THE IMPACT OF VISUAL COMMUNICATION AND USER EXPERIENCE

ON RESIDENTIAL WATER CONSUMPTION

by

Samual Lee Ward, B.F.A.

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Committee Members:

Grayson Lawrence, MFA, Chair

Sameera Kapila, MFA

Roselynn Newton, MFA

DEDICATION

I made a conscious decision after completing my undergraduate degree that I was NEVER going back to school again. For some reason though, I just couldn't stay away, and decided in 2008 to give it another go. My life has changed so much since I decided to attend graduate school 5 years ago. When I started back, my dog Dexter and I were two bachelors just "livin' the dream." Our steady diet of mac n' cheese and cold beer made for a pretty easygoing way of life. Little did I know then, that over the course of the next 5 years, I would meet and marry an amazing woman named Lana (and her dog Maggie…of course), have a son named Owen, and learn to write a thesis. Not bad for a glorified artist! My wife's support during this whole graduate school process was probably the thing that kept me going.

I would be remiss if I didn't share this dedication with my dad and mom, Joe and Mikki Ward. Whether they realize it or not, they have always motivated me to succeed because of the example they set. Since I was a kid, I watched them work hard for what they wanted, and work even harder for what they believed in. Their dedication to helping other people, helping the planet, and helping their family is such an inspiration to me and I love them very much for it. I just hope that I can do half as well for my own family as they did for me.

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It is so important that I thank Suzanne Williams, Roger Biggers, and New Braunfels Utility. Their willingness to help me in this process truly made my research study possible. Additionally, I must acknowledge all of my graduate educators, Claudia, Christine, Jeff, Bill, and the rest. They all make me very proud to have been a part of the MFA Communication Design program at Texas State University.

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ABSTRACT

The amount and availability of freshwater on the planet earth is threatened each day by factors such as rapid population growth, industrial contamination, and residential misuse. The need for greater technologies and programs aimed at water use education and conservation are now more important than ever. Without ample freshwater or the tools to help save it, the human way of life stands to suffer immeasurable consequences.

This thesis research examines some of the key issues facing earth's water supplies, while exploring the human habits of water consumption. Focused on resource consumption in typical American households, this research discusses technologies designed to promote energy conservation at home. The goal is to uncover the elements that make those technologies successful so that they can be applied to a device designed to promote smarter water consumption at home.

A 3-month study to examine the impact of visual communication and user experience on residential water consumption was conducted in support of this thesis. An Apple iPod Touch® application named Water Watch was developed specifically for this research. The function of the app was to provide its users with their daily water consumption in several different visual formats. Five households participated in the study and the results revealed that the availability of more frequent water consumption information led to a decrease in overall water usage.

CHAPTER I

INTRODUCTION

The purpose of this thesis research is to examine the impact of visual communication and user experience (UX) on residential water usage. This thesis will discuss factors contributing to the earths decreasing freshwater resources and will explore the effects of UX on a household's water consumption habits. A research study will be conducted in support of this project, consisting of daily household water usage data presented to its participants through an application (app) designed to operate on an Apple iPod Touch. The experimentation period will conclude with a follow-up survey focused on gauging individual experiences with the app as well as an analysis of each household's historical water consumption versus that of the study period. This research project will also investigate residential water misuse, examine the possible causes, and reinforce the importance of more prevalent conservation practices.

Water Resources

The volume of water on earth has remained fairly constant for millions of years, which often causes some debate when discussing its decline in availability. "One should consider the Earth as a 'closed system' for the most part, like a terrarium. That means that the Earth, as a whole, neither gains nor loses much matter, including water" (Global Water Cycle, 2013). With a mere 1% of the earth's water available for human consumption, factors such as rising demand from population growth, changing weather patterns, and industrial contamination and waste, threaten the long-term availability of the life-sustaining resource. In 1746, Benjamin Franklin proclaimed, "When the well runs dry, we know the worth of water" (Prud'Homme, 2011, p. 13). Little did Franklin know that his statement foreshadowed the increasingly critical need for greater conservation tools, practices, and programs for maintaining clean, affordable water supplies for future generations.

In a 2008 poll, 71 water utility managers and other experts were asked about ineffectiveness of communications regarding the value of water. They responded by highlighting a lack of audience attention to the value of water. In addition, the poll's respondents believed that people view utility services such as water as a right rather than a privilege (Chowdhury, Means, Passantino, Ruettan, Westerhoff, 2008, p. 72). The convenience, availability, and "on-demand" nature of water and electricity has created complacency among many consumers in the U.S. Professor of Human Dimensions and Natural Resources, Richard Knight points out that, "Historically, we have taken those services for granted, but an increasingly crowded planet and the degradation of lands and waters are causing people to appreciate how much it costs to pay for substituting those services once they are gone" (2008, p. 104). The rising costs Knight eludes to have already begun to occur as evidenced by a 12-year study conducted by *USA Today*. Researchers in that study found that in twenty-nine localities in the U.S., monthly water costs have increased by at least double (McCoy, 2012, p. 1A).

Technologies for Water and Energy Conservation at Home

In-home systems and technologies have begun to emerge that target change in human water and electricity consumption habits. Smart water meters, air conditioning thermostats like Nest, and new billing techniques by companies like Opower are beginning to show a profound impact on the way people consume water and electricity.

Nest

The Nest learning thermostat is a revolutionary device built to help save energy in the home. The Nest combines modern design with energy saving functionality into the electronic device driven human interactions of the 21st century (see Figure 1). The strength of Nest lies in its remote access capability and its capacity to learn the temperature habits of a given household.

Figure 1. Nest Learning Thermostat. (*Eco Rehab Reviews*, 2013).

The learning function of Nest is what makes it such a valuable device for energy conservation. *Wired* Magazine's Steven Levy writes, "If you're not home for a while, the Nest will figure out the house is empty. If you routinely turn down the air conditioning before your household goes to sleep, and you forget to do this one night, the Nest will figure it out and take action" (2011). The thermostat can also teach its users better habits by tracking their energy consumption as well as notifying them which temperature settings are optimum for saving money. Nest captures and learns the temperature adjustment habits of a household and builds custom schedules for the air conditioner (a/c) to run on. This feature eliminates the mistakes people typically make when programming traditional thermostats. As a result, Nest's adaptability allows a/c units to run more efficiently than statically programmed thermostats.

Opower Billing

Opower, a billing and software company based in Virginia has taken a much more user-friendly approach to promoting electricity conservation at home. Recipients of Opower utility bills are rewarded for conserving energy with the company's signature smiley face printed on their bill (see Figure 2). Additionally, they are provided with a monthly comparison of their energy consumption versus their neighbors.

Figure 2. Printed Example of Opower Utility Bill Featuring a Neighbor Comparison and Their Smiley Face in the Upper-Right Corner (Lundin, 2011).

The neighborly energy comparison plays a significant role in producing Opower's reported energy savings. First, it creates a competition-like situation among neighbors making them want to out perform each other in energy and dollar savings. Secondly, it raises awareness and encourages households to research and ask questions about how their "efficient neighbors" are successfully conserving energy. "The energy savings produced by the [billing] software could be significant. Dan Yates, the company's CEO, says the average Opower customer cuts 2% to 3% of his or her energy usage because of this snappily presented information" (Sutter, 2010).

Smart Water Meters

The aging infrastructure in most U.S. cities is a major contributor to water waste. As a result, utility providers (UP) are perpetually upgrading municipal water systems to stem decay and stay ahead of the demand caused by population growth. One unique element of these upgrades that has proved to be both reliable and conservation focused is the installation of smart water meters.

Smart meters are installed at the junction where a UP's main water pipes meet an individual home's water supply pipe. The primary function of the new smart meters is two-part: First, it is a more reliable valve with upgraded parts and functions for supplying water to UP customers. This helps to reduce leaks and breakages that cause water waste and service interruptions. Secondly, it utilizes wireless technology for two-way communication with the UP's technicians and billing systems. UPs can monitor leaks or other system issues without the need to dispatch a service technician.

An added benefit of the integrated wireless technology in smart water meters is their ability to communicate with software and hardware that allow homeowners to monitor their water usage on a real time basis. For a one-time fee of $200, homeowners in Boulder, Colorado can buy an LCD display unit that synchronizes with their smart water meter wirelessly. The LCD unit shows users the amount of water that is actively being consumed in their home.

Another advantage of the smart meter's two-way communication is its ability to integrate with total home management systems. These systems allow daily consumption data collected from both water and electric smart meters to display on web applications dedicated to individual utility customer accounts. The web application gives the UP customers the ability to monitor and manage their water and electricity consumption from anywhere they have internet connectivity.

Improving Smart Water Meters

Though devices that interact with smart water meters like the LCD unit exist today, their simplistic displays lack a UX capable of connecting with viewers at an emotional level. “User [Experience] (abbreviated as UX) is how a person feels when interfacing with a system. The system could be a website, a web application or desktop software and, in modern contexts, is generally denoted by some form of human-computer interaction (HCI)” (Gube, 2010). The device’s User Interface (UI) and UX are critical in delivering an actionable message about each household’s water usage.

The water monitoring app designed for this thesis research, nicknamed Water Watch, will attempt to enhance the capabilities of smart water meters by taking cues from the UX of Nest combined with the psychological response of Opower billing. Water Watch intends to evoke the same daily human interaction habits as common thermostats. Unlike most thermostat experiences though, the app focuses on creating a UX that resonates with its users. Water Watch will also seek to bolster its UI and UX by leveraging the ease of use of the iPod Touch platform.

Thesis Organization

This thesis project is organized into six chapters. After discussing factors that threaten earth’s current freshwater supplies, this thesis will present available water conservation programs and practices. The project will then examine the habits of daily water consumption in typical American households.

In the preliminary research chapter, this thesis will probe the relationships of visual communication and UI design with human interactions by researching mobile devices, visual cues, icon/symbol recognition, and the emotional connection between humans and technology. These components will be critical in understanding habits surrounding water consumption at home.

The next portion of this thesis will introduce the methods used to support the research study performed with the Water Watch app. This transitions into the presentation of the research study components as well as its results. This thesis project will conclude with a study analysis, conclusions made from the entire investigation of this topic, and projections for further research.

