Playful Bottle: a Mobile Social Persuasion System to Motivate Healthy Water Intake

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ABSTRACT

This study of mobile persuasion system explores the use of a mobile phone, when attached to an everyday object used by an everyday behavior, becomes a tool to sense and influence that behavior. This mobile persuasion system, called Playful Bottle system, makes use of a mobile phone attached to an everyday drinking mug and motivates office workers to drink healthy quantities of water. A camera and accelerometer sensors in the phone are used to build a vision/motion-based water intake tracker to detect the amount and regularity of water consumed by the user. Additionally, the phone includes hydration games in which natural drinking actions are used as game input. Two hydration games are developed: a single-user TreeGame with automated computer reminders and a multi-user ForestGame with computer-mediated social reminders from members of the group playing the game. Results from 7-week user study with 16 test subjects suggest that both hydration games are effective for encouraging adequate and regular water intake by users. Additionally, results of this study suggest that adding social reminders to the hydration game is more effective than system reminders alone.

Author Keywords
Persuasive technology, mobile computing, ubiquitous computting, hydration behavior.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human factors

INTRODUCTION
Water is essential for all life on earth, including humans.

Since water comprises 60%~70% of human body weight, sufficient water is needed to replenish bodily fluids and maintain health. However, recent studies [5] indicate that at all ages, most people do not drink enough water. Such chronic water deficiency can cause both long and short term health-related problems such as constipation, light-headedness, headache, shriveled skin, muscle spasms, mental status change, fatigue and etc.[25] The reported [4] benefits of adequate fluid intake include appetite suppression, healthy skin and removal of harmful bodily toxins. To keep the body healthy, constant hydration is essential. 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 along with a normal diet [24]. Factors affecting individual water needs include exercise habits, environmental temperature, health condition, pregnancy and, in new mothers, frequency of breast feeding.

Several commercial products for tracking water intake include HydraCoach [15] and Fluid Intake Tracker (F.I.T.) [11]. Although these products automatically or manually track water intake, they do not actively remind or motivate users to regularly drink sufficient quantities of water.

The work focuses on the design and evaluation of a Playful Bottle system that includes two games played on a mobile phone, the TreeGame and the ForestGame, to encourage healthy and regular water intake by office workers. The system reminders in the single-user TreeGame remind users to drink water according to their current water intake. Conversely, in the multi-user ForestGame game based on social reminders, hydration reminders from users are mediated by the system and sent to other users. The results of a 7-week user study of University office workers, as described in the user study section, suggest that the Playful Bottle improves the quantity and regularity of water intake by users. Additionally, the user study results suggest that social persuasion

enhances the effectiveness of the Playful Bottle more than system persuasion alone.

Social Persuasion
A growing interdisciplinary body of literature explores sociological and psychological aspects of computer-mediated communication (CMC). Persuasion computing is one technique that uses CMC as a medium for shaping individual behavior. Two intensively studied venues are system persuasion and social persuasion. 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 disapproval from peers [3][10][22]. Conformity can be defined as a personal behavioral change due to group influence, which increases the congruence between the individual and the group [1].

Organization
The rest of this paper is organized as follows. The Playful Bottle prototype is described including its physical components, the water intake tracker and the hydration games. The next section details the 7-week user study using randomized controlled trial design. Then, the related work is reviewed. Conclusions are finally drawn along with recommendations for future research.

PROTOTYPE DESIGN
Figure 1 shows the three components of the prototype Playful Bottle: the water bottle (Figure 1(a)), the mobile phone (HTC Touch Diamond) (Figure 1(c)), and the bottle-phone attachment constructed from various LEGO bricks (Figure 1(b)). The LEGO attachment piece is permanently glued to the outside of the water bottle and is used as a phone holder. A flat 2x2 LEGO brick glued to the back of the mobile phone (Figure 1(d)) enables easy attachment to the water bottle to use the mobile persuasion system and easy detachment from the water bottle to make or receive calls on the phone. 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.

The Playful Bottle system includes three main software components on the mobile phone: (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 drinking actions of the user as game input and (3) a system log for recording user and system events. The water intake tracker and the hydration games are explained below.

Water Intake Tracker
In an office environment, drinking from a bottle or mug typically involves the following four steps: (1) lift the bottle from a surface and move it toward the mouth; (2) tilt the bottle so that the liquid flows into the mouth; (3) if necessary, continue holding the bottle while repeating the second step; (4) place the bottle on the desk.

