國立臺灣大學電機資訊學院資訊網路與多媒體研究所

碩士論文

Graduate Institute of Networking and Multimedia

College of Electrical Engineering ＆ Computer Science

National Taiwan University

Master Thesis

利用遊戲鼓勵多喝水的行為: 結合行動裝置、人機互動技術、說服力科技的智慧型杯子

Playful Bottle: a Mobile Social Persuasion System

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中華民國99 年6 月

June, 2010

Acknowledgement

Playful Bottle 的這個點子是 2008 年 4 月開始實作。 在這 Playful Bottle 的設計、實作、實驗等，有許多人付出心力來參與，也有許多人花時間來與我討論、指導我，在此，我衷心的感謝這些夥伴們。

我特別要感謝我的指導教授 朱浩華老師。朱老師在 HCI 領域上不斷指導我，讓我學習更廣更深入的研究方法，另外還時常鼓勵我多接觸一些國際的 conference，或是給我機會讓我去報告我的作品，藉此讓我更能夠去接觸不同的思維，以擴大我的研究視野。除此之外，能夠完成這份碩士論文，朱浩華老師也付出了相當多的時間與精力，不厭煩的反覆與我討論做修改，沒有朱浩華老師，就不會有這篇碩士論文。

另一方面，我想要感謝台大護理系的陳佳慧老師，在實驗設計與執行上，陳老師給了我諸多幫助，從他身上，我學習到了許多資工系的學生並不會接觸到的實驗方法及設計，另外也學習到了如何與使用者作互動，讓我的作品並不僅僅是放在實驗室做測試，而是能夠讓現實生活上的人們做使用。這篇碩士論文能夠產生，陳佳慧老師功不可沒。

除此之外，我要感謝台大護理系的蕭妃秀老師，他在實驗的設計上，幫了我許多忙。從他身上，我也學習到了更嚴謹的實驗方法。另外，在 focus group 的執行上，也是由擁有豐富經驗的他來做主持，才能蒐集到這麼多寶貴的實驗資料。

在 Ubicomp Lab 的每一位好夥伴，無論是參與 Playful Bottle 研究的人，或是在旁邊爲我們加油的人，我都想要謝謝他們。他們除了在研究領域上給了我啓發，另外當我研究遇到瓶頸時會給予我關心，讓我在這碩士班階段，更有動力、也更有勇氣的迎接挑戰。

最後，我要感謝我的父母。他們在我研究所階段，提供我每日所需的照顧，讓我可以專心的做研究，不需擔心日常生活的食衣住行，對於他們，我獻上我最真摯的感謝。

Abstract

This paper presents the lessons learned in designing and evaluating a social persuasion system. This social persuasion system, called the Playful Bottle, consists of a mobile phone attached to an everyday drinking mug, and motivates office workers to drink healthy quantities of water. This study discusses the results of a 10-week quantitative user study and qualitative focus group interviews. We describe how users interacted with one other through the systems' care-giving and care-receiving interface and how the system's social effect influenced drinking behaviors. Based on our findings, we offer lessons learned on how to design an effective social persuasion system. We hope that these lessons will help researchers design effective social persuasion systems.

Contents

List of Figures

List of Tables

Chapter 1

INTRODUCTION

Persuasive computing is using digital technologies to motivate people to change their behaviors. Designing effective digital persuasion systems and successfully changing people's behaviors are challenging tasks. In general, digital persuasion systems [Arroyo 2005; Chang 2008; Chen 2010; Consolvo 2006; Consolvo 2008; Froehlich 2009; Lin 2006; Lo 2007; Nawyn 2006] consist of two parts: detection and feedback. The detection part uses a multitude of sensors and sensor-based activity recognition to identify people's behaviors. The feedback part involves preprogramming interaction between users and the system, and applies a suitable persuasive tactic to influence users. Previous research in persuasive systems [Chang 2008; Chen 2010; Lo 2007] shows that designing effective feedback mechanisms with humans is often more challenging than improving the sensing accuracy of machines through better sensors and activity recognition algorithms.

Several recent persuasion systems [Consolvo 2006; Lin 2006; Tosco 2006] explore social effects in their feedback design. Studies [Chiu 2009; Lin 2006] have shown that it is possible to amplify a system's persuasiveness by transforming it into social interaction. The theoretical basis of social persuasion is derived from the theory of social conformity and is based on the proposition that opinions and attitudes are constrained by the opinions of others and that many behaviors result from fear of peer disapproval [Asch 1955; Epley 1999; Nord 1969]. Conformity is a change in personal behavior due to group influence, which increases the congruence between the individual and the group [Allen 1965]. In digital social persuasion systems, people play the primary role of motivating each other, and computers play a secondary role of facilitating or empowering people to become better motivators. Social persuasion systems often fail when there is insufficient enticement to motivate caregivers and promote their care-giving efforts. This paper demonstrates the importance of this "motivating the motivators" concept and reveals lessons learned from the design and evaluation of a social persuasion system called the Playful Bottle. We believe that the "motivating the motivators" concept is a critical factor in designing effective feedback interaction in a social persuasion system.

The Playful Bottle [Chiu 2009] is a mobile social persuasion system that consists of a mobile phone attached to an everyday drinking mug. The goal of the Playful Bottle is to motivate office workers to drink healthy quantities of water. The mobile phone achieves both sensing and feedback, creating an all-in-one design. For behavioral sensing, the camera and accelerometer sensors embedded in the phone form a vision/motion-based water intake tracker to detect the amount and regularity of water consumed by the user. For feedback and interaction, the phone displays a hydration game in which natural drinking actions are used as inputs to a social persuasion game. In this social persuasion game, group members observe the water drinking behaviors of other players and exchange computer-mediated care-giving messages. User studies reveal the successes and failures of the design of this social persuasion game. One of the important lessons learned is the need to facilitate positive group dynamics by emphasizing the caregivers and reinforcing their care-giving actions with timely rewards from the care-receivers or computers. This differs from traditional persuasive systems, which emphasize encouraging under-performing users, who are often the care-receivers in a social persuasive system.

Two important contributions of this work are as follows:

- This study presents results from a 10-week quantitative user study evaluating how the Playful Bottle system affects user drinking behaviors. This study also reports findings from qualitative focus groups, in which subjects were interviewed about their experiences using the Playful Bottle system.
- This study present lessons on how to design an effective social persuasion system as learned from the Playful Bottle system. We hope that others can apply these lessons in the design of future social persuasion systems.

The rest of this paper is organized as follows. Section 2 provides a brief overview of the design and prototype of the Playful Bottle system. Section 3 details the 10-week user study and presents quantitative and qualitative results. Section 4 discusses lessons learned from the user study results. Section 5 reviews related work. Section 6 draws conclusions and discusses directions for future work.

CHAPTER 2

DESIGN OF PLAYFUL BOTTLE

2.1 Background

Water is essential for all life on earth, including human life. Since water comprises 60%~70% of human body weight, sufficient water is needed to replenish bodily fluids and maintain health. However, recent studies [Brady 2003] indicate that people of all ages do not drink enough water. This chronic water deficiency can cause both long and short term health-related problems, including constipation, light-headedness, headaches, shriveled skin, muscle spasms, mental status changes, fatigue and etc. [Davidhizar 2004] The reported [Batmanheilidj 2005] benefits of adequate fluid intake include appetite suppression, healthy skin, and removal of harmful toxins from the body. Constant hydration is essential to keeping the body healthy. Thus, this study developed the Playful Bottle, an augmented water bottle that uses the sensing, processing, and networking capabilities of currently-available mobile phones, to remind users to drink water regularly, particularly those working in fast-paced or physically demanding environments.

Although studies vary in their recommended daily water intake for healthy adults, a good approximation is 2 liters or about eight 8-ounce glasses of water a day with a normal diet [Mayo 2008]. Factors affecting individual water needs include exercise habits, environmental temperatures, health conditions, pregnancy and, in new mothers, frequency of breast feeding.

Commercial products for tracking water intake include HydraCoach [HydraCoach 2008] and Fluid Intake Tracker (F.I.T.) [Tri-More 2008]. Although these products can automatically or manually track water intake, they do not actively remind or motivate users to regularly drink sufficient quantities of water.

