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Water-Saving Tips With a Visualized Indicator Related to the Environment

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Water-saving tips are information-based interventions aimed at managing water demand. Studies of the effectiveness of qualitative water-saving tips to explain why and how water should be saved have not always found significant changes in water consumption. Some studies indicate that the addition of quantitative tips and videos are effective for water conservation. This study adds to the literature by attempting to verify the effectiveness of water-saving tips that visualize the amount of water that can be saved using illustrations of bathtubs. Furthermore, as not all people are interested in water saving, we include tips with a visualized indicator related to the environment, which is of more general interest. These tips used CO_2 emissions reductions to demonstrate the effect of water saving. As a result, for high-consumption households, it is more effective to present water-saving tips that present information on how their actions can limit CO_2 emissions than to illustrate the reduction in water consumption directly. At the same time, for low-consumption households, none of the tips had neither water-saving nor boomerang effects (i.e., increased the consumption while planning to reduce). Households were divided into high-and low-consumption using baseline water consumption per capita for their household size. The results of this study could serve as a tool for water demand management that can be easily utilized in many parts of the world.

Keywords: CO_2 emission reductions, visual indicators, water demand management, water-saving tips, information-based interventions

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INTRODUCTION

The growing need for more sustainable water use has inspired various methods for water demand management. Information-based interventions are an effective, non-price-related method of managing demand (Tortajadaa et al., 2019; Lu, 2020; Nemati and Pen, 2020; Abu-Bakar et al., 2021); and numerous types of information have been validated for this purpose, including water-saving tips (Kurz et al., 2005; Schultz et al., 2016; Goette et al., 2019), self-set water saving goals (Novak et al., 2018), social comparison (Brent et al., 2015; Bhanot, 2017; Schultz et al., 2019), and gamification (Erickson et al., 2012; Galli et al., 2015). Most information-based interventions are made possible by electronic and near-real-time usage captures using recently introduced smart water metering. However, smart water metering is widespread in only a small part of the world, and it will likely be introduced only in a limited number of regions. In addition, from the perspective of implementation, interventions using recent individual-use data or similar methods involves offering tailored rather than general information to residents, which requires policymakers to collect substantial information in advance. This often lowers the feasibility of practical implementation (Sun et al., 2018). In this context, water-saving tips are the best possible intervention method in areas where smart water metering has not and will not been introduced.

Households that received water-saving tips expressed greater water scarcity concerns and higher intentions to act than those that did not receive them (Addo et al., 2019). In addition to concern and intention, several studies have reported that textual water-saving tips have a positive impact on actual water use. Sun et al. (2018) indicated that water-saving tips on a refrigerator magnet significantly reduced subsequent water consumption. Goette et al. (2019) reported that receiving periodic information with water-saving tips promoted household water conservation. Kurz et al. (2005) found that attunement labels with tips placed near the point of water use led to significant water savings. Fielding et al. (2013) demonstrated that brief water-saving tips on a postcard led to lower levels of water consumption. However, some studies have found tips to be ineffective or have negative effects; that is, the tips alone either had no impact on water consumption (Kurz et al., 2005; Ferraro et al., 2011; Schultz et al., 2016), or they led to increased water use by high consumers (Seyranian et al., 2015).

Previous studies have typically provided qualitative tips that explain why and how water should be saved, e.g., taking shorter showers, avoiding running taps, brushing teeth with a cup, and so on (Sun et al., 2018). This sort of tip does not provide people with accurate, accessible, and actionable information on how best to achieve potential savings through their actions (Gardner and Stern, 2008). Quantitative evidence is more persuasive than qualitative evidence (Allen and Preiss, 1997), and attitude changes stimulated by statistical information, rather than exemplar information, tend to be more persistent (Kazoleas, 1993; McKinley et al., 2017). Sun et al. (2018) reported that tips explaining the possible amount of savings were effective for water efficiency. Other studies have reported that a visualized expression is more effective for water saving than numerical values (Otaki et al., 2017; Novak et al., 2018). Therefore, this study attempted to verify the effects of tips using a visualized expression of the possible amount of water saved.