CHAPTER II

STATEMENT OF PROBLEM

Issues Facing Freshwater Supplies

Without the continued establishment of policies created to protect water resources and smarter, more conservation-minded consumption at the residential level, humans will be facing catastrophic water shortages in the coming years. “Ismail Sergeldin, the [World] bank’s vice president for environmental affairs and chairman of the World Water commission, stated bluntly the ‘the wars of the twenty-first century will be fought over water’” (de Villers, p. 13). Rapid population growth, water waste, contamination, and climate change are just a few of the major issues facing earth’s freshwater supply.

Population

By the year 2030, the population of planet earth is predicted to exceed 8 billion people. That is an increase of over 1 billion consumers of todays already strained water supply. Alex Prud’Homme writes that in the U.S., “A report by the US General Accounting Office predicts that thirty-six states will face water shortages by 2013, while McKinsey & Co. forecasts that global demand for water will outstrip supply by 40 percent in 2030” (2011, p.12). In a 2009 report, the United States Geological Survey (USGS) estimates that the U.S. used nearly 410 billion gallons of water per day in 2005 (Kenny, Barber, Hutson, Linsey, Lovelace, Maupin, 2009). Though the water volume indicated in the 2005 findings is staggering, it marks the beginning of a leveling off of the water consumption in the U.S. through today. This leveling off can be attributed in large part to policy changes like the Clean Water Act, the Safe Drinking Water Act, as well as greater adoption of water conservation practices. Despite the increase in conservation efforts since 2005, there remains an urgency to reduce daily water consumption in the U.S. Targeting residential water consumers with conservation-focused technologies and services can help to ensure the availability of freshwater for years to come.

Population-driven demand is one of the greatest threats to the earth's water resources. This demand goes well beyond the human need to consume water for sustaining life. As population increases, the need for industries that supply consumers with essentials like, fuel, electricity, and food increase as well. Not surprisingly, each one of these industries relies heavily on the use of water for their production.

Industrial Water Use and Pollution

Industrial processes that produce fuel for transportation and electricity such as thermoelectric-power, hydraulic fracturing, and coal production use almost half of all the water consumed daily in the U.S. The twenty-two highest coal producing states in the U.S. use as much as 3.5 billion gallons of water per day in their mining operations (Maxwell, Yates, 2011, p. 92). The recent boom in Hydraulic Fracturing (fracking), a process used to remove oil and gas from shale deposits with high-pressure liquid, uses an estimated 40 and 70 billion of gallons of water each year in the U.S. according to the EPA (Kenworthy, 2013). The water used each day for fracking is only part of the threat to water resources. "Indeed, shale gas is a black hole for water. Exploiting it requires and pollutes massive amounts" (Biswas, 2013). The fracking fluid is a cocktail of thousands of gallons of water combined with toxic chemicals that include lead, uranium, and methanol to name a few. Most alarming is the fact that most of these chemicals cannot be refined from the wastewater created by the fracking process.

The fracking fluid has the potential to affect freshwater supplies in two significant ways. First, when fracking for oil and gas, the toxic fluids used can easily seep through shale deposits contaminating underground aquifers. Secondly, the perpetually contaminated water used for fracking is commonly stored in large, plastic-lined retention ponds that are treated to lessen the toxicity of the chemicals used. The liners in the ponds are at risk of failing, allowing contaminated water to drain back into the ground, aquifers, and rivers.

Commercial/Residential Irrigation and Contamination

Commercial and residential irrigation also make up a steadily increasing portion of the U.S. daily water consumption. The USGS estimates that in 2005, as many as 60 million acres were irrigated in the U.S. equaling 128 billion gallons of water per day. This issue is compounded by population growth, and aside from the water needs of commercial agriculture, much of it can be attributed to vanity and social pressure.

On average, 50% of a typical American home's total water consumption is attributed to lawn irrigation, while southern states can reach averages as high as 60%. Water dependent, non-native turf grasses and plants coupled with pressure from neighbors and homeowners association (HOA) regulations lead to water devouring lawns. In her 2008 article for *The New Yorker*, Elizabeth Kolbert writes, "The lawn has become so much a part of the suburban landscape that it is difficult to see it as something that had to be invented" (Water on the Home Front, p. 8).

In addition to the volume of water used, contamination is another aspect of commercial and residential irrigation threatening freshwater resources in the U.S. Lawn care products and insecticides such as glyphosate (commonly known as Roundup®)

runoff into storm drains, rivers and underground water supplies. In a 2013 literature review conducted to analyze the effects of glyphosate on humans, the authors concluded that:

> Contrary to the current widely-held misconception that glyphosate is relatively harmless to humans, the available evidence shows that glyphosate may rather be the most important factor in the development of multiple chronic diseases and conditions that have become prevalent in Westernized societies. In addition to autism, these include gastrointestinal issues such as inflammatory bowel disease, chronic diarrhea, colitis and Crohn's disease, obesity, cardiovascular disease, depression, cancer, cachexia, Alzheimer's disease, Parkinson's disease, multiple sclerosis, and ALS, among others. (Samsel, Seneff, 2013, p. 1443)

Rainwater runoff from city streets can include a myriad of harmful pollutants such as motor oil, paints, sewage, and pharmaceuticals (Prud'Homme, 2011, p. 43). The most concerning aspect of the water contamination resulting from irrigation and runoff is that trace amounts of the deadly chemicals will always exist in the water we use daily.

Climate Change

Climate change resulting from global warming is one of the most highly discussed and contested issues facing the planet earth. Regardless of which side one might take in this debate, scientific evidence has shown that earth's temperature is steadily rising. The EPA reports that in the U.S., temperatures have risen by an average of 0.14˚F per decade since 1901 (Climate Change Indicators in the United States, 2013). This trend is expected to continue with estimates showing an increase in temperature by as much as 11˚F by 2100. The rise in temperatures has adverse effects on the planets delicate ecology–all of which negatively impact the human way of life. Diane Raines Ward, author of *Water Wars: Drought, Flood, Folly and The Politics of Thirst*, quotes the German magazine *Der Spiegel* writing, "In human history . . . far smaller temperature shifts have doomed kingdoms, set off wars, forced peoples into exile, and created new religions" (2002, p. 22).

Earth's water supply is one of the most greatly impacted resources by climate change. Rising global temperatures will change where water is found due to increased evaporation rates. Alex Prud'Homme points out, "As a result, global warming will not change the amount of water in the world, but it will change the distribution of water, which will have many consequences" (2011, p. 129). Changing weather patterns resulting from rising temperatures have begun carrying the additional evaporated water to and away from regions that have had consistent weather patterns for many centuries.

The frequency of prolonged droughts will plague certain regions while deadly flooding will become more common in others. Recent drought conditions have greatly impacted the United States, with many regions considered to be "exceptional" in intensity according to the National Drought Mitigation Center (2013). The Mississippi river has reached historically low levels, threatening closures to major shipping channels. In South Texas, the lack of rain has scorched grasslands, forcing ranchers to burn the needles from native cactus in order to create additional food and water sources for their cattle. Additionally, cities like Denver, Austin, and Charlotte continue to see rapid population growth, further stressing the available water resources. All of these examples can be attributed to earth's water redistribution due to climate change. In the future, continued climate change will have immeasurable consequences on human life.

Conservation Programs and Practices

Water conservation programs and practices in the U.S. have made significant strides over the past 50 years. The Clean Water Act (CWA) of 1972 placed strict regulations on water used for industrial purposes in order to control water waste and pollution. The CWA opened the door for the Safe Drinking Water Act (SDWA), which was enacted to protect drinking water sources such as rivers, lakes, and underground aquifers. Additionally, the SDWA allowed the government to better monitor public water systems, ensuring quality, contaminant-free water is supplied to all Americans.

Apart from federally run programs focused on protecting water and its sources in the U.S., conservation practices on a municipal and individual level have become increasingly more common. Today, many utility/water providers across the country offer their customers monetary incentive programs aimed at conserving both water and electricity. Additionally, UPs have set more strict rules and penalties to counteract water waste during drought periods. These regulations commonly include limiting lawn irrigation to specific days and times.

Rebates for low-flow toilets, energy-efficient washing machines, and the use of reclaimed water from showers and sinks (greywater) are offered by UPs from coast to coast. New Braunfels Utility (NBU) located in New Braunfels, Texas offers its customers a rebate of up to $250 when residents purchase and install a rainwater harvesting system. The San Antonio Water Authority (SAWS), like UPs in many other southern cities, encourages water conservation by offering a rebate of up to $400 for replacing water-thirsty grasses with drought-tolerant landscaping.

Companies who provide water and electricity understand that conservation practices are critical to the sustainability of both quality resources and long-term revenue. *New York Times, Business Day* reporter Diane Cardwell points out, “While it seems counterintuitive for utilities to discourage use of their product, it actually makes financial sense as they face government mandates to encourage more energy conservation and deal with the rising cost and difficulty of building power plants and distribution systems” (2012). In light of this trend towards greater water conservation, more and more technologies have begun to emerge that make conservation practices at home easier for consumers.

Residential Water Costs and Billing

One dilemma surrounding the adoption of widely accepted residential conservation practices is that the financial burden of water use is somewhat minimal. It is estimated that the average American uses as much as 80-100 gallons of water per day at a cost of $1.50 per 1000 gallons (Water Science School, 2013). Based on these averages, a typical household in the U.S. will use 11,200 gallons of water per month, at a cost of $16.50. Therefore, it can be difficult for consumers to embrace a change in consumption habits when compared to their cable or cell phone bills; the cost of water is considerably less expensive.

Unless the dollar amount on a typical household’s monthly water bill is vastly different than anticipated, the consumer will generally assume that their usage is “normal”. This factor reinforces the issue that the cost of water is prohibitive to better conservation practices. “Water has generally been so cheap for so long, that people have become anchored to the past price, not realizing that sustainability costs money to achieve" (Walton, 2010).

