LSE Psychological and Behavioural Science

"Drip, drip"
Reducing Domestic Water Use in the U.K.

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0. Background

Water is one of the planet's most vital finite resources, which is swiftly being depleted. Already two billion individuals experience severe water stress on a regular basis, and if current water use patterns continue, 700 million people could be displaced by water scarcity within a decade. Indeed, many urban areas will soon experience water shortages due to city expansion and increased population density, making it critical that water be treated as a scarce resource ('Water Scarcity').

In 2008, the Intergovernmental Panel on Climate Change's report on water scarcity stated: 'freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide‑ranging consequences for human societies and ecosystems' (Bates et al., 2008). Environmentally, water scarcity has a damaging impact on aquatic and terrestrial ecosystems. Socially, there is evidence that variations in water availability have significant effects on human capital and can be a source of national and international conflict (Levy & Sidel, 2011). Economically, the impacts of water scarcity are widespread and can precipitate diverse consequences across industries since water directly or indirectly supports all economic activity (Garthwaite, 2019; Pfister et al., 2011; Damania, 2020). Consequently, there is a pressing need to take action now to preserve water supplies into the future.

In light of this urgency, we examine the behaviours and underlying drivers associated with household water use in order to develop feasible, curtailment-focused interventions (i.e. actions that conserve water). In doing so, we recognize the need for strategies that acknowledge the physical and infrastructural barriers to reducing water consumption as well as the psychosocial patterns underlying water-use behaviours. In the United Kingdom (U.K.), we see an opportunity to capitalize on the large-scale roll out of mandatory smart meters as a means to gather comprehensive real-time data about individuals' consumption patterns (Parker & Wilby, 2013). This provides a window of opportunity to link these devices with user-friendly information and communications technologies (ICTs), further supported by physical changes to the environment, in order to mitigate water waste activities.

1.0 Introduction

Typically measures aimed at ensuring water security address the supply-side of water management via technological solutions, including desalination plants and wastewater recycling (Randolph & Troy, 2008; Russell & Fielding, 2010). However, it is predicted that global trends such as population growth and increased urbanization will continue to increase water demand (Bates et al., 2008; Parker & Wilby, 2013). Within the U.K. specifically, it is projected that demand pressure on water suppliers will increase significantly in the next twenty years (Sim et al., 2005). In fact, already 11 out of the 22 water supply areas in the U.K. are characterized as under serious water stress (Owen et al., 2009). Thus, water demand management (WDM) has emerged as a complementary measure to supply-side solutions in order to secure national and global water supplies into the future (Brooks, 2006). WDM is defined as the reduction of the amount and/or quality of water used by consumers and therefore entails interventions and policies that address water use behaviours, in addition to considering how these behaviours are affected by technology and infrastructure (Russell & Fielding, 2010). While this applies to both industrial and household water use, this essay exclusively focuses on domestic demand, as private homes consume the bulk of supplied water in the U.K. (Owen et al., 2009).

While monetary savings are often a motivating driver to reduce domestic energy use, individuals are less compelled to curb their water consumption in order to cut costs due to the price-inelasticity of water (Energy Saving Trust, 2015). Since price reductions do not lead to reduced demand, most WDM approaches either tackle individuals' water use behaviour or entail replacing outdated appliances with more water-efficient models (Aitken et al., 1994; Sim et al., 2005). When employed individually, however, both approaches have significant weaknesses. Attempts to induce behavioural changes in water consumption habits often result in relatively small effect sizes that do not endure over time (Brent et al., 2015). Additionally, individuals' attitudes towards water conservation do not necessarily predict water use behaviour (Randolph & Troy, 2008). Thus, purely educative, information-based campaigns tend to not address the attitude-behaviour gap (Aitken et al., 1994). On the other hand, the retrofitting of water-efficient devices has proven to be an effective way of producing more immediate and larger reductions of household water consumption, however, this is not a feasible option for most individuals due to economic constraints (Barton, 2017). Researchers have also found that effect sizes significantly decrease over time due to individuals' tendency to gradually offset potential savings through increases in their consumption patterns (Fielding et al., 2012). There is little scholarship on the effectiveness of integrated WDM approaches that harness community-wide retrofit programmes while also reducing or preventing the effects of offsetting through behavioural interventions. Thus, the present work focuses on the analysis of household water use behaviours and the underlying psychosocial and physical drivers of water waste, thereby overcoming the limitations of singularly behavioural or infrastructural approaches.

We acknowledge that an integrated approach to WDM is both a time-consuming and costly endeavour. However, in the U.K. there is ample institutional support for the reduction of household water consumption. The Department for Environment, Food and Rural Affairs has set a target to significantly reduce household water demand by 2030, and consequently, the national

Water Services Regulation Authority is incentivizing water companies to adopt more impactful WDM strategies (DEFRA, 2008; DEFRA, 2011). Based on this governmental action, we envision a partnership between regulatory bodies and private water companies to facilitate short and long-term changes.

The structure of this essay is as follows: in Section 2 we introduce Installation Theory as a holistic framework to analyse domestic water use behaviour[1] (Lahlou, 2017). While water can be used for many different household purposes (e.g. cleaning, cooking, washing, drinking), in Section 3 we narrow down our focus to the four most water-consuming activities within the home that are susceptible to change. Employing Installation Theory, we distill these practices into their component parts and identify the underlying psychosocial and physical drivers of water waste. Based on these findings, we propose a number of short- and long-term solutions to improve domestic WDM by targeting all three layers of the identified installations in Section 4. Finally, in Section 5, we discuss the limitations to our interventions and address avenues for future research.

2.0 Theoretical Framework for Analysis

Existing research on the social and psychological determinants of water use is based primarily on general environmental and consumer behaviour theories such as household recycling, household energy conservation, and private good consumption (Jorgensen et al., 2009). Though this research has made relevant contributions to the literature, minimizing domestic water consumption requires further understanding of both how water in particular is used and how water-using behaviours can be shifted.

[1] We purposefully exclude water use related to gardens or other outside facilities as these do not apply to most city-based homes.