Furthermore, because not all people are interested in water saving, tips with a visual indicator related to the environment more generally, which may be of greater interest to participants, were used to verify the water-saving effect. In this case, the tips explained the effect on CO_2 emissions reductions. That is, significant quantities of energy are used to treat water to potable quality, deliver it to consumers, and dispose of wastewater; and water end uses account for almost 95% of all water-related energy use (Clarke et al., 2009; Fidar et al., 2010; Escriva-Bou et al., 2018). To the best of our knowledge, no studies have used expressions other than water, so this study presents and tests a novel approach to water demand management through water-saving tips. In addition, we propose a new approach to divide the households into high- and low-consumption using baseline water consumption per capita for their household size.

MATERIALS AND METHODS

Study Area and Participants

Participating households were selected from among residents living in cities with a population of more than 500,000 within 30 km of central Tokyo, Japan. All participants were registered with the survey company. Currently, in Japan, water meters are installed in each house. Because most are not smart water meters, meter readers go around to each house to read the value of the water meter to ascertain the amount used, which is then billed to the customer. Although the introduction of smart metering is being considered, it is not expected to be introduced on a large scale in the near future.

In the study, a total of 89 participating households were allocated randomly (i.e., by random number generation) to one of three groups: one control and two intervention groups that received water-saving tips through a website. The mean number of occupants in each household was 2.52 ($SD = 1.28$), with 29% of households having one occupant, 24% having two occupants, 19% having three, 22% having four, and 6% having five or more occupants. An analysis of variance indicated that there were no statistically significant differences in the number of occupants between the three groups [$F_{(2,\,86)} = 0.02, p = 0.888, \eta_p^2 = 0.000$].

Tracking Water Consumption and Interventions

As smart water meters are not currently installed, households were asked to take photographs of their water meters and upload them onto the system three times to report their water usage. Baseline usage was set for the first 2 weeks, after which the intervention groups received water-saving tips. Water use was again measured 1 month later to assess the impact of the intervention. The survey was conducted from the end of October to the beginning of December 2022.

The two intervention groups each received one visualized water-saving tip. The first group was given a tip explaining the amount of water (illustrated using bathtubs) that can be saved by performing the action. The second group was given information on the amount of CO_2 emissions that could be saved by performing the action. In the case of CO_2 emissions, households in this group were informed in advance that water use generates CO_2 because energy is used in water treatment plants, pumps that deliver water to homes, and sewage treatment plants. The two tips are shown in **Figure 1**.

Water Consumption Data and Analysis

The average daily water consumption per person at baseline and 1 month after the intervention was calculated from the water meter photograph. The change in the water consumption of each household was evaluated as follows:

$$log\ RP_i = log\left({}^{C_{i\_after}}\!/\!{}_{C_{i\_base}} \right) \quad (1)$$

where C_{i_base} is the daily water consumption in the baseline period (L/day/capita), C_{i_after} is that in the post-intervention period, and $logRP_i$ is the log-transformed relative proportion. When $logRP_i$ takes a value greater than (less than) zero, it signifies an increase (decrease) in water usage compared with the baseline.

As previous studies have reported different responses to information-based interventions between high- and low-consumption households (Schultz et al., 2007; Bhanot, 2017; Goette et al., 2019; Otaki et al., 2020), the analysis was divided into high- and low-consumption households, according

