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# Toward achieving persistent behavior change in household water conservation

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**Achieving persistence in household behavior modification has been a central but elusive goal of environmental conservation attempts that rely on behavioral interventions. We implemented a habit change intervention, designed to achieve persistent change in household water conservation behavior in an affluent residential community in urban India. We found a 15 to 25% reduction in household water consumption in the absence of any volumetric pricing. Most importantly, the effects of our 5-wk intervention persisted for more than a year, after which marginal pricing was introduced. The treatment gap was not bridged even after a year under the marginal price regime.**

persistent behavior change | objective sustainability goals | water conservation | dual process | goal performance

Consumption within households accounts for 10 and 25% of global freshwater and electricity use, respectively (1–4). The household has thus been an important site of research to understand behavioral pathways to conservation through inexpensive interventions in water, energy, and other sectors (5–7), despite difficulty in achieving persistent behavior change (8–11). A clear pathway leading to persistent household conservation remains elusive (11–13). While persistence of behavior change has been observed in a few cases, it is far more common for effects to decay or vanish (13–15) than to persist over the long term (10, 11, 16). The limited successes in achieving persistent behavior change are often based on social comparison (13–15, 17) rather than an objective, sustainability-driven goal. Prevalent social norms of consumption can be at deviance from sustainability or conservation goals (18). However, policy-driven objective goals have received scant attention.* An objective basis is theorized to be a more powerful basis of comparison of one's ability or opinion than a social basis (19), but is an objective basis also a useful reference for behavior change? This has largely remained untested in environmental conservation interventions. Furthermore, in the absence of a well-established theoretical framework for studying environmental conservation behavior change, the intervention efforts have been ad hoc and unsystematic (7, 20).

In this article, we report behavior modification results from a long duration household water conservation field experiment focused on habit change. Large and significant effects from our 5-wk behavioral intervention persisted over the entire postintervention observation period of nearly two years. We used an objectively defined and sustainable per-person per-day water consumption limit as the suggested goal. This is in contrast to social comparison–based goals that do not take into account the number of residents in a household or the environmental sustainability of benchmarks, such as the median consumption (7, 13, 14).

We use a difference-in-differences (DiD) design to estimate water conservation effects of our intervention. We compare per-person daily water usage between a control group and three treatment groups that received one, two, or all three components of our treatment. In the treated group with all three components (i.e., the most complete treatment), we find significant and large effects of 15 to 25% reduction in household water consumption and a spillover effect on electricity usage. The effects of our 5-wk intervention persisted for over a year, after which marginal pricing was introduced across groups. The treatment gap was not bridged even after the introduction of the marginal pricing. The treatment effects are especially strong (21 to 30%) for the households that were below the median level of usage before the intervention. Our results offer an inexpensive and effective template to design behavioral interventions for environmental conservation in both priced as well as unpriced settings.

**Achieving Persistent Behavior Change.** It has been widely argued that the human brain processes information in two fundamentally different ways: Type 1 processes that result in fast, associative, automatic, and intuitive thinking; and Type 2 processes that result in slow, analytical, sequential, and deliberative thinking (21, 22). Human behavior, researchers suggest, is a consequence of information processing that is routed through Type 1 processes, Type 2 processes, or (most commonly) their interactions. In routine, repetitive tasks in familiar settings, such as taking a shower or doing dishes at home, we operate largely through our habits, which are automatic scripted responses involving Type 1 processing (21–25).

Habits are part of automatic behavior. Habits involve three parts: 1) a situation or setting that acts as a stimulus; 2) a response to that situation (i.e., an action); and 3) an outcome, usually a satisfying one, that enables habits to form (25). Modifying bad habits (e.g., wasting water) or cultivating better habits (e.g., saving water) can target one or more of these three parts. In theory, settings

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## Significance

**Researchers have been successful in inducing environmental conservation behavior, but the effect is usually transient. Persistence in behavior change has been elusive. We developed a simple, cost-effective, and replicable behavioral intervention for household water conservation that achieved persistence of behavior change. Our method uses objectively defined, sustainability-based per-person goals rather than comparative social norms that can themselves be beyond the threshold of biophysical sustainability or policy goals. Per-person goals help transcend the limitations of extant social comparison interventions that ignore household size. This work also expands the scope of behavioral interventions to settings where resource pricing is not possible or is difficult.**

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The authors declare no competing interest.

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*In the water sector, a policy-based goal was used in the Target-140 program in South East Queensland, Australia (52). However, the program employed multiple interventions in parallel and does not lend itself to causal analysis.

can be modified or removed, responses can be restricted or new responses can be enabled, and outcomes or the utility and desirability of outcomes can be altered.

In the context of consumption habits, modifying the settings within which consumption takes place inside a household is intrusive and impractical. Instead, we propose interventions that invoke deliberative processing about the consumption activity and its outcomes that may then motivate a change in the response to the stimulus. We suggest that a sustainability-driven objective goal can activate the slow reflective mind such that it interferes with the automatic responses that we wish to change (21, 26). A difficult conservation goal, when presented in a way that is quick and easy to grasp, will increase the chance that the goal is actually understood. Once the goal is understood and a difficult challenge is accepted (which is more likely in households that are not too far from the goal), it remains available to guide subsequent actions and to interfere with automatic responses (26). A progress report recording a successful outcome (i.e., progress toward the goal) serves as further motivation, leading to a greater acceptance of the goal (19, 25) either directly (e.g., by feeling good) or indirectly (e.g., in pursuit of a larger good).