Therefore, our investigation of household water use draws on Installation Theory to holistically examine the multiple determinants and factors that guide water-use behaviours while considering the combined effect of these drivers (Lahlou, 2017). Lahlou conceptualizes installations as ‘specific, local, societal settings where humans are expected to behave in a predictable way’ (p. xxiii). These installations are composed of three layers--material affordances, embodied competences, and social regulations--which interact to produce and reproduce patterns of behaviour. Material affordances consist of external, physical objects that ‘inform, support and constrain activity’ (p. 97). Embodied competences refer to interpretive structures internal to the body, such as knowledge, habits, skills, experience, and common sense (p. 108). Finally, social regulations encompass rules, regulations, and conventions that encourage cooperation within the installation (p. 123).

Though there are individual differences across households, installations contain significant redundancy, which ensures resiliency of behaviour (Lahlou, 2017). Consequently, we can assume that individuals in varying home environments will behave in predictable ways given the water-using installations considered in this analysis.

3.0 Problem Analysis

Water is consumed in a diversity of activities inside the home, however, some households achieve the same goals while consuming less water than others. An average person in the U.S. consumes 445 litres per day at home while in Europe 240 litres per day are the standard, yet research suggests that 60 litres should be enough to satisfy basic water needs (Benzoni & Telenko, 2016; Gleick, 1996). Therefore, there is ample opportunity to reduce the amount of water used in typical domestic activities.

A 2015 report conducted on behalf of the British Department of Food, Environment and Rural Affairs found that a sample of 58 households in the Greater London area consumed a mean of 377 litres of water per day (Energy Saving Trust, 2015). This report noted that personal bathing was responsible for 33% of domestic water use while water from taps accounted for 31% of water consumption[2]. Research indicates that though individuals know that allowing water to pour directly into a drain is wasteful, they are typically unaware of the cumulative impact of this waste (Owen et al., 2009). Behaviours that precipitate water waste include dish washing, hand washing, tooth brushing, and other domestic tasks that require the intermittent use of a tap or the inefficient use of water-using appliances.

Here we employ Installation Theory to dissect the four most problematic (i.e. wasteful) yet malleable water-use behaviours in order to propose feasible interventions (Lahlou, 2017). For the purposes of this analysis, we narrow our focus to indoor, household water-use behaviours that take place in the kitchen and bathroom as these locations are where water-using appliances are typically located. We acknowledge that our assessment is not comprehensive and excludes many water uses, such as cooking and drinking.

3.1 Running a Partially-Filled Dishwasher or Washing Machine

Embodied Competences

The embodied competences needed to use a dishwasher or a washing machine concern operating these devices. Current machines are quite intuitive and require very few steps to run, which makes it very easy for people to use them after preliminary experience. Interestingly, some research has found that individuals use water unnecessarily by pre-washing dishes in the sink

[2] Toilet flushing was found to account for 22% of daily water use (EST, 2015). However, as this behaviour is less malleable than other water-using activities, we will not be addressing water used from toilets in our analysis.

before adding them to the dishwasher, despite the fact that most contemporary appliance models do not require this step (Emmel et al., 2003).

Material Affordances

Neither a clothes washing machine nor a dishwasher requires a full loading to operate. Consequently, there is potential for water inefficiency if individuals choose to run the dishwasher or washing machine when it is not at maximum capacity, therefore necessitating more frequent use of the machines in the long term.

Social Regulation

Individuals whose appliances are used by other people in the home will likely be influenced by the need to share these devices and accommodate multiple schedules. Some households may require each individual to wash their clothing and dishes separately, therefore necessitating more frequent, potentially inefficient use of these machines.

3.2 Hand-Washing Dishes

Embodied Competences

While running a machine dishwasher that is only partially filled facilitates inefficient water use, hand-washing dishes may prompt water waste if an individual steps away from the task while leaving the water running. The embodied competences involved in dishwashing include knowledge of how to perform the task derived from prior experience. However, a consequence of the repetitive nature of this activity is that water-waste behaviours may become habituated, such as allowing the water to run when collecting dishes (Lally & Gardner, 2013). Further, individuals may become distracted while completing the task, thereby allowing the water to flow while attending to something else. Finally, convenience can also impact water use when washing dishes: if it requires more time to repeatedly turn the tap on and off, individuals may allow the water to flow continually to minimize effort.

Material Affordances

The material environment of the kitchen can significantly inform the installation of dish washing. If the sink is too small to accommodate all the dishes at once or if the sink drain cannot be blocked, this may prompt users to wash fewer dishes at a time, thereby increasing the amount of water used. In addition, the floorplan and physical layout of a kitchen will affect the installation by directing how individuals move around the kitchen, the order in which tasks are completed, and the amount of time needed to complete each task. Further, if a kitchen tap is difficult to turn off or if the knobs are inconveniently located, individuals may allow the water to run unnecessarily. Finally, a tap that leaks and therefore allows water to drip into the drain enables gradual but continual waste.

Social Regulation

Individuals' dishwashing processes are likely to be influenced by whether or not they share their home with others. If the kitchen is a shared space, then dishwashing behaviours will be influenced by collective expectations in terms of cleanliness, individual or group responsibility, and timeliness. Though these social regulations could positively impact water use by encouraging people to be more efficient when hand washing dishes, it is also conceivable that these pressures could enable water waste by causing individuals to be distracted or less attuned to the need to turn off the tap.

3.3 Bathroom Toiletries (e.g. hand or face washing, tooth brushing, etc.)

Embodied Competences

As with washing dishes in a sink, the embodied skills required for performing bathroom-based toiletries are derived from previous experience. These include knowledge of how to turn on the tap, perform the behaviour, and turn the tap off. Once again, there is potential for water waste stemming from distraction or habit.

Material Affordances

The physical layer of this installation includes the bathroom layout, relative ease or challenge of turning on and off the taps, and the location of other toiletry necessities (e.g. toothbrush, soap). These material affordances have the potential to significantly influence individuals' water-use practices.

Social Regulation

Once again, people living in a shared home will likely face more restrictions in terms of time devoted to hygiene and tasks that require private use of the bathroom. Individuals may leave the water running to expedite efficiency or to remind themselves to be timely and considerate to others.

3.4 Showering

Embodied Competences

The act of showering requires multiple forms of embodied knowledge, such as understanding how to operate the shower head, adjust the water temperature, predict the time needed for the water to heat, among other idiosyncrasies of individual habit and preference.

