective of the quantitative analysis was to describe the effect sizes generally found in studies that provided enough information to calculate between condition effects.[6] Of the 38 interventions that included one, two, or three IMB components compared with a control group, water use was reduced by $M = 5.9\%$ ($SD = 8.0\%$). We then calculated the effects of different IMB combinations separately (see Table 2 for means and medians). Differences between conditions varied. Although there appeared to be a consistent reduction of water usage across different combinations of information, motivation, and behavioral skills (except for information alone), the ranges of effects were very large and the average effects between conditions were similar. One exception was that the motivation-only interventions appeared more effective. However, this result is driven by two studies with surprisingly

Table 2. Mean, Median, and Range of Changes in Water Use.

	Percent change in water usage compared with control group			
Intervention	Mean	Median	Range	Interventions
IMB	–4.9	–4.3	–12.3, –1.5	14
IB	–5.1	–4.4	–12.9, 0.0	9
MB	–3.8	–4.9	–5.1, –1.3	3
IM	–0.2	–0.2	–5.3, +4.8	4
M	–14.4	–13.3	–35.2, +9.5	7
I	+2.7	+2.7		1

Note. I = Information, M = Motivation, B = Behavioral skills. Combinations of the letters represent interventions that used multiple intervention components.

large effects, and motivation paired with behavioral skills and information shows much smaller average effects. Thus, there is neither strong nor consistent evidence to conclude a motivation component outperforms other interventions components. Statistical tests are provided in the Supplemental Material; however, we urge caution in interpreting differences between conditions given the small sample sizes and heterogeneity in methods across studies. It is also important to consider potential bias in the final study sample. Although it is likely that experimenters tried to reduce bias in their studies, there is nevertheless potential for biases to influence results, especially given the small effects among the studies considered here. However, without more explicit reporting of whether, for example, experimenters were blind to condition or whether participants were aware of being part of a study, it is difficult to rule out these potential sources of bias. Furthermore, few of the studies used representative samples, reducing the generalizability of the results. To help account for these potential confounds and to inform future interventions and reviews, we posted a comprehensive coding of study methodologies and contexts at https://osf.io/mf2cg/?view_only=28b82da86d1143c0af193b541cc29e1e.

Discussion

We used the IMB model to synthesize the design and effectiveness of previous experiments on household water consumption. In particular, more effective interventions can be designed by identifying the existing information, motivation, and behavioral skills levels of specific populations and using messaging to target gaps.

Information Components (Problem Awareness)

Information alone about a problem is often not sufficient to change behavior, but nonetheless can still be an important factor in a behavioral intervention. In many cases, populations already know about local water supplies. Although there are informational deficits with respect to specific behaviors among residential water users (Attari, 2014; Attari et al., 2017), many residents could have high levels of basic knowledge (e.g., that there is a drought), especially given the ubiquity of informational messaging by water districts and governments. For example, one study of water district managers found that nearly all California water districts include some type of informational messaging about water conservation (Anderson, 2019). Nonetheless, information along with motivation and behavioral skills, as posited by the IMB model, may increase the efficacy of an intervention.

Motivation Components

Social norms. Social norms are one of the most well-researched behavioral intervention approaches (Schultz et al., 2007). Following from social norms theory (Cialdini et al., 1990; Terry & Hogg, 2001), how much water people think others are using directs individuals' own water use such that they try to match their water use to the use of others. Thus, telling individuals that others are using less water can reduce individual water use.

The power of a social norms intervention is well illustrated by a study conducted in Atlanta that included more than 100,000 water utility customers (Ferraro et al., 2011; Ferraro & Price, 2013). In the social norm feedback condition, water users received a pro-social appeal (e.g., ". . . We need your help . . . We all have to do our part to protect Cobb County's precious water resources") plus direct comparisons of participants' own water use to their neighbors' average water use over the last billing cycle (see Figure 2). Households who received this social norm message reduced usage by up to 4.2% compared with a control group that received the pro-social appeal but not the social norm component. Similarly, a study of 374 affluent water users in Los Angeles found that informing users of how their average water use compared with that of their neighbors decreased water use by 1.0% 1 week and even 4 weeks after the intervention (Seyranian et al., 2015). Additional studies also reported that social norm messaging reduced water consumption (Aitken et al., 1994; Beal et al., 2016; Datta et al., 2015; Fielding et al., 2013; Goldstein et al., 2008; Kurz et al., 2005; Reese et al., 2014; Schultz et al., 2016; Thompson & Stoutemyer, 1991; Tiefenbeck et al., 2013).

