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Pledges counteract the boomerang effect in a sustainable showering intervention for children

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Water scarcity has become a growing concern due to climate change. As fresh water is going to become increasingly scarce in the future, inculcating water-conserving habits among young children is very important. We conduct a randomized field experiment that focussed on instilling the behaviour of showering within 5 min among primary school children ($N = 1121$) in Singapore. Alongside an educational show emphasizing the importance of a 5 min shower, we introduced two commitment interventions—private and public (written) pledges—to nudge children to adhere to the 5 min shower time goal. Unexpectedly, the educational show and the 5 min shower time goal had an undesirable boomerang effect: children with a baseline shower time above 5 min reduced their shower time, while those below 5 min increased it, resulting in no net reduction. The private and public pledge-based commitments effectively countered the boomerang effect, reducing overall shower time and increasing adherence to the 5 min target. The commitment interventions achieved this by increasing the participants' willingness to meet the target and by ensuring greater reductions for those more willing to reduce shower time.

Almost 1.1 billion people lack access to clean, fresh water for at least one month a year¹. Water scarcity is worsening due to climate change and increasing global water demand. Governments and researchers worldwide are working to reduce household water consumption^{2–6}. One effective way to save water is to limit shower time. In Singapore, where showers account for 30% of household water consumption⁷, reducing shower time by 1 min can save up to 9 litres of water⁸. The benefits of a 5 min shower have been emphasised globally. Governments in countries like the United States, Australia, Netherlands, and Singapore have encouraged people to limit their shower time to 5 min^{8–10}. Last year, hotels in Barcelona, Spain, challenged guests to shower within 5 min due to the city's acute water shortage¹¹.

However, when policymakers set a single behavioural goal, such as a 5 min shower time, two challenges arise. First, those who have not yet met the goal must overcome self-control problems to achieve it^{12,13}. Second, those who are already meeting the goal (e.g., whose shower time is less than 5 min) may be motivated to increase their consumption, as the goal conveys a social norm different from their current behaviour. This unintended consequence, known as the boomerang effect, was first empirically demonstrated by Schultz et al.¹⁴ in the context of energy conservation. In their study, households received feedback about the average energy consumption in their neighbourhood. While this descriptive norm-based message effectively reduced consumption among high-usage households, it unintentionally led low-usage households to increase their consumption. Crucially, Schultz

et al.¹⁴ found that this boomerang effect could be mitigated through injunctive norm-based interventions, such as the inclusion of positive or negative smiley faces alongside the feedback. These symbols conveyed social approval or disapproval of a household's energy behaviour. Low-consuming households who received a positive smiley (signalling approval) were less likely to increase their usage, thereby avoiding the boomerang effect. Subsequent research has built on these findings, examining the effectiveness of injunctive norm cues in promoting conservation behaviours across domains such as energy and water usage^{2,15,16}. The boomerang effect has also been observed in public health interventions, often attributed to psychological reactance, where perceived threats to autonomy prompt resistance to behaviour change^{17–19}.

In this paper, we study whether children exhibit the boomerang effect when they are provided a goal for shower time. We focus on children as participants for this randomised control trial (RCT) because we believe sustainable habits instilled early in childhood tend to persist throughout life²⁰. We also study the effectiveness of simple pledge-based interventions to counteract the boomerang effect.

Pledges, as commitment devices, help individuals fulfil plans for future behaviour by imposing psychological or economic costs for noncompliance²¹. A written pledge involves a promise to adopt a specific future behaviour, and individuals are motivated to follow through to avoid cognitive dissonance²² and remain consistent²³. Depending on whether the

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behaviour is observed, pledges can be private or public²⁴. Studies have shown pledges to be effective in increasing towel reuse²⁵, donations²⁶, savings²⁷, weight loss²⁸, and sustainable dietary habits²⁹. Pledges to save water have been implemented in cities across the USA and by the European Commission³⁰⁻³⁵. Despite their popularity, there is limited research on the effectiveness of such pledges to foster water conservation. Dickerson et al.³⁶ conducted a related study using public commitment to encourage shorter showers among female swimmers, but their focus was on encouraging others. In contrast, our study examines the effectiveness of a pledge aimed at reducing one’s own shower time, particularly among young children.

Our RCT evaluated the effectiveness of written pledges in enabling children to achieve a 5 min shower time goal. The RCT was conducted in collaboration with the Public Utility Board (PUB), which runs an educational programme called “Time to Save” show among primary school children in Singapore. The show focuses on water conservation and emphasises the importance of a 5 min shower through a skit and a dance. Our RCT introduced two pledge-based interventions alongside the programme.

