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Behavioral Economics and the Design of a Dual-Flush Toilet

Jade S. Arocha

10305 Dover Street #713

Westminster, CO 80021, U.S.A.

JSArocha83@gmail.com

970 310-1738

and

Laura M. J. McCann

Dept. of and Applied Agricultural Economics

212 Mumford Hall

University of Missouri

Columbia, MO 65203, U.S.A.

McCannL@missouri.edu

573 882-1304

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Abstract

Dual-flush toilets, which use a high-volume flush for solid waste and a lower-volume flush for liquid waste, can reduce water consumption. Behavioral economics was used to analyze the design of the dual flush mechanism of the Sloan Uppercut® toilet. The default option, pushing the handle down, results in a large flush. Because Americans have been "conditioned" to push the toilet handle down, it was expected that most users would push the handle down out of habit. A field experiment measuring up versus down flushes in eight women's toilets in a municipal building confirmed expectations. While Sloan predicted a 2:1 urination-to-defecation ratio, the observed ratio during the control period was 1:4, i.e. the ratio was the opposite of what would occur if people used the toilets correctly. Adding signage to each stall only increased the ratio to 2:5, emphasizing the importance of the default.

Key words: behavioral economics, choice architecture, dual-flush toilets, water conservation

1. Introduction

While water may appear to be an abundant, renewable natural resource, its supply is finite, and only 1% of all water is suitable and available for human use (World Bank, 2010). As the global population grows, so does the demand for fresh water for domestic, irrigation, and industrial uses, so new and improved methods of water conservation will be needed. Also exacerbating this scarcity is the general lack of incentives for people to conserve water, as discussed below. As such, there are several important approaches to reducing the general population's aggregate water use. One of these is educating the public on the importance of water conservation and encouraging adoption of water saving practices, while another involves developing fixtures that consume less water. This paper focuses upon the latter approach in a

commercial setting, and how the design of water fixtures, and dual flush toilets in particular, can affect the overall amount of water used. Such strategies may be more effective at solving water-related issues, especially in the short term.

Technological innovation is paramount to improving the eco-efficiency of water-using domestic appliances and fixtures. With this in mind, water-efficient fixtures such as dual flush toilets and high efficiency toilets (HETs) can be a valuable asset in water-scarce regions. It therefore makes sense to encourage the installation and use of these water-saving toilets. However, it is not sufficient that the toilet be designed to reduce water consumption; it is also imperative that its dual flush mechanism is clearly marked and easy for the user to operate correctly—that is, that the behavior of the user is taken into account as part of the design process.

With these factors in mind, this research project has: a) tested the hypothesis that the design of the flush mechanism on a dual flush toilet has a significant effect on human behavior and thus water usage; b) examined the effect of instructional signage on the use of the toilet; and c) estimated how much water can be saved by improving this design to account for the user's default behavior.

2. Background and Literature Review

2.1. Water Use in Toilets

While many researchers acknowledge that data collection in the U.S. with regard to the end uses of water is inadequate (e.g., Christian-Smith, Gleick, and Cooley, 2003; Simonovic, 2000; Schultz 2000), a brief summary is provided in order to indicate the relevance of this research. Water classified by the U.S. Geological Survey (USGS) as "public supply", which aggregates domestic (household), commercial, and industrial water usage that is not used in manufacturing and/or production processes, accounts for about 11% of total water withdrawals

in the United States (USGS, 2005). In urban areas, the commercial and industrial sector comprises roughly 20-40% of billed water demand (Vickers, 2001). This category includes water withdrawals by large institutional establishments such as hospitals, universities, government offices, and airports. It follows that research directed toward the commercial and institutional (CI) sector could have a significant impact on water savings. The research carried out in this paper focuses upon commercial dual flush toilets, thus addressing the CI sector.

The actual amount of water used exclusively by toilets in commercial and industrial firms is difficult to estimate accurately. One approximation by the U.S. Department of Energy (DOE) depicts the average end uses of water in commercial buildings in the United States. The "domestic" category euphemistically refers to water consumed in restrooms (i.e. toilets, faucets, and showers) and comprises 39% of total commercial water use (DOE, 2001).

Private and public interventions have reduced the amount of water that toilets use. In the first half of the 20th century, a standard toilet in the United States used between 5 and 7 gallons per flush (gpf). While not federally mandated, the standard gpf for most models had fallen to 3.5 gpf by the 1980s (Vickers 2001; Fernandez, 2001). This initial reduction in water usage was voluntarily initiated from within the industry itself, beginning with the first 3.5 gpf model in the U.S., the American Standard Cadet™ (Anon., 1998). The first major federal legislation to be implemented that addressed the water efficiency of household and commercial appliances was the Energy Policy Act of 1992 (102nd Congress, 1992). The new law, which was intended to reduce pumping and treatment costs as well as consumption, required that all toilets manufactured and installed after January 1, 1994 consume 1.6 gpf or less (102nd Congress, 1992). The manner in which the legislation was implemented had unforeseen consequences.

First, the new 1.6 gpf volume requirement had not been adequately researched in order to determine whether this specific flush volume was, in fact, efficient or effective (George, 2001). Second, toilet manufacturers had little more than a year to redesign, manufacture, and ship the new low-flow toilets; as a result, the new toilets were not physically redesigned to perform the same tasks with less than half the amount of water and performed very poorly (Fernandez, 2001). Finally, in some cases the existing plumbing infrastructure was incompatible with the lower flush volume. One study found that the reduced flush volume caused solid waste to travel a shorter distance through connecting pipes (known as 'drainline carry') than the higher flush volume (Gauley and Koeller, 2005). These and other performance issues caused some users to flush the toilet more than once, which sometimes negated the water-saving functions of the low-flow toilets and even increased water use compared to 3.5 gpf models in some cases. In addition, some consumers were very displeased with the first low-flow models, citing that the very small amount of water in the bowl caused frequent clogs and necessitated constant cleaning. Over the next few years, manufacturers invested in research for improved design and performance for the new low-flow toilets which has reduced those problems (Martin and Fernandez, 2003). Today, while water-efficient toilets usually meet or exceed user expectations, some people retain a negative perception of them due to the performance issues of the past (Gauley and Koeller, 2005).