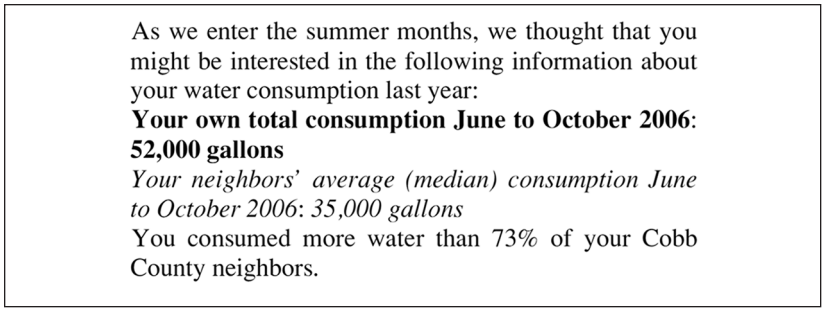

Figure 2. Example of a social norm message in water conservation. From Ferraro and Price (2013).

There is a risk that social norm messages presenting the average water use of neighbors might increase use among individuals already conserving water as they seek to match the norm. This boomerang effect has been observed with water and energy norms interventions (Ayres et al., 2013; Schultz et al., 2007). However, this effect can be counteracted by providing injunctive social norms (Cialdini et al., 1990) showing that others think using less water than average is good. Normative interventions often provide these injunctive norms by including smiley faces alongside feedback that an individual is consuming below the norm, thereby encouraging their counter-normative use (for discussion, see Schultz et al., 2007). An alternative method of providing injunctive norms includes providing the norm for efficient neighbors alongside the norm for all neighbors, allowing efficient households to recognize that their use is similar to fellow efficient households (Schultz et al., 2018). Effective social norm messages should include provisions to prevent the boomerang effect and ensure net reductions in water use.

Identity appeals. Identity-based interventions are alternative motivational tools that may be more feasible in situations where water usage data are not available or the resources are not in place to use a social norms approach. Identity framing—making a behavior relevant to an identity such as "Texan"—helps motivate water conservation by giving those behaviors personal and social significance. In one study using identity-framed messages, households that received personal ("our precious water resources") and social ("our city") messages reduced their water use compared with households that only received water saving tips (i.e., behavioral skills; Seyranian et al., 2015). In another study of 200 apartments in Massachusetts, the treatment group received feedback fliers weekly for 7 weeks (Tiefenbeck et al., 2013). Each flier included

Figure 3. Environmental appeal from Tiefenbeck et al., 2013. This was placed on apartment doors.

an environmental identity appeal and normative feedback (Figure 3). The identity and norm message group used 4.1% less water than the control group, which only received usage feedback at the end of the study.

It is important to use identities that have meaning to the target population. For example, the "Don't Mess with Texas" slogan was a highly effective identity-based message that reduced roadside littering by 72% in Texas, largely because this identity was very meaningful to residents of the state (McClure & Spence, 2006). Whether motivational social appeals promote behavioral change therefore depends on matching messages to personal situations and identities (Goldstein et al., 2008; Reese et al., 2014; Richetin et al.,

2016). Guests of a hotel were more likely to reuse towels when provided more specific identity appeals, ranging from "your fellow guests" (44% reuse) to "guests who stayed in this room" (49% reuse) (Goldstein et al., 2008), and all identity appeals were more effective than a generic pro-environmental appeal (35%–37% reuse; see also Reese et al., 2014). Elicitation research can determine which identities are meaningful and would likely be effective in a given population.

Financial appeals. Financial appeals may also motivate reductions in water consumption, although few of the reviewed water interventions included this motivational component. When customers were presented with the message "Saving water saves you money" alongside additional rate information, individuals reduced their consumption by 1.6% (Brent et al., 2017). Interestingly, this reduction persisted for the following months, possibly due to households taking larger, more permanent steps to capture savings such as replacing appliances (Brent et al., 2017). This is in contrast to another study that relied on a financial appeal to reduce water use. In this case, participants were asked to develop a water savings plan and hang a reminder to save water in their shower: a blue water droplet stating "as soon as you see me in the shower, remember our goal: saving water to save money" (Tijs et al., 2017). Those receiving the financial appeal did not reduce their self-reported shower frequency.

Behavioral Skills Components

In the IMB model, behavioral skills mediate the relationships between information, motivation, and behavior change. Skills enable individuals to transform information and motivation into action. One behavioral skills component common in the reviewed studies was how-to tips that provided specific suggestions for reducing water use (e.g., "a five-minute shower will save water"). Of the intervention conditions including behavioral skills, all but one included this form of a tip sheet or how-to list. A second kind of behavioral skills intervention focuses on improving self-efficacy by indicating that behavior change can effectively contribute to solving the problem. In one study, labels were placed on various appliances throughout homes and gardens informing residents of the water use of selected objects and appliances (Kurz et al., 2005). For example, labels in the shower informed participants that "conventional showerheads can use up to 25 litres of water per minute" and prompts them to think about specific behaviors to reduce water use, "How long have you been under the water? Have you considered fitting a water efficient showerhead that can use a little as 9 litres per minute?" (Kurz et al., 2005, p.