The RCT lasted for 14 days, and the intervention was on day 8. The classes in each participating school were randomly allocated to one of the three conditions: Control, Private, or Public commitment. In all three conditions, the students watched the show on day 8 and were provided with a 5 min shower time goal. (i) Students in control condition were given no further instructions. (ii) Students in private commitment made an anonymous private (written) pledge that they would keep shower time within 5 min and in addition, they were informed that their shower time would not be disclosed to anyone. (iii) Students in public commitment made a public (written) pledge, in front of their classmates and teacher, that they would keep their shower time within 5 min, and in addition, they were informed that their teacher may be able to see their shower time. The private pledge intervention leveraged self-signalling motives, where children sought to maintain a positive self-image³⁷⁻³⁹. On the other hand, the public pledge is made in front of the entire class. Therefore,

in addition to the intrinsic desire to maintain a positive self-image the children are also motivated by the desire to signal others that they are good (in this case, how their teachers will perceive them based on their actions as their teachers can observe their shower time)^{40,41}. Also since they see other students also making a public pledge, social norms also come into play²³.

Methods

The Singapore PUB has been conducting the “Time to Save” programme every year among primary school children in Singapore (see Figure S1 in Supplementary Information). The programme consists of a 30 min show that educates school children about the benefits of water conservation and emphasises the importance of a 5 min shower through a shower dance (available to watch at <https://www.youtube.com/watch?v=hXVoVadE5mA>). After the show, the PUB provides a timer to each child so that they can track their shower time and try to achieve the 5 min shower goal. Each child also receives an information booklet discussing the benefits of water conservation (see Fig. S2 in Supplementary Information). In our experiment, we introduce a written pledge as an intervention into the existing programme. Our field experiment was conducted among six public primary schools in Singapore. The participants were students from Grades 2 to 5 (Age 8–11 years).

The experiment was conducted in six primary schools over a period of 3 months. Due to logistical constraints, we could not conduct the experiment simultaneously across all schools. However, since the schools were widely dispersed throughout the city, the likelihood of communication between them was minimal. The classes in each school were randomly assigned into one of the three conditions (Fig. 1). The experiment lasted for 14 days with the intervention happening on day 8. We refer to the period before the intervention as the “baseline” period (7 days) and the period after the intervention as the “treatment” period (7 days).

However, the 14-day experimental period was consistent across schools, with the intervention happening on day 8. In each school, there was one teacher in charge for each class who took care of administering the