Drying wells, refinement processes, and increasingly complex distribution systems have all resulted in increased water costs. In fact, some regions have turned to very costly methods such as desalination because of their lack of a freshwater. Desalination is a process used to create freshwater by removing salts and other minerals from brackish or seawater. Paul Alois, research analyst for *The Arlington Institute* claims, "Desalination is an expensive and energy intensive technology, and currently only wealthy countries with serious water shortages consider it a viable option" (2007). Programs and technology that promote water conservation practices are vital to keeping this essential resource readily available and equally affordable for everyone.

Hypothesis

At the current rate of daily consumption in the United States, it is becoming clear that Americans lack an overwhelming concern for freshwater resources. Overall, water consumers lack an adequate understanding of their daily consumption, or the consequences of their water management decisions. In Texas, the EPA claims, "If just 20 percent of households in Texas retrofit with water-efficient fixtures and appliances, they could save more than 50 billion gallons per year—enough to fill the new Dallas Cowboys stadium, the largest domed structure in the world, more than 60 times" (Texas Water Fact Sheet, p. 2).

The misunderstanding of water consumption on a residential level supports the dire need to create an increased awareness through water conservation education, practices, and technologies. The Water Watch app, designed for participants of this research study, is a tool that will provide an increased awareness of the daily water usage by utilizing five distinct components.

The first of these components used by the app is the participating households actual daily water consumption. This will be displayed numerically in the upper-right hand corner of the UI. The second component, set in the center of the UI, is a set of icons used to illustrate a real-world equivalent of the numeric water volume. For example, if the participants water consumption on a given day is between 1500 and 2000 gallons, the app will display a round bale of hay, a four-door hatchback automobile, or 2-commercial propane tanks.

The mood of the app makes up the third component. Participants are allocated an acceptable water consumption range based on their household size. If the water consumption for that day is at or below the acceptable range, the app is happy and the UI will appear green in color with a smiling face icon representing a happy mood. If the household has consumed more than their acceptable range, but less than an additional 100 gallons, the app is indifferent and will appear yellow in color with an indifferent looking face icon representing a neutral mood. When the participating household has consumed more than 100 gallons of water above their acceptable range, the app will appear red in color with a sad face icon representing an unhappy mood.

The fourth component of the Water Watch app, used to help increase comprehension of daily water consumption is the last 7-day total display. This feature will appear numerically in the lower-right hand corner of the app's UI. The last 7-day total is intended to provide participants with a snapshot of their consumption over a week's time. Finally, the fifth component of the Water Watch app is the acknowledge button. Once tapped, this feature is one of the most vital elements of the app because it verifies that the study participants have viewed all of the elements discussed above each day.

By drawing from the strengths of other known conservation methods and technologies like the UI of Nest learning thermostat and the UX of Opower billing, the Water Watch app will help change the way its users consume water at home. As a result, the researcher expects that Water Watch app users will consume less water in July, August, and September of 2013 than their 3-year average water consumption from the same months.

CHAPTER III

PRELIMINARY RESEARCH

Emotional Connections Between Humans and Technology

In the 21st century, human interactions with technology have become increasingly inevitable. Everyday, humans are required to interact with a computer, appliance, or a mobile device to complete daily tasks. This can include activities like banking, work-related tasks, learning, and even watching television. It is with this overwhelming reliance on technology that humans have begun to form a much closer bond with their electronic devices. Furthermore, new research has shown that people have gained such an attachment to their technology and devices that they have even begun to build somewhat of a relationship with it.

Reciprocity, or human-to-human exchanges and interactions, plays a major role in the way relationships are formed and maintained. For example, if person-1 helps person-2 move from one apartment to another, person-1 would expect person-2 to reciprocate their deed by receiving help from person-2 at some point in the future. Stanford professor Clifford I. Nass, Ph.D., took this exchange a step further by performing a study to test the limits of the rule of reciprocity between humans and technology. In the experiment, study participants were given the opportunity to ask a computer a series of questions. Nass says, “In the first experiment, the computer was very helpful. When you asked a question, it gave a great answer” (Spiegel, 2013). After completing the question and answer (Q&A) session, half of the study group remained at the same computer (PC-A) while the other half was moved to a different computer (PC-B). Both PC-A and PC-B then asked the human participants for help with improving its performance by requesting that they complete complex tasks that included a series of color matching exercises.

Researchers found that the study participants that were moved to PC-B were less willing to help that computer improve since they had no prior relationship with PC-B. This was proven by the fact that the participants that were moved to PC-B completed far less of the color matching exercises than those who stayed at PC-A. In subsequent testing, both PC-A and PC-B participated in a Q&A session with study participants. PC-A provided “great answers” while the PC-B was considered, “a computer terrible at answering questions” (Spiegel, 2013). Once again, the participants were less willing to help PC-B improve itself because of its “terrible” answers, and therefore did not reciprocate.

Dr. Nass’ experiment shows that people tend to interact with machines and technologies using human social behaviors, even if they fail to realize it. “Change the way a machine looks or behaves, tweak it’s level of intelligence, and you can manipulate the way humans interact with it” (Spiegel, 2013). This theory of human-technology reciprocity supports the idea that people can, in fact, form an emotional bond with their technology and therefore will show concern for the needs of a machine. Of course, building this human-technology relationship is dependent upon the effectiveness of the UI and UX of the device they are interacting with.

User Interface and User Experience

UI/UX are vital interaction components impacting everything from consumer electronics such as washing machines and televisions to computers and smartphone applications. It is these two components that allow users to achieve a desired result from an appliance, smartphone, or mobile app. For example, when a person wants their coffee brewed before their morning alarm, they program the coffee maker to do so using digital interface, or UI. If operating the UI was intuitive and made programming easy, then they will have hot coffee awaiting them in the morning. The result is a satisfying and memorable UX.

UI

The UI of a digital or mobile application can best be thought of as the way the app looks and feels. In other words, the UI is the environment in which the buttons, levers, switches, inputs, and displays allowing users to interact with the app reside. By definition, UI is, "the aspects of a computer system or program which can be seen (or heard or otherwise perceived) by the human user, and the commands and mechanisms the user uses to control its operation and input data" (user interface, n.d.). The user's perception of the UI is the critical first step in creating a memorable interactive experience within an app.

It is imperative that the UI is intuitive and comfortable for users. This requires a UI design to present information in a well-organized manner while feeling somewhat familiar to the user. In other words, "Their perception of the display is based more on what their past experience leads them to expect than on what is actually on the screen" (Johnson, 2010, p. 4). In addition, the study of the relationships between signs and symbols to natural languages (Semiotics) plays an important role in the ability of the UI to appear familiar/recognizable to users.

What appears to be a very minimalist UI, the app "Forecast" (see Figure 3) is designed to provide powerful weather forecasting results.

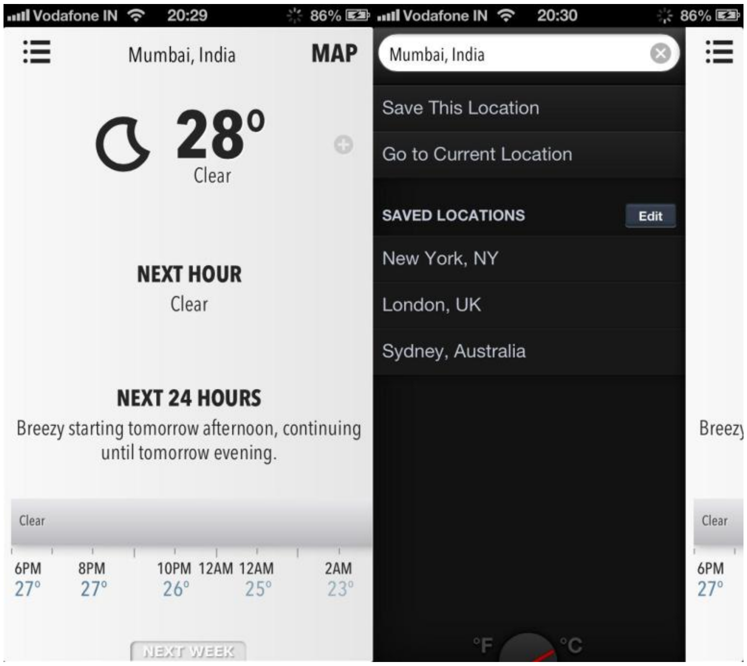


Figure 3. Screen Shot of *Forecast* Mobile App by The Dark Sky Company, LLC. (*Beautiful Pixels*, 2013).

The UI design of *Forecast* uses simplified, yet commonly recognizable, symbols to portray current weather conditions, alongside a straightforward presentation of weather data. All this while ultimately improving the UX by minimizing the number of button taps a user needs to gain additional weather information. This UI execution supports Human Factors teacher, Konrad Baumann's point that, "the interface should be equally suited for experienced and inexperienced users" (2001, p. 7).

Apple®, Inc. calls the UI of their mobile devices the "Human Interface (HI)." Apple urges designers/developers to consider the principles of their HI when creating new apps. In their iOS Human Interface Guidelines, Apple states:

> A great user interface follows human interface design principles that are based on the way people—users—think and work, not on the capabilities of the device. A user interface that is unattractive, convoluted, or illogical can make even a great

> application seem like a chore to use. But a beautiful, intuitive, compelling user interface enhances an application's functionality and inspires a positive emotional attachment in users. (2011, p. 8)

These HI principles have been successfully integrated into Apple's mobile devices since their first iPod shipped in 2001. In fact, in order for newly developed apps to be accepted and distributed by their Application Store (App store), Apple reviews each to ensure that it maintains the standards of quality and usability defined by the *iOS Human Interface Guidelines*. Today, the almost one million apps available in the Apple App Store have been downloaded over fifty billion times.

UX

The primary function of the UX is to establish how viewers consume and retain the information provided by the app. Yet, an app's UI and UX must work in concert to create both a fulfilling and lasting experience for its users. Though a UI may be designed masterfully, the key message/goal of an app can be threatened by an inefficient or disengaging UX.