Since 1992, other organizations have evolved that encourage—but do not mandate—the use of low-flow water fixtures. The EPA WaterSense program, which uses a third-party certification process to market and label high-efficiency water fixtures, tests products for both water efficiency *and* performance. WaterSense-labeled toilets must have an effective flush volume of 1.28 gpf or less, which is 20% less water than required by law (EPA, 2010). Another

program that is particularly relevant to commercial and industrial applications is the LEED® (Leadership in Energy and Environmental Design) certification system, which uses a third-party process similar to that of the WaterSense program to recognize building and construction practices that are environmentally sustainable. Ratings range from platinum (the highest rating) to gold, silver, and 'certified'. One of the specific criteria that LEED® certifiers use to evaluate buildings is water efficiency (U.S. Green Building Council, 2010). LEED®-approved water-efficient technologies include several types of water-conserving toilets, such as high-efficiency single-flush gravity toilets, pressure-assisted toilets, and high-efficiency flushometer toilets, as well as dual flush toilets.

2.2 Dual Flush Toilets

While there have been minimal and infrequent improvements to the typical flush toilet in the last 200 years, there have been a multitude of innovations in toilet technology in recent years. In the United States, these were driven primarily by legislation as previously discussed, as well as a high level of competition between manufacturers as performance data became available. In other areas, such as Australia, efficiency improvements in toilets came about due to the dire need for reduced water consumption due to an arid climate.

The dual flush toilet was introduced into South Australia in 1980 by the toilet manufacturer Caroma, which received a government grant for research and development (South Australia State Library, 2006). This first line of dual flush toilets by Caroma operated with two separate buttons, one for a small flush (1.45 gpf) for liquid wastes and the other for a large flush (2.9 gpf) for solid wastes. The toilet bowl also had to be redesigned to ensure that the bowl remained clear even with less water flow (as American toilet manufacturers would learn over a decade later). In 1993, Caroma introduced an even more efficient version of the dual flush toilet

that used 1.6 gpf for a large flush and 0.8 gpf for a small flush, which remains the industry standard today (South Australia State Library, 2006).

While many types of water-efficient toilets exist, it is important to note that dual flush toilets are the only type that present the user with a choice. This choice requires a specific decision or action on the part of the user, and some models of dual flush toilets may make a 'correct' decision more difficult than others. We thus hypothesized that the design of the flush mechanism, and thus user behavior, plays an important role in the amount of water saved. That is, if the user uses the toilet incorrectly or does not understand its design, the toilet may not be saving as much water as it was designed to. The next section of this paper focuses on the user behaviors and decision-making processes that affect virtually all areas of everyday life (including flushing the toilet). Human decision-making is highly related to the field of behavioral economics, which is an integral part of this research.

2.3 Behavioral Economics

The field of behavioral economics integrates both economics and psychology in an attempt to better understand human behavior and how people make decisions. According to Camerer and Loewenstein (2004), while behavioral economics does not reject the neoclassical concepts of market equilibrium, utility seeking and/or maximization, and efficiency, studies do often involve discarding certain simplifying assumptions, such as that of the perfectly rational economic actor. Bounded rationality—that is, the effects of limited cognitive ability on an individual's decision-making process—is a vital assumption in behavioral economics, stemming from Simon (1955). Simply put, it is unrealistic to assume that the decision-maker has the desire, time, and/or ability to carefully weigh the advantages and disadvantages of each decision he or she makes. Thaler and Sunstein (2008) draw from theories in the field of psychology and

distinguish between two cognitive systems, the Automatic and the Reflective. The differing attributes of each system are shown in table 1.

Examples of Automatic responses include braking quickly to avoid an auto collision, holding one's breath before diving underwater, or smiling at a young child; Reflective responses, conversely, include solving math problems, choosing a restaurant for dinner, or purchasing a birthday gift for a friend or relative. Automatic responses are linked to instinct and self-preservation, whereas Reflective responses enable the individual to think logically and rationally in order to reach a utility-maximizing decision (Cory, 2006). Each of these responses, whether deliberate or not, are actually discrete *decisions*, and individuals make hundreds, if not thousands, of these decisions each day. Under the neoclassical assumption of perfect rationality, each of these decisions is made with the complete and undivided attention of the decision-maker, who carefully weighs all the costs and benefits of each possible course of action before making a final decision. However, both behavioral economics research and common sense suggest that this is not the case (e.g., Simon, 1955; Thaler and Sunstein, 2003; Camerer and Loewenstein, 2004).

There are in fact a wide range of cognitive biases that influence the decisions individuals make. One such bias, known as the 'default option' or status quo, is particularly relevant to our research: this is what occurs when a decision maker takes no action or an automatic result occurs. Examples of default options include 'opt-in' versus 'opt-out' retirement savings plans and organ donation programs; the latter default causes much higher rates of savings and organ donations, respectively (Thaler and Sunstein, 2008). The implications of the default option with regard to dual flush toilets will be examined in more detail below.

"Libertarian paternalism", a term coined by Thaler and Sunstein (2003), implies encouragement without coercion toward a particular decision or unconscious behavior. In this

school of thought, 'choice architects' frame the decision and therefore attempt to influence the outcome of the decision, 'nudging' individuals toward choices that are considered to be 'better' in some way, such as eating more healthfully or exercising. In many situations, decision-makers have an incentive (e.g., their own personal health and well-being) to make choices that benefit themselves. But what about a situation in which an individual's decision has *no effect* on him or her personally—for example, the decision whether to flush a dual-flush toilet correctly in a commercial or public setting? While some incentive may still exist (for example, the sense of ethical or altruistic satisfaction one receives from saving water), the user does not have to pay for the water he or she uses; there is also no risk of others observing the user's decision and disapproving of it. Furthermore, the habit of flushing a toilet in a certain manner (e.g., by pushing a handle down) is virtually ingrained (that is, an Automatic versus a Reflective response).