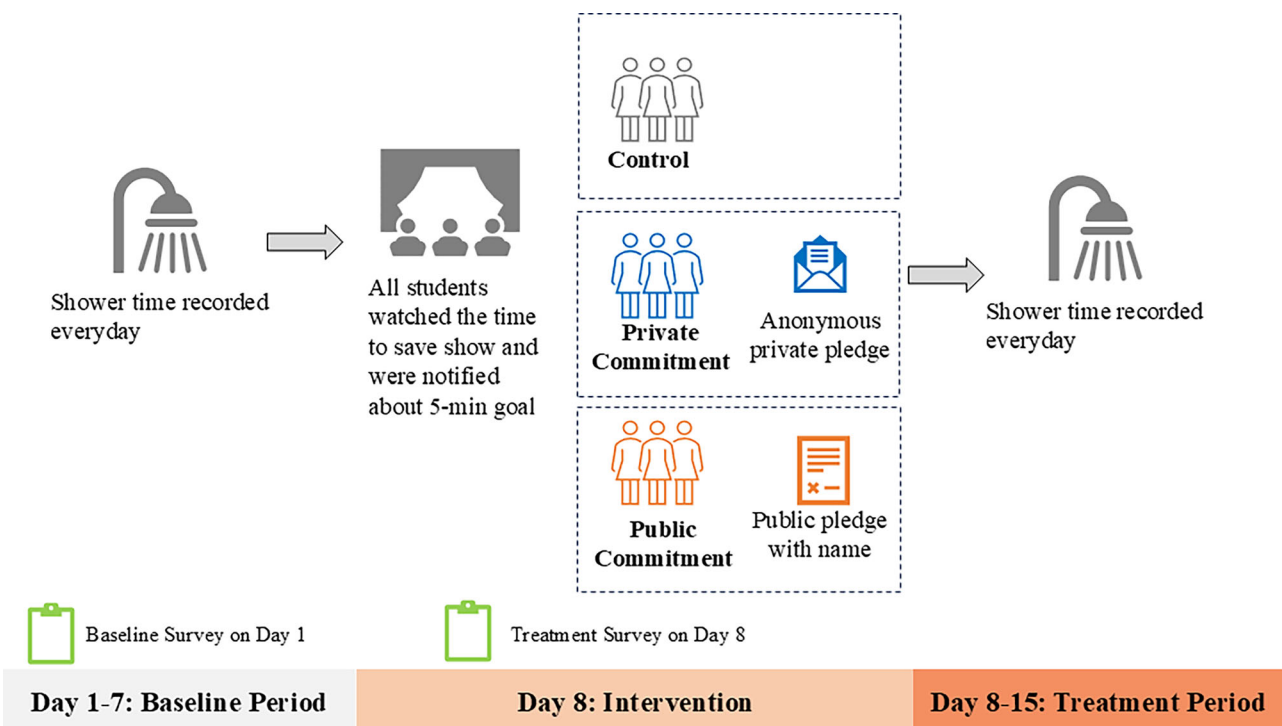


Fig. 1 | Experimental Design. Each class of a school is randomly assigned into one of the three conditions (control, private commitment, and public commitment). The pledge content is “I will keep my shower time to less than 5 min”. All Participants
b Participants with Baseline Avg. <= 5 min. (Number of participants: Control = 396,

Private = 364, Public = 361) (Number of participants: Control = 290, Private = 266, Public = 246).
c Participants with Baseline Avg. > 5 min. (Number of participants: Control = 106, Private = 98, Public = 115)

experiment to that class (typically referred to as the “class teacher”). The class teacher helped convey experimental instructions and distribute experimental materials to the participants. All experimental instructions, surveys, data and code are in the OSF link - https://osf.io/k3xqv/?view_only=65a90cf33ce640c39c32e06c2c0adadb.

Before the experiment

Our research team and PUB reached out to schools two weeks before the experiment. We explained the logistics of the experiment and handed out hard copies of experimental instructions to each class teacher to ensure that they were clear about the instructions. These teachers distributed the informed consent form to the participants’ parents at least 10 days before the experiment. The parents had to provide consent if they planned to allow their child to participate in the experiment. The experiment was not pre-registered. However all experimental surveys and interventions were approved by the institutional review board of the National University of Singapore and then vetted, approved by the Ministry of Education, Singapore (see OSF for the approval).

Baseline period

On day 1 of the experiment, each participant received an experimental package. The package included a timer and a self-reported data sheet (see Figs. S3 and S4 in Supplementary Information). The participants watched a video instruction on how to use the timer to measure their shower time and record it in the self-reported data sheet (available to watch at <https://www.youtube.com/watch?v=QFKxD5O8dK0&feature=youtu.be>). Note that the timer automatically recorded the shower time duration in its memory (with no timestamp) when the participant pressed the start and stop buttons. The timer had memory to store 30 data points. Throughout the whole experiment period, the participants were asked to time their first shower every day and enter the value in the self-reported data sheet. As the timer did not have a timestamp, in order to know if the data corresponded to the baseline or the treatment period, we used two different timers. The children were required to exchange their timer at the end of the baseline period for a new timer to be used during the treatment period. The reported data is strongly correlated with the data from timer memory (correlation = 0.73) during the treatment period, supporting its reliability across conditions (see Table S1 in Supplementary Information).

Treatment period

The “Time to Save” educational show was conducted on day 8. Participants from all conditions were required to attend the 30 min show in the school assembly (see Fig. S1 in Supplementary Information). The show consisted of a dance, skit and a quiz that educated students the importance of water conservation and emphasised the importance of the 5 min shower. Besides, participants from all conditions received an information booklet discussing the benefits of water conservation. The participants in the control group received no further instructions and were asked to continue measuring and reporting their shower time as they already did in the baseline period. However, participants in private and the public commitment conditions were given an opportunity to pledge after watching the show on day 8.

In the private commitment condition, the participants were given an option to make an anonymous pledge (“I will keep my shower time to less than 5 min.”) on a A5-size pledge sheet without their name or signature, place it in an envelope (see Figure S5 in Supplementary Information) and drop it in the cardboard box located in the back of the classroom. Participants were informed that their shower time will be kept completely anonymous and will not be disclosed to anyone. All participants irrespective of whether they chose to pledge or not were asked to place the sheet in an envelope and drop it in the cardboard box.

In the public commitment condition, the participants pledged in an A1 size poster pasted in the front of the class room (see Fig. S6 in Supplementary Information). If the participants chose to pledge then they were asked to write “I will keep my shower time to less than 5 min” and sign (or write their name) below. All participants in a particular class were required

to write their pledges on the same A1 poster. Unlike private commitment, participants in the public commitment condition were informed that their names and shower time will be shared with PUB and their teacher. However, it was also emphasised to the participants that they will not be rewarded or penalised by their teacher based on their shower time. The pledge sheet remained pasted in the class until the end of the experiment. Note that in both the commitment conditions, the pledge content was identical and the participants were not obligated to pledge. In both the conditions, the experimental team collected the data sheet and timer at the end of the experiment. All anonymized data was shared with PUB. In the public commitment condition, both teachers and PUB were informed that participants’ names and shower times would be disclosed upon request. At the end of study, participants were briefed and thanked for participation. All participating children received a water valley timer, custom designed tooth brush mug, and a notebook as a token of appreciation for their participation (see Fig. S7 in Supplementary Information).