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.

Motion-based Drinking Action Detection
Drinking motions such as picking up the container, tilting it back to drink and placing it on the desk are detectable by the accelerometer attached to the mobile phone. The motion-based detection of drinking actions works as follows. First, the accelerometer sampling rate on the mobile phone is set to 2 Hz, which is fast enough to recognize a drinking motion. Second, 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. Third, 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 when the water inside the bottle stabilizes to form a steady water line. This steady state triggers the vision-based water-level detector using the mobile phone's camera located on its back side. The experiments revealed that a 5-second time window is long enough for the water contained in the bottle to stabilize after movement. If the system detects further drinking actions during this 5-second window, it restarts the 5-second window countdown to water-level detection and records both drinking actions as a single drinking action. When a user refills water to the bottle, there may not be a tilting motion to trigger new water level detection. Therefore, a user presses a refill button located on the upper right corner of the phone display (shown in Figure.5) to activate the detection process.

Evaluation of Motion-based Drinking Action Detection System
Figure 2 shows the results of tests to determine the accuracy of the motion-based drinking action detection system. The data are for the final day of the user study with a tilt angle threshold of 30 degrees and a 5-second steady window. At these settings, the system accurately detected all drinking actions by the users. However, several (21.1%) false-positive detections occurred when users were shaking the bottle rather than actually drinking from it. Although these false positives wasted battery power by triggering the mobile phone camera and processing the camera image, they did not affect the hydration games as the camera images revealed no changes in water level.
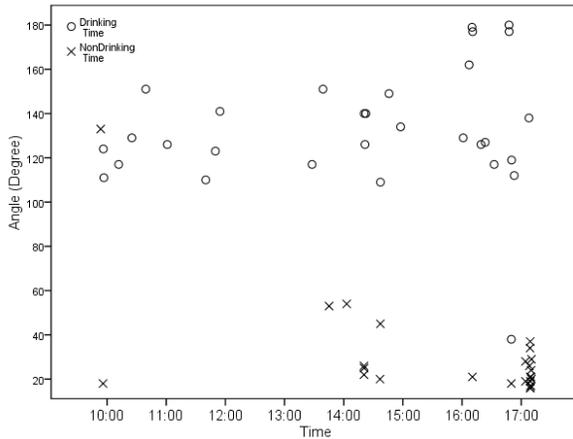
Figure 2. Accuracy of the motion-based drinking motion detection system during a single day by user subject. The "o" indicates true positive, and the "x" indicates false positive.

Vision-based Water Level Detection Algorithm

To avoid privacy issues arising from use of the mobile phone camera in an office environment, its focal length were intentionally adjusted to blur all captured images such that any accidentally captured faces or objects were indistinguishable. 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 Figure 3, parallel rows of bars were painted on the outer surface of the bottle so that they could be imaged 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 4 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 depending on whether the bars were above, near or 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 considerably affected by water refraction, appeared much thinner than normal and became indiscernible near the bottom of the bottle.

The vision-based water level detection algorithm works as follows. In step (1), when the accelerometer-based motion detection recognizes a possible drinking action, it triggers the phone's camera to capture a water level image of the bottle. In step (2), the image is cropped to the area covering only the pattern bars. Additionally, the image is enhanced to reduce the blurring and refraction distortion effects of fog and mist formed inside the bottle and resulted from drinking hot water. Note that drinking hot water is common for people in Taiwan. The image enhancement techniques uses median filter to filter out noises and overlapping local

Figure 3. Pattern bars are shown on the right. The pattern bars painted on the outer surfaces of water bottle are shown on the left.

Unaffected by water refraction with normal size

Slightly affected by water refraction with moderate size shrinkage

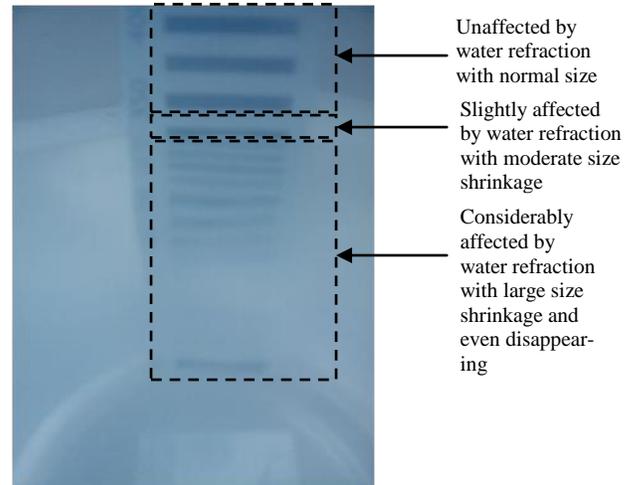Considerably affected by water refraction with large size shrinkage and even disappearing