As such, libertarian paternalism is arguably most useful in situations where the decision-maker has little or no personal incentive to 'do the right thing' *and* where the design of the default option strongly influences user choice. The dual flush toilet which was chosen for this study, and its use in commercial and institutional environments, fits this description very well. The following section provides the conceptual framework of this project and analyzes the specific designs of several dual flush toilets at length.

3. Conceptual Framework

3.1. Overview

As previously noted, the purpose of this project was to determine the extent to which the design of the flush handle on a dual-flush toilet impacts the actual amount of water saved. The Sloan Uppercut® flushometer was selected as the research focus due to the fact that it presents

the user with a choice: pull the handle up for a small flush, or push it down for a large flush. As most toilet users have been "conditioned" to push the handle down, it is hypothesized that most will automatically push the handle down out of habit even when they do not need a large flush, thus wasting water. Therefore, the primary research question is as follows: do toilet users inadvertently push the handle down due to the default design of the handle? If so, how much water is wasted as a result of this design? Does adding instructional signage to the stalls help to reduce water consumption? In order to address these questions, some basic assumptions about water use in toilets must be identified and analyzed.

Manufacturers of dual flush toilets advertise that their products conserve water and often provide numerical estimates of the potential amount saved. For example, Sloan Valve Company, the maker of the Sloan Uppercut® flushometer, estimates a 21% water savings when compared to a standard 1.6 gpf model, though they do not elaborate on the methods by which they arrived at this figure (Sloan Valve Company, 2010a). Sloan also offers an online water savings calculator tool, which assumes that men use urinals twice daily and toilets once daily and that women use the toilet three times daily in commercial buildings (Sloan Valve Company, 2010b). It should be noted that Sloan does not attempt to estimate the ratio of small to large flushes in women's restrooms, but it is reasonable to infer that the 2:1 ratio for men is the same for women. A 2002 Canadian study of dual flush toilets assumes a 3:1 urination-to-defecation (U/D) ratio (Veritec Consulting Inc., 2002). Other estimates are as high as 4:1 or 5:1. Few estimates of U/D ratios in humans exist, and there is significant variation between those that do. While this may be due to the wide range in the daily bodily needs of individuals, it is important to note that some individuals demonstrate avoidance behavior with regard to public defecation (Avvannavar and Mani, 2008; Watkins, 2000), which would imply that U/D ratios may be higher in commercial

buildings (i.e., the workplace) than in the home. As such, the provision of a low-volume flush option, as exists in dual flush toilets, may be especially suitable for commercial buildings.

3.2. Discussion and Analysis of Dual Flush Toilets

As of July 2011, there were 313 different models of WaterSense-approved dual flush toilets listed on the WaterSense website, and 801 toilets in total (EPA, 2011). While an analysis of all of the different dual flush models and manufacturers was not feasible, a description of common types of dual flush toilets and flushometers is necessary before evaluating the soundness of the design of the Sloan Uppercut®. Emphasis in the section is placed not on the design of the toilet itself, but on the user interface—that is, the flush mechanism.

Figure 1 shows a brand that is especially popular in households, dual flush pioneer Caroma. It is designed such that there is no default option; the user chooses between two equally accessible buttons, which are large and clearly visible on the top of the toilet tank. Most importantly, it is obvious to the user which button produces a low- versus a high-volume flush. In terms of user interface, this flush mechanism is designed quite well from a behavioral economics standpoint in that it is easy for the user to make the 'correct' choice, even if he or she is unfamiliar with the design.

There are several other flush mechanism designs, which are not as easy for a new user to comprehend. Typically, these mechanisms consist of two buttons, one larger than the other, embedded within a circular silver ring. Like the Caroma model, these other flush mechanisms are also usually located on the top of the toilet tank, but the similarities end there. Neither button is clearly marked, and a new user must think about which button to push. A user desiring a small flush may reason that the smaller button results in a smaller flush. Alternatively, he or she may reason that because a small flush is needed much more frequently, the toilet's manufacturers

designed the mechanism so that the small flush button is larger and therefore slightly easier to push. According to a plumbing distributor that sells many models with this type of flush mechanism, "Button designs vary from toilet to toilet, but most often the smaller button is used for the liquid-waste flush" (Signature Hardware, 2011, p. 1). This quote implies another problem, that a button that produces a small flush in one flush mechanism may produce a large flush in another. Even if the user is aware of the correct use of the flush mechanism, the chrome finish may cause one's finger to slip (thus accidentally pushing the larger button). In light of these observations, this design is much less clear than the Caroma model, making it more likely that the user will make an 'incorrect' decision, thus wasting water. In sum, while certain flush mechanisms may be more aesthetically pleasing, they are poorly designed when analyzed using behavioral economics. Of course, this would be less of a problem for repeat users, such as in one's home, as one would expect that the user would eventually 'learn' the correct behavior.

Figure 2 shows the subject of this study, the Sloan Uppercut® flushometer, model number WES-111. This is a specific type of dual-flush mechanism in which the user must choose between pulling the handle up or pushing it down, depending on whether he or she desires a small or large flush. The Uppercut®, which is designed for use in commercial and/or public buildings, is a flushometer rather than a toilet and can therefore be installed on most types of commercial toilets. Many older toilet models can be retrofitted with new flushometers, such as the Uppercut®. The major point of interest in the Sloan Uppercut® for the purpose of this paper is that, unlike the other dual flush mechanisms discussed, it presents the user with a 'default' option. More specifically, the handle is pulled up for a low-volume flush (1.1 gpf) and pushed down for a large-volume flush (1.6 gpf). The primary design flaw, as far as water savings, in the Uppercut® is that the default option—pushing the handle down—produces the larger flush. As

virtually all toilet users in the U.S. have been taught to push toilet handles down from childhood, it is hypothesized that much water is wasted due to people inadvertently and automatically choosing the 'incorrect' flush for their needs. Lifelong habits, such as flushing a toilet handle downwards, are powerful and difficult to change. Logically speaking, based upon a 2:1 or 3:1 U/D ratio, individuals need a low-volume flush most of the time. The Sloan Uppercut®, by virtue of its design, requires users to 'retrain' themselves to use the toilet in the intended manner. If saving water is the desired outcome, reversing the flush mechanism, so that pushing the handle downwards produces a small flush, should produce far superior results. At least one company, AMTC®, manufactures a dual flush flushometer that is designed in precisely this way.