Goal-setting theory states that assigned goals translate into actual performance when goals are specific and difficult and when the person has the motivation and skills to act with self-efficacy (26, 27). Furthermore, feedback and personal commitment affect the outcome positively, while situational constraints and complexity of task affect the outcome negatively (26). Informational aids can help steer response to the stimulus and enhance self-efficacy, making it easier for an individual to adopt the modified action. When such interventions are repeated, the modified response to stimulus turns habitual over time and becomes part of a new automatic response (24).

## Study Design

Our study is based on a two-year–long field experiment (88,560 household days). We implemented a habit change mechanism by deploying the framework depicted in Fig. 1. The initial Type 1 processes representing existing behavior are on the left. Our intervention that invokes Type 2 processes and its underlying behavioral mechanism are depicted in the middle, and the transformed Type 1 processes are on the right.

The experimental design (depicted in Fig. 1) involves an initial random assignment of households into three treatment groups (named T1, T2, and T3) and a control group. The experiment used three variants of a one page weekly water usage report, one per treatment group, with small incremental components, as illustrated in Fig. 2. The report contained three components: A—simplified usage information, B—suggested objective goal and feedback, and C—water saving tips. T1 households received only component A, T2 received components A and B, and T3 received all the three components. The control group did not receive any weekly report. Before the start of our intervention, all households

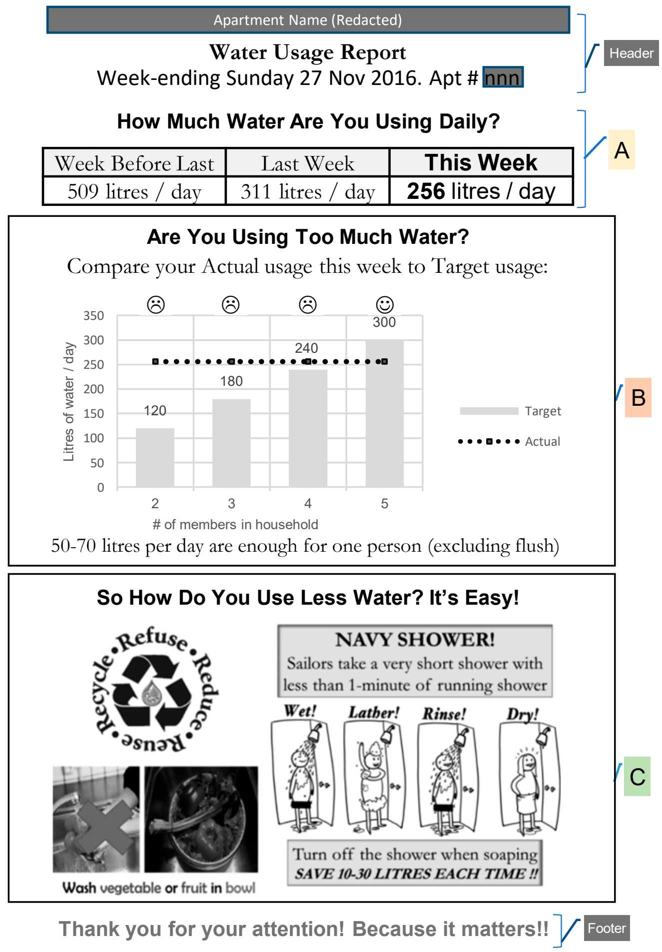


**Fig. 2.** Sample water usage report. *A*, *B*, and *C* correspond to our three intervention components. Every household in a treatment group received this one-page printed report on Wednesdays around noon for 5 wk. Treatment group 1's report contained *Header*, *A*, and *Footer*. Treatment group 2's report also contained *B*. Treatment group 3's report contained all the components.

(including those in the control group) were informed by email that some households would receive water usage reports.

Our weekly treatment communication incorporated key influencing factors identified by goal-setting theory and, as a matter of hygiene, recommendations from the influence and communication literature (18, 28, 29). The report combined concepts from antecedent interventions (e.g., tips before water use) as well as consequence interventions (e.g., feedback) in water conservation interventions (30). In component B of our treatment communication, the suggested goal is specific and difficult (a per-person freshwater consumption