2.2 Prototype Design

Figure 1 shows the three components of the prototype Playful Bottle: the water bottle (Fig. 1(a)), the mobile phone (HTC Touch Diamond) (Fig. 1(c)), and the bottle-phone attachment constructed from LEGO bricks (Fig. 1(b)). The LEGO attachment piece is permanently glued to the outside of the water bottle and serves as a phone holder. A flat 2x2 LEGO brick glued to the back of the mobile phone (Fig. 1(d)) makes it easy to attach the mobile persuasion system to the water bottle, and easily detach it from the water bottle to make or receive phone calls. Note that the mobile phone must be detached to avoid damaging the phone when washing or refilling the water bottle. The LEGO "stud-tube" connection adequately secures the mobile phone during normal use of the water bottle.

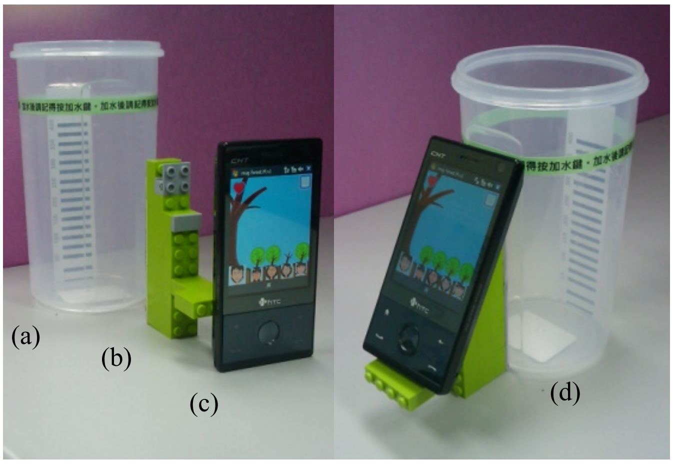

Figure 1. Three physical components of the Playful Bottle prototype: (a) water bottle, (b) bottle-phone attachment made from LEGO bricks, (c) a mobile phone, and (d) the mobile phone clipped to the bottle through the LEGO attachment.

The mobile phone in this Playful Bottle system includes three main software components: (1) a vision/motion-based water intake tracker for detecting when users drink from the bottle, (2) hydration games played on the phone display using the user's drinking actions as game inputs, and (3) a system log for recording user and system events. The following section explains the water intake tracker and the hydration games.

2.2.1 Motion-based Drinking Action Detection

The accelerometer in the mobile phone detects drinking motions such as picking up the container, tilting it back to drink, and placing it on the desk. This motion-based detection of drinking actions works as follows. The accelerometer sampling rate on the mobile phone is set to 2 Hz, which is fast enough to recognize a drinking motion. Experimental analysis of different users drinking from the water bottle indicates that the tilting angle must be at least 30 degrees to draw water from the bottle into the mouth. Therefore, the threshold tilting angle was set at 30 degrees. The drinking action is complete when the bottle is placed on a surface or is held motionless by the user. This creates a time window of low accelerometer readings, during which the water inside the bottle stabilizes to form a steady water line. This steady state triggers the vision-based water-level detector via the camera on the back of the mobile phone. Experiments reveal that a 5-second time window is long enough for the water in the bottle to stabilize after movement. If the system detects further drinking actions during this 5-second window, it restarts the 5-second countdown to water-level detection and records all drinking actions as a single drinking action. When the user refills the bottle, there may not be a tilting motion to trigger new water level detection. Therefore, the user must press a refill button located on the upper right corner of the phone display (shown in Fig. 4) to activate the detection process.

2.2.2 Vision-based Water Level Detection Algorithm

To avoid privacy issues arising from use of a mobile phone camera in an office environment, its focal length was intentionally adjusted to blur all captured images, such as accidentally captured faces or objects. Additionally, given the limited processing capability of a mobile phone and the need to quickly generate responses for the hydration game, a pattern-bar image processing approach with low computation requirements was applied. The pattern-bar approach operated as follows. According to Fig. 2, parallel rows of bars were painted on the outer surface of the bottle for easy imaging by the mobile phone camera. The pattern-bar approach enabled accurate detection by leveraging the different effects of water refraction on bars above, near, or below the water line. Figure 3 shows a sample photograph of the interior of the bottle taken by the cell phone camera. The water refraction effects on the pattern bars varied for bars above, near, and below the water line. Since the bars above the water line were unaffected by refraction, their size appeared normal. Because the pattern bars near the water line were partially affected by water refraction, they appeared thinner than normal. The pattern bars below the water line, which were seriously affected by water refraction, appeared much thinner than normal, and became indiscernible near the bottom of the bottle.

Figure 2. Pattern bars are shown on the right. The pattern bars painted on the outer surfaces of water bottle are shown on the left.

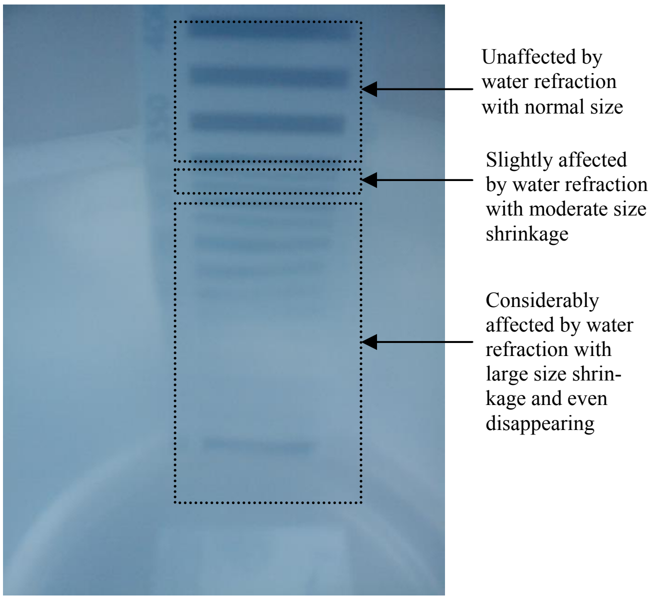

Figure 3. A water-level picture captured by the mobile phone's camera. Water refraction affects the sizes of the pattern bars differently, depending on whether the bars are above, near, or below the water level.

The vision-based water level detection algorithm functions as follows. In Step (1), the accelerometer-based motion detection mechanism triggers the phone's camera to capture a water level image of the bottle when it recognizes a possible drinking action. Step (2) crops the image to the area covering the pattern bars. Additionally, since drinking hot water is a common practice for people in Taiwan, the image is enhanced to reduce the blurring and refraction effects of fog and mist that hot water creates inside the bottle. Our image enhancement techniques first use a median filter to filter out noise. The detection algorithm then applies overlapping local equalization to increase contrast and reduce unbalanced brightness in the image. Furthermore, image binarization convert an image of various gray levels to a black and white image, from which the pattern bars are extracted. To accommodate camera tilting, a voting method identifies the tilted pattern bars in the image. Step (3) extracts dominant image features, including the lengths of the pattern bars, the distance between two adjacent pattern bars, the y-axis positions of the pattern bars, and the average intensity of the pattern bars. Step (4) uses these extracted features as inputs to a decision tree classifier, which then outputs the position of the water line. The decision tree classifier in this study was first trained offline using several hundred images with different water levels.

2.2.3 Hydration Games

Two hydrations games were developed to remind and encourage users to regularly drink healthy amounts of water. The first game is single-user, and the second is multi-user. Figures 4 and 5 are screenshots of these two games. In both games, the act of caring for and watering a virtual tree is a metaphor for caring for the body by regularly drinking water. When a user did not drink enough water regularly, his/her virtual tree, shown as the foreground tree on the left of the screen (Fig. 4), would slowly transform from a beautiful green tree with many leaves (Fig. 5(a)) to one with bare and withered branches (Fig. 5(e)). In both hydration games, the virtual tree progressed through five stages of withering. In addition to the visual display of withering, changing tree levels were accompanied by a vibration, which provided an additional reminder to drink water. If the user drinks sufficient water regularly and continuously, the virtual tree maintains its beautiful green leaves. The game feedback is designed to be subtle to avoid disrupting the user's daily activities.

While this withering tree is a negative feedback, the system also provides positive feedback if users achieve certain predefined goals. There are two types of positive feedbacks. The first one is focusing on the water intake amount. If users drink more than the system recommended volume, a flower appears on their screens as a reward for the individual. This positive feedback appears in both single- and multi-user games.