Figures 3 and 4 show the two types of instructional signage that are intended for use with the Uppercut®. Figure 3 depicts instructional stickers that are attached to the base of the handle itself. The handle, which is a conspicuous bright green color, draws attention to the stickers and thus may help signal to users that the Uppercut® is not a standard flushometer. However, various individuals associated with this project (including university faculty/students and employees at the research site) commented that the stickers were not very noticeable and that the instructions provided were unclear. These stickers come pre-applied to the flush handle. Figure 4 is an engraved stainless steel plate with an adhesive backing that is typically mounted on the wall above the flushometers, on the back of the stall doors, or both. It should be noted that the current specification sheet for the Sloan Uppercut® claims that the wall plates are included with the purchase of the flushometer; however, they are in fact *not* included and must be ordered separately at an additional cost. Before this research project was undertaken, it was unknown what effect, if any, these instructional graphics had on user behavior or whether they helped to reduce water consumption.

3.3. Explanation of Hypotheses

The general hypotheses of this study were as follows. In order to test these hypotheses, the 2:1 U/D ratio used by Sloan was used as a benchmark, i.e. the null hypothesis is that the percentage of up flushes will be equal to or greater than 66.667%.

1. The default option of a Sloan Uppercut® flushometer often causes the user to inadvertently choose the 'incorrect' flush type for their needs, thus wasting water. That is, during the control period, the actual ratio of up-to-down flushes are hypothesized to be less than the company-projected ratio of 2:1 or 66.667%, or:

H_{A1}: *% up flushes*^{control} < *66.667%*

2. Adding the instructional wall plates shown in figure 4 will reduce user error, but still not reach the level of projected water savings. Therefore, during the treatment period, the actual ratio of up-to-down flushes are hypothesized to be greater than during the control period, but still less than the projected ratio of 66.667%, or:

H_{A2}: *% up flushes*^{control} < *% up flushes*^{treatment} < *66.667%*

3. Due to the flushometer's design, projected water savings are overestimated and actual water usage is higher than expected.

4. Methods and Procedures

Lusk (2010) presents a typology of field experiments for work in behavioral economics. He indicates that natural field experiments are generally considered to be the most desirable type because the researcher has a high degree of control and they mimic 'real-world' situations due to the context-rich experimental environment. This research qualifies as a natural field experiment because a) the subjects are self-selected, b) data collection takes place in actual restrooms in a public building, and c) a majority of the subjects are not aware of the experiment.

The restrooms for the experiment are located in the City Hall building of a small city in the American Midwest. The building was newly constructed and opened to the public in March, 2011, about three months prior to the start date of this study. The building has been awarded gold-level LEED® certification from the Department of Energy. There are Sloan Uppercut® flushometers installed in each of its restrooms as part of the requirements for LEED® water efficiency. The dual-flush toilets in the building are installed in the intended fashion, such that pulling upward on the handle produces a small flush and pushing down produces a large flush. The flushometers were installed as part of the new construction and therefore had not been retrofitted to existing toilet bowls. Additionally, no signs had ever been posted to alert the user as to the handle's specialized functions other than the instructional stickers attached to the flush handles themselves (see figure 3). Approval to install sensors (described below) and collect data was obtained from the City Hall Office of Sustainability. Other than the Sustainability Manager and maintenance personnel, building employees and other users were not given any information about the study or the flush counting sensors unless they requested it. Those who did ask were told only that the mechanisms counted the number of flushes and were part of a project to measure water use in the building. It is worth noting that no performance or maintenance issues were reported during the course of this particular study, but anecdotal evidence suggests clogs and incomplete bowl clearance can sometimes be problematic with retrofits due to older toilet bowl designs.

The exclusive use of women's restrooms was deemed necessary due to the fact that men typically utilize urinals rather than toilets if they desire a low-volume flush. Data were collected from a total of eight separate women's toilet stalls (two separate restrooms on different floors of the same building with a total of four stalls each). The toilets were fitted with sensors that count

the number of up and down flushes. As detailed below, these sensors were designed, fabricated, and fitted by the University of Missouri (MU) Engineering Lab. An additional flushometer was purchased in order to allow the lab to design the flush counters off-site.

A device able to accurately count the number of up and down flushes for this type of toilet, and to differentiate between the two, did not exist before the start of this project. As such, the collaboration of the MU Engineering Lab was needed to design and manufacture a total of eight flush counters. In order to accurately count the number of up and down flushes, a series of sensor magnets were attached to plastic rings that were then fitted onto the flushometer and handle. The plastic components and magnets were attached firmly to the flushometer and handle to assure that they could not be removed, misaligned, or easily tampered with. Electrical wiring (coated with plastic for safety) connected the magnetic rings to a wall-mounted plastic case, which housed a small digital flush count tracker and a battery pack. Finally, a reproduction of the instructional sticker on the handle was attached to the larger sensor ring. This was necessary in order to replicate ordinary conditions as closely as possible, as the flush counters covered the original stickers. Photos of the flush counter, magnetic rings, and housing are provided in figures 5 and 6. Prior to the trial, a prototype flush counter was installed for several weeks in one stall in order to determine whether the design needed to be modified. After this initial period, during which the prototype functioned accurately and reliably, the seven remaining flush counters were fabricated and installed.