In *UX Book: Process and Guidelines for Ensuring a Quality User Experience*, Rex Hartson states:

> User experience is the totality of the effect or effects felt by a user as a result of interaction with, and the usage context of, a system, device, or product, including the influence of usability, usefulness, and emotional impact during interaction, and savoring the memory after interaction. (2012, p. 5)

Hartson points out that UX is responsible for how the interactions make the user feel about the information presented in the app. He goes on to say that, "'Interaction with' is broad and embraces seeing, touching, and thinking about the system or product, including admiring it and its presentation before any physical interaction" (2012, p. 5).

Like the Q&A sessions in Dr. Nass' experiments, an exceptional UX has a reciprocating relationship with its users. In an article for *Smashing Magazine*, web designer Paul Boag writes, "A happy user is considerably more likely to recommend your services and is more patient when things occasionally go wrong. Enthusiastic users can also become valuable volunteers; they have innumerable ideas about how your website and products can be improved" (2011). The goal of the UX should be to recruit the happy and enthusiastic users that Boag points to because of the willingness of those users to reciprocate with the app.

The Water Watch app in this thesis research must embody the principles of compelling UI and UX in order to accomplish a human-technology relationship. Without an emotional connection between the app's water consumption data and the user, it is unlikely that a voluntarily adoption or promotion of water conservation practices will take place.

Visual Cues and Symbol/Icon Recognition

Human beings have relied on symbols for thousands of centuries. Ancient civilizations utilized symbols as representations of directions, landmarks, warnings, or even as simplified representations of their life experiences. Psychologist Harold Gardner writes, "Because humans isolate events and draw inferences about them, we have developed linguistic and pictorial symbols that can handily capture the meanings of events" (1999, p. 38). Not unlike past civilizations, humans today rely on symbols for much of the same reasons, many of which are essential to human existence.

The form and interpretation of symbols can vary based on cultural and social differences. Yet, what links symbols across cultures is that they are used to provide humans with visual cues to remind them of actions or experiences that they have or will encounter. According to Gardner, humans have become quite adept to this, stating, “the human brain seems to have evolved to process certain kinds of symbols efficiently” (1999, p. 38). Based on Gardner’s assessment, utilizing symbols and icons is relevant when examining, and perhaps even altering human behavioral habits.

One of the most easily comprehended symbols in the U.S. is the stop sign. In a given day, humans repeatedly encounter the red octagon with the word “STOP” posted on it. Though a very simple example of a symbol, what makes the stop sign unique is how its make-up has transformed how humans interpret it’s visual cues. The scientific analysis of this human perception is known as the Sequence of Cognition. In this sequence, the human brain first recognizes and acknowledges visual communications before it decodes the meanings of words or phrases (Wheeler, 2013, p. 52). Because of the abundance of stops signs people see daily, its shape, color, and meaning are ingrained in the human brain. Even with word “STOP” absent from the sign, the red octagon is still be capable of making drivers understand its meaning. Furthermore, since the color red is often associated with a warning or danger, the typographical element of a stop sign is almost unnecessary in order for it to achieve its intended message.

Due to the human brain’s ability to recognize symbols, the combined shape and color of the stop sign can communicate a similar message in applications other than driving. The same logic can be applied to the green, yellow, and red colors of a traffic light. Though these visual cues contain no identifiable icon, the symbolism of light’s color transcends their traffic control application. “Many experiments have shown, however, that the color experiences we have are the result of the total situation in which they are obtained” (Kuehni, 2012, p. 51). Therefore the experiences gained from the colors used in something like a traffic light have the ability to invoke the same human reactions when used in a different medium. Green has a positive connotation and indicates to viewers that they can safely proceed, while yellow is neutral and hints at the possibility of approaching danger.

Icons

Icons can be considered a subset of symbols, as they are more category-specific representations of objects. Much of their interpretation depends on how universally recognized the symbol or icon is across cultures. For example, the cross is a “symbol” known throughout the world as a representation of Christianity, whereas an “icon” depicting a telephone may be specific to only modernized cultures. One definition identifies icons as, “a sign or representation that stands for its object by virtue of a resemblance or analogy to it” (icon, n.d.). Icons, like symbols have the ability to condense powerful messages into minimal visual cues.

Of key importance to an icon in a UI is its systematic relationship to what it is representing. The trash can icon on a computer represents the disposing of something, which in this is example is files. In his book *Visual Intelligence,* Donald Hoffman writes:

> The trash can icon is systematically related to that of erasing software, but the relation is arbitrary: the trash can icon doesn’t resemble the erasing software in any way. It could be any color or shape you wish and still successfully do the job of letting you interact with the erasing software. It could be a pig or toilette icon

> instead of a trash can icon. All that matters is the systematic connection. (1998, p. 193)

Hoffman shows that the stylistic elements of icons are often of less importance than the systematic relationship they create. In other words, in the appropriate context, an icon portraying an elephant does not have to be full-size, or gray in color in order for a person to understand that it represents an elephant, a large animal, or something of substantial size.

Energy Consumption Resulting from In-Home Technology

When examining methods of altering water consumption habits, it is important to understand how homes use other resources like electricity. Households today are inundated with technology in the form of appliances, computers, and mobile devices; each designed to provide automation and convenience. In the U.S., people often minimize the technological aspect of conveniences like air conditioners, refrigerators, and washing machines because they are seen as common requirements in a home. But, as Ed Sobey writes, “technology isn’t all connected to your computer. It’s in every widget and gizmo that you use” (2007, p. 8). One aspect, universal to all of these in-home technologies, is that they all consume energy. This commonality is of great importance when attempting to examine how people interact with these technologies each day, as it is directly connected to a homeowner’s monthly energy expense.

Household energy consumption habits are most often impacted by the level of concern a homeowner has for saving money. Therefore it is no coincidence that a 2006 nationwide survey conducted by the Pew Research Center found that 77% of Americans considered themselves to be always looking for opportunities to save money (2007).

Programs like the Energy Star Certification promote savings by ensuring that appliances and consumer electronics are manufactured to operate at minimum energy consumption and operating costs.

The U.S. Department of Energy estimates the average annual energy costs of a typical American home to be over $2000.00 (see Figure 4).

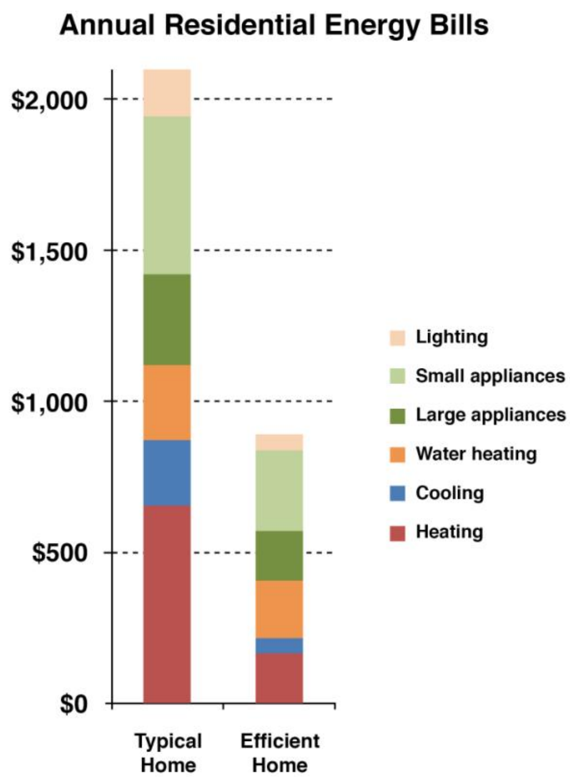


Figure 4. Annual Residential Energy Bills. (*Home Energy Saver*, n.d.)

Residential heating and cooling is shown to be the greatest contributor to home energy costs. Though a thermostat controls the a/c operations, this household device's daily operation and energy consumption is most impacted by human factored interactions. In a study examining these habits and behavior, researchers concluded that, "Family size and composition, besides presence or absence at home, had a direct effect on behaviour and energy consumption" (Guerra, 2010, p. 125). The question of what motivates a change in technology usage habits and energy consumption at home seems clear: Monetary savings is of much greater value to the average American than conserving the resources required to supply their homes with energy (i.e., oil, gas, water).

CHAPTER IV

METHODS

The quantitative study performed for the purpose of this thesis research will attempt to discover if visual cues and UX are capable of altering a household's daily water consumption behaviors. Participants of a 3-month study will be provided an iPod Touch with a preinstalled version of the Water Watch app, designed exclusively for this research. The focus of the app's UI and UX will be to aid study participants in making informed, more conservation minded decisions about their home water usage.

Explanation and Validity of Exploratory Research

The research study and data collection conducted for this thesis project will be exploratory in nature. This data gathering method is often used when there is a need to gain qualitative data from a relatively small sample size. Business and Law Professor Martyn Denscombe explains, "An exploratory sample is used as a way of probing relatively unexplored topics and as a route to the discovery of new ideas or theories" (2010, p. 24). Denscombe goes on to write, "The point of the sample is to provide the researcher with a means for generating insights and information" (2010, p. 24). The insights and information Denscombe points to provide researchers with the ability to determine the validity of conducting further full-scale scientific studies.

The primary goal of exploratory research is to help expose flaws in study methods, while collecting valuable observations and feedback. Most often, exploratory research is used initially to clarify and define the problem rather than to provide conclusive evidence. (Hyman, 2010, p. 39). Though the results of the exploratory method cannot be considered definitive, they are extremely valuable in creating a foundation for the ongoing research of this thesis project.

Pre-Study Executions and Logistics

In order to conduct this research study, there are a number of logistical matters that must be addressed prior to its commencement. This includes items such as the purchase of five iPod Touch devices, the preparation of applicable legal consent forms for study participants, establishment of criteria for study eligibility, and creation of methods for water volume data collection and distribution during the study period.

Study Consent

Since all participant households will be water customers of New Braunfels Utilities (NBU), written legal consent is required from each. The NBU legal department will assist in drafting a consent form granting the utility provider permission to release participant account information for the purposes of this research. Each participating NBU account holder will be required to sign this document before they are authorized to take part in this study. The specific account information of each participant released by NBU to this research will include:

- Monthly water consumption volumes for the years 2010, 2011, and 2012;
- Daily water consumption volumes for the study period of July, August, and September 2013;
- Monthly water consumption volumes for 6-months following the completion of the study period.