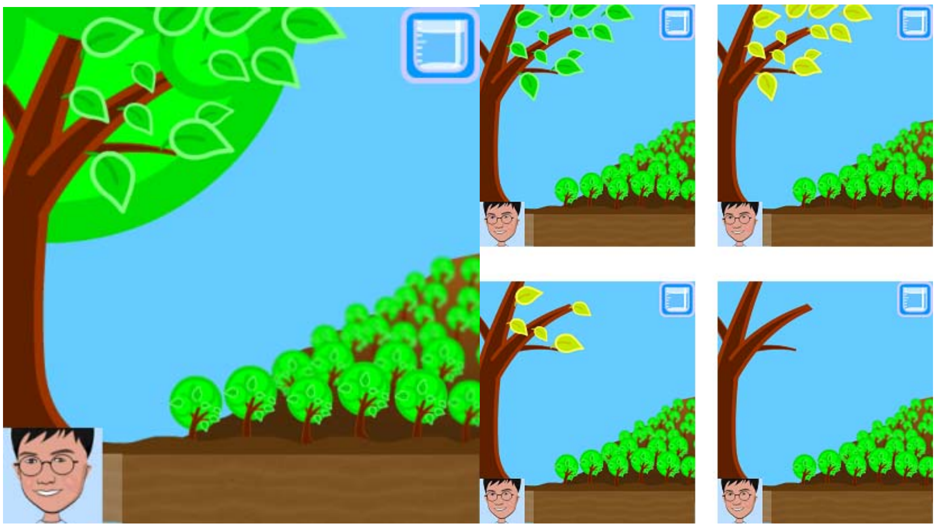

Figure 4. On the left is a screenshot of the single-user TreeGame. On the right is the five-level sequence (the first level is shown to the left) of withering trees.

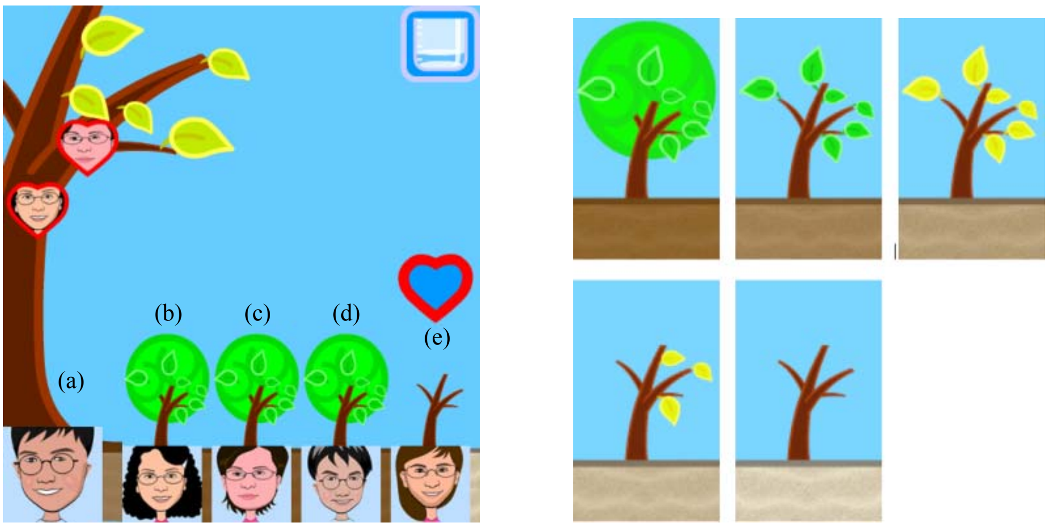

Figure 5. On the left is a screenshot of the multi-user ForestGame. On the right is the five-level sequence of withering trees.

While the single-user game only displays the player's own virtual tree with his/her unique avatar below, the multi-user ForestGame interconnects the Playful Bottles of multiple players via the WiFi networking capabilities of the mobile phones. Figure 5 (left) displays a screenshot of avatar images for five players and their virtual trees above their avatars. By interconnecting their Playful Bottles, players can monitor changes in the tree health and water drinking habits of other players. This virtual grouping in the ForestGame introduces elements of social persuasion through both competition and collaboration between players. To encourage collaboration, the ForestGame is designed to transform the social interactions of care-giving and care-receiving into social persuasion. For example, the ForestGame enables players to send hydration reminders to other players who are not drinking enough water – this provides players with opportunities to express concern for each another. Before sending a social reminder, a player must perform a water drinking action to earn a credit. This design is based on the idea that a caregiver must take care of himself/herself before providing care to group members.

Figure 6 shows a sequence of interaction and screenshots when John (a caregiver) sends a social reminder to Mary (a care-receiver). First, John must drink some water to earn a loving heart, which appears on his tree (Fig. 6(a)). Second, when John touches his loving heart on his phone screen to send a loving heart, heart-shape buttons appear above the trees of his group members (Fig. 6(b)). Third, John selects Mary as the target care-receiver by touching the heart-shape button above her tree. Then, John's loving heart turns blue, indicating that a social reminder has been sent to Mary (Fig. 6(c)). When Mary receives John's social reminder, a new loving heart imprinted with an avatar image of the caregiver appears on her tree (Fig. 6(c)). When Mary responds to John's social reminder by drinking water, Mary's phone plays a fun animation of the loving heart. At the same time, John’s phone also plays a fun animation of the loving heart to show that Mary has responded to his loving heart reminder. Finally, the loving heart on John’s screen and the avatar image on Mary’s screen disappear to complete the social reminder process (Fig. 6(d)). Figure 5(d) shows a more complex screenshot of the ForestGame. The player is at tree level 3. She received loving heart reminders from players B and C, and she sent a loving heart reminder to player E. However, player E has not yet responded to her loving heart reminder to drink water.

Figure 6. A sequence of screenshots as John, a caregiver, sends a loving heart reminder to Mary, a care-receiver. (a) John drinks some water to earn a loving heart. (b) John touches his loving heart to initiate the sending of this social reminder. He selects Mary as the target care-receiver by clicking on a heart-shape button above her tree. (c) On John's screen, his heart turns blue showing the status that his loving heart has been sent. On Mary's screen, a heart imprinted with John's avatar hangs on her tree. (d) When Mary responds to John's social reminder by drinking water, the hearts on both John's and Mary's screens disappear to complete this care-giving process.

The second type of feedback is designed only for the ForestGame. When all virtual trees in a group are at their highest levels, a rainbow appears on the phone screens of all group members (Fig. 7). This reinforces the ForestGame game concept that each individual player is a tree in this forest. When all group members take good care of their virtual trees, together they become a beautiful, healthy forest. Thus, the rainbow reward is designed to provide group recognition and encourage group collaboration in care-giving and care-receiving. In summary, the computer-mediated social persuasion in the ForestGame is designed to not only introduce social competition, but more importantly, to encourage group collaboration. We believe that the addition of social persuasion (including both social competition and collaboration) in the ForestGame will enhance the effectiveness of the Playful Bottle in motivating healthy water drinking behaviors more than using only the system persuasion in the TreeGame. The user study described in the next section tests this hypothesis.

Figure 7. When all the virtual trees in a group are at their highest levels, a rainbow appears on the phone screens of all group members as a reward for group effort.

CHAPTER 3

USER STUDY

This section describes the design and experimental results of both quantitative and qualitative user studies.

3.1 Quantitative User Study

The effectiveness of the Playful Bottle system was tested in a 10-week user study using a randomized controlled trial design. We designed our study to examine the following questions:

- How effective are the Hydration games (TreeGame and ForestGame) in improving the water drinking behaviors of users?
- What aspects of water drinking behavior were affected by use of the Hydration games (TreeGame and ForestGame)?

The way in which the Hydration games impacted drinking behaviors was evaluated by comparing typical drinking behavior without playing the games (i.e., baseline performance), with that while playing the games (i.e., intervention performance), and finally, with that without playing games (i.e., the post-test performance). During the first three weeks, subjects were instructed to use only the Playful Bottle when drinking water. The time of each drinking event and the amount of water consumed were recorded for both TreeGame and ForestGame conditions. The following sections describe the details of the user study.

3.1.1 Subjects

Sixteen university hospital staffers (thirteen females, three males) were recruited for this user study. Their ages ranged from 26 to 51 years, with a mean of 38.06 years and a standard deviation (SD) of 6.82. Table I shows their individual profiles. All subjects worked regular hours from 8:30AM to 4:30PM in various university hospital offices. All were Taiwan residents at the time of the study. All subjects gave informed consent to the study. Each subject was compensated with NT$500 (approximately US$15) per week.

Table I. Profiles of sixteen subjects (three groups of 5-6 subjects each).