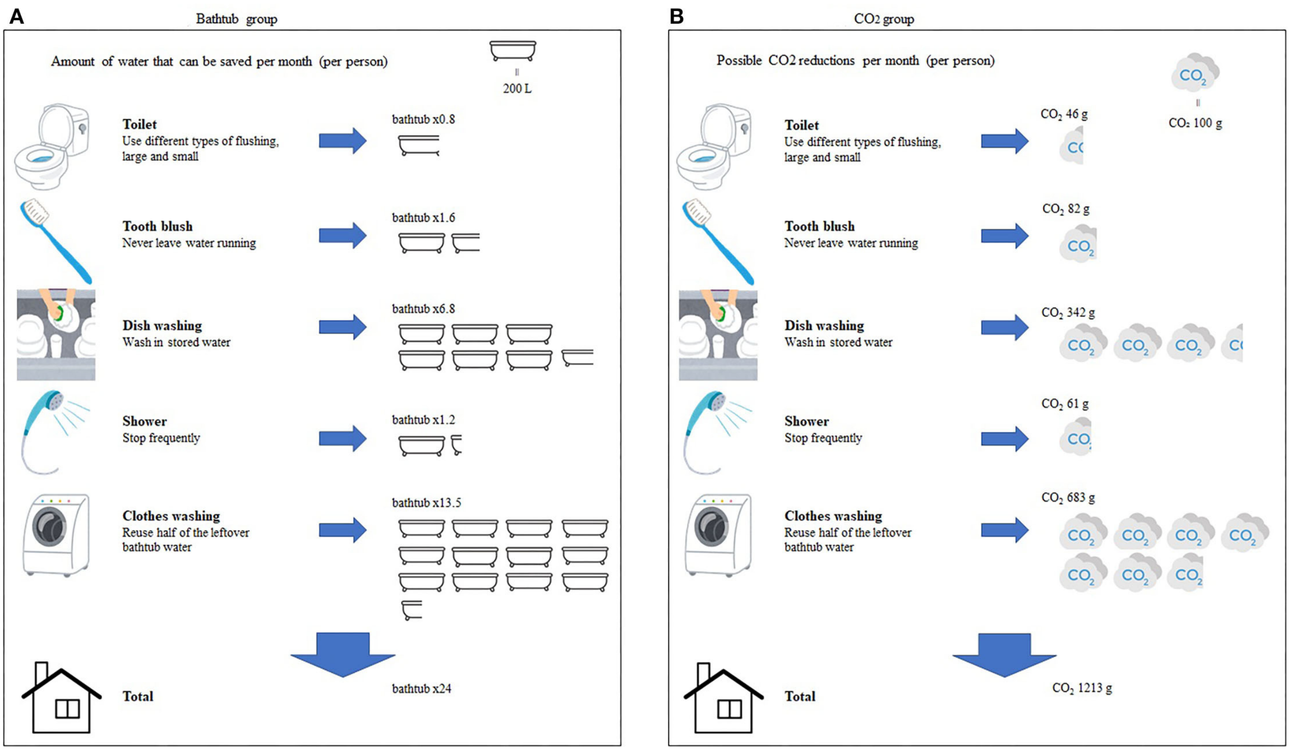

FIGURE 1 | Water-saving tips. **(A)** Water-saving tips for bathtub group. **(B)** Water-saving tips for CO_2 group.

to baseline water use. It is generally understood that as the number of household members increases, water consumption per capita decreases. To eliminate the influence of household size, we converted each household's baseline water consumption per capita into a value assumed for a one-person household as follows:

$$C_{i\_base\_one} = C_{i\_base} \times \left({}^{C_{ave\_1}}\!/\!_{C_{ave\_n}} \right) \quad (2)$$

where $C_{i\_base\_one}$ is the daily water consumption converted to the equivalent for a one-person household in the baseline period (L/day/capita), C_{ave_1} is the average per capita daily water consumption of one-person households in the Tokyo metropolitan area (273 L/day/capita), C_{ave_n} is the average per capita daily water consumption of n-person households in the Tokyo metropolitan area (C_{ave_2}: 265, C_{ave_3}: 227, C_{ave_4}: 203, C_{ave_5}: 193, C_{ave_6}: 188), and n is the number of people in household i. In this way, each household was distributed into "high" (more than 205 L/p/day) or "low" (<205 L/p/day) water use groups.

Questionnaire

Before the survey began, participants were asked what they thought of their households' water use. They responded using a visual analog scale (VAS) ranging from 0 (extremely low users) to 100 (extremely high users). We defined this value as the self-reported water consumption. In addition, they also asked about their thoughts on the need for water conservation in society and the seriousness of climate change using a VAS ranging from 0 (extremely unnecessary and extremely not severe) to 100 (extremely necessary and extremely severe).