1289). Households with labels reduced their water usage by 10% compared with households who did not have appliance labels. Combining the two types of behavioral skills interventions is also promising. One study presented messaging emphasizing the necessity of individual actions to reduce water use and a list of 25 actions to reduce use. This combination resulted in a reduction in water use among low- and middle-class households (Thompson & Stoutemyer, 1991). However, there is evidence that tips or skills alone often fall short of achieving behavior change. For example, when customers in Northern Nevada were given six tips to conserve water, water use remained the same (Brent et al., 2017). When tips were paired with household use data, rate information, or social norms—information and motivation components—customers reduced their consumption.

Moderators and Heterogeneous Effects

Water conservation interventions differ in effectiveness across individuals. For example, high-income and high-use households often reduce the least in response to conservation appeals (De Oliver, 1999). Yet in one case, individuals who were high-use, lived in more expensive homes, and were homeowners as opposed to renters conserved more when they received a strong social norm message (see heterogeneous effects in Ferraro & Miranda, 2013). These differences in the behavior change of higher income households could be a result of differing levels of pretreatment IMB that are not accounted for in previous study designs. Understanding the factors that drive these divergent effects is especially important because wealthier individuals are the least likely to respond to pricing policies (Grafton et al., 2011). Future water use interventions that seek to understand the behavior of subpopulations can use elicitation research to evaluate the pre-treatment levels of IMB within subgroups, and these factors could help explain heterogeneous treatment effects.

Enduring Effects

In the reviewed studies, the water use reductions persisted across months, but the effects appear to weaken over time. Furthermore, the strength of different intervention effects was mixed in studies that included two or more follow-up time periods. The six studies encompassing 15 interventions that measured water usage again at a later time (T_2)[7] demonstrated a median reduction in water usage of 2.9% in T_2 compared with the median water use reduction of 4.4% in T_1. The 11 intervention conditions that incorporated each of the three IMB components also had a median decrease in water usage of 2.9% between T_2 and T_0. Those studies that contained information and behavioral skills

(four interventions) showed lower water use at T_2 as compared with complete IMB conditions, with a median reduction of 6.0%.

Before any strong conclusions can be reached about the long-term effects of IMB interventions, more research is needed to investigate how such interventions may continue to affect water use after the intervention is completed. Only one study included the measurement of intervention effects over an extended period of time, finding that intervention effects were still detectable and policy-relevant 6 years later (Bernedo et al., 2014; original study, Ferraro & Price, 2013). Although this study is encouraging about the potential enduring effects of these interventions, future research is still needed. Future research should consider how the modality and extensiveness of interventions (e.g., a multimodal, multi-contact intervention vs. a single postcard intervention) may influence the longevity of behavior change effects and what specific behaviors are most responsible for continued behavior change.

There are two general types of behaviors users can engage in: efficiency behaviors (e.g., shorter showers) and single-investment or curtailment behaviors in water efficiency (e.g., new efficient appliances; Stern & Gardner, 1981). Both behavior types are important for water conservation, but there is little evidence about what people actually do in response to behavioral interventions. One study has found effects persist at the household level even after residents move (suggesting household investments; Brandon et al., 2017), whereas another found no effect once residents move (suggesting conservation was driven by repeated behaviors; Bernedo et al., 2014). Future research should aim to better disentangle these behavioral changes.

Implications for Research and Theory

The IMB model is a useful way to synthesize the literature on water conservation and may serve to advance other areas of sustainability psychology. First, the IMB model identifies evidence gaps in the current literature, generates potential explanations for mixed findings (i.e., unmeasured pre-levels of I, M, and B), and recognizes the common processes underlying behavior change (IMB) even when not all components are manipulated. The IMB model proposes that providing information, motivation, and behavioral skills to individuals when one or more are missing will increase the likelihood of behavioral change. Without accounting for preexisting levels of information, motivation, or behavioral skills through elicitation research, it is unclear whether to expect each of the three components of the model to promote behavior change. This disconnect may be the underlying reason for the varied efficacy of different interventions we reviewed. None of the studies included elicitation research, and thus it is unknown how informed, motivated, and

efficacious the different populations were. A motivated and informed population may only respond to an intervention that includes behavioral skills, and any other combination of information or motivation might have no effect.