Groups	Sub-jects	Sex	Age	Weight	Daily base-line water intake(ml) AVERAGE
Forest-Game	1	F	33	50	564
	2	F	37	53	862
	3	F	46	67	604
	4	F	35	53	1,757
	5	F	40	57	980
Control	6	M	28	60	1,780
	7	F	37	47	955
	8	F	51	53	788
	9	F	43	56	1,142
	10	F	44	56	866
TreeGame	11	M	32	73	1,448
	12	M	42	72	1,328
	13	F	35	50	1,097
	14	F	26	47	845
	15	F	35	50	977
	16	F	45	60	607

3.1.2 Procedure

Two hydration games developed for the Playful Bottle system were used on different groups in this user study. The first two hydration games, the TreeGame (single-user game with system reminders) and the ForestGame (multi-user game with social reminders), are described in a previous section. A NoGame version of the Playful Bottle was also implemented to record baseline drinking behaviors. Although the mobile phone screen provided no feedback for user drinking actions, the water intake tracker was active in the background, recording water intake levels. The NoGame Playful Bottle was used to track the baseline water intake of users before using the TreeGame and ForestGame.

The user study trial was performed during workdays over 10 weeks. Three phases of the trial were (1) pre-test, (2) intervention, and (3) post-test. During the 3-week pre-test phase, subjects were asked to drink water using the Playful Bottle. During the 4-week intervention phase, the sixteen subjects were randomly divided into three groups: the Control and the ForestGame groups had five subjects each, and the TreeGame group had six subjects. Different Playful Bottle systems were given to different groups to measure changes in their drinking behaviors. Subjects in the ForestGame group played the Forest Game. Subjects in the Tree Game group played the Tree Game. Subjects in the Control group played no game as the pre-test phase. During the 3-week post-test phase, subjects were ungrouped and continued using our Playful Bottle without playing any game.

In the pre-test, subjects' characteristics such as sex, age, weight, and average daily baseline water intake (measured from the pre-test phase described below) were tested using Kruskal-Wallis test for continuous variables and by Fisher's exact test for categorical variables. There were no significant differences between groups in sex (p=0.7321), age (p=0.4796), weight (p=0.7999), and average daily baseline water intake (p=0.6269). The average daily baseline water intake was calculated from the 3-week pre-test phase, during which subjects used our Playful Bottle system to track their water intake during normal office hours (8:30AM to 4:30PM) but did not play any hydration games.

Since the three groups had different gaming experiences during the intervention phase, their briefing sessions were conducted separately such that they received instructions only for their current games. Prior to the end of regular working hours at 4:30 PM, we collected all mobile phones from the subjects for safekeeping. The drinking logs were also retrieved from the mobile phones for analysis. Subjects kept the bottles for use on the following days of the study. After the 7-week pre-test and intervention period, we removed the hydration games from all mobile phones and continued collecting subjects' drinking logs in the 3-week post-test.

3.1.3 Measures

To determine how effectively the system improved subject's water intake, the primary measure was each subject's volume of daily water as measured by the Playful Bottle system. Note that daily water intake only tracks water consumed from the Playful Bottle system during regular working hours from 8:30 AM to 4:30 PM. The secondary measures were the regularity (frequency) of water intake, and the response time (drinking some water) for each system or social reminder. These measures were derived by analyzing the following time-stamped event logs: (1) bottle refilling event, (2) water drinking event, (3) heart sending event, (4) heart receiving event, and (5) tree change event.

3.1.4 Results & Findings

A mixed model was used to analyze and compare the amount and regularity of daily water intake among the three groups during the three experimental phases. A mixed model is a popular statistical method used in a wide variety of disciplines, including physics, biology, medicine, public health, and economics. It is particularly useful when the same variables are repeatedly measured over time. Mixed models, which include fixed effects and random effects, can be viewed as a generalization of variance component and regression analysis models, and are used to describe the relationships between a response variable and independent variables [Diggle 2002; McCulloch 2001].

Figure 8 plots the average daily water intake volume for the three groups (ForestGame, TreeGame and Control) over the 10-week user study period. Table II shows the volume of daily water intake (ml) for the three groups during the three experimental phases. Experimental groups (i.e., the TreeGame and ForestGame groups) significantly increased their volume of water intake during the intervention phase, and then decreased slightly during the post-test phase. In addition, variations among groups were quite different in the pre-test phase. These variations contracted moderately from the pre-test to the post-test, especially in the ForestGame group, suggesting increased congruence between the individual and the groups. This increased congruence supports the theory of social conformity in behavior change.

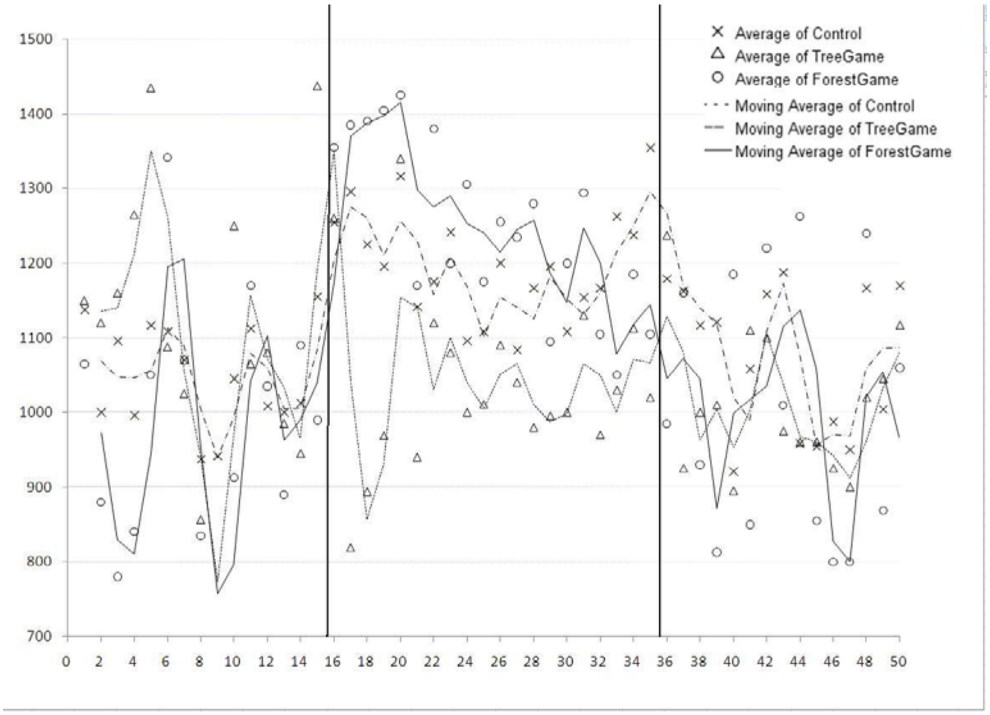

Figure 8. Daily water intake volumes for the three groups (ForestGame, TreeGame and Control) over the 10-week user study period. Unweighted moving averages are plotted using a window size of 3 days. The 3-week pre-test phase is from day 1 to day 15, the 4-week intervention phase is from day 16 to day 35, and the 3-week post-test phase is from day 36 to day 50.

Table II. Average volume of daily water intake (ml) among groups during three experimental phases, mean(SD).

	Control (n = 5)	TreeGame (n = 6)	ForestGame (n = 5)
Pre-test			
Week 1	1,226	1,069	916
Week 2	1,002	1,003	901
Week 3	1,077	1,071	1,035
Average (SD)	1,106 (399)	1,050 (311)	953 (482)
Intervention			
Week 4	1,233	1,258	1,392
Week 5	1,030	1,153	1,246
Week 6	1,021	1,163	1,242
Week 7	1,044	1,235	1,132
Average (SD)	1,060 (353)	1,202 (313)	1,255 (387)
Post-test			
Week 8	984	1,100	1,062
Week 9	1,031	1,063	1,027
Week 10	1,001	1,064	941
Average (SD)	1,008 (318)	1,075 (270)	1,013 (387)

Applying mixed model analysis to the amount of water intake reveals that the two main effects on the amount are groups and phases. The control group is defined as a reference group and the pre-test phase is defined as a baseline phase. The amount of daily water intake is estimated using the following equation:

Daily water intake = $\beta_0 + \beta_{1g} * \text{Group}(g) + \beta_{2p} * \text{Phase}(p) + \beta_{3gp} * \text{Group-Phase}(g, p) + \varepsilon$,

where ε is an error term representing a subject's difference between the model estimation and true value. The variable Group(g) represents which group a subject belongs to (g = TreeGame, ForestGame), and Phase(p) denotes observed phases (p = intervention, post-test); coefficient β_0 is an intercept representing the control group's average daily water intake in the pre-test phase, β_{1g} is the difference between g and the control group in the pre-test phase, β_{2p} is the improvement in daily water intake from the pre-test to the p phase, and β_{3gp} is the difference in the improvement in the volume of daily water intake between g and the control group from the pre-test to the p phase.