The amount of water used per-shower can be affected by the motivation of the shower and the individual's emotional state. For example, a person may take a brief shower strictly to clean themselves and at other times take longer showers in order to relax, calm down, or become more alert. Individuals' habits regarding the frequency of showering and activities performed during showering (i.e. brushing teeth, washing hair, using conditioner, etc.) can also play a role in excessive water use. Finally, water waste can occur if individuals allow the shower to run while unoccupied. This can be prompted by individual habits or momentary distractions.

Material Affordances

The material affordances of a shower are particularly critical when it comes to water waste, as one of the key triggers is allowing the water to heat or cool before entering the shower. The time needed for the boiler to adjust the water temperature and for adjusted water to reach the bathroom piping will significantly impact how much water is wasted in the moments before the shower is used. Excessive water use when showering may be driven by the material affordances of the bathroom and shower, including the size of the space, bathroom layout, and appliances that determine the water flow, heating, and control mechanisms.

Social Regulation

The social regulations of showering might vary depending on cultures, number of people sharing the bathroom, and the scarcity of water presented in the installation. Individuals who live alone and do not share their bathroom with others will face fewer social regulations in their showering routines than people who must share their living space. In fact, the social expectations of sharing bathroom space could reduce water waste, as individuals may be conscious of the need to shower efficiently to allow others to use the room. Alternatively, sharing a home with multiple people also creates opportunities for distraction, which could result in the shower water being allowed to run without being used for longer than necessary.

3.5 Determinants of Water Waste

From the above analysis, we identify the primary determinants of wasteful or inefficient water use behaviour and separate these factors into two categories: psychosocial and physical determinants.

3.5.1 Psychosocial Determinants of Water Waste

We identify four main psychosocial drivers of wasteful water use behaviour:

1. **Habit**: Waste can occur as a consequence of habit. Individuals' embodied habits lead them to maintain routines within the home, which may lead to inefficient or wasteful water use (Lahlou, 2017; Mutinelli, 2020; Owen et al., 2009). Water consumption behaviour is primarily habit-driven (Jorgensen et al., 2009; Fielding et al., 2012; Novak et al., 2018).
2. **Distraction**: This can occur when a person's attention is pulled away from a task because of an internal distraction (cognitive) or an external distraction (environmental). Distraction interrupts the continuity of a task, which can precipitate inefficiency or wastefulness (Mutinelli, 2020).
3. **Convenience**: Another driver of water waste is convenience, or individuals' tendency to behave in ways that are time efficient or easy, regardless of the wasteful consequences. The importance of considering convenience when developing strategies to reduce food waste is well documented (Bernstad, 2014). Our analysis indicates that convenience may be an equally critical factor for WDM.
4. **Unawareness:** Underlying the three previously stated drivers of water waste is lack of awareness about the consequences of excessive water use and the need to be conservative with water use. Owen et al. (2009) found that lack of awareness was a primary factor for

excessive domestic water consumption. Consequently, alerting individuals to the need to preserve water and making this message salient could motivate people to change their behaviours.

3.5.2 Physical Determinants of Water Waste

In line with Fielding and colleagues (2012), we identify the importance of water efficient appliances that, by design, encourage the reduction of household water consumption. The installation of faucet aerators, low-flow shower heads or other efficiency devices could help individuals reduce water consumption almost automatically. This would bypass the material affordances at play when engaging in water using activities. Simultaneously, physical changes to the environment might positively affect the underlying psychosocial determinants of water use as the embodied, social, and physical layers are not mutually exclusive.

4.0 Proposed Interventions

Using Installation Theory, we identified four psychosocial determinants of excess water use as well as physical factors that cause wasteful water behaviours. Prior research suggests that behavioural interventions alone are not sufficient to precipitate significant behavioural change, while device-focused strategies can prompt initial reductions in water use but later show rebound effects (Brent et al., 2015; Jorgensen et al., 2009). To combat these challenges, we propose an integrated intervention that encompasses both behavioural and physical approaches. The proposed behavioural interventions primarily address individuals' embodied competences while leaving the physical environment unchanged. In addition, we believe that norm-driven peer-to-peer interactions both online (within the ICT environment) and offline (in the home) will prove valuable in amending the social layer of installations (Wolske, Gillingham, & Schultz, 2020). Our physical interventions, on the other hand, address individuals' material affordances in the first instance. However, these environmental changes will also combat convenience-driven waste and distraction, hereby, potentially extending individuals' embodied competences.

4.1 Behavioural Interventions

Psychosocial drivers of water use behaviour impact how we engage with the current water infrastructure and appliances in the home. Therefore, WDM strategies that target these factors promise an immediate and comparatively low-cost approach to reducing household water consumption. Accordingly, we selected an ICT model in the form of a mobile application to synthesize multiple behavioural interventions that target the underlying psychosocial drivers of waste. ICT platforms are flexible, effective tools for managing and reducing resource waste (Bastida et al., 2019; Fantozzi et al., 2014; Rebelo, at al., 2014; Strzelecka et al., 2017). As such, we leverage the fact that water providers across the U.K. are in the process of installing mandatory smart meters (i.e. water meters that gather real-time data on household water consumption) to digitize monitoring and payment processes ('Getting a smart water meter'). Based on this, we suggest partnering with a water company to develop and integrate said mobile application into the current technological landscape. Gathering water use data from smart meters will be essential for multiple application features and to assess the effectiveness of the interventions. To mitigate the effects of inertia and boost the uptake of the mobile application, we suggest that water companies make it the default option for customers to access bills and submit payment (Liu & Riyanto, 2017). Lastly, given that the application is linked to account holders, one primary individual in each household will be encouraged to use the application and share the information with others in the home.

Behavioural Interventions

	Habits	Unawareness	Distraction
Mobile app features			
Activity Timer	✓		✓
Tips & Rules of Thumb	✓	✓	
Gamification and normative feedback		✓	
Education on water scarcity	✓	✓	

Table 1. Summary of Behavioural Interventions

In the following, we list four behavioural interventions that constitute the four key features of our proposed mobile application.

4.1.1 Activity Timer

We propose incorporating a timer feature, which would allow users to monitor the time they spend completing water-using tasks. The app would include pre-set timers for common water-use activities (e.g. showering) based on conservative estimates of the time needed to complete the activity. When the allotted time ends, an alarm would sound, alerting users to finish the behaviour (see Figure 1I). This feature would combat wasteful habits and encourage the development of more efficient routines by acting as a frequent reminder of the necessity of conserving water (Hobson, 2006). The activity timer will also reduce distraction and encourage individuals to remain focused on water-using tasks until completion. This would be reinforced with messages prompting users to continue with the task (Figure 2I).