The participants were also surveyed at the beginning of the baseline (on day 1) and treatment on day 8 (after the intervention and the show). There are no statistically significant differences in the baseline survey responses across conditions (see Table S2 for survey results). Overall, $N = 1353$ students participated in the experiment. The sample size was calculated assuming 80% power, $\alpha = 0.05$, an effect size of $d = 0.25$ for the difference between the commitment and control conditions, class size of 20, and an intra-class correlation of 0.08. We employ non-parametric tests to analyse model free evidence and robust standard errors in the regression to account for potential deviations from normality.

Results

Out of the 1353 students, $N = 1121$ students ($N = 529$ girls, $N = 558$ boys, 34 missing values for gender) participated in the experiment and returned their self-reported data sheets with at least one entry in each of the baseline and the treatment period (almost all of them had at least five entries, see Table S3-4 in Supplementary Information). The remaining 232 students (1353 minus 1121 students) who had no entries during either the baseline or treatment period were excluded from the analysis, as it was not possible to determine whether their usage changed between the two periods. Table 1 lists demographics of participants across different conditions. There is no significant difference in demographics across different conditions. Our participants’ gender ratio (boy : girl) is 1.04 and the average age is 9.7 years. The majority of our participants (74%) resided in the Singapore’s housing development board (HDB) buildings. All HDB buildings have similar facilities and amenities (including house layout and water flow). The remaining participants live in private apartments or condominiums, but the quality of facilities such as water flow is similar to that of HDB buildings. We observe that no statistically significant difference in the proportion of participants chose to pledge in both the private (70%) and the public (74%) commitment conditions (using a two-sided 2-sample proportion test with continuity correction: $df=1$, $p = 0.177$). There was no statistically significant difference in gender or baseline shower time of participants who made the public pledge (see Table S5 in Supplementary Information). Our analysis will focus on the *intent-to-treat effect*, which examines the impact of being assigned to the treatment, regardless of whether the participants actually pledged.

Model-free evidence

We use the shower time data reported by the participants to understand their behaviour and motivation. We used the data reported by participants instead of the timer data for the following reasons: The timer data had no time stamps, so we were not able to know accurately the shower time for a particular day. In addition, as the timer can store only 30 data points in the memory and children can accidentally press the timers, initial data may be overwritten.

Figure 2 (a) displays daily shower time across all the conditions during the experiment period (days 1–7 of the baseline period and days 8–14 of the treatment period). We also show the daily shower time change from the

Table 1 | Demographic Factors of Participants Across All Treatment Conditions

Treatment ^a	Obs	Class (No.)	% of Data Reported ^b		Girls (%)	Age ^c (Year)	Living in HDB ^d (%)	Occupants At Home	Pledge Rate ^e
			Baseline (S.D.)	Treatment (S.D.)					
Control	396	20	99.5% (3.1%)	99.4% (3.5%)	46.9%	9.6 (0.9)	73%	5.0 (1.8)	-
Private	364	19	99.8% (2.0%)	99.6% (2.7%)	47.2%	9.6 (1.0)	70%	5.0 (2.0)	70%
Public	361	19	99.4% (3.0%)	99.4% (3.6%)	52.2%	9.8 (1.1)	77%	4.9 (1.6)	74%
Total	1121	58	99.6% (2.8%)	99.5% (3.3%)	48.7%	9.7 (1.0)	74%	5.0 (1.8)	72%

Notes: ^aThere is no significant difference in gender ratio, the number of occupants, and proportion occupying HDB between the control and the treatment (For gender ratio, using a two-sided 2-sample proportion test with continuity correction against a null hypothesis that there is a difference between different conditions: control vs private, $df = 1, p = 0.997$; control vs public, $df = 1, p = 0.177$; private vs public, $df = 1, p = 0.213$. For number of occupants, using a two-sided Welch's t-test against a null hypothesis that there is a difference between different conditions: control vs private, $df = 559.87, p = 0.797$; control vs public, $df = 528.66, p = 0.391$; private vs public, $df = 540.16, p = 0.276$. For proportion occupying HDB, using a two-sided 2-sample proportion test with continuity correction against a null hypothesis that there is a difference between different conditions: control vs private, $df = 1, p = 0.419$; control vs public, $df = 1, p = 0.315$; private vs public, $df = 1, p = 0.062$).

^bThe self-reported data sheet distributed to the participants has seven blanks to fill in during the baseline and seven blanks to fill in during the treatment period. Participants are supposed to fill in their shower time for each day in the self-reported data sheet. The percentage of data entry in each period equals the number of actual data entries divided by 7 for each individual. Participants have almost full entries during every day of the experimental period.