The Sloan Uppercut® flushometer, model number WES-111, toilets were monitored for a total of seven weeks to count the number of up versus down flushes. During the first four weeks, the control period (Monday 20 June—Friday 15 July), there were no instructional signs in the stalls other than the small stickers attached to the flush handles (figure 3). The ‘treatment’ for

this experiment took place during the final three weeks of the seven-week trial (Monday 18 July—Friday 6 August). The treatment, as previously discussed, was to install two instructional wall plates (figure 4) in each stall, one on the wall directly above the flushometer and the other on the rear of each stall door. At the end of the trial, all equipment associated with data collection was removed from the stalls with the exception of the wall plates.

Data were collected each morning and recorded as data for the previous day; for example, data collected on Tuesday morning were counted as Monday's data. In addition to recording flush counts daily, the digital counters were reset and each flush counter apparatus was carefully inspected to ensure proper function and fit. Due to the sensitive nature of the magnetic counters, the magnetic rings occasionally moved out of place and yielded several highly unusual observations. 'Highly unusual' denotes either extremely high counts (usually in the hundreds, as opposed to the single- or low-double-digits usually observed) or none at all. These observations are considered as missing and not included in the data set. Data were collected only on business days as City Hall is closed on the weekends. Data were also not collected on Monday 4 July, which occurred during the third week of the control period, as the building was closed.

5. Results

Count data of up versus down flushes for the control period, by floor and stall, is summarized in table 2. The table includes the dependent variable "percentage of up flushes". As the table clearly shows, average flush counts were well below the expected 2:1 up-to-down ratio during the control period; only 26.6% of total flushes were up flushes, which is much less than the expected percentage of 66.67%. The failure to reach the projected percentage of up flushes holds true even when the two different floors of the building are analyzed independently. Floor 2 had an average up flush rate of 35.3%, while floor 3 had a rate of only 17.6%. The difference between projected and actual percentages of up flushes is stark; the ratio is essentially the exact

opposite of what is predicted by Sloan. Thus the first alternative hypothesis of H_{A1}: % up flushes^{control} < 66.667% is therefore supported and the null hypothesis of H_O: % up flushes^{control} ≥ 66.667% is rejected.

Data for the treatment period, during which wall plates were displayed in each stall, is summarized in table 3. During treatment, an increase in the percentage of up flushes was observed but it still did not reach the projected level of 66.67%. The average percentage of up flushes for the treatment period was 38.8%. Again, even when floors 2 and 3 are examined independently of each other, neither meets the projected percentage; the percentages of up flushes were 49.5% and 27.6%, respectively.

Figure 7 depicts the weekly averages graphically. The thick dotted black line represents a constant value of 66.67%, the expected percentage of up flushes. The lighter dotted lines indicate data plots by day for floors 2 and 3, while the solid lines are weekly averages. The vertical dotted line at week 5 indicates the beginning of the treatment period. Several inferences can be made. First, as indicated in tables 2 and 3, there is an obvious divergence between the observed and projected percentages of up flushes. Second, one can easily see the increase in percentage of up flushes at the beginning of the treatment period, although as previously indicated, even with instructional signage, the actual percentage of up flushes is far below the company projection. Third, there is a clear difference between the up flush rates between the second and third floors. While the averaged trend lines illustrate a similar pattern between the two floors, the second floor maintains a higher percentage of up flushes during the entire course of the seven-week trial. The potential reasons for this will be discussed in Section 6.

Table 4 depicts an analysis of variance for the dependent variable ‘percentage of up flushes’ and the predictor variable ‘treatment’. The significance value, 0.000, confirms that the

treatment has a statistically significant effect on the percentage of up flushes. Therefore, the second alternative hypothesis, H_{A2}: % up flushes^{control} < % up flushes^{treatment} < 66.667% is supported and the null, H_{O2}: % up flushes^{treatment} ≥ 66.667%, is rejected. However, the treatment had *some* effect, it did raise the percentage of up flushes closer to the projected level.

User behavior is clearly impacted by the Uppercut's® design, but it is also important to note how much water is wasted as a result of that behavior. For illustrative purposes, multiplying up and down flushes by their respective 1.1 and 1.6 flush volumes (assuming that actual flush volume is roughly analogous to the manufacturer's claims) produces the data in table 5. The amount of water wasted may seem insignificant; many enterprises use hundreds or even thousands of gallons of water per *day* in their operations. However, it should be noted that traffic into City Hall is relatively low. Over the entire course of the seven week-trial, there were 3091 total flushes counted. Water waste should therefore be evaluated as a percentage of the total rather than in absolute terms; the more water consumed by a business or other enterprise, the greater the volume of water that is wasted. Table 6 shows estimated water use if our results were extended over the course of a year, and compares it to what standard 1.6 gpf and high-efficiency 1.28 flushometers would consume. The effects of this flush design appear more substantial when extrapolated over a year's time. Even with additional instructional signage, over 3200 gallons of water are wasted each year due to the flushometer's design.

6. Discussion

As the previous analysis has shown, the data collected for this research trial strongly support both alternative hypotheses. In other words, even with instructional signage, the Sloan Uppercut® does not result in the expected 2:1 U/D ratio. It is worth repeating that Sloan uses this ratio in their own water savings calculation tool, and that this ratio is a conservative estimate of

actual U/D ratios. Again, the ratios are essentially the opposite of what would be expected, indicating the importance of the choice of a default. Additionally, the data show that Sloan's own claim of the Uppercut's® ability to save 21% more water than a conventional 1.6 gpf model is, at least in some cases, inaccurate. Even during the treatment period, only a 12.1% decrease in water use would have been realized relative to1.6 gpf flushometers. As such, where water efficiency is the goal, the Uppercut® does not perform nearly as well as it is advertised to do in a real-world setting. It is especially important to note that in a public restroom, users have no cost-saving incentive to conserve water. If an individual does not have intrinsic motivation to be environmentally conscious, then they may not take note of, or care about, the correct use of the toilet. However, if the default option was the water-saving option (a low-volume flush), then the user would most often choose the correct action despite their lack of incentive to do so.