At the end of the survey period, they were also asked what they thought their water use had been using the VAS ranging from 0 (decrease significantly) to 100 (increase significantly). We also asked the intervention groups to provide an open-ended response explaining how they felt about receiving the water-saving tips. Details of the questionnaire are described in **Supplementary Material 1**.

RESULTS AND DISCUSSION

Prior to the intervention, all groups had similar baseline water consumption [$F_{(2, 86)} = 0.934, p = 0.337, \eta_p^2 = 0.011$]. The survey questionnaire, scored on a scale of 101, indicated that participants were aware of the need for water conservation in society (M = 76.6, SD = 16.5), and they recognized the seriousness of climate change (M = 77.9, SD = 21.1); the higher the value, the more water conservation is needed in society and the more serious climate change is perceived to be. The detailed results are described in **Supplementary Material 2**. All groups were equally aware of the need for water conservation [$F_{(2, 86)} = 0.252, p = 0.617, \eta_p^2 = 0.003$] and the seriousness of climate change [$F_{(21, 86)} = 0.052, p = 0.821, \eta_p^2 = 0.000$].

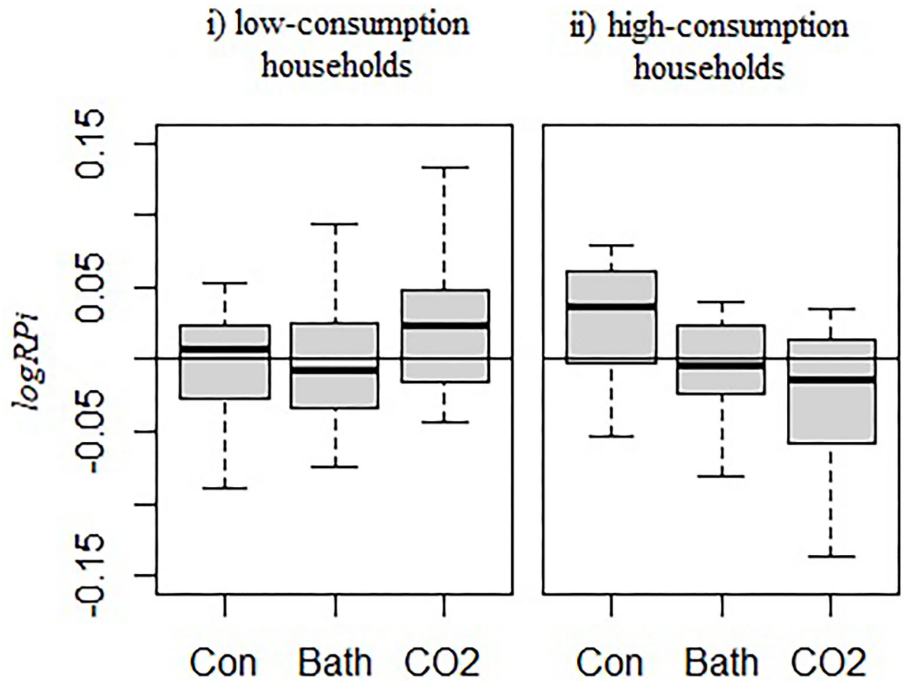

FIGURE 2 | Distribution of *logRPi* for each group. Con, Bath, CO_2 on x-axis indicate control, bathtub, CO_2 group, respectively.

Previous studies reported that there were significant but weak relationships between self-reported water consumption and actual water consumption (Kormos and Robert Gifford, 2014; Fielding et al., 2016). However, in this study, baseline water consumption per capita, converted to the equivalent of a one-person household ($C_{i\_base\_one}$), was correlated with self-reported water consumption ($r = 0.41$, $p = 0.000$). It can be seen that participants in this study tend to be correctly aware of their water use.