^cAge is approximated by the participants grade plus 6 (which is the typical age when participants enter into the primary school).

^dHDB is the public housing estate developed by Singapore's public housing authority. It aims to provide affordable homes of high quality to Singaporeans.

^eThe pledge rate equals the number of participants who pledged divided by the number of participants who participated in the experiment. The difference in the pledge rate between private commitment and public commitment is not significantly different (using a two-sided 2-sample proportion test with continuity correction against a null hypothesis that there is a difference in the pledge rate between the private and the public condition: $df = 1, p = 0.177$).

baseline average during the treatment period in Supplementary Fig. S8. The control condition has no significant change in the daily shower time across periods (baseline daily average = 262 s, treatment daily average = 259 s, Wilcoxon signed-rank test: $p = 0.587$, Cohen's d: mean 0.020, 95% CI: [-0.030, 0.070]). In contrast to the control condition, there is a significant reduction in the daily shower time in private (baseline daily average = 248 s, treatment daily average = 234 s, Wilcoxon signed-rank test: $p < 0.001$, Cohen's d: mean 0.103, 95% CI: [0.048, 0.157]) and the public commitment conditions (using a baseline daily average = 276 s, treatment daily average = 259 s, Wilcoxon signed-rank test: $p < 0.001$, Cohen's d: mean 0.118, 95% CI: [0.059, 0.176]) during the treatment period.

Figure 2(b) focuses on participants with the baseline daily average shower time below 5 min. It is observed that the participants in the control condition in fact increased their shower time in the treatment period (the boomerang effect) (baseline daily average = 187 s, treatment daily average = 196 s, Wilcoxon signed-rank test: $p = 0.054$, Cohen's d: mean -0.114, 95% CI: [-0.197, -0.030]). In contrast, participants in the private and public commitment have no statistically significant change in their shower time from baseline to treatment period (for private, baseline daily average = 187 s, treatment daily average = 188 s, Wilcoxon signed-rank test: $p = 0.435$, Cohen's d: mean 0.077, 95% CI: [-0.093, 0.077]; for public, baseline daily average = 197 s, treatment daily average = 193 s, Wilcoxon signed-rank test: $p = 0.121$, Cohen's d: mean 0.067, 95% CI: [-0.028, 0.162]).

Figure 2(c) focuses on participants with baseline daily average shower time above 5 min. It is observed that the participants in all conditions decreased their shower time during the treatment period (for control: baseline daily average = 465 s, treatment daily average = 430 s, Wilcoxon signed-rank test: $p = 0.002$, Cohen's d: mean 0.159, 95% CI: [0.039, 0.277]; for private: baseline daily average = 412 s, treatment daily average = 357 s, Wilcoxon signed-rank test: $p < 0.001$, Cohen's d: mean 0.322, 95% CI: [0.192, 0.451]; for public: baseline daily average = 444 s, treatment daily average = 398 s, Wilcoxon signed-rank test: $p < 0.001$, Cohen's d: mean 0.289, 95% CI: [0.140, 0.437]). This indicates that the "Time to Save" show and the pledge were effective in reducing shower time among participants whose baseline daily average shower time was higher than the 5 min goal.

Regression analysis

We can visually see in Fig. 2, the trend in baseline shower time is identical across all conditions. Therefore, we run a difference-in-difference regression^{42,43} with daily shower time as the dependent variable (DV):

$$y_{it} = \beta_0 + \beta_1 T_i + \beta_2 D_t + \beta_3 T_i D_t + \beta_4 Z_{it} + \alpha_i + \theta_t + \varepsilon_{it}, \quad (1)$$

where y_{it} is the shower time of participant i on day t , T_i is the vector of treatment dummies for the private and the public commitment conditions, D_t is the dummy for the treatment period, Z_{it} is the vector of other control variables including the average outside temperature (in Celsius), the dummy for weekday (vs. weekend), α_i is the individual-level fixed effect of participant i , and θ_t is the week fixed effect. In the regression, β_3 captures the additional shower time reduction in the private and the public commitment conditions (compared to the control condition) during the treatment period. To account for repeated measurements, the standard errors in the regression are clustered at the student level. Table 2: Column 1 reports the regression results. Overall, we find that the private commitment condition reduced the shower time compared to the control group ($\beta_3 = -11.728, p = 0.026$, clustered S.E. = 5.279, 95% CI = [-22.087, -1.37]). Similar is the case with the public commitment condition ($\beta_3 = -17.179, p = 0.003$, clustered S.E. = 5.861, 95% CI = [-28.678, -5.679]). However, there is no statistically significant difference in the quantum of reduction between the private and public commitment conditions (Wald test comparing coefficients of private commitment and public commitment conditions, $df = 1, p = 0.356$). We also compare the reduction in private and public commitment condition using the Bayes factor, but the evidence shows that reductions have no statistically significant difference (Alternate $r = 0.707$ vs Null (difference in reduction is zero): Bayes factor = $0.096 \pm 0.2\%$).