The effect of the different floors of the building can be explained by the fact that the City Hall Office of Sustainability is located on the second floor. One may surmise that sustainability-oriented employees would be more likely to both have knowledge of the dual-flush nature of the flushometers and also to be motivated to use them correctly. Conversely, the third floor of City Hall contains the Office of Public Works, which has a greater amount of foot traffic from people who do not work in the building and thus are even less likely to use the flushometer correctly.

If maximizing water efficiency is the intended function of a dual flush toilet, then it is clear that the Sloan Uppercut® falls short of this goal. The question, then, is not *whether* the Uppercut® wastes water, but *why* it does so. Returning to the previous discussion of behavioral economics, recall that flushing the toilet is what Sunstein and Thaler (2008) refer to as an Automatic response—a decision that is made quickly and unconsciously. This experiment indicates that even with abundant instructional signage in each stall, and even with a population

sample that is biased *toward* choosing the appropriate action, the ‘decision’ to push down isn’t really a decision at all. Instead, it is a reflexive, ingrained response that, for most users, requires a deliberate mental effort on the part of the user to override—that is, the design of the ‘default’ option works against the toilets’ water-saving features.

The results of this study indicate that the design of the Uppercut® prevents the mechanism from maximizing water savings. Given that individuals need a low-volume flush a majority of the time, a more intuitive design would be to reverse the mechanism such that pushing the handle down results in a low flush. Alternatively, those seeking to conserve water could also choose a different design of dual flush mechanism. Those that have two separate buttons (for example, the Caroma model shown in figure 1) eliminate a default option altogether; the user must choose between one button or the other, rather than using the same mechanism to perform two distinct functions. Alternatively, a non-dual flush, high-efficiency 1.28 flushometer would also save a considerable amount of water over the Uppercut®.

It is important to note, however, that firms and individuals may have objectives other than just water savings. Some customers may seek only to save money on utility bills, while other parties may purchase the Uppercut® in order to conform to LEED® building requirements, as the City Hall building represented in this study did. Still others may choose to purchase the Uppercut® in order to promote themselves as a sustainability-oriented enterprise or due to personal value systems. Indeed, many commercial and industrial firms have embraced the growing trends of sustainability and ‘green’ practices, not only to improve their public image, but also because water and energy savings improve their bottom line. Additionally, because the *buyer* and the *user* of a dual flush toilet are usually not the same person in commercial applications, it should be noted that the user of a dual flush toilet is not paying for the water used

and therefore does not have any financial incentive to choose the correct flush mechanism. This lack of user incentives makes the design of the default option even more important.

There is variation among the incentives of dual flush toilet *buyers*, but there are entirely different motivations where the *manufacturers* are concerned. Manufacturers, as firms, are interested primarily in profitability. Decreasing the amount of water consumed in a toilet helps the manufacturer to target a specific, eco-conscious market for toilets. However, in contrast to the buyers, who often seek to maximize water savings, manufacturers seek to maximize profit—and a part of this process is maintaining brand reputation. Manufacturers will not likely sacrifice aesthetics or performance—that is, reliable operation without clogs or the need for repair—for water savings. While a reputation for reliable and strong performance at a reasonable price benefits both the manufacturer's status *and* its bottom line, minimizing the water use of toilets does not appear to directly benefit the manufacturer in the same way as the buyer. Thus, for the purposes of saving water, the incentives of manufacturers, buyers, and users are misaligned.

7. Conclusions and Opportunities for Further Research

The overall goal of this project was to determine the relationship between the design of a fixture intended to save water and the impact on user behavior and thus water consumption. The specific conclusion drawn was that for the purposes of saving water, the Sloan Uppercut® should be redesigned in order to be more intuitive to the user. This experiment has also provided original and quantifiable data with regard to behavior in the context of default options, behavioral economics, and decision-making in general. To our knowledge, this is the first research to examine water fixture design using behavioral economics.

While our research has provided answers to a number of questions, additional research is needed to expand on these findings. One experiment could involve a longer treatment period to

determine whether the initial effects of adding signage decrease over time in situations with a stable population. Another study that focused upon a flushometer with a reversed design from that of the Uppercut® such that pushing the handle down produces a small flush could be especially helpful in determining the influence of Automatic responses versus that of instructional signage and whether any toilet performance issues arose. Conducting the experiment in a large venue such as a sports stadium, where learning is less of a factor than in a work environment, would be useful. It would increase the population size and researchers could have some bathrooms with each type of mechanism at the same time since individuals would probably only use one bathroom during an event. A study of other types of dual flush toilets in public settings could help to determine which designs are the most conducive to water savings.

It is also important to note that while this research is helpful in understanding water conservation in commercial and industrial settings, it does not address potential problems 'downstream' due to more concentrated wastewater.

In summary, it is hoped that this research has provided insight into a fixture that many individuals pay little attention to—which, in reality, is the reason why the default option is so important in its operation. This research also suggests that behavioral economics can be a useful tool in examining the effectiveness and design of all water-using appliances and fixtures, not just toilets. Unless actual, real world human behavior is taken into account by the parties that design and market water fixtures and/or other appliances, the maximization of water savings (or that of any other scarce resource) will not be achieved.