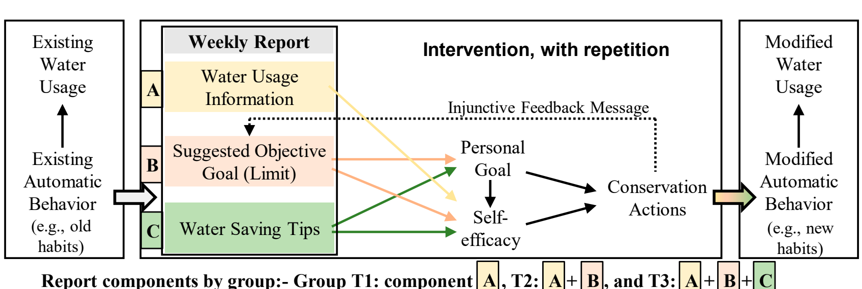


**Fig. 1.** Household environmental conservation framework and experimental design.

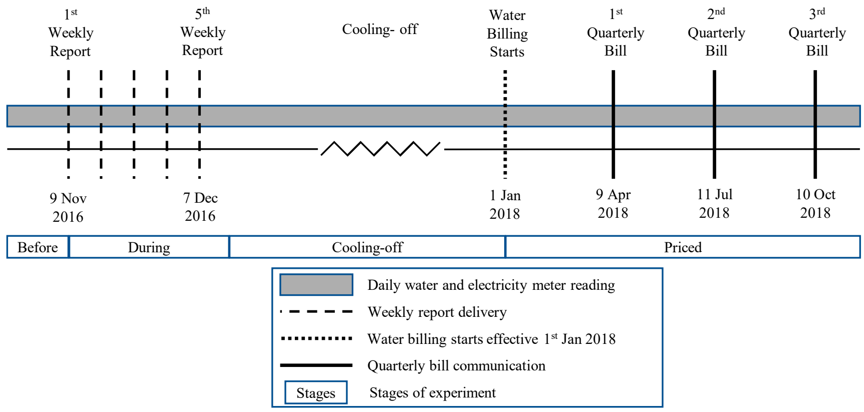


**Fig. 3.** Experiment timeline. $n$ = 88,560 household days.

limit of 60 liters per capita per day [lpcd]) and combined with an injunctive feedback to motivate conservation actions.[†] The goal is presented both as a number and as a comparative chart (Fig. 2). T2 households received weekly usage information and the suggested goal but did not receive any conservation tips. Their response is modulated by the extant level of self-efficacy, which is based on their existing ability and their level of acceptance or personal commitment toward the goal (27). Only T3 households received water-saving tips (component C of the report) that can help individuals move to higher levels of self-efficacy and a greater commitment toward the suggested goal. These tips help remove some of the situational constraints and reduce complexity of tasks that act as barriers to conservation. As an example, our tips included influencing domestic staff who may have a conflicting goal; the staff might wash dishes with a high flow rate, consistent with their productivity objectives. The tips are also varied and designed to be engaging in nature such that both efficiency and curtailment channels are targeted (31, 32). Components B and C of our intervention combine to enable higher conservation potential in group T3 relative to group T2 based on reduced complexity of actions, higher self-efficacy, and higher acceptance of the goal.[‡]

We hypothesize that we will see a significant conservation behavior (reduced water usage) in T3 households, a relatively smaller effect in T2 households, and no significant effect in T1 households. With repetition of our weekly communication over 5 wk of intervention, we expect the new conservation behavior to persist over time with little or no attenuation. We also expect a heterogeneous response within groups, with greater conservation behavior in households relatively close to the suggested goal (60 lpcd). We use a DiD framework to estimate both the average treatment effects (ATEs) for each of our three treatment groups as well as intragroup heterogeneity.

## Experimental Setting and Data

Our field site is an affluent residential community in Bengaluru, India. All 120 dwelling units in this gated residential community had water meters installed (three separate meters in each unit). The primary attraction of this site was the absence of a marginal price regime for fresh water consumed by the households. The residents paid a fixed condominium fee, and the property manager did not charge households based on the actual volume of water consumed. This setting allowed for observing the effects of our behavioral intervention without the influence of a price incentive signal in the preintervention stage or during intervention.

Our dataset was compiled by conducting three daily water use measurements for every dwelling unit (corresponding to the three water meters in each unit) and additionally measuring daily electricity consumption.[§] The presence of multiple meters provides insights into the share of water conservation by location (and plausible water use activity) within each household. DiD estimates are made possible by an initial randomization of households into four groups of equal size; any difference in differences between control and treated households at any stage is explained by the respective treatments. The high-frequency (daily) water consumption data collected over 738 d at 356 water use locations is the source of statistical power in our field experiment. Electricity data are also collected on a daily basis to detect any spillover effects from water usage to electricity usage.

Our intervention timeline is summarized in Fig. 3. The study contained four stages spread over 738 d: "Before," "During," "Cooling off," and "Priced." The "Before" stage corresponds to the baseline period before the start of our experiment. The "During" stage corresponds to the 5 wk intervention period (November 9 to December 14, 2016). The "Cooling off" stage corresponds to the long period from December 15, 2016, to December 31, 2017, when no intervention was made. The "Priced" stage corresponds to the period starting January 1, 2018, when marginal pricing for water was introduced. The first water bill was delivered in April 2018. It was based on the volume of water used by each household in the January to March 2018 quarter.[¶] We conducted a household survey only after the introduction of price to delay any possible contaminating effect of in-person contact with the research team. We collected basic occupancy information from each household, such as number of full-time residents and one-time as well as periodic movements. The in-person survey was conducted after approval by an institute ethics committee registered with the US Department of Health and Human Services. We obtained consent from each surveyed individual as well from the property management office before the start of data collection. We also complemented survey data with records from the property manager's office to identify attrition in our sample and, in general, to make the household occupancy information more complete (see *SI Appendix*, Fig. S4 for the main survey form).

## Results

Fig. 4 depicts the average lpcd water consumption across all four stages of our experiment. For each group, we have normalized lpcd values to the respective preintervention (i.e., the "Before"

[†]This limit excludes toilet flush and private garden, which do not use fresh water.

[‡]See *SI Appendix*, Behavioral Intervention—Water Usage Report for details.

[§]The three meters in each dwelling unit (also known as household) are for the kitchen and utility area, master bathroom, and common bathroom.