4.1.2 Quick Tips and Rules of Thumb

Individual embodied habits can lead to inefficient water use because individuals may not know how to perform activities efficiently. This mobile application will provide users with tips and rules of thumb to empower them with skills that help reduce water waste. For example, when the shower activity timer is selected, users would also be advised to collect waste water from the shower in a bucket and to use this water for tasks such as watering plants, cleaning, or manually flushing a toilet (Figure 3I). Simple though it may be, reusing waste water from the shower can have a positive, cumulative effect when widely adopted (Waskom et al., 2018). Combining the tips and rules of thumb with the activity timer feature is crucial in order to deliver information at the point of activity execution (Lahlou, 2017). This increases the likelihood of people adopting the desired behaviour. A list of example rules of thumb can be found in Appendix II.

4.1.3 Gamification and Normative Feedback

Gamification, or the use of game features in non-game contexts, has been shown to increase user engagement in interventions designed to spark behavioural change (Deterding et al., 2011; Novak et al., 2018). According to Reiss's (2000) basic desires theory, gamification appeals to the fundamental human needs of achievement, competition, and social status. Chib and Lin (2018) support this position, noting that 'gamification through the use of rewards and incentives, or a literal game component [...] increase[s] willingness to use and adhere to an app.' In addition, gamification has also been found to augment a product's hedonic quality, which increases engagement by offering a stimulating and entertaining user experience (Hassenzahl 2004; Hassenzahl 2008; Wang & Capiluppi, 2015).

Accordingly, our suggested application would include a gamified component to promote water savings. Already many applications incorporate visual cues to motivate behaviour, such as the application Forest, which incentivizes focused studying with the graphic of a growing tree. Our proposed application would draw on a similar framework by motivating individuals to efficiently complete water-using tasks through the visual depiction of accumulating water in a pond. Users would also be able to monitor their water consumption and compare their usage against that of other app users, which would further incentivize the reduction of water use to align with social norms (Thaler & Sunstein, 2009). Additionally, normative feedback regarding users' water consumption would be included to maximise the likelihood of behavioural change by shifting individuals' norm perception (Tankard & Paluck, 2016). People often misjudge the prevalence of a behaviour (i.e. the descriptive norm of 'what others do'). Simply correcting these false perceptions can elicit unwanted boomerang effects, while highlighting discrepancies between descriptive and injunctive norms (i.e. what 'is' done versus what 'should' be done) can also lead to unwanted results (Miller & Prentice, 2016; Neville et al., 2021; Schultz et al., 2007). Instead, the communication of dynamic norms (i.e. indicating that people's behaviour is changing) might be more suited to elicit water conservation in 'over-consuming' societies (Sparkman & Walton, 2017). An example of this interface is shown in Figure 4 in the appendix.

4.1.4 Education

The mobile application would include an educational component, providing messages about the problem of water scarcity. These messages would be displayed alongside a user's water bill each month in order to increase the salience of the information. To increase the effectiveness of this element and encourage social learning within homes, the app could also feature quizzes or virtual card games to influence the water conservation culture of households (Fielding, et al., 2012; Jorgenson, et al., 2009). An example of this educational feature can be seen in Figure 5.

4.2 Water Efficient Devices

To address the material affordances at play when engaging in water consuming activities, we propose the installment of water efficient devices. While this is a more costly approach, we see potential for water companies and local authorities to invest in retrofit programmes that replace inefficient appliances and fixtures to reduce household water consumption (Campbell et al., 2004). Several studies investigating the effects of such programmes suggest large effect sizes for the reduction of water consumption, ranging between 9 percent and 50 percent, depending on the efficacy of the new devices (Fielding et al., 2012). In this essay, we focus on two kinds of fixture replacements that promise immediate results, acknowledging that this list could be extended. In particular, we propose the installation of low-flow appliances with automatic shut-offs and smart showerheads with inbuilt consumption displays.

4.2.1 Low-Flow Appliances with Automatic Shut-off

The amount of water that appliances dispense per minute (i.e. water flow) significantly affects water consumption. Therefore, installing low-flow appliances, such as toilets, shower-heads, or faucets, is an impactful way of reducing water waste (Price et al., 2014; Stewart et al., 2013). For faucets and showerheads, this effect can be supported and heightened by an automatic shut-off function. Such a feature can either be based on predetermined settings or triggered by movement sensors that detect whether a faucet or showerhead is currently in use (Stewart et al., 2013). While the former significantly disrupts and restricts an individual's water behaviour (e.g. by restricting the water flow of a sink faucet to 30 seconds at a time), movement sensors allow more individual freedoms when engaging in water using activities. If no movement is detected (e.g. the user steps out of the shower), the water flow is automatically stopped and requires further manual indication to re-start, thereby disrupting existing shower habits.

4.2.2 Smart Showerheads with Built-In Consumption Display

The common showerhead is a basic, manually-controlled fixture that provides no feedback to the user about water consumption (Hand et al., 2005). As mentioned in Section 3, material affordances (along with psychosocial factors) drive excess water consumption during bathing activities, specifically showering. We propose the installation of 'smart showerheads' with inbuilt consumption displays to replace traditional ones. While this method changes the material affordances of showering, it also addresses underlying psychosocial drivers. Using smart meter data, LED-displays indicate real-time water consumption during every shower and therefore increase the salience of water use while serving as a prompt to conserve (Stewart et al., 2013; Kappel & Grechenig, 2009). This adjustment to the physical environment mitigates the negative impacts of habit, in addition to targeting lack of awareness or potential distraction.

5.0 Discussion and Limitations

Our proposed integrated model has the potential to significantly reduce domestic water use by targeting the primary drivers of wasteful behaviour. However, several limitations must be acknowledged.