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Figure 1: Caroma flush mechanism

Figure 2: Sloan Uppercut® flush mechanism

Figure 3: Instructional signage for the Sloan Uppercut®, flush handle mount

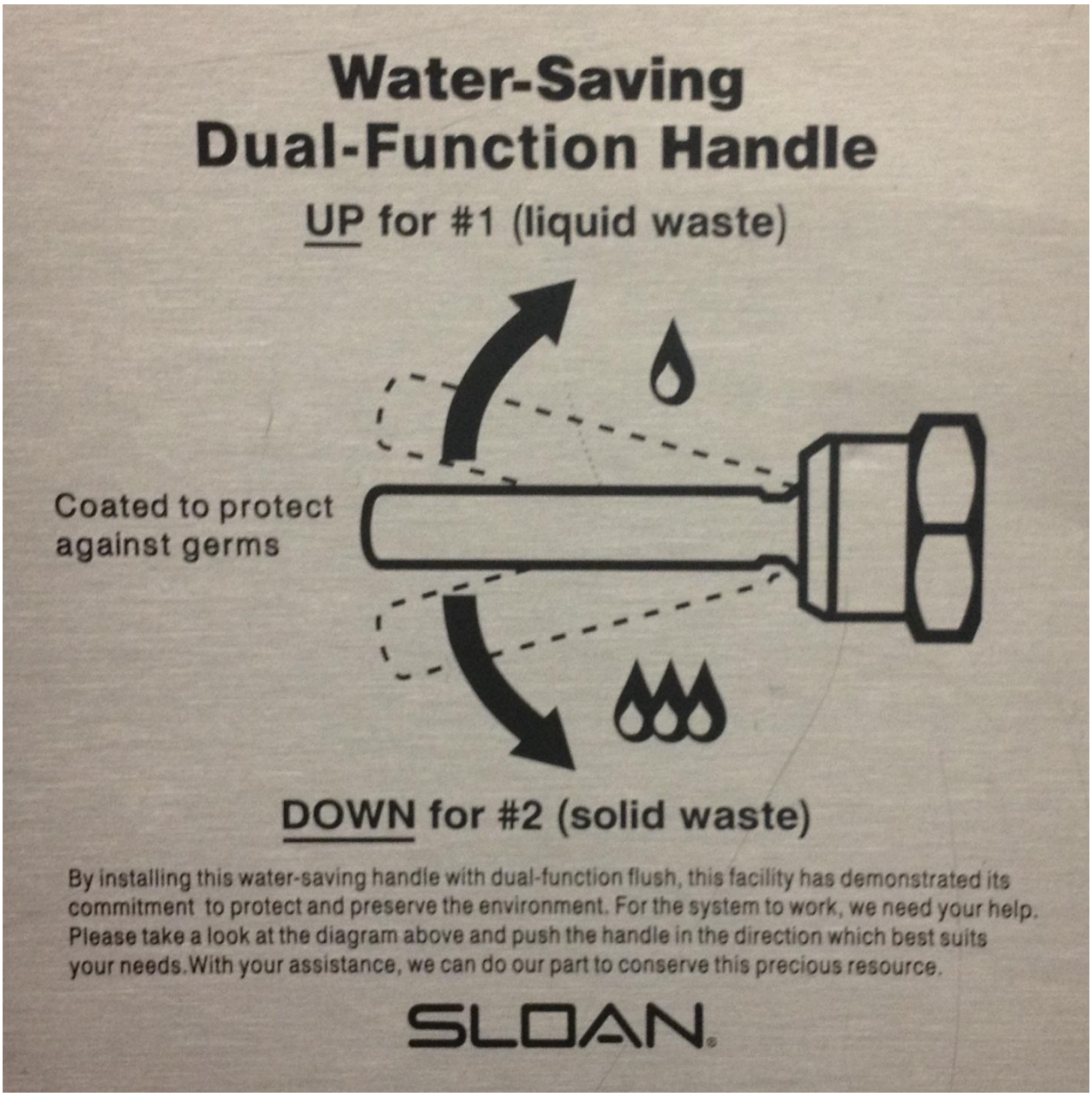

Figure 4: Instructional signage for the Sloan Uppercut®, door/wall mount

Figure 5: Magnetic sensor rings

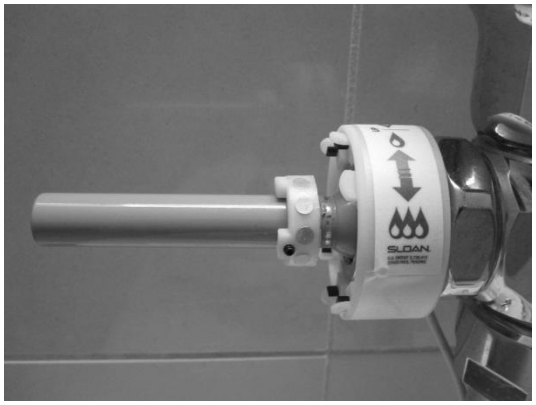

Figure 6, Flush counter rings and housing, installed

Figure 7: Observed vs. projected percentage of up flushes by week

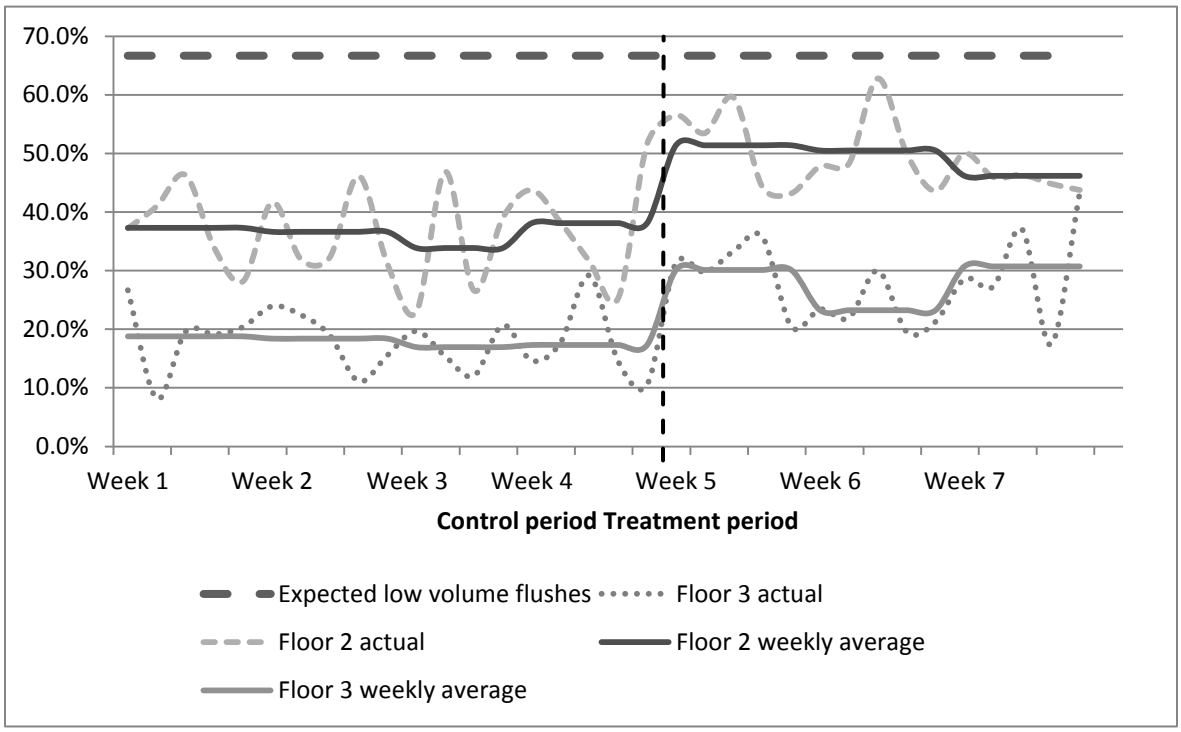

Table 1: Characteristics of two cognitive systems

Automatic	**Reflective**
Uncontrolled	Controlled
Effortless	Effortful
Associative	Deductive
Fast	Slow
Unconscious	Self-aware
Skilled	Rule-following

Source: Thaler and Sunstein 2008, p.20

Table 2: Control period results summary

Floor and stall	Number of flushes			Proportion of flushes
2nd floor	# of up flushes	# of down flushes	# of total flushes	% of up flushes
Stall 1 totals	126	100	226	55.8%
Stall 2 totals	122	214	336	36.3%
Stall 3 totals	56	185	241	23.2%
Stall 4 totals	30	112	142	21.1%
2nd floor totals	334	611	945	35.3%
3rd floor				
Stall 1 totals	33	252	285	11.6%
Stall 2 totals	84	92	176	47.7%
Stall 3 totals	26	213	239	10.9%
Stall 4 totals	20	205	225	8.9%
3rd floor totals	163	762	925	17.6%
Totals for both floors	**497**	**1373**	**1870**	**26.6%**

Table 3: Treatment period results summary

Floor and stall	Number of flushes			Proportion of flushes
2nd floor	# of up flushes	# of down flushes	# of total flushes	% of up flushes
Stall 1 totals	85	75	160	53.1%
Stall 2 totals	86	111	197	43.7%
Stall 3 totals	91	60	151	60.3%
Stall 4 totals	47	69	116	40.5%
2nd floor totals	309	315	624	49.5%
3rd floor				
Stall 1 totals	32	148	180	17.8%
Stall 2 totals	69	85	154	44.8%
Stall 3 totals	47	74	121	38.8%
Stall 4 totals	17	125	142	12.0%
3rd floor totals	165	432	597	27.6%
Totals for both floors	**474**	**747**	**1221**	**38.8%**

Table 4: Analysis of variance for the independent variable ‘treatment’

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.949	1	0.949	20.962	0.000[a]
	Residual	10.505	232	0.045		
	Total	11.454	233			

a. Predictors: (Constant), Treatment

b. Dependent Variable: % Up flushes

Table 5: Projected vs. actual water consumption of toilets during experiment[a]