[¶]More details of our intervention and our field site can be found in the *SI Appendix*.






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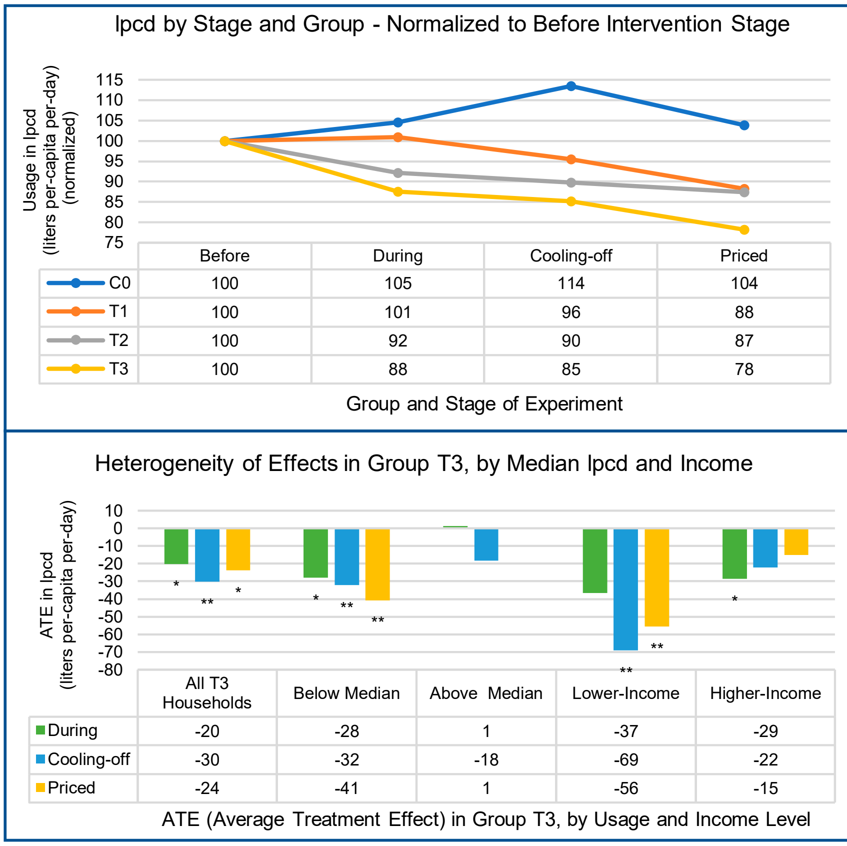


**Fig. 4.** Summary and heterogeneity. (*Upper*)The trend of water usage in normalized lpcd by household groups across stages of study. For each group, we have normalized lpcd values to the respective preintervention (Before) stage lpcd. C0 is the control group and T1, T2, and T3 are three treated groups. (*Lower*) The heterogeneity of ATEs in the treatment group T3 that received all the three components of our intervention. Median level is the median lpcd before the intervention. Note that all households responded in the "During" stage (−23.1***) and in the Priced stage (−27.04**) across all four groups (see *SI Appendix*, Table S16 for median heterogeneity results). Lower-income households are those earning three million rupees or less per annum. Approximately 25% of the data points correspond to "Lower-Income" and 38% to "Higher-Income." For the remaining 37% of the data points, we do not have income information (*SI Appendix*, Table S19). ***$P < 0.01$, **$P < 0.05$, and *$P < 0.1$.

stage) lpcd. The figure shows that change in water usage is consistent with our hypotheses. There is a large and immediate effect in group T3, as seen in the short "During" intervention stage. The gap between the treated and control households grows through the "Cooling off" stage, especially in T3 and to a lower extent in T2. This persistence in conservation behavior is also likely related to the fact that households could retain the five weekly report sheets for reference during the "Cooling off" stage. The treatment gap marginally reduced when the price signal was introduced; on an average, the control group and T1 households had much more remaining potential to reduce usage in the "Priced" stage relative to the households in treated groups T2 and T3.[#] However, T3 continued to reduce significantly even in the "Priced" stage.

We used a DiD econometric model to estimate the ATE, with a fixed effects panel specification as follows:

$$W_{ijt} = \beta_0 + \beta_1 StageN_t + \beta_2 Month_t + \beta_3 Weekend_t + \beta_4 Nores_{it} + \delta_1 T1_i StageN_t + \delta_2 T2_i StageN_t + \delta_3 T3_i StageN_t + FEHH_i + e_{it},$$

where $W_{ijt}$ is the volume of water consumed by household ($i$) at the within-household location ($j$) on the day ($t$) (we use both aggregate volume and lpcd as dependent variables). $StageN_t$ are three experimental stage dummies, one each for the "During" intervention stage, "Cooling off" stage, and "Priced" stage (dummy = 1 [if day, $t$, falls in that stage; dummy = 0 if otherwise]). $Month_t$ is the calendar month of the year (as a factor variable), and $Weekend_t$ is a dummy indicating the end of week (Saturday and Sunday). $T1_i$, $T2_i$, and $T3_i$ are three treatment dummies for the respective treatment group (= 1 if household [$i$] is part of that treatment group; = 0 if otherwise); $Nores_{it}$ is the number of residents (also known as size of the family) living in household ($i$) on the day ($t$); $FEHH_i$ is the fixed effects term for household ($i$); and $e_{it}$ is the error term.