Study Population Criteria

Each of the five participating households will be selected based on their ability to meet four requirements. First, they must have received water services from NBU for a minimum of 3-years prior to the study period. Second, their homes must have smart water meters installed. Third, each household will be required to have a wireless internet connection for the duration of the study period. Finally, they must agree to the terms and conditions of the consent form as defined by NBU. In addition to the consent form, participants will be provided with a document explaining the guidelines of thesis data gathering under Texas State University policy. This will include information regarding the non-disclosure of participant's personal information and/or likeness in the final published research.

When selecting households for this research study, it will be important to identify potential candidates that have little or no prior relationship with the researcher. This is critical because it will help prevent participants from altering their water consumption habits during the study period based on assumptions they may have about a preferred outcome of this research. In other words, participating households may believe that the expected outcome of this study is to demonstrate a reduction in water consumption based on prior interactions or conversations with the researcher. As a result, they may be inclined to involuntarily change their water usage habits during the study in order to help provide this research with results that they believe to be considered as favorable.

Data Collection, Distribution, and Acknowledgment

Water volume data for each participating home will be received via email from NBU each night at 8:30pm in spreadsheet format. This efficient data delivery method is made possible by the capabilities of the smart water meters installed at each home. Without the wireless connectivity of the smart water meters, data collection for this study would require physically reading meters at participating homes each day.

Once the spreadsheet containing the daily water consumption for each household is received, the data will be input into a web-based interface (see Figure 5).

Figure 5. Screen Shot of Water Volume Input Interface.

Upon submission, the web interface will post each participant's water consumption volume to a database used to distribute the data to each of the participants Water Watch app. The app will then display household specific numeric and visual water volume data based on the calculations made by the database.

Though Water Watch will be designed as a singular application, it will be programmed to display only the water volume of the household in which it is located. None of the study participants will be permitted to view or acknowledge the water volume data for any household other than their own during the study.

Post-Study Survey

Following the completion of the research study period, participants will be asked to provide answers to a follow-up survey. The goal of this survey will be to quantify the reactions and perceptions of participants during the study. This will include questions such as:

- Which of the app's visual elements impacted water consumption decisions the most?
- What is the level of concern for water conservation before and after participation in the study?
- Did participation in this study impact future water consumption decisions?

Though fluctuations in household water consumption during the study should provide some telling results, a post-study questionnaire will be necessary to gauge the overall emotional impact of the Water Watch app on the participants.

Baseline for Data Analysis

In order to evaluate the impact of the Water Watch app on the water consumption of the participating households, baseline consumption volumes must be established. Calculating the 3-year average water consumption during the months of July, August, and September in each participating home will achieve this. With average historical water consumption values set for each household, this research will have a month-by-month baseline volume with which to compare the study results to.

Current and historical factors such as rainfall totals, and watering restrictions will be evaluated as well. All of these conditions will be considered before any assumptions will be made from the results of the research study.

Water Watch App Design

The primary function of the Water Watch app will be to communicate a household's daily water consumption in a way that allows its users to gain a greater understanding of their actual volumes. The app will provide users with relatable visual cues in an effort to guide them towards making their own decisions about how they consume water at home.

The UI of the Water Watch app must be designed to accommodate each of the five daily water volume display elements (daily water consumption volume, volume equivalent icon, mood of the app, and last 7-days total volume), in a visually compelling and engaging manner. This will require that appropriate spacing and visual hierarchy be established for each element. Since the app will be designed to operate on the 4th generation iPod Touch platform, all UI elements must be adapted to fit appropriately within the 3.5-inch diagonal screen size (see Figure 6).

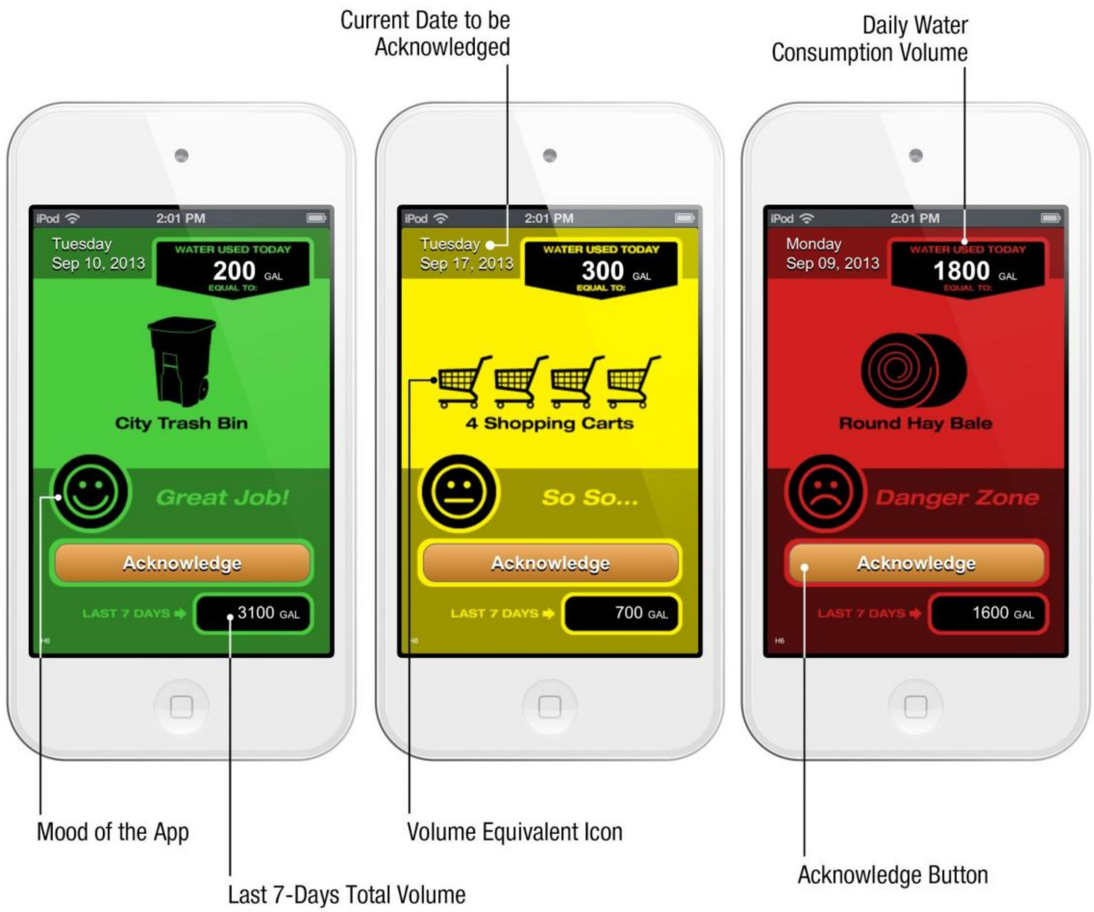


Figure 6. Water Watch UI Displayed on the 4th Generation iPod Touch.

Additionally, the Water Watch app will require both a home screen icon and a start-up screen in order to launch and operate properly once installed on the iPod Touch (see Figure 7).

Figure 7. Water Watch Icon and Launch Screen on iPod Touch.

Daily Water Consumption Volume

The daily water volume will be displayed in the upper-right corner of the app each day (see Figure 6). Because of the systems NBU currently has in place, some of the smart water meters display a home's water consumption where an increase of one metered unit equals 100 gallons. While in another home, one metered unit can equal 10 gallons. Each participating home's total daily water consumption value will be determined by a database calculation of the current days water meter read subtracted from the previous day, and then multiplied by 10 or 100 (depending on the participants meter type). For example, the current day's water usage report for a single home may show a meter reading value of 1398; while the previous day read was 1390. Once the current and previous days values are subtracted and multiplied by 100, the Water Watch app will display the current days water consumption value as 800 gallons (e.g., [1398 - 1390] x 100 = 800).

Volume Equivalent Icon

The volume equivalent icon displayed in the Water Watch app will consume the largest portion of the apps UI (see Figure 6). The intent of this iconography will be to portray relatable visual references that are volumetrically equivalent to a given households daily water usage. People may lack the ability to quickly equate their water consumption volume to something familiar. In other words, people have an inadequate visual frame of reference that would allow them to make a judgment about whether or not they consider the amount of water they consumed to be a lot or a little. By displaying more relevant, real life objects, these icons will provide participants with a visual reference to help communicate water consumption.

There will be up to three icons per predetermined volumetric range. Based on the household's daily water consumption volume, Water Watch will randomly display one of the three available icons from the appropriate volumetric range (see Table 1).

Table 1. Equivalent Iconography by Water Volume Range

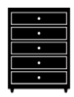
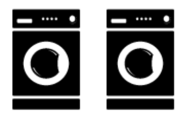
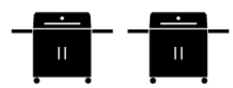
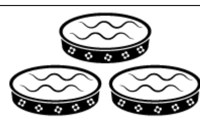
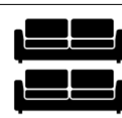
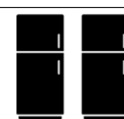
Water Consumption Ranges (Gallons)	**Image 1**	**Image 2**	**Image 3**
0-100	 4 Kitchen Sinks	 Fish Tank	 2 Water Heaters
101-200	 5 Drawer Dresser	 City Trash Bin	 Hot Tub
201-300	 2 Bathtubs	 4 Shopping Carts	 2 Washing Machines
301-400	 King-size Bed	 Jon Boat	 Refrigerator
401-500	 Truck Bed	 2 Recliner Chairs	 2 Gas Grills
501-600	 3 Kiddie Pools	 2 Couches	 2 Hot Tubs
601-700	 5 City Trash Bins	 2 King-size Beds	 2 Refrigerators