We also find identical results when we add class-level fixed effects or when we cluster the standard errors at the class-level (to account for the fact that students are nested within a class) instead of the individual level (see Table S6 in the Supplementary information). We also show our results are robust to adding or removing controls (see Table S7 in the Supplementary information). We also find similar results when we run a OLS regression with number of days target achieved as the dependent variable (see Table S8 in Supplementary Information). In Supplementary Table S9, we also complement the above intent-to-treat analysis with an estimate of the local average treatment effect among compliers—those who made a public pledge.

In Table 2: Column 2, we also estimate the model by including an interaction terms that captures the effect of private and public treatment on shower time of participants based on whether their baseline shower time was higher or lower than 5 min. The absolute reductions in each condition are estimated based on this regression in Table S10 of Supplementary Information. In the control condition, the participants with baseline daily average lower than 5 min increased their shower time by 8.5 s (Wald test : $df = 1, p = 0.024$), while the participants with baseline daily average higher than 5 min reduced their shower time by 30.4 seconds (Wald test : $df = 1, p = 0.006$), thereby exhibiting the classical boomerang effect. There is no statistically significant difference in the impact of private commitment on

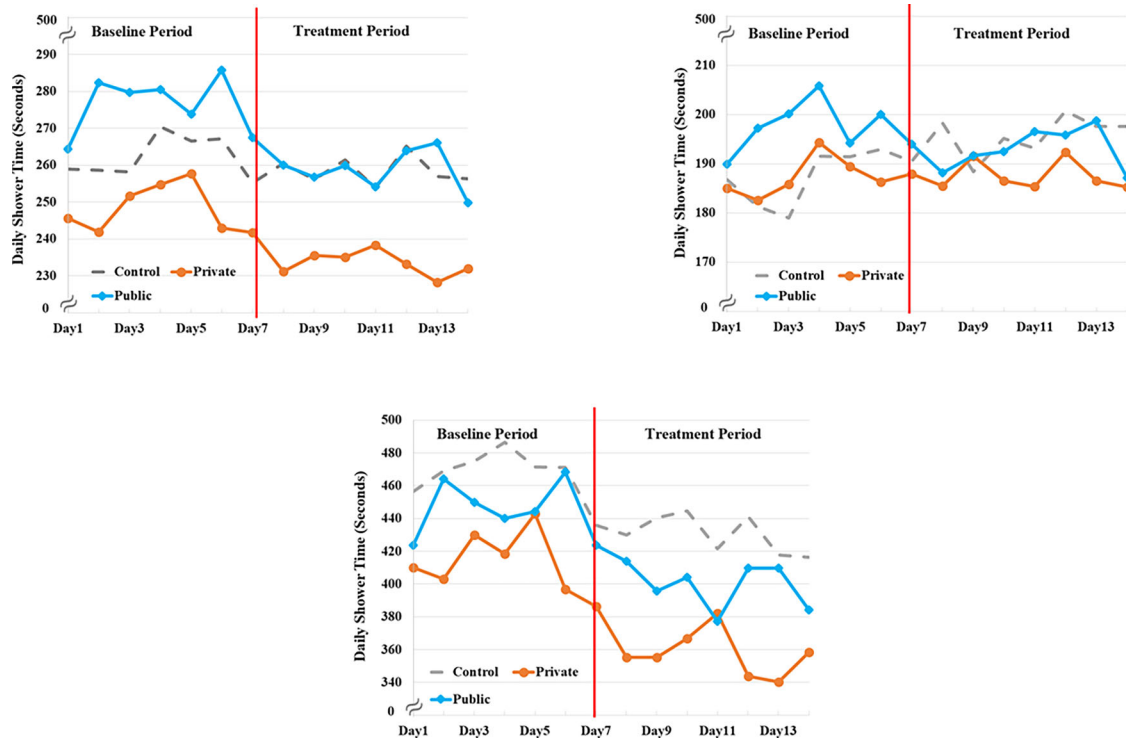


Fig. 2 | Average Daily Shower Time During the Baseline and Treatment Period.

the shower time of the participants with baseline daily average less than 5 min (Wald test: $df = 1, p = 0.835$), but private commitment significantly decreased the shower time of participants by 51 s with baseline daily average higher than 5 min (Wald test: $df=1, p < 0.001$). Similarly, there is no statistically significant difference in the impact of public commitment on the shower time of the participants with baseline daily average lower than 5 min either (Wald test: $df=1, p = 0.140$), but public commitment significantly decreased the shower time of the participants with baseline daily average higher than 5 min by 46 s (Wald test: $df=1, p < 0.001$). Thus, commitment conditions effectively cancelled out the boomerang effect and ensured that overall shower time is reduced.