Figure 4. A sample camera photograph of the interior of the bottle. Water refraction affected the size of the pattern bars differently depending on whether the bars were above, near or below water level.

equalization to increase contrast and reduce unbalanced lightness in the image. Furthermore, image binarization is applied to 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 is used to identify tilted pattern bars in the image. In Step (3), 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, are extracted. In step (4), these extracted features are fed as inputs to a decision tree classifier, which then outputs the position of the water line. The decision tree classifier was trained offline using several hundred images with different water levels.

Evaluation of Vision-based Water Level Detection

An experiment was performed to determine the accuracy of the vision-based water intake tracker. Data were analyzed

from 6,077 images captured over 4-week intervention phase of the user study (described in the next section) involving 16 test subjects. The error rates were calculated as follows. First, these 6,077 water-level images processed by the vision-based water level detection algorithm were logged and hand-labeled with the ground-truth water levels. Recognition accuracy was then computed as the difference between recognized water level from the vision-based detection and the ground-truth water level labeled by humans. Since each water-level detection was independent, there was no error propagation effect from one image to the next one. Table 1 shows the average error rate over the 16 subjects to be 3.86%.The user study did not indicate that this small amount of recognition errors confused or otherwise, affected the subjects.

Subjects	Daily water intake AVERAGE (ml)	Daily detection error AVERAGE(ml)	Error Rate(%)
1	778	28	3.54%
2	1,108	47	4.28%
3	1,110	41	3.72%
4	1,762	80	4.56%
5	1,290	49	3.78%
6	1,562	97	6.21%
7	836	42	5.04%
8	964	19	1.95%
9	1,089	74	6.77%
10	744	30	4.03%
11	1,472	18	1.25%
12	1,294	21	1.64%
13	1,358	15	1.10%
14	1,068	50	4.68%
15	1,153	19	1.63%
16	654	50	7.65%
Average			3.86%

Table 1. Daily water intake error rate in the vision-based water-level detection for sixteen subjects during 4-week intervention phase.

Additional Implementation Details

To effectively implement the system, two key tasks were selecting an appropriate water bottle and a mobile phone attachment. A transparent bottle was needed so that the camera could acquire a clear image of the water line. Additionally, the aggregate weight of the mobile phone, the bottle and the phone-bottle attachment could not be excessively heavy to users. The aggregate weight of the prototype was 210 grams. Additionally, the phone and attachment were positioned to avoid interfering with the expected handling of the bottle by the user.

Other important considerations were the position and vertical tilt angle of the mobile phone to the bottle, which had allow the mobile phone camera to capture images of the bottle interior at a wide viewing angle so that a wide range of water levels from high to low could be detected. Experimentation with the bottle in various positions revealed that the ideal position for the smart phone was at a 60-degree angle to the flat plane with its bottom 2.9 cm from the surface (Figure 3). Other bottles would likely require different settings.

Hydration Games

Two hydrations games were developed to remind and encourage users to regularly drink healthy amounts of water. Figure 5 and 6 show 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 (Figure 5), would slowly transform from a beautiful green tree with many leaves (Figure 6(a)) to one with bare and withered branches (Figure 6(e)). In both hydration games, the virtual tree could go through five progressive stages of withering. In addition to the visual display of withering, changing tree levels were accompanied by a vibration, which provided an additional system 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 so as to avoid disrupting the daily activities of the user.
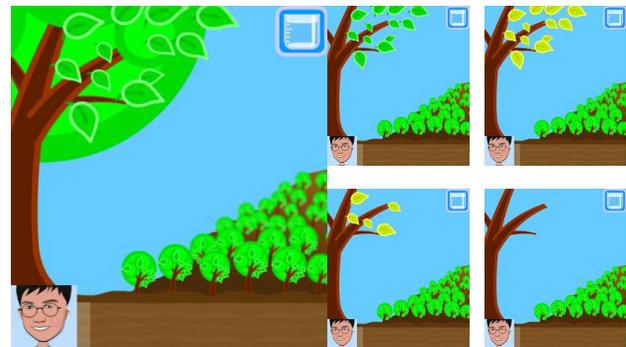