First, we recognize that interventions in the physical environment, such as smart showerheads and automatic shut-off mechanisms, are costly tools that require significant upfront investment. For example, an automatic shower shut-off from the bathroom fixture company Bath Select costs upwards of 400 pounds. Installing these devices would require additional charges as well as commitment, time, and the ability to make changes to one's living space. We recognize that infrastructural reforms are long-term solutions that will be more challenging to feasibly implement than our ICT-based interventions. Still, we believe that government support for water conservation might be sufficient to mobilize the funds necessary for community-wide retrofit programmes. The Department for Environment, Food and Rural Affairs' (DEFRA) 2008 water strategy set a target to reduce household water consumption by 13 percent by 2030, cutting usage from 150 litres per person per day to 130 litres. As our integrated interventions have the potential to significantly reduce domestic water use, we aim to gain financial support from DEFRA and other water authorities.

Second, the success of our behavioural interventions delivered through the mobile application is contingent on individuals' voluntary use of the platform. Recognizing this hurdle, we suggest that the application be offered through water companies. Individuals would be prompted to download the application in order to access further information about their water usage and billing. In addition, modest monetary incentives could be used to motivate uptake of the app and encourage customers to keep the application for an extended period of time (Sun et al., 2019). Further, use of the application might be limited to the primary account holder, as there is less incentive for other household members to download the app. However, research has shown that peer influence can be an important driver for changing behaviours (Wolske et al., 2020). We therefore rely on a contagion effect and social norms to diffuse the impact of the interventions among all the members of each household. Nevertheless, the present work does not address how to encourage users to regularly use all features of our suggested ICT nor does it discuss its financial sustainability. Since these are significant challenges that extend beyond the scope of this essay, we suggest that future research investigate methods of tackling these issues.

Finally, we acknowledge that socioeconomic status, age, and other demographic factors may preclude some individuals from using the mobile application. Though 88% of adults in the U.K. own smartphones, people aged 45 and older are less likely to own a smart device than young adults (Deloitte, 2020). Consequently, it may be more difficult to engage some older users in using this application. Further, though we recognize the effect of demographic factors on water use, we choose not to target these drivers at present, as addressing the impact of social and economic disparities on consumption requires large-scale investigation of systemic inequality.

Future research should focus on piloting integrated programmes, such as the method proposed here, to evaluate their long-term effectiveness. Additionally, there is an equally urgent need to investigate industrial WDM strategies to mitigate water scarcity effectively within the global context.

We believe that the proposed strategies have the potential to precipitate meaningful changes in people's domestic water-usage. By addressing the psychosocial and physical aspects of water use, we hope to gradually shift the way people think about and how they use water. If this is supported by both infrastructural and policy reforms, we will be one step closer to ensuring the long-term sustainability of our national and global water reserves.

References

Aitken, C. K., McMahon, T. A., Wearing A. J., & Finlayson, B. L. (1994). Residential water use: Predicting and reducing consumption. *Journal of Applied Social Psychology,* 24, 136-158. https://doi.org/10.1111/j.1559-1816.1994.tb00562.x

Barton, C. (2017, June 9). Home ownership and renting: demographics. *House of Commons Library.* Retrieved from https://commonslibrary.parliament.uk/research-briefings/cbp-7706/

Bates, B. C., Kundzewicz, Z. W., Wu, S., and Palutikof, J. P. (2008). Climate Change and Water. *Intergovernmental Panel on Climate Change.*

Bastida, L., Cohen, J., Kollmann, A., Moya, A., and Reichl, J. (2019). Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming. *Renewable and Sustainable Energy Reviews,* 103, 455-462. https://doi.org/10.1016/j.rser.2019.01.004

Benzoni, N., and Telenko, C. (2016). A Review of Intervention Studies Aimed at Domestic Water Consumption. *International Conference of Design, User Experience, and Usability.* https://doi.org/10.1007/978-3-319-40355-7_41

Bernstad, A. (2014). Household food waste separation behavior and the importance of convenience. *Waste Management*, 34, 1317-1323. http://dx.doi.org/10.1016/j.wasman.2014.03.013

Brent, D. A., Cook, J. H., Olsen, S. (2015). Social Comparison, Household Water Use, and Participation in Utility Conservation Programs: Evidence from Three Randomized Trials. Journal of the Association of Environmental and Resource Economists, 2(4), 597-627. https://doi.org/10.1086/683427

Brooks, D. B. (2006). An Operational Definition of Water Demand Management. *International Journal of Water Resources Development*, 22(4), 521-528. https://doi.org/10.1080/07900620600779699

Campbell, H.E., Johnson, R.cM., and Larson, E.H. (2004). Prices, devices, people, or rules: the relative effectiveness of policy instruments in water conservation. *Review of Policy Research*, 21, 637–662.

Chib, A., and Lin, S. H. (2018). Theoretical Advancements in mHealth: A Systematic Review of Mobile Apps. *Journal of Health Communication*, 23(10-11). https://doi.org/10.1080/10810730.2018.1544676

Damania, R. (2020). The economics of water scarcity and variability. *Oxford Review of Economic Policy*, *36*(1), 24–44. https://doi.org/10.1093/oxrep/grz027

Deloitte (2020). Global Mobile Consumer Survey: UK cut. *Deloitte*. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/technology-media-telecommunications/deloitte-uk-plateauing-at-the-peak-the-state-of-the-smartphone.pdf

DEFRA (2008). Future Water: The Government's Water Strategy for England. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69346/pb13562-future-water-080204.pdf

DEFRA (2011). Department for Environment, Food and Rural Affairs. Guidance on Reporting Greenhouse Gas Removals and Emissions from Domestic Woodland Creation.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining "gamification". In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments* (pp. 9-15). https://doi.org/10.1145/2181037.2181040

Energy Saving Trust (EST) (2015). *At Home With Water 2*. Retrieved from https://www.energysavingtrust.org.uk/sites/default/files/reports/AHHW2%20final.pdf

Emmel, J., Parrott, K., and Beamish, J. (2003). Technology and dishwashers: Are users still wasting water? *Canadian Home Economics Journal*, 52(2), 14-18.