Table 1. Equivalent Iconography by Water Volume Range–Continued

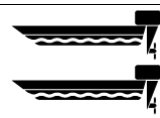
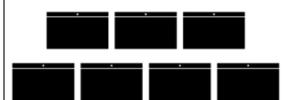
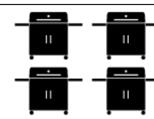
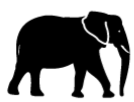
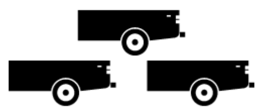
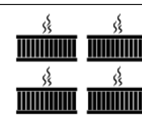
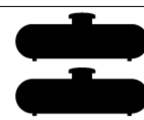
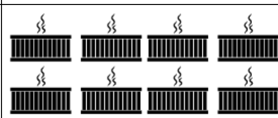
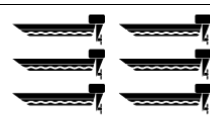
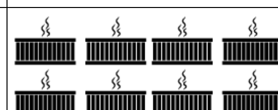
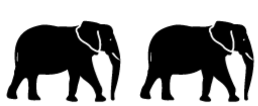
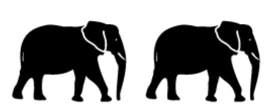
Water Consumption Ranges (Gallons)	**Image 1**	**Image 2**	**Image 3**
701-800	 2 Jon Boats	 7 Bathtubs	 8 River Tubes
801-900	 5 Kiddie Pools	 6 Washing Machines	 7 Deep Freezers
901-1000	 Commercial Propane Tank	 3 Garden Tractors	 4 Gas Grills
1001-1500	 Elephant	 3 Truck Beds	 4 Hot Tubs
1501-2000	 Round Hay Bale	 4-Door Hatchback	 2 Commercial Propane Tank
2001-2500	 8 Hot Tubs	 6 Jon Boats	 8 Hot Tubs
2501-3000	 2 Elephants	 8 King-size Beds	 2 Elephants

Table 1. Equivalent Iconography by Water Volume Range–Continued

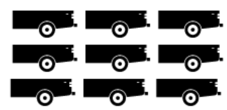
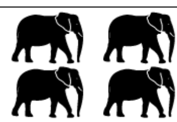
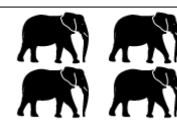
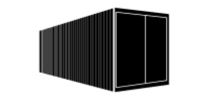
Water Consumption Ranges (Gallons)	**Image 1**	**Image 2**	**Image 3**
3001-3500	 Sport Utility Vehicle	 Storage Shed	 Sport Utility Vehicle
3501-4000	 4 Door Hatchback	 2 Round Hay Bales	 4 Door Hatchback
4001-4500	 Killer Whale	 9 Truck Beds	 Killer Whale
4501-5000	 Cargo Van	 5 Commercial Propane Tanks	 Cargo Van
5001-6000	 4 Elephants	 Statue of Liberty's Tablet	 4 Elephants
6001-7000	 2 Storage Sheds	 2 Sport Utility Vehicles	 2 Storage Sheds
7001-8000	 School Bus	 2 Killer Whales	 School Bus

Table 1. Equivalent Iconography by Water Volume Range–Continued

Water Consumption Ranges (Gallons)	**Image 1**	**Image 2**	**Image 3**
8001-9000			
9001-10000			
10001-222222			

Mood of the App

As evidenced by the energy savings resulting from Opower billing and the outcomes of Dr. Nass' human/technology reciprocity testing, the mood of the device will play a key factor in the effectiveness of the Water Watch app. The app's mood will be based on a predetermined range of acceptable water volumes depending on household size. The EPA estimates that the average American household uses over 300 gallons of water per day, with an average family size of almost three people (Water Use Today, 2013). With these estimates in mind, each participating household will be allotted 100 gallons per person, per day. This total volume will represent the maximum amount of water that a home can consume in order to make the Water Watch app appear green in color and in a happy mood (see Table 2).

Table 2. Allotted Water Volume and Mood of the App Based on Household Size. Shown in Gallons Per Day (GPD)

Household Size (# of people)	Happy/Green	Neutral/Yellow	Unhappy/Red
1-2	≤200	≤300	>300
3-4	≤400	≤500	>500
5-6	≤600	≤700	>700
6-7	≤800	≤900	>900

Last 7-Days Total Volume

The last 7-days total volume will be calculated by the database as a weekly running total of the water consumed by each participating household. This value will have no impact on either the mood of the app or the volume equivalent icon. Once app users have begun to better comprehend the volume of their daily water consumption, the last 7-days total will help them to understand its impact over the course of a full week.

Acknowledge Button

Since it is imperative to the outcomes of this research study to verify that the information displayed on the app has been viewed each day, the app will require an acknowledgment from its users in the form of a single button tap. Once tapped, a record will be sent to the database confirming that an acknowledgement from the user has occurred. The app will be designed to display only the most current, unacknowledged day's water consumption information, thereby requiring participants to acknowledge each days usage before the next day can be viewed.

CHAPTER V

RESULTS

This research study was conducted from July 1, 2013 to September 30, 2013 in New Braunfels, Texas. Based on the study requirements, five households were identified by the researcher and New Braunfels Utilities as authorized participants. Each household was given an iPod Touch with the Water Watch app preinstalled on the device. After the iPod was connected to their home's wireless network, participants were given instructions on how the device and app would be used throughout the study.

Participants were told that between 8:30 pm and 9:30 pm each night, the Water Watch app installed on their iPod Touch would display their household's total water consumption for that day. They were then asked to review the information presented on the Water Watch UI and tap a single button, acknowledging that they had done so (see Figure 6). This process only required one to two minutes of the participants time each day.

Additionally, each participant was given a brief tutorial on the operation of the iPod Touch. This included instructions on charging the device as well as launching the Water Watch app should the app be closed or the iPod be turned off. Participants were given contact information for the researcher in the event that they experienced any issues during the study period. Furthermore, as a show of appreciation for their involvement in this study, participants were told that they would be allowed to keep the iPod Touch for personal use after completing the study.

Study Demographics and Water Consumption Allotments

Each participating household was assigned a unique app ID number. This number was used for app/database coding and data tracking, as well to provide anonymity among the study participants. The adults in the five participating households ranged in age from twenty to seventy years of age. Three of the five households had children living at home, making the number of individuals consuming water for observation by this study a total of sixteen (see Table 3).

Table 3. Study Participant Demographics

Household (App ID)	**Adult Occupants**	**Age Range**	**Additional Occupants**	**Age Range**
H-1	2	30-40	2	0-10
H-2	2	60-70	0	n/a
H-3	2	20-30	0	n/a
H-4	2	40-50	2	10-20
H-5	2	50-60	2	10-20

Daily water consumption allowances were established for each home based on the number of occupants. As previously stated, the purpose of these allowances was to set baseline water volume ranges used in determining the mood of the Water Watch app (see Table 4). For example, if in a given day, H-1 consumed more than 400 gallons water, but less than 500 gallons, their app would appear yellow in color with a neutral mood.

Table 4. Allotted Gallons Per Day (GPD) Based on Actual Participants Household Size

Household (App ID)	Happy/Green	Neutral/Yellow	Unhappy/Red
H-1	≤400	≤500	>500
H-2	≤200	≤300	>300
H-3	≤200	≤300	>300
H-4	≤400	≤500	>500
H-5	≤400	≤500	>500

Study Period Water Consumption Versus Historical Water Consumption

The results of this research study were determined by comparing the participating household's average historical water consumption (see Table 5) to their water consumption volume from the study period (see Table 6). Historical averages were calculated using the water consumption from July, August, and September of 2010, 2011, and 2012 in each household.

Table 5. Average July-September, 2010-2012 Water Consumption in Gallons Per Month (GPM)

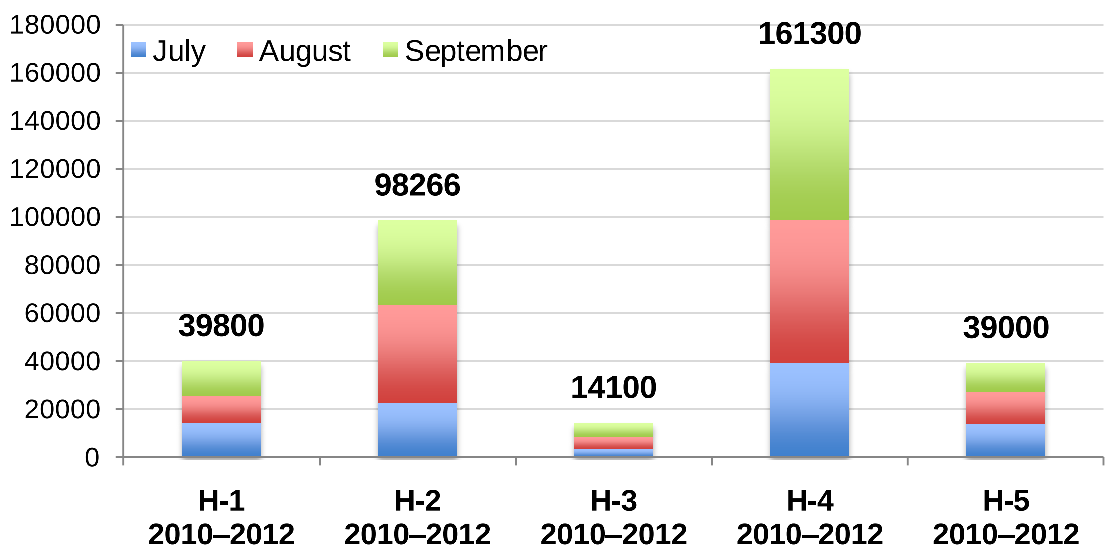
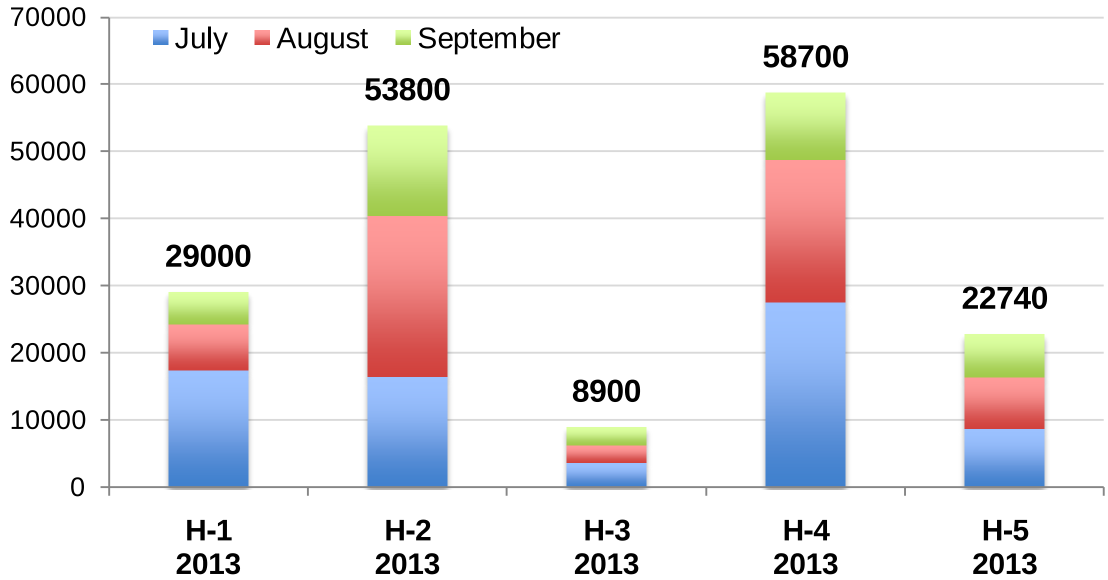