Table III shows the results of this mixed model estimation. The middle columns of Table III estimate the improvements in the volume of daily water intake from the pre-test phase to the intervention/post-test phase adjusted for correlations from repeated measurements. All tests are based on a significance level of $p < 0.05$. Although the control group has more daily water intake volume than other groups during the pre-test phase, no significant group differences ($p = 0.8084$ and $p = 0.5190$) were observed among the three groups, suggesting that they all shared a similar baseline daily water intake volume. During the intervention phase, there were significant differences in improvements between the TreeGame group and the control group ($p = 0.0015$), and between the ForestGame group and the control group ($p < 0.0001$). This suggests that the Hydration games affected subjects' water drinking behaviors during the intervention phase. Moreover, in the post-test phase, only the ForestGame group improved more than the other two groups. There is no significant difference in improvement between the TreeGame group and the control group ($p =0.0504$), as the difference of improvement between the control and TreeGame groups was 121ml. However, the difference in improvement between the ForestGame group and the control group is 154 ml, which is statistically significant ($p = 0.0202$).

Table III. Improvement in the volume of daily water intake (ml) based on the mixed model estimation (n = 16). Notes: Daily water intake = 1104 - 53 × $I_{TreeGame}$("Group") -148 × $I_{ForestGame}$("Group") – 44 × $I_{intervention}$("Phase") – 97 × $I_{post\text{-}test}$("Phase") + 196 × $I_{TreeGame}$("Group") $I_{intervention}$("Phase") + 343 ×$I_{ForestGame}$("Group") $I_{intervention}$("Phase")+ 121 ×$I_{TreeGame}$("Group") $I_{post\text{-}test}$("Phase") + 154 ×$I_{ForestGame}$("Group") $I_{post\text{-}test}$("Phase"), where $I_A(x)$ is an indicator function having the value 1 for x belonging to A and the value 0 for x not belonging to A. For example, a ForestGame group subject's average daily water intake in the intervention phase is estimated as 1,255ml (= 1104 – 148 – 44 + 342).

	Control	TreeGame	ForestGame
Intervention phase	-44	152	299
Post-test phase	-97	24	57

Table IV shows the average regularity of daily water intake, or the average time interval between drinking actions. This table reveals that in the two experimental groups, the regularity of drinking water declined moderately during the intervention phase, followed by a moderate increase in the post-test phase. In addition, variations in the control group's regularity of water intake were largest during three phases. The standard deviation of the control group increased slightly from 1,590 seconds in the pre-test to an all-time high or 1,867 seconds in the intervention period. After that, it decreased slightly to 1,685 seconds. In contrast, variations in the regularity of water intake in the TreeGame and ForestGame groups decreased sharply from 820 and 598 seconds , respectively, in the pre-test before hitting all-time lows in the intervention (554 and 258 seconds, respectively), and then increased dramatically to 814 and 956 seconds, respectively. This suggests increased congruence between the individual and the groups.

Table IV. Average regularity of daily water intake (seconds) among groups during the three experimental phases, mean(SD).

	Control (n = 5)	TreeGame (n = 6)	ForestGame (n = 5)
Pre-test			
Week 1	2,418	2,525	2,659
Week 2	2,660	2,539	3,019
Week 3	2,719	2,514	2,788
Average(SD)	2,584 (1,590)	2,543 (820)	2,806 (598)
Intervention			
Week 4	2,212	2,043	1,924
Week 5	2,927	2,190	2,504
Week 6	2,577	2,470	2,565
Week 7	2,596	2,283	2,708
Average(SD)	2,587 (1,867)	2,247 (554)	2,416 (258)
Post-test			
Week 8	2,571	2,563	3,002
Week 9	2,334	2,781	3,129
Week 10	2,793	2,437	3,398
Average(SD)	2,556 (1,685)	2,596 (814)	3,171 (956)

Applying the mixed model analysis to the regularity of water intake shows that the two main effects on the amount of daily water intake are groups and phases. The regularity of water intake is measured by the time interval between two subsequent water intakes. Like the daily water intake, the regularity of water intake is modeled as follows:

Regularity of water intake = $\beta_0 + \beta_{1g} * \text{Group}(g) + \beta_{2p} * \text{Phase}(p) + \beta_{3gp} * \text{Group-Phase}(g, p) + \varepsilon$.

The middle columns of Table V show the improvement in the regularity of daily water intake from the pre-test phase to the intervention/post-test phase for all groups based on mixed model estimation. In the pre-test phase, all three groups drank water at a similar frequency ($p = 0.9284$ and $p = 0.7758$). During the intervention phase, all groups reduced their average intervals of daily water intake. The TreeGame and the Forest-Game groups increased their frequencies of water intake more than the control group, but there was no statistical significance among groups ($p = 0.1987$and $p = 0.1144$). In the post-test phase, both the TreeGame and the ForestGame groups reduced their frequencies of daily water intake. Specifically, the improved interval of daily water intake in the TreeGame group was an average of 58 seconds longer than that in the control group, -41 seconds, while that of the ForestGame group was an average of 379 seconds longer than that in the control group. However, there was no statistically significant difference among the three groups ($p = 0.6619$ and $p = 0.0889$).

Table V. Improvement in regularity of daily water intake among groups based on mixed model estimation (n = 16). Notes: Regularity of water intake = $2{,}597 - 60 \times I_{TreeGame}(\text{"Group"}) + 195 \times I_{ForestGame}(\text{"Group"}) - 14 \times I_{intervention}(\text{"Phase"}) - 41 \times I_{post\text{-}test}(\text{"Phase"}) - 277 \times I_{TreeGame}(\text{"Group"})\ I_{intervention}(\text{"Phase"}) - 362 \times I_{ForestGame}(\text{"Group"})\ I_{intervention}(\text{"Phase"}) + 99 \times I_{TreeGame}(\text{"Group"})\ I_{post\text{-}test}(\text{"Phase"}) + 420 \times I_{ForestGame}(\text{"Group"})\ I_{post\text{-}test}(\text{"Phase"})$.

	Control	TreeGame	ForestGame
Intervention phase	-14	-291	-376
Post-test iphase	-41	58	379

In the user study, we recorded time-stamped receiving heart and tree leaf falling event logs to analyze the social and system reminders. Both the TreeGame and Forest-

Game provided system reminders. The response times for system reminders were calculated as the interval between the time when the phone showed the withering tree reminder and the time when the subject rehydrated the tree by drinking water. Similarly, the response time for social reminders was calculated as the interval between the time when the phone presented a heart-sending animation and the time when the subject responded by drinking water from the bottle.

We applied survival analysis to explore the response time to system reminders (i.e., seeing a withering tree) and social reminders (i.e., receiving a heart from a group member), which are shown in Table VI. There were 21 censored events to which users did not respond when a reminder displayed, including two (4%) heart-sending events in the ForestGame, 11 (2%) system reminder events in the ForestGame, and 8 (2%) system reminder events in the TreeGame. The median response time, which represents the response duration for 50% of the reminder events, is 18:50 min:sec for system reminders in the TreeGame, 20:16 min:sec for system reminders in the ForestGame, and 11:57 min:sec for social reminders in the ForestGame. Survival analysis reveals a significant difference in reminder response times with p=0.0039, suggesting that users responded to social reminders faster than they did to system reminders. Figure 8 shows the estimates of response probability based on survival analysis. These results show that people treated another person's exhortation more seriously than they did machine notifications.

Table VI. Characteristics of response times (i.e., drinking water) from receiving system reminders (withering tree) and social reminders (heart-giving from group members) (n=11).