Figure 5. On the left is a screenshot of the single-user Tree-Game (the refill button is in the upper right corner). On the right is the five-level sequence (the first level is shown on the left) of withering trees.
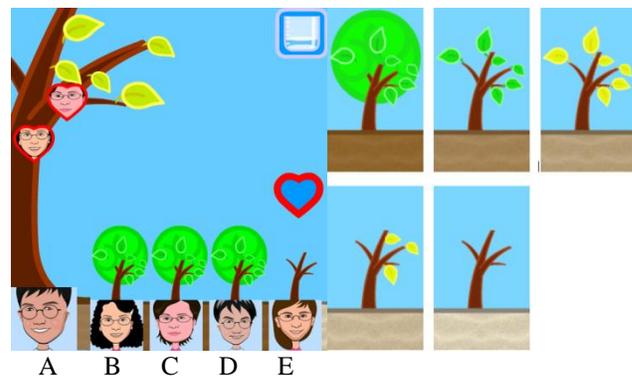

Figure 6. On the left is a screenshot of the multi-user Forest-Game. On the right is the five-level sequence of withering trees.

One hydration game is single-user, and the other is multi-user. The single-user TreeGame displays an avatar of the player below his/her tree (Figure 5, left). The multi-user ForestGame interconnects the Playful Bottles of multiple players via the WiFi networking capabilities of the mobile phones. Figure 6 (left) displays a screenshot of avatar images for five players and their virtual trees above their avatars. By interconnecting their Playful Bottles, players could monitor changes in the tree levels and water drinking habits of other players. This virtual grouping in the ForestGame introduces elements of social persuasion through competition between players. In addition to competition, the ForestGame is designed to transform 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 sufficient water, which 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. Sending a social reminder works as follows. First, the caregiver simply touches the tree icon representing the care-receiver on the phone screen to send a social reminder. A loving heart representing the sender then appears above the tree (Figure 6, left). Upon receiving the social reminder, the care-receiver sees a new loving heart (along with an avatar representing the caregiver so that the care-receiver can identify the caregiver) dangling on the tree of the care-receiver (Figure 6, left). When the care-receiver then responds to the social reminder by drinking water, a loving hearts animation appears and the virtual tree progresses one level forward. At the same time, to acknowledge that the care-receiver has responded to the loving heart of the care-giver, the phone screen of the caregiver also plays a short animation. Finally, at the end of the social reminder, the loving heart on the phone screen of the caregiver disappears to complete the social reminder.

Figure 6 (left) shows a screenshot of the ForestGame. The player is at tree level 3. She has received loving hearts from players B and C and has sent loving hearts to player E. However, player E has not responded to her loving heart by drinking water.

The ForestGame is designed to introduce virtual group competition and, more importantly, social persuasion through care-giving mediated by computers. Including computer-mediated social persuasion in the ForestGame was intended to enhance the effectiveness of Playful Bottle in motivating and changing healthy water drinking behaviors, in addition to the system persuasion in the TreeGame. The user study described in the next section tested this hypothesis.

USER STUDY

The effectiveness of the Playful Bottle system was tested in a 7-week user study using randomized controlled trial design. This section describes the design and the experimental results of the user study, which were guided by the following inquiries.

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

Exactly how the Hydration games impact drinking behaviors was evaluated by comparing typical drinking behavior without playing the games (i.e., baseline performance) with that while playing the games. 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 Tree-Game and ForestGame conditions. The following sections describe details of the user study.

Subjects. Sixteen university hospital staffers (thirteen female, three male; mean age 38.06 years; age range 26~51 years old) were recruited for this user study. Table 2 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 for NT$500 (approximately US$15) per week.

Figure 7. Sixteen Playful Bottles.

Procedure. Two hydration games developed for the Playful-Bottle system were used on different groups of the 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 PlayfulBottle was also implemented to record baseline drinking behaviors. Although the mobile phone screen provided no feedback to user drinking actions, the water intake tracker active in the

background recorded water intake from the bottle. NoGame was used to track the baseline water intake of users before using the TreeGame and ForestGame with varying feedback.

Groups	Subjects	Sex	Age	Weight	Daily baseline 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
Tree-Game	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

Table 2. Profiles of sixteen subjects (three groups of 5-6 subjects each).