Elster, J. (1989). Social norms and economic theory. *Journal of Economic Perspectives*, 3(4), 99-117. https://doi.org/10.1257/jep.3.4.99

Fantozzi, M., Popescu, I., Farnham, T. … and Bimpas, M. (2014). ICT for Efficient Water Resources Management: The ICeWater Energy Management and Control Approach. *Procedia Engineering*, 70, 633-640. https://doi.org/10.1016/j.proeng.2014.02.069

Fielding, K. S., Russell, S., Spinks, A., and Mankad, A. (2012). Determinants of household water conservation: The role of demographic, infrastructure, behavior, and psychosocial variables. *Water Resources Research*, *48*(10). https://doi.org/10.1029/2012WR012398

Garthwaite, J. (2019, March 22). The effects of climate change on water shortages. *Stanford Earth*. Retrieved from https://earth.stanford.edu/news/effects-climate-change-water-shortages

Getting a smart water meter (n.d.). *Thames Water*. Retrieved from https://www.thameswater.co.uk/help/water-meters/getting-a-water-meter

Gleick, P. H. (1996). Basic Water Requirements for Human Activities: Meeting Basic Needs. *Water International*, 21(2), 83-92. https://doi.org/10.1080/02508069608686494

Hand, M., Shove, E., & Southerton, D. (2005). Explaining showering: A discussion of the material, conventional, and temporal dimensions of practice. *Sociological Research Online, 10*(2), 101–113. https://doi.org/10.5153/sro.1100

Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products. *Human–Computer Interaction*, *19*(4), 319-349. https://doi.org/10.1207/s15327051hci1904_2

Hassenzahl, M. (2008, September). User experience (UX) towards an experiential perspective on product quality. In *Proceedings of the 20th Conference on l'Interaction Homme-Machine* (pp. 11-15). https://doi.org/10.1145/1512714.1512717

Hobson, K. (2006). Bins, bulbs, and shower timers: on the 'techno-ethics' of sustainable living. *Ethics Place and Environment, 9*(3), 317-336. https://doi.org/10.1080/13668790600902375

Jorgensen, B., Graymore, M., and O'Toole, K. (2009). Household water use behavior: An integrated model. Journal of Environmental Management, 91(1), 227–236. https://doi.org/10.1016/j.jenvman.2009.08.009

Kappel, K., & Grechenig, T. (2009, April). "Show-me" water consumption at a glance to promote water conservation in the shower. In *Proceedings of the 4th international conference on persuasive technology* (pp. 1-6). https://doi.org/10.1145/1541948.1541984

Lahlou, S. (2017). *Installation theory: The societal construction and regulation of behaviour.* Cambridge: Cambridge University Press.

Lally, P. and Gardner, B. (2013). Promoting Habit Formation. *Health Psychology Review*, 7(1), S137-S158. https://doi.org/10.1080/17437199.2011.603640

Levy, B. S., and Sidel, V. M. (2011). Water rights and water fights: Preventing and resolving conflicts before they boil over. *American Journal of Public Health*, 101(5), 778-780. https://www.doi.org/10.2105/AJPH.2010.194670

Liu, J., and Riyanto, Y. (2017). The limit to behavioral inertia and the power of default in voluntary contribution games. *Social Choice and Welfare*, 48(8). https://doi.org/10.1007/s00355-017-1036-

Miller, D. T., and Prentice, D. A. (2016). Changing Norms to Change Behavior. *Annual Review of Psychology*, 67, 339-361. https://doi.org/10.1146/annurev-psych-010814-015013

Mutinelli, S. (2020). *The Psychology of Waste* [Unpublished master's dissertation, London School of Economics and Political Science].

Neville, F. G., Templeton, A., Smith, J. R., and Louis, W. R. (2021). Social norms, social identities and the COVID‑19 pandemic: Theory and recommendations. *Social and Personality Psychology Compass*, e12596.

Novak, J., Melenhorst, M., Micheel, I., Pasini, C., Fraternali, P., Rizzoli, A. E., (2018). Integrating behavioural change and gamified incentive modelling for stimulating water saving. *Environmental Modelling and Software, 102*, 120-137. https://doi.org/10.1016/j.envsoft.2017.11.038

Owen, L., Bramley, H., and Tocock, J. (2009). Public understanding of sustainable water use in the home: A report to the Department for Environment, Food and Rural Affairs. Synovate. Defra, London.

Parker, J. M., and Wilby, R. (2012). Quantifying Household Water Demand: A Review of Theory and Practice in the UK. *Water Resources Management*, 27(4), https://doi.org/10.1007/s11269-012-0190-2

Pfister, S., Bayer, P., Koehler, A., and Hellweg, S. (2011). Environmental impacts of water use in global crop production: Hotspots and trade-offs with land use. *Environmental Science & Technology*, 45(13), 5761–5768. https://doi.org/10.1021/es1041755

Price, J., Chermak, J., and Felardo, J. (2013). Low-flow appliances and household water demand: An evaluation of demand-side management policy in Albuquerque, New Mexico. *Journal of Environmental Management,* 133C, 37-44. https://doi.org/10.1016/j.jenvman.2013.11.025.

Randolph, B., and Troy, P. (2008). Attitudes to Conservation and Water Consumption. *Environmental Science & Policy*, 11(5), 441-455. https://doi.org/10.1016/j.envsci.2008.03.003

Rebelo, M., Smith, J. R., and Menezes, M. (2014). Prioritizing use cases for water smart technology development: Similarities and differences from Portugal and UK case studies. *Procedia Engineering*, 89, 998-1003.

Reiss, S. (2000). *Who am I: The 16 basic desires that motivate our actions and define our personalities.* New York: Tarcher/Putnam.

Russell, S., and Fielding, K. (2010). Water demand management research: a psychological perspective. *Water Resources Research*, 46(5). https://doi.org/10.1029/2009WR008408

Sim, P., McDonald, A., Parsons, J., and Rees, P. (2005). The Options for UK Domestic Water

Reduction: A Review. Working Paper. The School of Geography, University of Leeds.

Schultz, P. W., Nolan, J. M., Cialdini, R. B. … and Griskevicius, V. (2007). The Constructive, Destructive, and Reconstructive Power of Social Norms. *Psychological Science*, 18(5), 429-434. https://doi.org/10.1111/j.1467-9280.2007.01917.x

Sparkman, G., & Walton, G. M. (2017). Dynamic norms promote sustainable behavior, even if it is counternormative. *Psychological science, 28*(11), 1663-1674. https://doi.org/10.1177/0956797617719950

Stewart, R. A., Willis, R. M., Panuwatwanich, K., and Sahin, O. (2013). Showering behavioural response to alarming visual display monitors: longitudinal mixed method study. *Behaviour & Information Technology*, 32(7), 695-711.