	Control period	Treatment period
Projected water usage (in gallons):	2369[b]	1547[c]
Actual water usage (in gallons):	2745	1717
Water waste (in gallons):	376	170
Water waste (percent of projected):	15.87%	11.00%

[a] These calculations were derived as follows:

- Projected water use: ((Total number of flushes during period x 66.67%) x 1.1 GPF) + ((Total number of flushes during period x 33.33%) x 1.6 GPF)
- Actual water use: ((Total number of flushes during period x actual percentage of up flushes) x 1.1 GPF) + ((Total number of flushes during period x actual percentage of down flushes) x 1.6 GPF)
- Water waste (in gallons): Actual water use – projected water use
- Water waste (percent of projected): Water waste (in gallons) / projected water usage (in gallons)

[b] 1870 total flushes over a four-week period

[c] 1221 total flushes over a three-week period

Table 6: Estimated water consumption of toilets in one year[a] based on experiment results[b]

	Without treatment	With treatment
Projected water usage (in gallons):	29250	29250[c]
Actual water usage (in gallons):	33894	32468
Water waste (in gallons):	4644	3218
Water use of a 1.6 GPF flushometer (hypothetical):	36947	N/A
Water use of a 1.28 GPF flushometer (hypothetical):	29558	N/A

[a] These calculations were derived as follows:

- Total number of flushes per year (not shown): (3091 total flushes / 34 days of research trial) x 254 working days per year = 23092
- Projected water usage: ((Total number of flushes per year x 66.67%) x 1.1 GPF) + ((Total number of flushes per year x 33.33%) x 1.6 GPF)
- Actual water use: ((Total number of flushes per year x actual percentage of up flushes during each period) x 1.1 GPF) + ((Total number of flushes per year x actual percentage of down flushes during each period) x 1.6 GPF)
- Water waste (in gallons): Actual water use – projected water use
- Water use of a 1.6 GPF flushometer (hypothetical): total number of flushes per year x 1.6
- Water use of a 1.28 GPF flushometer (hypothetical): total number of flushes per year x 1.28

[b] Weekends and holidays excluded (estimated 254 working days per year)

[c] Assuming same water usage with and without treatment

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