The three main coefficients of interest are $\delta_1$, $\delta_2$, and $\delta_3$—the DiD coefficients derived from interaction of three groups with stage dummies. Based on our intervention design, we expect each $\delta_i$ to be negative, supporting reduction in usage due to the behavioral treatment. We summarize the results from our DiD regression in Table 1. Once price is introduced, the consumption level in the three initially treated groups depends on both price and behavioral treatment. The presence of the initial control group's households allows for estimation of behavioral treatment's ATE in the "Priced" stage through the corresponding interaction terms (i.e., product of "Priced" stage dummy with the respective treated group dummies).

The results in Table 1 confirm the efficacy and persistence of our behavioral intervention. The effect is especially large and strong in T3, the group that received all three components of our intervention. Since the number of people in a household varies

[#]See *SI Appendix*, Fig. S5 for more detailed (weekly) trends.

**Table 1. The estimated ATE**

| Stages | During | | Cooling off | | Priced | |
|---|---|---|---|---|---|---|
| DV | Usage | lpcd | Usage | lpcd | Usage | lpcd |
| Variables | (1) | (2) | (1) | (2) | (1) | (2) |
| T1 ($\delta_1$) | 2.974 | −3.352 | −39.96 | −21.28 | −25.26 | −17.87 |
| | (27.24) | (11.11) | (31.28) | (13.07) | (35.82) | (13.19) |
| T2 ($\delta_2$) | −22.28 | −12.79 | −41.72 | −25.97* | −11.03 | −14.12 |
| | (22.11) | (10.38) | (31.67) | (13.81) | (31.78) | (12.89) |
| T3 ($\delta_3$) | −48.41* | −20.09* | −70.80** | −30.28** | −56.64 | −23.75* |
| | (28.88) | (11.57) | (33.64) | (13.33) | (35.99) | (13.56) |

The estimated ATE of behavioral intervention across three stages of experiment, with household aggregate water usage (1) and lpcd (2) as two different dependent variables (DV). The T3 group has the largest and most persistent effects, as expected, suggesting formation of modified automatic behavior toward conservation. Robust SEs are in parentheses and clustered at household level. ***$P < 0.01$, **$P < 0.05$, and *$P < 0.1$.

by date, lpcd results in columns (2) better reflect the actual effect of our treatment—people, and not households, consume water.

In treatment group T3, the ATE is −20 lpcd in the "During" stage as compared to a "Before" stage lpcd of 128 (i.e., there is an average reduction of 16% during the short 5 wk intervention). This nearly instantaneous reduction in water usage suggests that the "During" stage results are being driven by curtailment actions (e.g., shorter showers) rather than efficiency measures related to hardware retrofits that can take time to plan and implement (e.g., installing low-flow shower heads). The ATE for T3 increases in size to −30 lpcd in the year-long "Cooling off" stage (i.e., a 23% reduction) and persists at −24 lpcd in the "Priced" stage (i.e., a 19% reduction), suggesting additional actions such as efficiency retrofits in the "Cooling off" stage. Thus, the effects in T3 persist for the entire observation period and never fall below 16% across experiment's stages; this suggests that conservation behavior has become a habit in T3 households. The effects are relatively weaker in T2 and not as persistent. The conservation effect in T1 is not statistically significant. The differences in observed ATE magnitudes between T2 and T3 show how both goals (T2 and T3) as well as tips (T3 only) contributed to behavior change and its persistence. Given the strict implementation of the DiD model (robust errors clustered at the household level), we are unable to statistically discriminate between the model coefficients $\delta_2$ and $\delta_3$. However, several other tests support a difference between T2 and T3, as noted in Table 1.[||]

We report heterogeneous effects within T3 in Fig. 4 and heterogeneity tests in the *SI Appendix*, Tables S15 to S19. Tests using meter-wise data show heterogeneous effects by water usage location within a household (*SI Appendix*, Tables S20 and S21). Significant conservation effects are seen in the T3 group for usage recorded in the kitchen utility meter. Effects are also significant for the master bathroom in T3 in the "Cooling off" stage, additional evidence that T3 intervention was the most powerful, further confirming the role of informational tips. Not surprisingly, the kitchen utility area, which accounts for half of the total usage, accounted for a large share of the overall reduction in usage.

## Discussion and Conclusion

Interventions to induce conservation behavior often result in small effects (5, 16). More broadly, effects from nudge-based interventions might not scale well even when large effects are reported in academic studies (33). Beyond the efficacy of our intervention framework, the large effect size (15 to 25%) that we report here is also related to the fact that our behavioral response was not contaminated by a preexisting price signal. Relatively small effects are obtained when individuals have already optimized their level of resource consumption in response to a price signal. The reduction in water usage that we observe is comparable to a first-time introduction of marginal price (34–36). This suggests that behavioral pathways for resource conservation are attractive when marginal pricing of resources is not feasible for technical or political reasons (36, 37). In the context of urban water, our effect sizes are comparable to both condominium-scale (15 to 45%) and city-scale (10 to 30%) reduction in water usage following the introduction of volumetric pricing (34, 35).