Strzelecka, A., Ulanicki, B., Koop, S., Koetsier, L., van Leeuwen, K, and Elelman, R. (2017). Integrating water, waste, energy, transport and ICT aspects into the smart city concept. *Procedia Engineering*, 186, 609-616. https://doi.org/10.1016/j.proeng.2017.03.277

Sun, T., Shi, L., Viswanathan, S., & Zheleva, E. (2019). Motivating effective mobile app adoptions: Evidence from a large-scale randomized field experiment. *Information Systems Research, 30*(2), 523-539. https://doi.org/10.1287/isre.2018.0815

Tankard, M. E., and Paluck, E. L. (2016). Norm Perception as a Vehicle for Social Change. *Social Issues and Policy Review*, 10(1), 181-211.

Thaler, R. H., and Sunstein, C. R. (2009). *Nudge*. New York: Penguin.

Wang, Z., & Capiluppi, A. (2015, September). A social-centred gamification approach to improve household water use efficiency. *7th International Conference on Games and Virtual Worlds for Serious Applications (VS-Games)* (pp. 1-4). IEEE. https://doi.org.10.1109/VS-GAMES.2015.7295761

Waskom, R., Kallenberger, J., Bauder, T., Wardle, E., & Neibauer, M. (2018). Household water conservation. *Colorado State University Extension*. Retrieved April, 2021.

Water Scarcity (n.d.). UN Water. Retrieved from https://www.unwater.org/water-facts/scarcity

WaterSense for Kids (2021, April 15). *U.S. Environmental Protection Agency*. Retrieved from https://www.epa.gov/watersense/watersense-kids#Simple%20Ways%20to%20Save%20Water

Wolske, K. S., Gillingham, K. T., & Schultz, P. W. (2020). Peer influence on household energy behaviours. *Nature Energy*, 5(3), 202-212.