The user study trial was performed during workdays over 7 weeks. Two phases of the trial were (1) pretest and (2) intervention. During the 3-week pretest phase, subjects were asked to drink water using our Playful Bottle. During the 4-week intervention phase, the sixteen subjects were randomly divided into three groups: the Control and the Forest-Game groups had five subjects each, and the TreeGame group had six subjects. Different Playful-Bottle systems were given to different subject groups to measure change in their drinking behaviors. For the ForestGame group, the subjects played the ForestGame. For the TreeGame group, the subjects played the TreeGame. For the Control group, the subjects played NoGame as the pretest phase.

Subjects' characteristics at pretest, including sex, ages, weight, and the average daily baseline water intake (measured from the pretest phase described later) are tested by Kruskal-Wallis test for continuous variables and by Fisher's exact test for categorical variables. There are no significant differences between groups in sex ($p=0.7321$), ages ($p=0.4796$), 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 pretest phase in which subjects used our PlayfulBottle system to track their water intake during their office hours (8:30AM to 4:30PM) but without playing any hydration game.

Since the three groups followed different games 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 their 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.

Measures. To determine how effectively the system improved water intake by the subjects, the primary measure was the daily water intake volume from our Playful Bottle system per subject. Note that the daily water intake tracks only the water consumed from the Playful Bottle system during subjects' working hours from 8:30 AM to 4:30 PM. The secondary measures were the regularity (frequency) of water intake, and the response time in drinking some water to 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) receiving heart event and (5) tree change event.

Results. The equality of each evaluated variable among three groups (ForestGame, TreeGame and Control) is examined based on ANOVA with factors of the game condition group and the experimental day during intervention. As well as, multiple comparisons between pairwise group conditions are tested by Tukey HSD test.

Figure 8 plots the average daily water intake for the three groups (ForestGame, TreeGame and Control) during the 7-week user study period. Column 2 in Table 3 calculates the improvement of water intake volume, which is measured as the difference between the average daily water intake during pretest and the daily water intake during intervention. There is a significant difference among group conditions in improvements in water intake volume ($F(2, 253)=43.785$, $p<0.0001$), where improvements in daily water intake of the Control, TreeGame, and ForestGame groups were -43ml, 153ml, and 305ml respectively. Pairwise comparisons show significant differences between Control and TreeGame ($p<0.0001$), Control and ForestGame ($p<0.0001$), and TreeGame and ForestGame ($p<0.0001$), which suggested that the daily water intake volume of the ForestGame group was higher than that of the TreeGame and Control groups, and the daily water intake volume of the TreeGame group was higher than that of the Control group.