Table 6. Actual Water Consumption in GPM During Study Period (July-September, 2013)

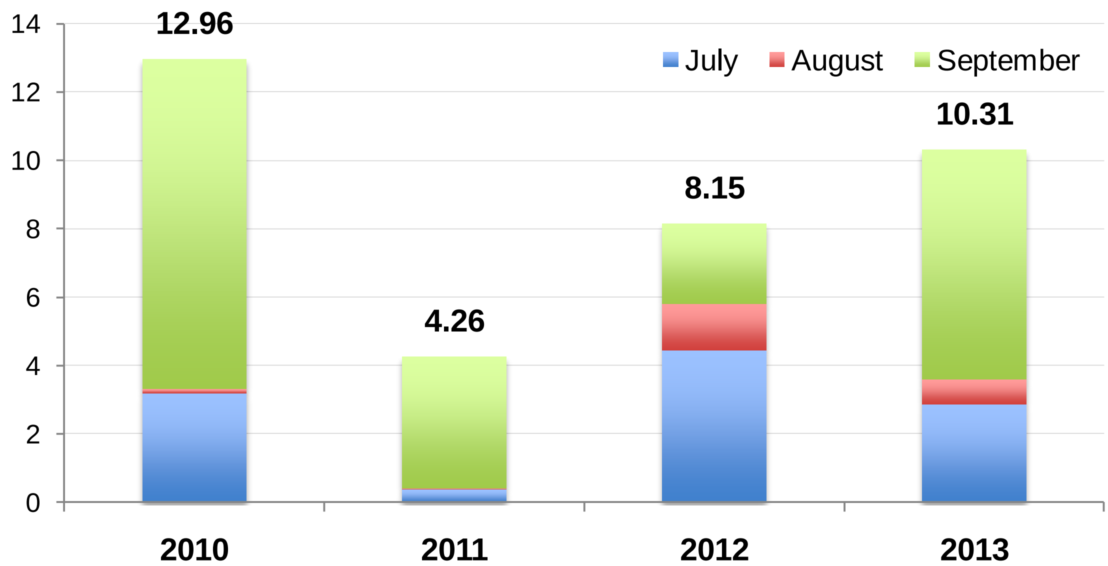


The data indicates that study participants reduced their 3-month water consumption by an average total of 43% during the research period (see Appendix A and B). Study data revealed that over time, participants conserved greater amounts of water while using the Water Watch app. In the first month, participants reported an average total decrease in water consumption of 12%, but by the third month, that total improved to 62%. In a longer study duration utilizing the Water Watch app, the water consumption volume would begin to plateau, rather than continually decrease month-over-month. Though compelling, these results cannot be substantiated until the mitigating factors of the study period are examined.

Mitigating Factors

Certain mitigating circumstances must be considered when conducting a quantitative study of this nature. In this study specifically, rainfall totals and the resulting water use restrictions are the two factors most effecting each households water consumption. It is critical to compare the rainfall totals from July, August, and September of the 3-years prior to this study, to the rainfall totals during the research period (see Table 7). Since irrigation makes up the largest portion of most households water consumption, comparing rainfall and restriction data will help validate the research findings.

Table 7. Monthly Rainfall Totals in Inches



In order to conserve water for indoor use, the water restriction stages enforced by NBU are used primarily to limit irrigation. Enactment of these restrictions is driven by the amount of available freshwater in the lakes and aquifers that supply NBU customers. Stage I limits watering with irrigation systems to two-days per week, while Stage II reduces irrigation to one-day per week. Stage III restrictions mandate that homeowners only water their lawns with irrigation systems one-day every two weeks. Participants in this study were subject to the constraints of Stage II until mid-August. Due to sustained drought conditions and rapidly decreasing supplies, NBU then increased water restrictions to Stage III. Table 8 illustrates water restrictions by month for both the study period and the 3 years prior.

Table 8. Water Restriction Stages by Month

	2010	2011	2012	2013
July	N/A	Stage II	Stage II	Stage II
August	N/A	Stage II	Stage III as of 8/10/2012	Stage III as of 8/19/2012
September	N/A	Stage II	Stage II as of 9/24/12	Stage III

Analysis of Study Findings

By analyzing the data and mitigating factors impacting the water consumption of the participants in this study, the true effectiveness of the Water Watch app begins to emerge. In the first month of the study, three of the participating households showed a reduction in water consumption over their 3-year average, while the other two homes actually increased their July consumption by as much as 22%. In subsequent study months though, all participants showed a decrease in their overall water use.

By comparison, the mitigating factors of July, August, and September of 2012, are very similar to those of the study period (see Table 7 and 8). Yet, all five households consumed an average of 39% less water while using the Water Watch app than they did in 2012 (see Appendix A and B). It can be stated that the threat of penalties from water restriction violations is a major factor in convincing people to consume less water. Despite that, the participants in this study consumed considerably less water than they did during water restriction stages of previous years.

In-Study Observations

A few observations made during the study period were important to note in this research. The most surprising of these focused on the acknowledgement of the data presented in the Water Watch app each day. Since the study was introducing people to a new habit of checking and acknowledging their daily water consumption, the researcher anticipated that there would be a need to provide frequent reminders to gain full compliance. Though, that was not the case. Study participants acknowledged their water consumption data daily, without requiring any intervention or reminder throughout the study period. This occurrence indicated that either the study participants were able to easily adopt new habits, or that they had a genuine interest in the Water Watch app UI and its water consumption data.

The Water Watch app appeared to indicate a rise in water consumption awareness by the participants. One example that provided evidence for this was an email received on August 18, from participant H-2. H-2 shared concerns about the amount of water the Water Watch app was reporting by stating:

> Unbelievable we have a water leak. I am sure you noticed that we had been running 1000, 500, 500, and we were only watering by hand 30 minutes. This morning we turned everything in the house off and the water meter was still going slowly. At 8:00 we will call a Plumber to fix our leak. Your little program may have saved us a lot of money. Thank you. (Study Participant H-2, personal communication, August 22, 2013)

This communication was very encouraging, as it reinforced the value of more real time water consumption data. Because of the observation made by H-2, they were able to quickly identify that they had a water leak. This alertness not only saved them money on their water bill, but it also prevented thousands of gallons of water from being wasted.

Follow-Up Survey Results

At the conclusion of the research period, each participating household completed a nineteen question follow-up survey. The survey asked questions ranging from, which aspect of the Water Watch UI did they consider most effective, to, where did they rate the importance of water conservation before and after participating in this study (see Appendix C)? While many of the answers were somewhat consistent among the five participants, the survey provided a snapshot of how each household reacted to the information provided by the Water Watch app.

Water Consumption Perceptions

Capturing how each household perceived their water consumption before and after participating in this study was an important element of the survey. The participants were asked what they believed the average daily water consumption of homes in their area to be. Over half responded by selecting 400 to 700 gallons per day (see Appendix C). This is a significant finding because it begins to shed light on what the participating households might consider a "normal" daily water consumption amount. NBU claims that on average, their accounts use 365 gallons per day. With that in mind, four of the five participants believed that the water consumed by their household was at or below average when compared to other homes in their area. Three homes, did in fact, consume less than the NBU average by 56, 123, and 270 gallons per day during the study period (see Appendix A).

It should be noted that sixty-percent of participants believed that they used less water during the research period than their 3-year historical averages. Yet, when asked if they altered the amount of water they used following a higher than expected daily Water Watch app reading, four out of five participants responded "not really."

Water Watch App UI Elements

One primary goal of this survey was to attempt to identify which of the Water Watch apps four visual elements (daily water consumption volume, volume equivalent icon, mood of the app, last 7 days value) had the greatest impact on the participants' water usage. From the survey responses, that identification remains unclear with two of the participants noting that the daily water consumption volume was most helpful in understanding their water use. Two others claimed that the volume equivalent icon helped them the most, while the fifth benefited most from the mood of the app. However, when asked if the volume equivalent icon gave them a greater understanding of the amount of water they used daily, four of the five participants responded "yes". Consequently, none of the participants were able to recall the largest volume equivalent icon that appeared on their app during the study period.

Emotional Connection

With regards to the emotional connection between the Water Watch app and its users, the survey provided interesting results. When asked how they felt about viewing and acknowledging their household's daily water consumption, two participants responded that they did not have strong feelings about it, while three responded that they looked forward to it. In contrast, when asked how they felt if on a given day, their actual water consumption was higher than what they anticipated it to be, most participants answered either that they were "concerned" or "irritated." Almost all of the participants indicated that if technology similar to the Water Watch app were available through their utility provider, most would utilize it on a weekly basis.

Overall Reactions

All of the households responded positively to the survey question regarding their overall reactions to participation in this study. H-2 and H-4 noted that they gained a greater understanding of the amount of water used by items at their homes like sprinkler systems and clothes washers. H-1 stated, “I liked it. I think it’s a good idea to educate people on water and just how important it is” (see Appendix C).