	ForestGame social reminders	ForestGame system reminders	TreeGame system reminders
Number of events	50	451	496
Responded events	48 (96%)	440 (98%)	448 (98%)
Censored events	2 (4%)	11 (2%)	8 (2%)
Median response time (95% CI)	11:57 min:sec (7:30, 16:05)	20:16 min:sec (18:38, 22:47)	18:51 min:sec (17:34, 22:43)

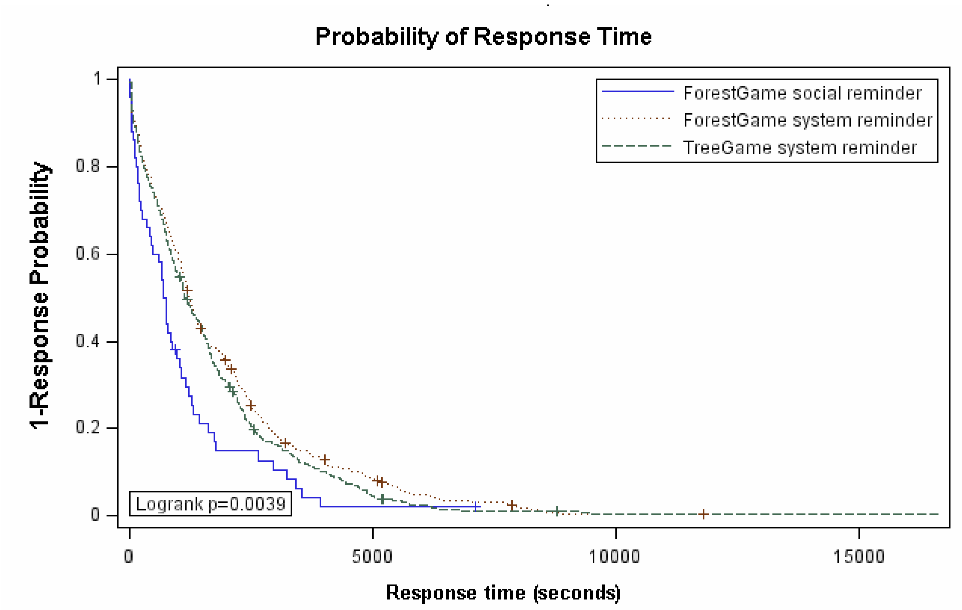

Figure 9. Probability function estimates of response time from receiving reminders among three groups

Summary. Hydration games were effective in increasing the subjects' water intake; however, the hydration games did significantly improve the regularity of water intake. Moreover, social persuasion produced faster subject responses than system persuasion.

3.2 Qualitative User Study

After completing the experiment, fifteen subjects from the user study participated in three separate semi-structured focus group interviews. The first focus group included five subjects from the Control group, the second focus group included five subjects from the TreeGame group, and the third focus group included five subjects from the ForestGame group. These focus groups explored how Playful Bottle and two hydration games influenced the subjects' drinking behaviors. Particularly, we were interested in understanding the following top-level issues:

- How does the use of Playful Bottle impact on your water intake and daily life?
- How do tree changes influence the volume and regularity of your water intake?
- How do group member interactions impact on your water intake and daily life?

Each focus group was approximately 60 minutes in duration. At the start of the focus group, an experienced moderator prepared a list of issues to be discussed. After a quick introduction explaining the purpose and format of the focus group, the moderator initiated the group discussion with several open-ended questions related to the issues mentioned above. Then in the rest of the meeting, the moderator encouraged subjects to share their thoughts, feelings, and attitudes while talking with other group members. An audio recorder was used to capture discussion. The recorded audio logs were then transcribed for analysis. We reviewed the transcripts, and coded and analyzed the data. The following section describes the findings of these focus group interviews.

Reward caregivers. The ForestGame focus group revealed the importance of encouraging care-giving activities to foster positive group dynamics, whereas lack of encouragement adversely reduced care-giving activities and led to negative group dynamics. One subject said that after she sent a heart reminder, she seldom noticed any response from the care-receiver, even when the care-receiver responded to her reminder by drinking water. A subject said, “When I gave heart to a person, it was usually because she drank less water, as I noticed that her tree was not healthy. However, I didn’t know what led her to drink water later. Was it because she wanted to respond to my care-giving, or did she just want to drink water? In the end, her tree was restored, so I knew that she drank some water. But I didn’t know when she drank the water.” The current interface design presented the care-receiving’s response on the caregiver’s screen as a short 1.3-second animation, in which the heart hanging on the care-receiver’s tree joyfully exits. While a care-giver is focusing on his/her office task, he/she may easily miss this short animation, which may arrive several minutes after the care-giving reminder was sent. Many subjects reaffirmed this concern by saying that they would be more motivated to send heart reminders given stronger and more explicit responses and/or rewards for their care-giving actions.

Enable care-receivers to respond to care-givers other than by drinking water. In our game interface, drinking water was the only channel through which the care-receiver could respond to care-giving reminders. However, when a care-receiver simply cannot or is unwilling to drink water, frustration may occur because the care-receiver is unable to express appreciation to the caregiver. For example, a subject said, “I didn’t want to give hearts anymore because sending a (heart) reminder did not work. She just did not want to drink water, so I was reluctant to give (a heart). Also, she wanted me to stop giving her hearts that day.” The response from the care-receiver was, “Don’t give me a heart. The water I drank was enough. I don't want to drink anymore." The care-receiver expressed her frustration by explicitly telling the caregiver not to send her reminders, which stopped all caregivers from sending future reminders to her. Her frustration was echoed by a regretful feeling that she couldn't respond to the caregiver by drinking more water and this "let down" the care-giving effort. The care-receiver continued by saying, "(Let me give you an idea) You can add a new feature, such as a thank-you message, to this system. This will be useful." Her suggestion is a good example of how fostering positive group dynamics can improve the system's effectiveness.

Heart receiving linked with under-performance. The ForestGame focus group revealed another interesting aspect of group dynamics, in which the lowest-performing group member became the center of attention for group care-giving. A subject said "I liked to send reminders. However, at the end (of the study), I did not send any hearts because I found there was one person who had the lowest drinking amount. She ought to be everyone's target. (That one person was the one who asked others not to send her any more hearts.)" In other words, this subject was reluctant to send care-giving messages to an under-performing group member who was not the worst performer because the care-giving messages could wrongly imply that the care-receiver was the worst performer. Unfortunately, care-receiving was linked with under-performance.

Individual preferences on what are considered helpful and motivational game features. Many subjects mentioned that glancing at the game display helped remind them to drink water. Many subjects commented that the game's visual design was appealing. For example, a subject said "Both the game graphics and the overall system were beautiful to look at. When a delivery person came in and saw the Playful Bottle, he also commented that this was beautiful." Most participants stated that without the Playful Bottle, they often forgot to drink water. A subject said "There was a big difference between with and without the hydration games. You could actually see that everyone drank less water (during the post-test)."

However, different subjects found different game features helpful and motivational, suggesting diversity in individual preferences. Many subjects liked the blossoming flowers and regarded them as successful feedbacks. A subject said "The appearance of a flower was encouraging". Another subject stated "When I found that the flower had disappeared, I drank water immediately and the flower appeared again." Many subjects in the ForestGame group noted that they paid attention not only to how their own trees looked, but also to how their trees compared with other trees in their group. One subject said "When I noticed the differences between my water drinking behavior and others' (my group members') water drinking behaviors, my doubt about how much more water people could drink went away. I started to realize that I drank too little water."

A subject from the ForestGame group said "For me, knowing the volume of water intake was more important than playing the game. I cared less about whether other friends sent me reminders or not. I also didn't care about the flowers. I didn't care much about the fun aspect. I just looked for the volume of water intake." A subject from the TreeGame group commented "I checked the precise volume of water intake only when my tree leaves fell down. When the tree was green, I would not check the precise volume of water intake."

Pressure to perform. Subjects mentioned that participating in the user study pressured them to drink only plain water at the office. For some subjects, a side effect of this pressure to perform was a growing sense of deprivation and a desire for flavored beverages. A subject said "(Toward the end of the study) I had a desire to drink flavored beverages. I am not sure if this desire was caused by drinking plain water over such a long time period. There was a pressure. Perhaps I drank too much flavorless water. I really wanted to try other beverages." Another subject commented "I dislike plain water, but (because of this user study) I didn't want to drink other beverages at the office. Therefore, my total water consumption at the office (including other beverages) was less than what it was before (the user study). When I went home, I had more soup for dinner." A third subject expressed her negative experience, "I don't like drinking flavored beverages. For example, I drank mostly plain water at office and home. Occasionally, I drank coffee. However, after the user study, I want to drink (flavored) beverages." This sense of deprivation for flavored beverages may explain the gradual decrease in the volume of water intake toward the last few weeks of the quantitative user study. This gradual decrease was particularly noticeable in the TreeGame and ForestGame groups (Fig. 8).