How did the pledge-based interventions work?

In order to understand the reason for the effectiveness of commitment interventions, we analyse the survey data. Participants in (public and private) pledge conditions showed a higher desire to meet the target (yes:1, maybe:0, no:-1) than control group (mean: control group = 0.636, treatment groups = 0.733, Mann Whitney U test: $p = 0.034$, Cohen’s d: mean -0.191 , 95% CI: $[-0.354, -0.029]$). In addition, the participants with higher desire to meet the target did actually achieve the 5 min target more frequently (mean: participants who said “Yes” meet the target for = 5.681 days, who did not say “Yes” = 4.265 days, Mann Whitney U test: $p < 0.001$, Cohen’s d: mean 0.636, 95% CI: $[0.462, 0.811]$). A mediation analysis based on 5000 bootstrap samples⁴⁴ shows that the willingness to meet the target mediated the relationship between our pledge conditions and actual target achievement (average causal mediation effect: 0.116, 95% CI = $[0.011, 0.230]$, $p = 0.029$). The pledge-based commitment interventions especially had a stronger effect on the willingness to meet the target for participants with baseline daily average less than 5 min and thereby reducing the boomerang effect (mean: control group = 0.692, private = 0.820, public = 0.810; private vs control: Mann Whitney U test: $p = 0.020$, Cohen’s d: mean -0.269 , 95% CI: $[-0.485, -0.054]$; public vs control: Mann Whitney U test: $p = 0.058$, Cohen’s d: mean -0.244 , 95% CI: $[-0.472, -0.016]$, see Table S11 in Supplementary Information for other details).

We not only focus on the desire to meet the target, but also on the willingness to reduce shower time. Post the data-collection, we found that

the average willingness to reduce shower time was high (a rating of 5.8 on a scale of 1–7), so we focus on the participants with the willingness higher than the average, i.e., 6 or 7 on a 7-point scale. For the participants with higher willingness to reduce shower time (6 or 7 on a scale of 1–7, median 6), we find that participants in (public and private) pledge conditions had higher actual reduction in shower time compared with the control condition (mean: control group = 2 s, treatment groups = 22 s, Mann Whitney U test: $p = 0.001$, Cohen’s d: mean -0.264 , 95% CI: $[-0.467, -0.062]$). In summary, pledge-based interventions effectively reduced shower time and increased target achievement by boosting willingness to meet the target and ensuring greater reduction for participants with a higher willingness to reduce shower time.

Discussion

In our field experiment, a normative goal of shower within 5 min was introduced to the primary school students in Singapore through the PUB’s “Time to Save” show. The students were educated about the significance of reducing their shower time through the show. In fact, more than 90% children were able to recall the characters in show, and also the correct water saving habits mentioned in the show ($N = 676$, see Table S2 in Supplementary Information for survey results). While the show and 5 min shower time goal effectively nudged students with an average shower time exceeding 5 min to reduce their shower duration, it unfortunately led to an increase in shower duration among students whose average shower time was below 5 min resulting in net zero reduction overall. By combining goal setting with a simple private or public pledge, we can counteract such undesirable boomerang effect and reduce the overall shower time of the participants.

The participants in both the private and public commitment groups reduced their shower times by 14 and 19 s, respectively, compared to the control group. This resulted in water savings of between 2.1 and 2.9 litres per shower. Given that, on average, individuals in our study shower 1.8 times per day, this equates to an average daily water saving of approximately 4 litres. With the average household water consumption per person in Singapore at 140 litres per day, this represents a 3–4% reduction. The Singaporean government aims to reduce average household water consumption to 130 litres per day by 2030⁴⁵—an overall decrease of 10 litres or 7%. In