CHAPTER VI

CONCLUSION

After considering human-technology interactions as well as the mitigating factors impacting water use during the research period, this thesis research demonstrates that visual communication and UX can help reduce residential water consumption. This research supports the importance of making water consumption information more readily available to residential water consumers. Furthermore, the combination of more real-time data, relatable visual cues, and a willingness to reciprocate with technology create a greater influence on human water consumption habits than simple monthly paper billing.

In an age that has seen mobile and digital technology become so integrated into the daily human experience, it is logical to leverage the human-technology relationship for conserving a resource as essential as water. People are often more concerned about the remaining battery life of their mobile phone than they are of the remaining amount of drinkable water available to sustain their own lives. In his novel, *The Picture of Dorian Gray,* Oscar Wilde wrote, “Nowadays people know the price of everything, and the value of nothing” (Murray, Wilde, 2000). His statement is particularly true with regard to the earth’s freshwater supply. Like other natural resources, people have taken the convenience and low-cost of freshwater for granted for too long. With factors like rapid population growth, water waste/contamination, and climate change, it is more crucial than ever that water conservation practices become much more common.

Further Research

Though the outcomes of this research were positive, further development of the Water Watch app can improve its effectiveness in helping reduce residential water consumption. Due to the limitations of the exploratory research method, the findings of this research study cannot be considered definitive. Because of this, a study with a sampling size of 50-100 participants should occur to scientifically validate its results.

One key consideration in future developments of the Water Watch app is its ability to learn and adapt based on a household's water consumption. Like the technology available in the Nest thermostat, the app can help conserve more water by providing individualized feedback based on the learned water usage habits of the home. In order to accomplish this, the Water Watch app would require more home-specific data. This could include property size, user ages, and an ability to monitor the individual sources that draw water in the home (i.e. faucets, dishwashers, etc.). User age is an important factor for future iterations of the Water Watch app to consider. This user aspect will allow the app to tailor its feedback more effectively. For example, children can perhaps learn and respond to the information provided by the app if the UI is presented more like a game or animation. Conversely, adults may prefer the water consumption feedback to be displayed as practical water saving tips with more information and links to additional resources.

Further exploration of the smart water meter's data transfer capabilities will provide a number of new possibilities for the Water Watch app. Similar to Opower's billing statements, app users could begin to compare their water consumption to that of their neighbors, even on a more real-time basis. In addition to the app, the data provided by the smart water meters could be displayed on a variety of internet-connected interfaces. These systems would allow for real-time management of household water consumption, even when users are away from the home.

The survey question regarding which of the Water Watch apps elements affected the participant's water consumption the most proved to be inconclusive. To identify if the daily water consumption volume, volume equivalent icon, mood of the app, last 7-day value, or the daily acknowledgement had the greatest impact, further testing is required. In future studies, each app element would be tested independently in order to identify which one resulted in the highest reduction of water consumption.

Finally, NBU and the participants of this study have authorized this research to record their water consumption volumes for six months following the completion of this study. That participant water volume data will be compared to their 2010, 2011, and 2012 water usage of the same period. The objective is to understand if the study participants continue to reduce their monthly water consumption even after the Water Watch app is no longer available to them. This will demonstrate whether or not the app was able to provide lasting education and experiences with its users.

APPENDIX SECTION

APPENDIX A

STUDY PARTICIPANT HISTORICAL WATER CONSUMPTION DATA
(SHOWN IN GALLONS)

Monthly Totals		**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
2012	SEPTEMBER	12000	32000	2200	57500	12300
	AUGUST	14500	44300	8400	26400	9100
	JULY	18000	25800	2000	38900	12300
	Total	**44500**	**102100**	**12600**	**122800**	**33700**
2011	SEPTEMBER	18900	45800	4500	46300	11700
	AUGUST	7700	46300	2800	41200	19700
	JULY	8300	22800	3200	29200	10400
	Total	**34900**	**114900**	**10500**	**116700**	**41800**
2010	SEPTEMBER	13000	26900	10700	84800	11600
	AUGUST	10500	32200	3900	111000	11800
	JULY	16500	18700	4600	48600	18100
	Total	**40000**	**77800**	**19200**	**244400**	**41500**
Avg 3 Month Volume	SEPTEMBER	14633	34900	5800	62867	11867
	AUGUST	10900	40933	5033	59533	13533
	JULY	14267	22433	3267	38900	13600
	Average Total	**39800**	**98266**	**14100**	**161300**	**39000**

APPENDIX B

PARTICIPANT WATER CONSUMPTION DATA RECORDED DURING THE RESEARCH
STUDY PERIOD: JULY 1 – SEPTEMBER 30, 2013
(SHOWN IN GALLONS):

		H-1	**H-2**	**H-3**	**H-4**	**H-5**	
Monthly Totals	SEPTEMBER	4800	13400	2700	10000	6390	**Total Average increase/decrease**
% increase/decrease		**67%**	**62%**	**53%**	**84%**	**46%**	**62%**
2013	AUGUST	6800	24000	2600	21200	7710	
% increase/decrease		**38%**	**41%**	**48%**	**64%**	**43%**	**47%**
2013	JULY	17400	16400	3600	27500	8640	
% increase/decrease		**22%**	**27%**	**10%**	**29%**	**36%**	**12%**
2013 Total Volume		**29000**	**53800**	**8900**	**58700**	**22740**	
% increase/decrease		**27%**	**45%**	**37%**	**64%**	**42%**	**43%**
Average Daily Volume		**309**	**572**	**95**	**624**	**242**	

APPENDIX C

COMPLETE PARTICIPANT SURVEY RESULTS

1. Where do you think the amount of water your household consumes ranks when compared to other homes in your area?

    a. Below average

    b. About average

    c. Above average

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	A	B	A	B	C

2. What do you believe the average daily amount of water consumed by households in your area to be?

    a. 100-400 gallons

    b. 400-700 gallons

    c. 700-1000 gallons

    d. More than 1000 gallons

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	B	A	B	A

3. Do you feel that the total amount of water your household consumed during this study was more or less than the amount your household consumed from July to September in the previous 3 years?
    a. More
    b. Less

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	B	B	N/A	A

4. Who in the household reviewed and acknowledged the daily water consumption on the iPod application?
    a. Always the same person
    b. Multiple people

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	A	B	A	A

5. If you have children under 18 years old in your home, did any of them ever review and/or acknowledge the daily water consumption on the iPod application?
    a. Yes
    b. No
    c. Not sure
    d. Not applicable

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	B	D	A	B

6. How did you feel about viewing and acknowledging your households daily water consumption?
    a. I dreaded it every day.
    b. I didn't have any strong feelings about it either way
    c. I looked forward to it

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	C	B	C	C

7. Which aspect of the water monitoring application did you find most helpful in understanding your water consumption? (Circle all that apply)
    a. Daily volumes
    b. Icons representing the amount of water consumed
    c. Mood of the app (happy, neutral, sad)
    d. Last 7 day volume

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	C	A	A	A & B	B

8. Within the first 2-weeks of this research study, your daily water consumption displayed on the app was:

   a. About what you expected

   b. Higher than you expected

   c. Lower than you expected

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	A	A	A	B	A

9. Did the icon representing the equivalent of your water consumption give you a greater understanding of the amount of water you use daily?

   a. Yes

   b. No

   c. Somewhat

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	A	A	A	A

10. Do you recall what largest equivalent icon/volume you used in one day during the study? If so, please note it:

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	No, but it was red	N/A	300	No, but Tuesdays we water the yard, so it was 4000-5,000	No

11. If your water app displayed a yellow or red screen on a given day, did you alter the amount of water you used the following day?

    a. Yes, a lot
    b. Yes, but very little
    c. Not really

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	C	C	B	C **Note:** Well, not for yard irrigation– but we tried on other days	C

12. Did the 7-day total water consumption readout on the app impact the amount of water you used the following week?

    a. Yes, a lot
    b. Yes, but very little
    c. Not really

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	C	C	C	C **Note:** I didn't look at that so much	B

13. If your utility provider offered a device or system that allowed you to easily view your household's water consumption, would you use it?

    a. Yes
    b. No
    c. Perhaps

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	A	A	C	A	A

14. If you answered yes to the previous question, how often do you think you might check your water consumption total?

    a. Daily
    b. Weekly
    c. Monthly

APP ID	**H-1**	**H-2**	**H-3**	**H-4**	**H-5**
Answer	B	B	B	C	A

15. How did you feel if on a given day, your actual water consumption was higher than what you expected it to be?

    a. Disappointed
    b. Concerned
    c. Irritated
    d. Didn't really care
    e. None of these

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	B	B	C	B	D

16. Do you anticipate altering your water consumption at home in the future as a result of your participation in this research study?

    a. Definitely

    b. Maybe

    c. Doubtful

    d. No idea

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	B	C	B	A	B

17. With 10 being extremely important and 1 being extremely unimportant; Before participating in this research study, what did you consider the importance of water conservation to be?

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	10	8	7	5	7

18. With 10 being extremely important and 1 being extremely unimportant; After participating in this research study, what do you consider the value of water conservation to be?

APP ID	H-1	H-2	H-3	H-4	H-5
Answer	10	8	7	10	9

19. What was your overall reaction to participating in this study?

APP ID	Response
H-1	I liked it. I think it is a good idea to educate people on water and just how important it is. I think a lot of people just do not know or think about water (other than, I turn the tap and it comes out). Fresh clean water is a big deal and everyday people never think about what a huge advantage that is compared to other parts if the world.
H-2	Really positive – understand what our sprinklers now use. So much better than soaker hoses–soaker hoses are very wasteful. Soakers use 800-1000 gals an hour - (1 area). My whole yard can be watered with sprinklers with 3600 gallons.
H-3	My reaction was glad to see that the water used daily so I could think about what made it go up and try not to do that again.
H-4	I enjoyed it. We had bought a water efficient washer and I wonder how that affected water consumption. I used to fill my sink with water to soak dishes several times a day
H-5	Interesting; the icons helped me understand our use of water better.

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