There is growing research on options for behavioral policy interventions toward environmental conservation in households (7, 38, 39). However, there remain important gaps, including a lack of guidance on intervention design (20), especially in the face of mixed results (40–42). In pursuit of persistence that has hitherto remained elusive in environmental conservation behavior interventions, we draw on the dual-process model (21–23) and apply it to a create our behavior change framework. Our approach is in contrast to extant interventions that primarily target the fast, automatic Type 1 route of information processing and avoid the slow and difficult Type 2 route (43–45). Reflective Type 2 processes are at the heart of both curtailment and efficiency actions when such actions are voluntary and not coerced (22, 24, 25). In household settings, policymakers cannot (or, as most would argue, should not) use intrusive or coercive measures to modify the consumption choice architecture to nudge automatic actions in the desired direction or to make efficiency-enhancing infrastructural changes. For example, interventions such as a curtailment reminder exhorting shorter showers placed next to showers or a mandatory change to new water-efficient appliances would be intrusive and impractical in a household setting (31, 32). As a normatively desirable, practically scalable, and, above all, a theoretically stronger and more replicable alternative, our intervention incorporates the pathways offered by Type 2 reflective processing.[**]

A persistent reduction in consumption happens through actions directed at curtailment, efficiency, or a multiplicative combination of the two (31, 32). Curtailment achieves lower consumption through (usually repeated) change in consumption actions, whereas efficiency employs a (possibly one-time) structural change, such as installing a more water-efficient dishwasher. While it is difficult to disentangle the relative contributions of curtailment and efficiency in our study, our data suggests that curtailment played an important role. Reduction is observed immediately from the first week, particularly in the treated group T3, which is much more likely through curtailment; structural changes are likely to take time (*SI Appendix*, Fig. S5). The further reduction of consumption in group T3 after the introduction of price is also more likely through curtailment actions. Any structural changes were likely implemented in the long "Cooling off" stage, as suggested by a large ATE during this stage. Regardless of their relative shares, our framework enables persistence of effects through both these routes and their combination.

The role of information in effecting persistent change is contested; information or education interventions seem to have little or no independent effect (14, 29, 46). We test the role of informational tips by subjecting only one of the three treated groups to this component. This design is unlike two other long-duration studies that achieved persistence of effects (13, 17) wherein all treated groups received informational tips. In the Cobbs County

[||]See *SI Appendix* for a number of additional tests, including spillover to electricity usage and nonparametric tests.

[**]In principle, it may sometimes be possible to gain access to inside of homes, say through community-based social marketing (53), but it is an expensive option for policymakers due to the effort and cost involved, unless a community undertakes it through their own efforts and voluntary contributions. We designed a hands-off treatment to avoid contamination by contact with a research team member and to enhance the replicability and external validity of our study.

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experiment (17), tips alone did not have an effect as compared to the control group. This has also been observed in other studies (29, 46). We conditionally combined tips (component C) with usage (component A) and goal (component B). The results show that informational tips played a role in size of effect and its persistence. This suggests that while information alone may not lead to a modification in automatic behavior, it is a critical component without which behavior change, if any, will likely not persist.

While the data support the overall effect and its persistence, we also see strong heterogeneity in the response (e.g., based on median level of water consumption in the "Before" stage). The households above median (113 lpcd) are not likely to be motivated by a 60 lpcd goal and thus might lack commitment (26); their level of usage is about twice the suggested goal or more, making it difficult as an actionable personal goal. This result provides a useful, complementary insight to studies that use the median or the average for comparison (13, 47) wherein the users above the median tend to respond more compared to those below the median. However, our study design does not allow us to directly test the relative efficacies of social norms and objective personal goals. Policy instruments can combine these two points of reference, based on objective and social norms, to aim for higher overall conservation by differently treating households on either side of the median. Furthermore, we used an lpcd-based reference, whereas most studies rely on household aggregate usage. Per capita water usage is a much better basis of comparison than total usage; it does not erroneously consider smaller size households as conserving users or large families as wasteful users. Information on lpcd water usage personalizes the communication and thus maps it to individual habits and daily routines. This enables every individual in the household to examine their water use behavior.

Our intervention field site was an affluent community. Per capita consumption levels, and thus, the potential for conservation, is higher in affluent households (48, 49). However, our results are likely not driven by the economic status of households. While less affluent households will have a greater price incentive to conserve water, our results show that these households exhibited a stronger conservation response even in the absence of a price signal (Fig. 4 and *SI Appendix*, Table S19).

Our study design used the well-established DiD design for causal inference. Our results are robust and consistent with DiD assumptions (50, 51). DiD estimation rests on a parallel trends assumption. Our groups were randomly constructed and also unknown to the residents (see *SI Appendix*, Fig. S1 and Table S3 for details on our parallel trends confirmatory tests). We have reported our DiD model results using robust SEs, clustered at the level of randomization (i.e., household; *SI Appendix*, Tables S13 and S14). Our results are also robust to several additional tests that we perform (*SI Appendix*, Tables S22–S27). The spillover effects that we observe in the electricity conservation response in treated households lends further credence to the likely external validity of our findings (*SI Appendix*, Table S27).

Our study demonstrates that it is possible to achieve persistence of effects through behavioral interventions that target conservation behavior. In our intervention, repeated activation of deliberative thinking disrupts automatic behavior. This approach helps in achieving persistence of effects through change in both curtailment habits (e.g., shorter showers) and efficiency (e.g., retrofitted shower head). We used suggested goals that were based on objectively defined sustainability norms. Our large and persistent effects are comparable in size to the effects that follow the introduction of marginal pricing (34–36). Our findings demonstrate the possibility of achieving large conservation effects without the economic, political, and social challenges associated with periodic billing at high enough price points (36, 37).