Table 2 | Effect of Assignment to Treatment Conditions on Shower Time

Dependent variable: daily shower time in seconds			
	(1)	(2)	
Treatment period	Coefficient	-2.123	8.499*
	Std. Error	4.167	3.768
	95% CI	[-10.291, 6.046]	[1.112, 15.886]
	p-value	$p = 0.611$	$p = 0.024$
Daily outside average temperature (C)	Coefficient	2.354*	2.544*
	Std. Error	1.184	1.168
	95% CI	[0.034, 4.674]	[0.255, 4.832]
	p-value	$p = 0.047$	$p = 0.030$
Weekend	Coefficient	4.141*	4.098
	Std. Error	2.106	2.109
	95% CI	[0.013, 8.27]	[-0.036, 8.231]
	p-value	$p = 0.050$	$p = 0.052$
Private × Treatment period	Coefficient	-11.728*	-7.706
	Std. Error	5.279	4.381
	95% CI	[-22.076, -1.38]	[-16.294, 0.881]
	p-value	$p = 0.027$	$p = 0.079$
Public × Treatment Period	Coefficient	-17.179**	-14.307**
	Std. Error	5.861	4.455
	95% CI	[-28.667, -5.691]	[-23.040, -5.575]
	p-value	$p = 0.003$	$p = 0.001$
(Baseline shower > 5 mins) × Treatment Period	Coefficient		-38.883***
	Std. Error		11.493
	95% CI		[-61.411, -16.355]
	p-value		$p = 0.001$
Private × Treatment Period × (Baseline shower > 5 min)	Coefficient		-12.906
	Std. Error		15.199
	95% CI		[-42.699, 16.886]
	p-value		$p = 0.396$
Public × Treatment Period × (Baseline shower > 5 min)	Coefficient		-1.936
	Std. Error		(17.126)
	95% CI		[-35.504, 31.633]
	p-value		$p = 0.910$
Fixed effect			
Individual student	Yes	Yes	
Week	Yes	Yes	
Observations	14,602	14,602	
R²	0.683	0.686	
Adjusted R²	0.657	0.661	
Residual Std. Error	100.264 (df = 13506)	99.741 (df = 13503)	

Note: * $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$. Standard errors are clustered at the student level. (Baseline shower > 5 min) = 1 when avg. shower time of a participant during baseline is higher than or equal to 5 min and (Baseline shower > 5 min) = 0 when avg. shower time of a participant during baseline is less than 5 min.

light of this goal, we believe the impact of our intervention is significant. Additionally, our intervention may have positive spillover effects, potentially encouraging other water-saving habits.

Our pledge-based interventions work by increasing the willingness to meet the target, which in turn increases the target achievement. This higher psychological desire and motivation to meet the target in pledge conditions might have stemmed from self and social signalling motives. However, deviating from our expectations public pledge did not outperform private pledge in spite of being a multi-pronged intervention where self-signalling, social signalling, and social norms might have played a role. This may indicate that, under public pledge, social signalling motive (as teachers can observe shower time) might have displaced some intrinsic self-signalling motive, e.g., one cannot feel good about oneself when one does it to signal others and under social compulsion. Thus, our results also show that, when the baseline willingness to change behaviour is high (such as in our context – the average willingness to reduce shower time is 5.8 out of 7), an anonymous private pledge might work as good as a public pledge.

In addition to the above mechanism, for participants with higher willingness to reduce shower time, pledge based interventions also led to higher shower time reductions compared to similar participants in the control group. Our results demonstrate that pledge-based intervention not only heightened the desire to meet the target but also ensured that this desire translated into actual behaviour. This is in line with the predictions of cognitive dissonance²² and signalling theories^{37,39}.

Thus, our study contributes to the literature on using pledges to promote environmentally friendly behaviour²⁵ by comparing the effectiveness of private versus public pledges in encouraging the same behaviour and exploring the underlying mechanisms. Additionally, it advances the literature on the boomerang effect¹⁴ by demonstrating a simple, pledge-based intervention that can counteract this effect. It is worth noting that our public pledge intervention may operate through the same mechanism as injunctive norms, by leveraging social approval. In contrast, the private pledge intervention likely engages a different process, drawing on internalised personal norms¹⁵.

Limitations

We end our discussion with the following caveats. First, our experiment focuses on Singaporean children. Although we believe our pledge-based intervention would generalise to other cultures, there might still be some idiosyncratic factors specific to Singapore (such as higher levels of conformity) that might affect the effectiveness of the intervention⁴⁶. Second, we asked children to record the first shower of the day. Some students might have showered for the second time and may have taken a longer time in the second shower. Our data is not able to capture this behaviour. Third, many of our students were already meeting the 5 min goal (on average) during the baseline. Our effects might have been larger if not many were meeting the 5 min goal initially. Fourth, we tracked the shower times for only one week post-treatment. Future research could evaluate the long-run effectiveness of such pledge-based interventions and help tease out the marginal contribution of self and social signalling motivations more clearly.

Data availability

The CSV data that support the findings of this study are available in the OSF with the identifier <https://doi.org/10.17605/OSF.IO/K3XQV>.

Code availability

The R code used for data analysis is also available in the OSF with the identifier <https://doi.org/10.17605/OSF.IO/K3XQV>.

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Author contributions

Both authors contributed equally to this manuscript. J.S. designed the experiment, collected the data, co-developed the empirical estimation strategy, conducted supplementary analyses, and wrote the manuscript. Z.W. co-developed the empirical estimation strategy, conducted the main analysis, and contributed to refining and editing the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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