The IMB model helps provide an explanation for why we observe that IMB (and any combination thereof) seem to reduce water usage, but vary widely in their magnitude of effect. This application of the IMB model as an organizing framework would facilitate future work that can more systematically investigate the strength of various IMB intervention component combinations and optimize future intervention approaches by only addressing the needed psychological components in ways that most strongly resonate with water users. Academic-practitioner collaborations can further optimize IMB interventions and assess the real-world impacts of these interventions. These studies would allow for empirical evaluations of the utility of the IMB model and allow for later meta-analyses that are not possible with the current available literature. Furthermore, to best strengthen IMB interventions, future research will also need to consider additional contextual and individual-level factors that may moderate different IMB components, such as local drought conditions, residence type (e.g., single family house, townhome, apartment), and household members' socioeconomic status.

Implications for Water Conservation Efforts

Using the IMB model may help individuals and organizations design and implement more effective water interventions. Behavioral interventions like those reviewed in this paper can be cost-effective, relevant, and necessary for change. Often, moderate reductions in water use can be accomplished with only one to three customer contacts, and the IMB model provides a comprehensive framework for what these contacts should include and how to tailor them to a target population. Furthermore, the IMB model is flexible in the sense that it does not prescribe exactly how messages need to be crafted, but instead identifies the key psychological components for success and allows communicators to select the specific approach (e.g., social norms, identity appeals, how-to lists) that would work best for a given water district and their customers. The IMB model also establishes a common (and useful) shared language of water conservation intervention components. Providing common definitions of information, motivation, and behaivoral skills can reduce confounding of key approaches such as when some researchers treat social norms as a motivational approach and others as an informational approach (as in a social norms intervention provides information on what others do). With a shared language and framework, practitioners and researchers alike can

better identify what approaches work and help to establish best practices in the domain of residential water conservation.

Nonetheless, the effects of these interventions are often modest and short-lasting, with reductions only lasting a few weeks in some cases. Depending on the needs of the water district at a given time, alternative demand management strategies, like pricing changes or restrictions on use, may be more effective. Behavioral interventions may be particularly well suited to situations where demand reductions are required over the short term, such as in areas where drought conditions are rare, more expensive long-term solutions are not viable, and cost effectiveness is an important consideration. In addition, these approaches may be valuable when drought concerns diminish and there is no political viability for mandated restrictions, requiring water districts to promote voluntary reductions. When these small reductions are scaled up across the country, they can have a significant effect. Even a reduction of 1% of daily residential water use across all U.S. households translates to an estimated 266 million gallons saved per day (estimation methods provided at https://osf.io/mf2cg/?view_only=28b82da86d1143c0af193b541cc29e1e).

Conclusion

The application of the IMB model to water conservation provides new insights into behavior change in the context of residential water conservation through a theoretical framework that identifies the main psychological components driving behavior change. Furthermore, this theoretical knowledge can be used by water utilities, nonprofits, and other water conservation practitioners to more effectively change behavior. Reducing residential water consumption is a considerable and complex problem that will require multiple approaches targeting policy, technology, and water users themselves. Behavior change interventions are a versatile and valuable tool that when applied thoughtfully and strategically can be an integral part of a comprehensive approach to water conservation.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. For example, voluntary water conservation avoided more than US$11 billion in supply costs between 1990 and 2016 at the Los Angeles Department of Water and reduced customer water bills by 26.7%.
2. These search terms were [(water intervention OR water experiment) AND (conservation OR saving OR use)] in all three databases, [(water use OR water conservation) AND (residential)] in PsycINFO; [(water use OR water conservation) AND (social norms OR norms)] in PsycINFO; and [(water intervention OR water experiment OR field trial) AND (conservation OR saving OR use)] in EconLit.
3. The 23 papers are a small proportion of all existing interventions because most are conducted by water districts, municipalities, or consultants and have proprietary data and results. However, those interventions may also be less likely to have internal validity, adequate controls, and theory-informed manipulations compared with the peer-reviewed literature.
4. Despite the inclusion criterion of experimental or quasi-experimental studies, some papers reported only conditional effects or within-subjects water use. These effects were excluded because they did not estimate a true intervention effect and may be contaminated by confounds.
5. These percentages do not total 100% because the treatments were not mutually exclusive within studies.
6. Due to publication bias (Fanelli & Ioannidis, 2013; Franco et al., 2014), these effect size estimates are likely biased and possibly inflated. The studies were also highly heterogeneous. For example, they used different time frames, populations, and messaging mediums and content. This heterogeneity means that effect sizes should be compared between treatments and generalized with other contexts only with caution.
7. Only one study (Ferraro et al., 2011; Ferraro & Price, 2013) contained the necessary information to calculate treatment effects beyond a second measuring period.

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