Column 3 of Table 3 shows the 7-week result of regularity of daily water intake (or the average drinking interval) from the three groups. The improvement was measured as the difference between the average drinking interval during pretest and the drinking interval during intervention. Improvements in the regularity of water intake reveals that a significantly difference among groups ($F(2, 253)=3.58$, $p=0.029<0.05$), where the drinking interval of Control, TreeGame, and ForestGame were -24sec, -298sec, and -400sec respectively. Control and ForestGame show a pairwise significant difference ($p=0.023<0.05$), suggesting that the regularity of water intake of the ForestGame group was higher than that of the Control group.
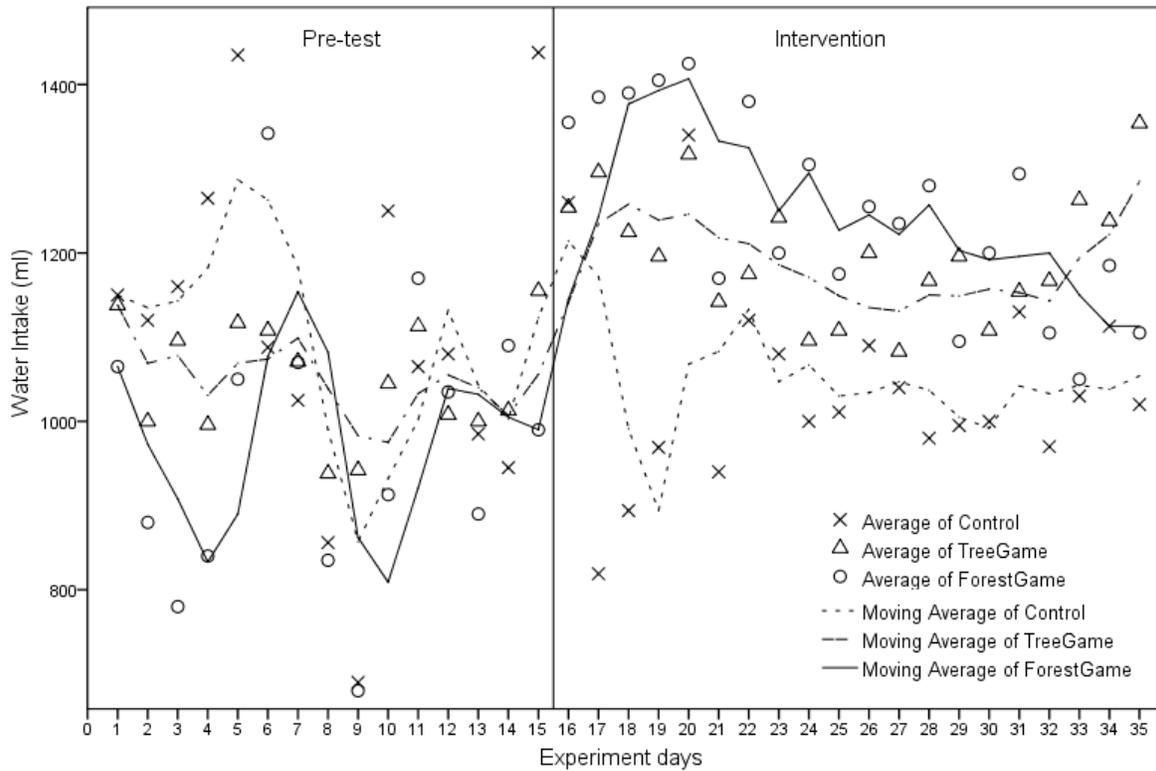
Figure 8. Daily water intake volume for the three groups (ForestGame, TreeGame and Control) over the 7-week user study period. Unweighted moving averages are plotted using a window size of 3 days. The 3-week pretest phase is from day 1 to day 15, and the 4-week intervention phase is from day 16 to day 35.

	Improvement in the volume of daily water intake (ml) AVERAGE(SE)	Improvement in the regularity (interval) of water intake (sec) AVERAGE (SE)
NoGame		
Week 4	64	-377
Week 5	-76	343
Week 6	-85	-7
Week 7	-63	-61
Average	-43(27)	-24(104)
TreeGame		
Week 4	207	-501
Week 5	102	-353
Week 6	113	-69
Week 7	185	-260
Average	153(24)	-298(93)
ForestGame		
Week 4	439	-377
Week 5	293	343
Week 6	294	-7
Week 7	184	-61
Average	305(26)	-400(102)

Table 3. Improvements in the daily water intake volume and **regularity (drinking interval) for sixteen subjects (n=16).**

Row 5 of Table 4 shows the median response time of users to system reminders (i.e., withering tree) and social remind-ers (i.e., receiving a heart from a group member) during the ForestGame period. Note that both TreeGame and Forest-Game provided system reminders. Response times for system reminder 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 reminder was calculated as the interval between the time when the phone presented the 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 different reminders. There were 21 censored events which were not responded by users when a reminder displayed, including two (4%) events of heart-sending in ForestGame, 11 (2%) events of system reminders in Forest-Game, and 8 (2%) events of system reminders in TreeGame. The median response time, which means the duration for 50% events of reminders responded, to system reminders in TreeGame is 1,131 seconds; to system reminders in Fo-restGame is 1,216 seconds; to social reminders in Forest-Game is 717 seconds. As well as, the analysis reveals a significant difference between response time of reminders with p=0.0039, suggesting that users responded to social reminders faster than to system reminders. Figure 9 presents the estimates of response probability based on survival analysis.