Large-scale replication studies are needed to determine whether our results will scale up (33). High costs, privacy concerns that can potentially limit large-scale household data, coarseness of historical usage data, and paucity of existing long-duration studies all can add to the challenges of replicating an intervention like ours at scale (7, 39). However, our results that include both priced and unpriced settings point to the possibility of designing city-scale interventions. With the rapid proliferation of relatively inexpensive off-the-shelf "smart meters" that allow for automatic high-frequency recording of water use with minimal plumbing retrofits, it is possible to extend the scale of our intervention to even existing housing stock.

The urgency of the urban water sustainability question notwithstanding, the implications of our study are not limited to water conservation and can potentially be applied in other sectors in both priced and prepriced settings. With some alterations, the framework can be extended to offices, where billing to end users is not practical, and it can be extended to diverse resources such as free or unlimited access to data, network, storage, and various natural resources where conservation is desirable, if not as pressing as in the case of freshwater in large, fast-growing urban centers.

**Data Availability.** All study data are included in the article and/or supporting information.

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1. IEA, World electricity final consumption by sector, 1974-2018: Overview. (IEA, Paris, 2020). https://www.iea.org/data-and-statistics/charts/world-electricity-final-consumption-by-sector-1974-2018. Accessed 4 September 2020.
2. G. Olsson, *Water and Energy: Threats and Opportunities* (IWA Publishing, 2015).
3. United Nations, *United Nations World Water Development Report 2019 Leaving No One Behind* (UNESCO WWAP, 2019).
4. R. I. McDonald *et al*., Urban growth, climate change, and freshwater availability. *Proc. Natl. Acad. Sci. U.S.A.* **108**, 6312–6317 (2011).
5. H. Allcott, S. Mullainathan, Energy. Behavior and energy policy. *Science* **327**, 1204–1205 (2010).
6. F. Carlsson, O. Johansson-Stenman, Behavioral economics and environmental policy. *Annu. Rev. Resour. Econ.* **4**, 75–99 (2012).
7. S. H. A. Koop, A. J. Van Dorssen, S. Brouwer, Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. *J. Environ. Manage.* **247**, 867–876 (2019).
8. M. Costanzo, D. Archer, E. Aronson, T. Pettigrew, Energy conservation behavior: The difficult path from information to action. *Am. Psychol.* **41**, 521–528 (1986).
9. M. P. Kelly, M. Barker, Why is changing health-related behaviour so difficult? *Public Health* **136**, 109–116 (2016).
10. K. S. Fielding *et al*., An experimental test of voluntary strategies to promote urban water demand management. *J. Environ. Manage.* **114**, 343–351 (2013).
11. A. Brandon, P. J. Ferraro, R. D. Metcalfe, M.K. Price, F. Rundhammer, *Do the effects of social nudges persist? Theory and evidence from 38 natural field experiments* (National Bureau of Economic Research, Cambridge, MA, 2017). https://doi.org/10.3386/w23277. Accessed 16 October 2020.
12. E. Frey, T. Rogers, Persistence: How treatment effects persist after interventions stop. *Policy Insights Behav. Brain Sci.* **1**, 172–179 (2014).
13. H. Allcott, T. Rogers, The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *Am. Econ. Rev.* **104**, 3003–3037 (2014).
14. P. J. Ferraro, J. J. Miranda, M. K. Price, The persistence of treatment effects with norm-based policy instruments: Evidence from a randomized environmental policy experiment. *Am. Econ. Rev.* **101**, 318–322 (2011).
15. M. Bernedo, P. J. Ferraro, M. Price, The persistent impacts of norm-based messaging and their implications for water conservation. *J. Consumer Policy* **37**, 437–452 (2014).
16. P. J. Ehret *et al*., Systematic review of household water conservation interventions using the information–motivation–behavioral skills model. *Environ. Behav.* **53**, 485–519 (2020).
17. P. J. Ferraro, M. K. Price, Using nonpecuniary strategies to influence behavior: Evidence from a large-scale field experiment. *Rev. Econ. Stat.* **95**, 64–73 (2013).
18. R. B. Cialdini, Crafting normative messages to protect the environment. *Curr. Dir. Psychol. Sci.* **12**, 105–109 (2003).
19. L. Festinger, A theory of social comparison processes. *Hum. Relat.* **7**, 117–140 (1954).
20. P. W. Schultz, Strategies for promoting proenvironmental behavior: Lots of tools but few instructions. *Eur. Psychol.* **19**, 107–117 (2014).