Novelty effect. The novelty effect often appears with the introduction of a novel technology using flashy multimedia feedback for behavior reinforcement. Technology-based intervention may produce some good short-term effect as subjects are initially interested in the technology; but this effect is often unsustainable in the long-term. Some subjects from the ForestGame and TreeGame groups agreed on a novelty effect of approximately two weeks. One subject said, "During the 2nd week (of the intervention phase), the feeling of novelty wore off." Several subjects agreed with this opinion. They commented that they became less aware of the Playful Bottle and viewed it as an everyday artifact for daily use. Another subject said “After the 2nd week (of the intervention phase), I looked at the game interface only occasionally, and not as frequently as before.” However, some subjects experienced a much shorter novelty effect. One subject said, “I felt that everything ran normally after two days (from the beginning of the intervention phase) because it (the Playful Bottle) did not have a big attraction for me.”

Limitations. Subjects reported several limitations of the Playful Bottle system. The first limitation was that since the Playful Bottle system could not record water intake from other bottles and containers, the volume of water intake reported by the Playful Bottle system was less than their actual water intake. Many subjects mentioned that they did not bring their Playful Bottles with them when working outside their offices. As a result, the Playful Bottle system could not track water intake outside their offices. A subject said “For some of us, our jobs needed us to walk to other offices frequently. Sometimes, we went out all afternoon. It was like we were on leave, and the bottle couldn’t record anything.”

The second limitation was the high-temperature water (e.g., near boiling) in the Playful Bottle. Since hot water generates an excessive amount of fog and mist inside the bottle, it adversely affects the accuracy of vision-based water detection; therefore, subjects were told not to put high temperature water into the Playful Bottle. However, this restriction became an issue for some subjects. One subject said “I don’t like to drink cold water. This system’s limitation annoyed me.” Another subject said “Sometimes, this limitation caused me to drink less water (during cold days) when the water temperature (in the bottle) dropped quickly.”

The third limitation was a lack of user adjustment in the water intake under special conditions. Several subjects mentioned that they were sick during the user study, and wanted to increase the required water intake volume. One subject said “Due to a cold, my throat felt uncomfortable, and I drank a lot of water.”

CHAPTER 4

LESSONS LEARNED

Our previous analysis of quantitative and qualitative data shows that some aspects of our Playful Bottle system were successful and some were unsuccessful. Several themes emerged, from which we present the following three lessons learned for designing social persuasive technologies to promote everyday behavioral changes. We hope that future designers of social persuasive technologies can apply these findings in their designs.

- Motivate the motivators
- Reduce pressure and lessen the feeling of deprivation
- Combine positive and negative reinforcements

4.1 Motivate the motivators

In a social persuasion system, people play the primary role of motivating each other, and computers take the secondary role of facilitating or motivating people to become motivators. A social persuasion system will not work without caregivers and their care-giving activities. Therefore, caregivers and their care-giving efforts must be properly rewarded and reinforced so that they are motivated to continue their care-giving activities. There is also a vital difference between the feedbacks of a social persuasion system and those of a non-social persuasion system. The primary purpose in a social persuasion system is to encourage care-giving and care-receiving activities, which indirectly contribute to improving or maintaining group performance. In contrast, the primary focus of a non-social persuasion system is often to directly motivate subjects to improve and/or maintain their performance.

This study proposes two additional feedback channels through which a social persuasion system can reinforce care-giving action: (1) a human feedback channel in which caregivers and care-receivers can share and exchange feelings, and (2) a system feedback channel to acknowledge and encourage care-giving efforts. This system feedback channel may be especially helpful in the presence of unresponsive care-receivers. These two feedback channels are further discussed below.

The human feedback channel enables a care-receiver to communicate his/her emotions and feelings to a caregiver as an alternative to physical drinking behavior. For example, the Playful Bottle system can present a care-receiver with an emoticon menu upon receiving a heart reminder. The care-receiver then selects and replies with his/her feelings using thankful, regretful, happy, frowning, indifferent, or obedient emoticons, etc. This emoticon channel not only reduces performance pressure for a care-receiver, but also encourages him/her to express and communicate feelings in a care-receiving action. A caregiver can also leverage this emoticon feedback channel by attaching an emotion to a care-giving reminder, such as concerned, playful, or tearful emoticons, as a way to enhance the message. For example, a caregiver can send a follow-up care-giving reminder with a tearful emoticon (in case the care-receiver did not respond to the previous care-giving reminder) or a smiling emotion (in case the care-receiver responded to the previous care-giving reminder).

This system feedback channel encourages care-givers by rewarding them based on their care-giving actions. For example, the Playful Bottle can reward points to each care-giving action that successfully elicits a drinking response from a care-receiver. Users could then compete to be the most successful care-giver(s) or see who could get the most difficult (i.e., unresponsive) care-receiver to reply with a successful drinking response. The winner could receive a crown on his/her avatar as a reward.

4.2 Reduce pressure and lessen the feeling of deprivation

Dale Carnegie, an old-time master of interpersonal skills, wrote a classic book called “How to Win Friends and Influence People” [Carnegie 1953]. Carnegie’s book offers fundamental and practical techniques for how to influence and persuade people. One key principle is to “Arouse in the other person an eager want”. In other words, if we want to get the other person to do something (i.e., even with good intentions for his/her benefit), simply telling them what to do or (worse) applying pressure to force their compliance often produces half-hearted efforts or backfires in resentment. Instead, a more persuasive method to influence another person is to talk about what the other person wants and what motivates him/her, rather than what we want him/her to do. In the Playful Bottle system, the feedback design was explicit in communicating what the system wanted subjects to do (i.e., drink water until flowers blossom on the tree), but was unconcerned about what subjects wanted. Both social and system feedbacks offered extrinsic motivation to subjects by putting them under the pressure of social conformity and responsibility for the health of a virtual tree. The findings of our focus group interviews show that subjects experienced unwanted pressure and developed a negative feeling of deprivation.

It is important to try to minimize the negative effects of a persuasion system. This study proposes two approaches for doing so. The first approach is to design feedback that asks about their preferences and offers them choices in selecting the most appealing interface to boost their motivation. For example, instead of the tree feedback, some subjects may prefer fish [Lin 2006], polar bears [Froehlich 2009], or cartoon characters [Lo 2007], etc. Previous studies [Chorpita 1998; Lo 2009; Mirowsky 1991; Ross 1999; Seeman 1883] indicate that presenting choices to subjects gives them a sense of internal control of the outcome of an activity, reduces their sense of pressure, and improves their task satisfaction.

The second approach is to design feedback that enables subjects to discover their "own creative ways" of using the persuasion system, rather than being told by the system exactly what to do and what not to do. That is, rather than assuming that users should obey instructions from the system (i.e., using falling leaves as a directive to drink water), a more subtle persuasion system would use subjects' own clever ideas to create self-improvement systems. This could be realized by presenting a persuasion system as a tool that enables subjects to construct their own persuasion interface. For examples they could tailor how and when the system communicates with them under different behavioral conditions, their preferred form of behavior reinforcement and rewards, and how to adjust the difficulty and progression of the behavior modification program, etc.

4.3 Combine positive with negative reinforcements

The design of the Playful Bottle is unlike most other persuasive technology projects, such as UbiFit Garden [Consolvo 2008] or Houston [Consolvo 2006]. Playful Bottle uses negative reinforcement to persuade people to drink water. For instance, if the user's water intake is too low, the user's tree withers on the screen. However, this system also uses positive reinforcements, such as flowers and rainbows. On this topic, we found a surprising result in the quality interview. Subjects mentioned they had a very strong affinity for the flower, more than other components in the game. A subject said "The flower is very courageous." Another subject said, "When I saw the flower had disappeared, I would drink immediately, and the flower would emerge again." Moreover, both females and males are sensitive to the flower. A male subject said "I was very happy when I saw the flower on my avatar. At that moment, I thought that I drank enough water and I felt good." Further discussion suggested that if positive reinforcements were presented in an environment of negative reinforcements, users felt a noticeable positive/negative contrast in game reinforcements and this contrast could make a positive reinforcement "stand out." For example, since ForestGame subjects were always under pressure of their tree fading (i.e., a negative reinforcement), the flower (i.e., a positive reinforcement) not only represented a reward for good drinking behavior, but also released subjects from the fear of their tree fading right away. In other words, we learned that a persuasion system could be more powerful and persuasive when positive reinforcements were included in a system whose design base used negative reinforcements.