Figure 2 shows the $logRP_i$ distribution for each group. For high-consumption households, the CO_2 group showed reduced water consumption, while the bathtub group showed no significant reduction ($p = 0.05$). Regarding high-consumption households in the CO_2 group, there was no correlation between their self-reported change in water use and the actual change, revealing that their own perception of an increase or decrease did not match their actual change in use (**Figure 3**). That is, the actual increase or decrease in use was not consistent with self-reported changes. For low-consumption households, none of the tips had a water-saving or boomerang effect. Aggregating free-text statements about how participants felt after receiving the tips, more than 40% of high-consumption households in the CO_2 group commented that they wanted to save water, which was more than any other group (**Figure 4**). In particular, the difference between high-consumption households in the bathtub and CO_2 groups was significant.

In the psychological–social mechanisms of behavior change, there are three distinct behavioral conditions: capability, opportunity, and motivation (Hine et al., 2013; Michie et al., 2014). In this study, capability and opportunity were met by the inclusion of specific reduction actions in the tips, and motivation may have increased because the actions were made visible in a way related to climate change, which is perceived as a serious problem.

In a previous study in the Tokyo metropolitan area, participants were given information that made them aware of water as a public good, and only low-consumption households decreased their consumption (Otaki et al., 2020). Considering the results of this study, it is assumed that information related to water was not appealing for high-consumption households, but information that was more generally related to the environment, such as CO_2 emission conversions, was more appealing.

However, this study has some limitations. First, we were only able to conduct this study for a short time. Although assessments should normally be made for the short and long term, the COVID-19 pandemic has caused people's lifestyles to become unstable due to the stay-at-home measures recommended by the government, and it is uncertain when they will be lifted. Residential water consumption is strongly related to time spent at home; consumption becomes zero when residents are absent from their home all day and increases if the frequency of teleworking increases. This makes it difficult to conduct long-term research in the current uncertain situation. The second limitation stems from the way the water consumption data were collected. As smart water meters were not installed, we had to ask surveyed households to take photographs of their water meters to determine water consumption. Therefore, it

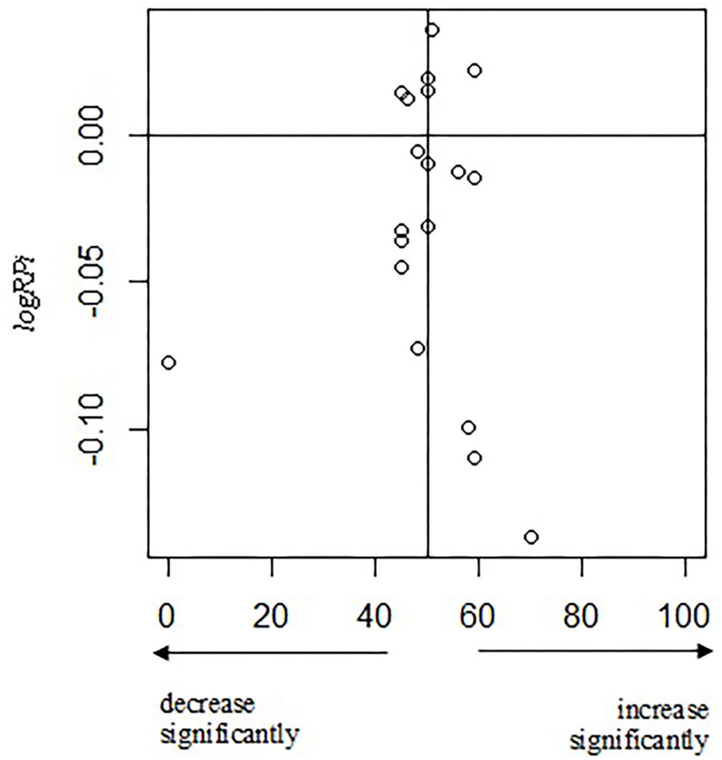

FIGURE 3 | Relation between self-reported change and actual change among high-consumption households in the CO_2 group. X-axis is self-reported change and y-axis is actual change.