Appendix I. Application Interfaces

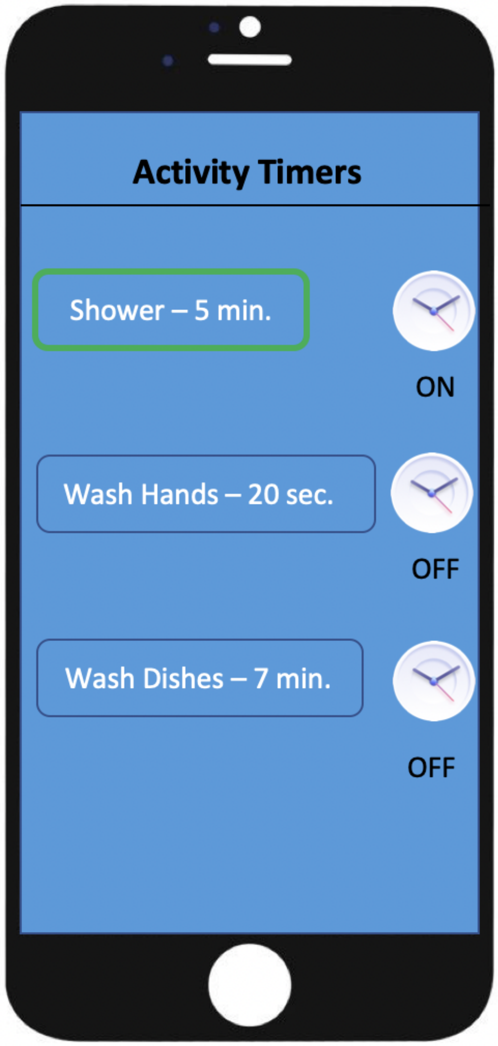

Figure 1. Activity Timers Page

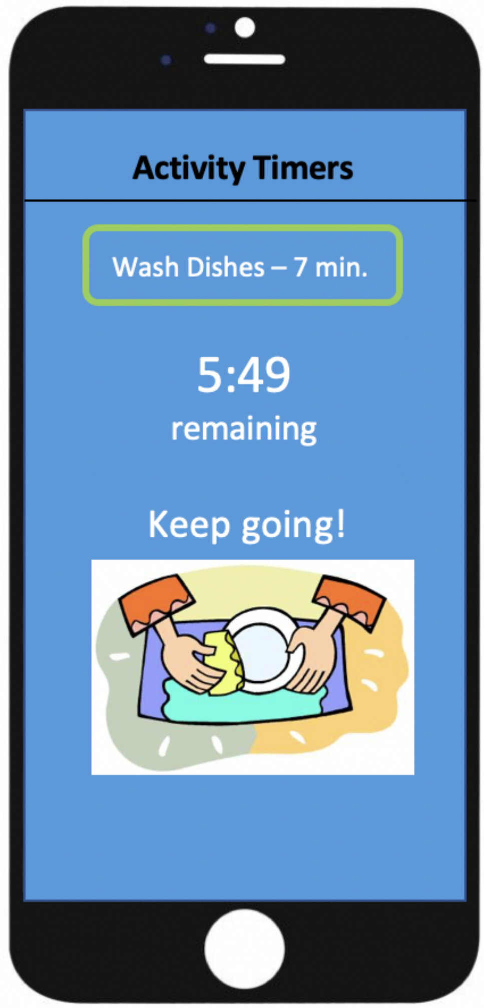

Figure 2. Activated Activity Timer

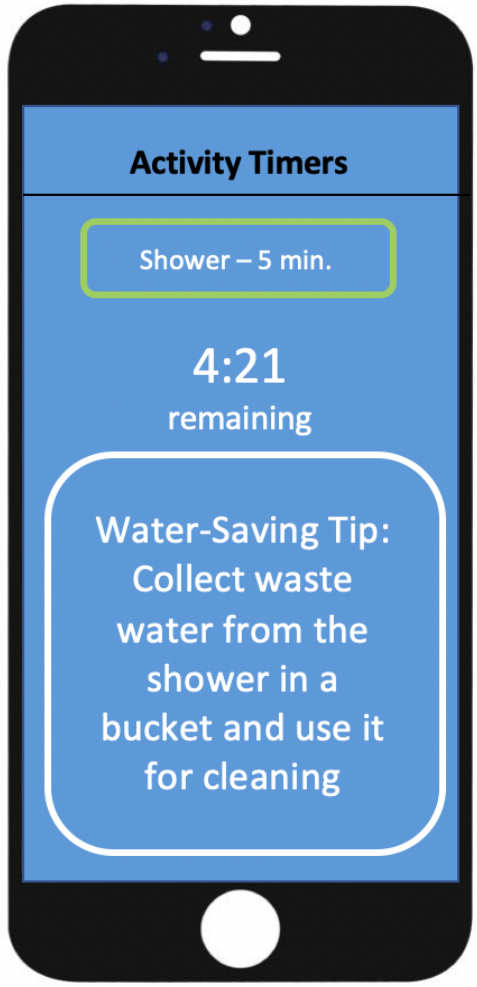

Figure 3. Activated Activity Timer and Conservation Tip

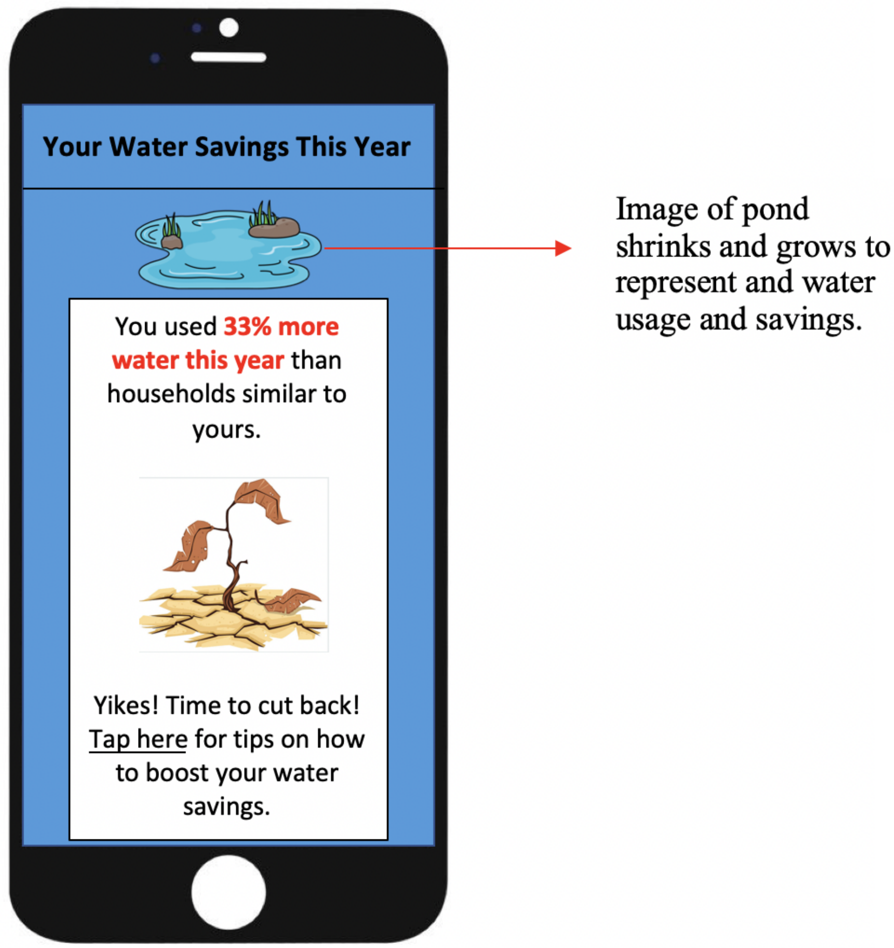

Figure 4. Gamification and Feedback

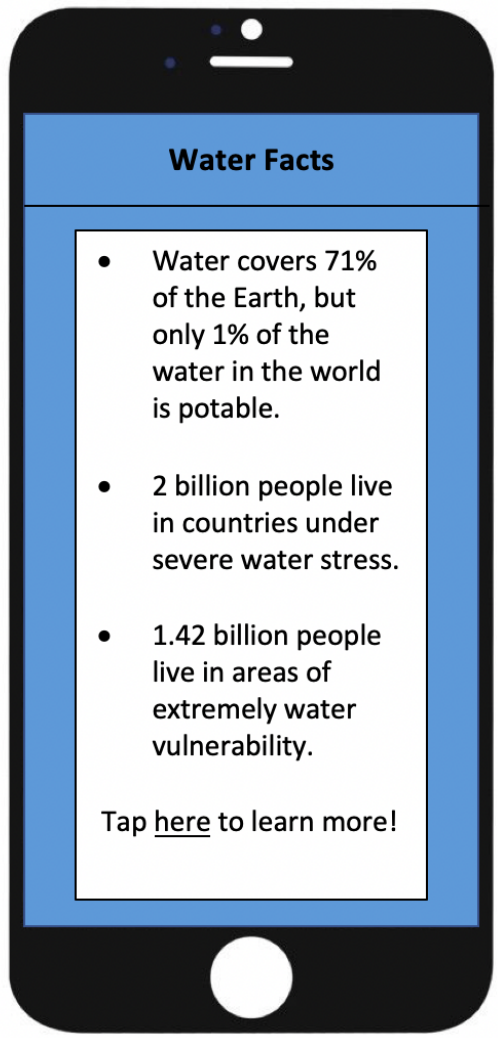

Figure 5. Education Page

Appendix II. Example "Rules of Thumb"

1. *Skip the rinse.* Most modern dishwashers do not require dishes to be pre-rinsed before loading. Skipping this step will save thousands of litres each year.
2. *When in doubt, turn off the tap.* You can save 30 litres of water a day just by turning the faucet off while brushing your teeth. That amounts to over 900 litres a month, enough to fill a fish tank that holds six small sharks ('WaterSense for Kids').
3. *Don't dawdle in the shower.* If every U.K. household took just one minute less in the shower each day, it would save £215 million on collective energy bills a year (EST, 2015).
4. *The toilet is not a trash can*. One unnecessary flush per day wastes up to 4,500 litres of water over the course of a year ('WaterSense for Kids').
5. *Soap first.* Avoid wasting water when washing hands by applying soap first and then turning the tap on and washing for no more than 25 seconds.
6. *Fix faucet leaks.* A leaky faucet can waste up to nine litres of water per day ('WaterSense for Kids'). Repair any leaky faucets and ensure that your taps are completely off.