Next, this study extends the outlook of this finding to Persuasion Technology. Recall what people do when teaching children: they give out encouragement when children behave well, and give out punishment when children behave badly. Most of the time, these two methods are used in conjunction instead of just one of them. We believe that the same strategy should be carried out when trying to persuade people to change undesirable habits. In our user study, we found that compared with traditional systems that only used positive feedback, such as UbiFit Garden [Consolvo 2008] and Houston [Consolvo 2006], the use of both positive and negative feedback in the Playful Bottle system created a greater impression on users.

The results of this study contradict the fifth strategy in Theory-Driven Design Strategies for Technologies that support behavior change in everyday life [Consolvo 2009], which claims that only positive feedback can effectively improve behavior. Although positive reinforcement is generally regarded as more desirable than negative reinforcement or punishment, the distinction between positive and negative reinforcement has proven difficult [Baron 2006]. When the distinction is made purely in operational terms, experiments reveal that positive reinforcement has aversive functions. On a practical level, positive reinforcement can lead to deleterious effects, and is implicated in a range of personal and societal problems [Perone 2003].

The focus groups in this study show that on one hand, using withering trees as a drinking reminder can arouse users' empathy and be viewed a punishment. On the other hand, the flower shown when users behave well makes them feel proud and confident. This mixed withering tree and flower approach makes the flower more stand out than usual, and users tend to focus on the flower. More than 70 percent (5/6) of all subjects using TreeGame aimed to obtain the flower. One possibility for this majority is that while both positive and negative reinforcement strengthen behavior, their strengthening effects are in some important way different from one another. This implies that using a mixture of both positive and negative feedback to motivate people can actually be more effective than using only positive feedback when designing persuasion technology objects.

CHAPTER 5

RELATED WORK

Many researchers have examined how persuasive technology can motivate behavioral change in our living environment. Their work can be divided into three categories: (1) design theories and strategies for persuasive technologies, (2) computer-mediated social persuasion systems targeting specific everyday behaviors, and (3) non-social computer persuasion systems targeting specific everyday behaviors.

King et al. [King 1999] described five persuasive strategies for using digital technology to change people's attitudes and behaviors, four of which are relevant to the proposed Playful Bottle system: virtual groups, simulated experience, surveillance, and an environment of discovery. The virtual group strategy motivates people through collaboration or competition in a group setting. The simulated experience strategy simulates an environment or object, sufficiently similar to its real-life counterpart, which enables users to experience the results of different behavior choices. The surveillance strategy uses monitoring and tracking to affect behavior. The environment of discovery strategy presents a fantasy environment in which positive rewards are given for good behavior. Fogg [Fogg 2003], a pioneer in the Captology field (i.e., the study of computer-based persuasion), proposed a functional triad for analyzing how people view or respond to computers: as tools, as media, or as social actors. Different functions suggest different types or designs of persuasive influence. Consolvo et al. [Consolvo 2009] listed eight design strategies for persuasive technologies that target everyday use. The Playful Bottle system relates to three of the eight design strategies: abstract and reflective, public, and aesthetic. The abstract tree presentation on the mobile display enables users to quickly see and understand whether or not their current water intake volume is sufficient. The bottle's display adapts the public design strategy, in which nearby people or group members can observe the user's drinking behavior. Finally, the tree and forest visualization is not only functional, but also aesthetic.

The second category of related work targets computer-mediated social persuasion. Waterbot [Arroyo 2005] is a device installed at a bathroom sink to track the amount of water used in each wash. This system contains flow sensors to detect the amount of water usage. By displaying current water usage compared to average household water usage, the system encourages behaviors that conserve water. Fish'n'Steps [Lin 2006] is an interactive computer game that encourages physical activity. This game is based on a metaphor in which the act of exercising the body by walking symbolizes the act of growing a virtual fish in a tank. That is, the more players walk, the bigger their virtual fish grow. By showing the fish of different players in the same virtual fish tank, this game adds the elements of social competition among players. Houston [Consolvo 2006] is a mobile phone application that encourages physical activity by sharing step counts and supportive comments among friends. Sharing step counts and supportive comments provides a social influence to persuade users to increase their daily step counts. Chick Clique [Toscos 2006], a preventive health application on a mobile phone, motivates teenage girls to exercise by exploiting their social desire to stay connected with their peers. MAHI [Mamykina 2008] is a health monitoring application that assists individuals recently diagnosed with diabetes to acquire and develop reflective thinking skills through social interaction with diabetes educators. Gasser et al. [Gasser 2006] compared the effectiveness of a mobile lifestyle coaching tool and a traditional desktop web application.

The results of their comparison studies reveal no significant differences in lifestyle goal achievement, task compliance, and usage patterns between the mobile and desktop applications. Additionally, they did not find any difference between the group with social facilitation and the group without, which is in contrast to the current findings. We believe that this difference in findings is based on significant difference in targeted behaviors and game design.

The third category of related work includes attempts to exploit smart everyday objects for behavior modification without the intervention of social power, which generates both positive and negative influence. The Playful Tray [Lo 2007] monitors the eating habits of a child through a mobile weight-sensing tray. The eating actions are then communicated via Bluetooth to a mobile phone and used as inputs for a game on the mobile phone. The game is designed to encourage positive eating behaviors by integrating digital play with eating. The UbiFit Garden [Consolvo 2008] senses and encourages different types of physical activities. UbiFit displays user exercise levels using a virtual flower garden shown on a cell phone screen. The UbiGreen project [Froehlich 2009] used personal ambient displays on mobile phones to provide environmental feedback to users about their transportation behaviors to persuade them to adapt transportation choices with less impact on the environment. Vito (as opposed to TiVo) [Nawyn 2006] is a persuasive TV remote control implemented on a PDA. This technology targets excessive TV watchers. By suggesting alternatives to TV watching, such as playing Non-Exercise Activity Thermogenesis (NEAT) games (i.e., simple puzzles that use physical activity as their input), ViTo promotes reduced television viewing time. The Playful Toothbrush [Chang 2008] is an augmented toothbrush that helps parents and teachers motivate kindergarten children to learn proper and thorough tooth brushing skills by linking their brushing actions to a game. The Nutrition-aware Kitchen [Chen 2010] is a smart kitchen that uses UbiComp technology to improve home cooking by providing calorie awareness of food ingredients used in prepared meals during the cooking process. The kitchen has sensors to track the number of calories in food ingredients and provides real-time feedback to users through an awareness display. Breakaway [Jafarinaimi 2006] encourages people whose job requires them to sit for long periods of time to take breaks more frequently with an ambient display. Superbreak [Morris 2008] is a break reminder program that encourages computer users to periodically take a break from typing to prevent repetitive strain injuries. This program motivates users to take a break by interrupting them with several fun hand-gesture game activities that are keyboard-free and mouse-free.

This study compares the above two approaches (social persuasion and non-social persuasion) to determine which method is more effective in constructing a system for encouraging healthy water drinking behaviors. Both methods enhance the effect of mobile persuasion in guiding and motivating healthy water drinking in university office workers. Furthermore, a group collaborative approach using computer-mediated care-giving and care-receiving has a greater effect on usage. This study shows that multi-user social persuasion is a good match for behavior modification.

CHAPTER 6

CONCLUSION & FUTURE WORK

This study presents a social persuasion system consisting of a mobile phone and an everyday object to sense and influence an everyday behavior associated with that everyday object. This social persuasion system, called Playful Bottle, digitally interfaces the physical activity of drinking water with a social game of care-giving and care-receiving to guide and remind office workers to drink sufficient amounts of water on a regular basis. We conducted a 10-week quantitative user study and qualitative focus group interviews. We observed how users interacted with each other through the systems' care-giving and care-receiving interface and how the system's social effect influenced drinking behaviors. Our main finding reveals the importance of rewarding caregivers and producing positive group dynamics, as a social persuasion system does not work without caregivers and their continuous care-giving efforts. Other findings are that care-receivers should be able to respond to caregivers other than by drinking water, heart receiving was linked with under-performance, individual preferences differed on what were considered as helpful game features, individuals felt pressure to perform, and technology-based intervention produced novelty effect.

Based on the findings of our user study, we share lessons learned on how researchers in the persuasive computing community can improve the effectiveness of their social persuasion systems. The main lesson is to motivate the motivators by exploring both human and system feedback channels to encourage caregivers and care-giving actions. The second lesson is to reduce performance pressure for users, explore ways to give users choices in personalizing their interfaces, and furthermore, present the system as a tool with which users can create their own clever self-improvement systems. The third lesson is that positive reinforcements can stand out and become stronger when they are combined with negative reinforcements in a persuasion system.

Designing effective digital persuasion systems remains challenge task for future research. We hope that this study will lead to design and technology opportunities for the research community to explore.

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