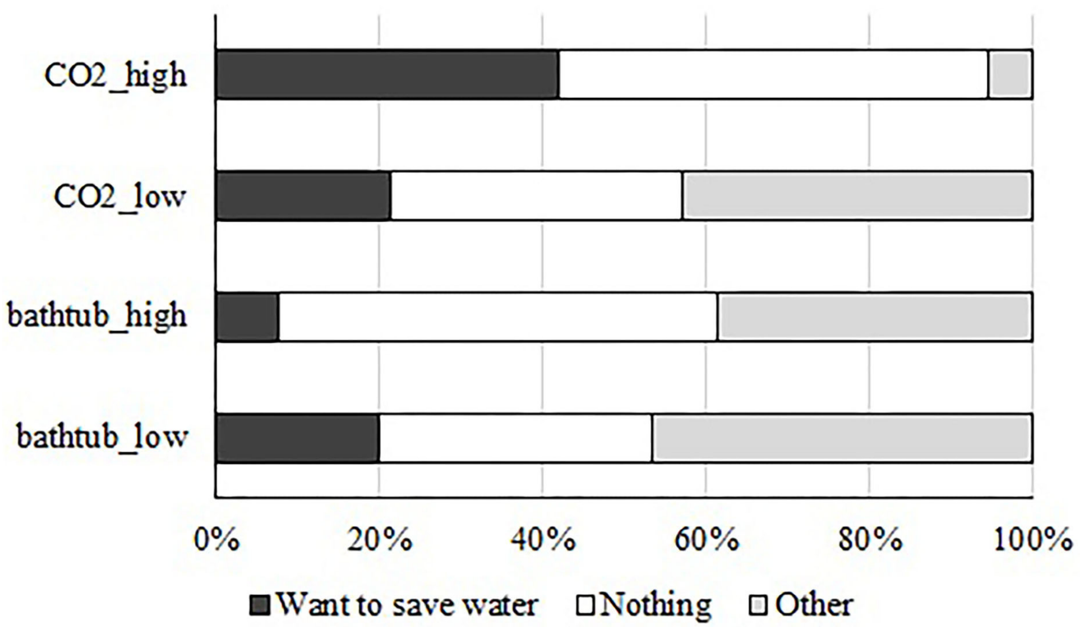

FIGURE 4 | Summary of free-text statements on how participants felt after receiving the tips. CO_2_high, CO_2_low, bathtub_high, and bathtub_low indicate high-consumption households in CO_2 group, low-consumption households in CO_2 group, high-consumption households in bathtub group, and low-consumption households in bathtub group, respectively.

was difficult to secure sufficient survey data. However, there are only a limited number of regions in the world where smart water meters will be installed in the near future, and the findings of this study should be of benefit to most regions of the world.

CONCLUSION

Interventions providing water-saving messages will encourage behavior changes that lead to sustainable water saving. It is also believed that such tips are likely to be easy for policy makers to implement and effective in many parts of the world. However, these assessments have not been adequately established (Liu and Mukheibir, 2018). A variety of ingenious tips are currently being explored; for example, viewing videos (Addo et al., 2019). In this study, we attempted to verify the effects of tips using visualized expressions of either the potential water saved or the amount of CO_2 emissions reduction.

The intervention was performed once, and changes in water use were observed 1 month after the intervention. Consequently, when the amount of water that could be saved was presented in terms of CO_2 emissions, water consumption by high-consumption households decreased. However, there was no change in consumption among low-consumption households for any of the tips. When asked how they felt after receiving the tips, high-consumption households who received the tips explaining the effect on CO_2 emissions were more likely to say that they wanted to save water.

Thus, the water-saving tips used in this study reduced water use among high-consumption households in the short term in a hassle-free manner. Although the long-term effects need to be investigated in the future, at the very least, this method can be utilized during temporary water shortages, for example.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Hitotsubashi University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

YO: conceptualization, methodology, resources, validation, formal analysis, investigation, writing—original draft preparation, project administration, and funding acquisition. AM: conceptualization, methodology, data curation, formal analysis, and investigation. Both authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2022.914665/full#supplementary-material

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