21. J. St. B. T. Evans, K. E. Stanovich, Dual-process theories of higher cognition: Advancing the debate. *Perspect. Psychol. Sci.* **8**, 223–241 (2013).
22. D. Kahneman, *Thinking, Fast and Slow* (Macmillan, 2011).
23. K. Mukherjee, A dual system model of preferences under risk. *Psychol. Rev.* **117**, 243–255 (2010).
24. W. Wood, D. Rünger, Psychology of habit. *Annu. Rev. Psychol.* **67**, 289–314 (2016).
25. W. Jager, "Breaking bad habits: A dynamical perspective on habit formation and change" in *Human Decision Making and Environmental Perception: Understanding and Assisting Human Decision Making in Real-Life Settings: Liber Amicorum for Charles Vlek*, L. Hendrickx, W. Jager, L. Steg, Eds. (Groningen, 2003), pp. 149–160.
26. E. A. Locke, G. P. Latham, New directions in goal-setting theory. *Curr. Dir. Psychol. Sci.* **15**, 265–268 (2006).
27. G. P. Latham, E. A. Locke, Self-regulation through goal setting. *Organ. Behav. Hum. Decis. Process.* **50**, 212–247 (1991).
28. R. B. Cialdini, *Influence: Science and Practice* (Pearson Education, ed. 5, 2009).
29. L. R. Kidd *et al*., Messaging matters: A systematic review of the conservation messaging literature. *Biol. Conserv.* **236**, 92–99 (2019).
30. N. Benzoni, C. Telenko, "A review of intervention studies aimed at domestic water conservation" in *Design, User Experience, and Usability: Novel User Experiences*, A. Marcus, Ed. (Springer International Publishing, 2016), pp. 427–438.
31. B. D. Inskeep, S. Z. Attari, The water short list: The most effective actions U.S. households can take to curb water use. *Environment* **56**, 4–15 (2014).
32. S. Z. Attari, Perceptions of water use. *Proc. Natl. Acad. Sci. U.S.A.* **111**, 5129–5134 (2014).
33. S. DellaVigna, E. Linos, *RCTs to scale: Comprehensive evidence from two nudge units* (National Bureau of Economic Research, 2020). https://doi.org/10.3386/w27594. Accessed 12 January 2021.
34. P. Herrington, Household water pricing in OECD countries. Working Party on Economic and Environmental Policy Integration, Environment Policy Committee report ENV/EPOC/GEEI(98)12/FINAL (OECD, 1999). https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/epoc/geei(98)12/final.
35. J. M. Dalhuisen, C. A. Rodenburg, H. L. f. De Groot, P. Nijkamp, Sustainable water management policy: Lessons from Amsterdam. *Eur. Plann. Stud.* **11**, 263 (2003).
36. C. Ornaghi, M. Tonin, The effects of the universal metering programme on water consumption, welfare and equity. *Oxf. Econ. Pap.* **73**, 399–422 (2021).
37. M. Mangold, G. Morrison, R. Harder, P. Hagbert, S. Rauch, The transformative effect of the introduction of water volumetric billing in a disadvantaged housing area in Sweden. *Water Policy* **16**, 973–990 (2014).
38. S. Russell, K. Fielding, Water demand management research: A psychological perspective. *Water Resour. Res.* **46**, W05302 (2010).
39. M. A. Delmas, M. Fischlein, O. I. Asensio, Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy* **61**, 729–739 (2013).
40. S. M. Olmstead, R. N. Stavins, Comparing price and nonprice approaches to urban water conservation. *Water Resour. Res.* **45**, W04301 (2009).
41. D. Saurí, Water conservation: Theory and evidence in urban areas of the developed world. *Annu. Rev. Environ. Resour.* **38**, 227–248 (2013).
42. J. E. Bogard, M. A. Delmas, N. J. Goldstein, I. S. Vezich, Target, distance, and valence: Unpacking the effects of normative feedback. *Organ. Behav. Hum. Decis. Process.* **161**, 61–73 (2020).
43. T. M. Marteau, G. J. Hollands, P. C. Fletcher, Changing human behavior to prevent disease: The importance of targeting automatic processes. *Science* **337**, 1492–1495 (2012).
44. R. H. Thaler, C. R. Sunstein, *Nudge: Improving Decisions about Health, Wealth, and Happiness* (Penguin, 2009).
45. P. Dolan *et al*., Influencing behaviour: The mindspace way. *J. Econ. Psychol.* **33**, 264–277 (2012).
46. W. P. Schultz, A. M. Khazian, A. C. Zaleski, Using normative social influence to promote conservation among hotel guests. *Soc. Influence* **3**, 4–23 (2008).
47. P. J. Ferraro, J. J. Miranda, Heterogeneous treatment effects and mechanisms in information-based environmental policies: Evidence from a large-scale field experiment. *Resour. Energy Econ.* **35**, 356–379 (2013).
48. J. M. Dalhuisen, R. J. G. M. Florax, H. L. F. de Groot, P. Nijkamp, Price and income elasticities of residential water demand: A meta analysis. *Land Econ.* **79**, 292–308 (2003).
49. D. E. Agthe, R. B. Billings, Equity, price elasticity, and household income under increasing block rates for water. *Am. J. Econ. Sociol.* **46**, 273–286 (1987).
50. M. Bertrand, E. Duflo, S. Mullainathan, How much should we trust differences-in-differences estimates? *Q. J. Econ.* **119**, 249–275 (2004).
51. J. D. Angrist, J.-S. Pischke, *Mostly Harmless Econometrics: An Empiricist's Companion* (Princeton University Press, 2008).
52. A. Walton, M. Hume, Creating positive habits in water conservation: The case of the Queensland Water Commission and the target 140 campaign. *Int. J. Nonprofit Volunt. Sect. Mark.* **16**, 215–224 (2011).
53. D. Mckenzie-Mohr, Promoting sustainable behavior: An introduction to community-based social marketing. *J. Soc. Issues* **56**, 543–554 (2000).