	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)

Table 4. Characteristics of response times (i.e., responding by drinking water) from receiving system reminders (withering tree) and social reminders (heart-giving from group members) (n=11).
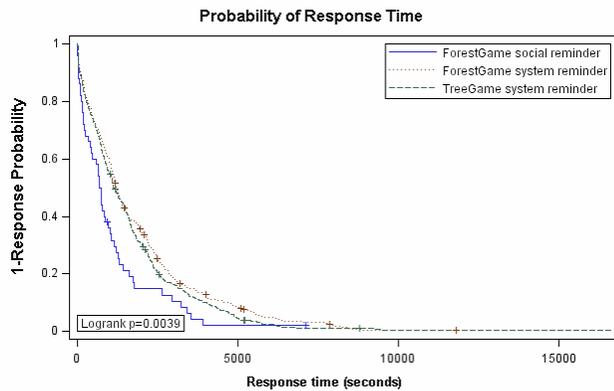

Figure 9. Probability function estimates of response time from receiving reminders among three groups

To summarize our results in the previous section, social and system reminders are effective in improving the water intake volume with social reminders being more effective than system reminders. Second, social reminders are effective in improving the water intake regularity. Last, users respond to social reminders faster than they respond to system reminders.

DISCUSSION

We have found several interesting issues for discussion here: (1) social interaction in the ForestGame group and (2) support for social conformity theory.

The mechanisms of the positive impacts of ForestGame on motivating healthy drinking behavior might be related to enhancing people's caring behaviors through the heart-giving and people's desire to meet social expectation through heart-receiving in social reminder. For example, Table 5 shows the social interaction (i.e., heart-giving and heart-receiving) among the five subjects in the ForestGame group. From analyzing the 50 heart-giving/heart-receiving events, we found that different subjects moved into the role of caregiver or that of care-receiver in the ForestGame. For examples, subjects #3, #4 and #5 were the main caregivers by sending most of the heart reminders (22, 13, 13 heart reminders respectively), whereas subjects #1 and #2 acted as care-receivers from receiving most of heart reminders (21 and 16 heart reminder respectively). For subject #3, her

desire to become a caregiver gave her the motivation to improve her daily water intake from 630 ml (pretest) to 1,165 ml (game play intervention).

Table 6 shows the standard deviations of daily water intake volume of three groups. They shrink from pre-test to intervention phases suggesting that increased congruence between the individual and the group. For example, in ForestGame group, SD shrinks from 506.32 in pre-test phase to 409.84 in intervention phase. This increased congruence supports the theory of social conformity in behavior change.

	# of heart reminders received by each subject					
Subjects	1	2	3	4	5	Total
1		4	0	1	0	5
2	0		0	0	0	0
3	13	2		3	4	22
4	4	5	4		0	13
5	4	5	4	0		13
Total	21	16	8	4	4	

(left-side rotated label: # of heart reminders sent from each subject)

Table 5. Social interaction in ForestGame. It tracks the number of heart reminders sent by and received from each of 5 subjects in the ForestGame.

	Pretest: SD of water intake volume	Intervention: SD of water intake volume
ForestGame	506.33	409.84
Control	489.79	405.37
TreeGame	372.67	337.56

Table 6. Standard deviations of daily water intake volumes of three groups in pre-test and intervention phases.

RELATED WORK

King et al. [17] described five persuasive strategies of using digital technology to change people's attitudes and behaviors. Among the five persuasive strategies, four are relevant to the proposed Playful Bottle system: virtual groups, simulated experience, surveillance and 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 [12], 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 of or designs for persuasive influence.

Many researchers have examined how persuasive technology in our living environment can motivate behavioral change. Their work can be grouped into two general categories: (1) computer-mediated social persuasion and (2) non-social computer persuasion.

The first category targets computer-mediated social persuasion. Waterbot [2] is a device installed at a bathroom sink to track the amount of water used in each wash. The system contains flow sensors to detect the amount of water usage. By displaying current water usage in comparison to the average household water usage, the system encourages behaviors that conserve water. Fish'n'Steps [18] is an interactive computer game that encourages physical activity. This game is based on a metaphor in which the act of growing a virtual fish in a tank symbolizes the act of exercising the body by walking. That is, the more players walk, the bigger their virtual fishes grow. By showing fishes from different players in the same virtual fish tank, this game adds the elements of social competition among players. Houston [8] 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 [23], 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 [20] is a health monitoring application that assists newly diagnosed individuals with diabetes in acquiring and developing reflective thinking skills through social interaction with diabetes educators. Gasser et al. [14] compared the effectiveness between a mobile lifestyle coaching tool and a traditional desktop web application. The results of their comparison studies revealed no significant differences in lifestyle goal achievement, task compliance, and usage patterns between the mobile and desktop application. Additionally, they did not find any difference between a group with social facilitation and a group without, which is in contrast to our finding. We believe that such difference in findings is expected given the significant difference in targeted behaviors and the game design.

The second category includes attempts to exploit smart everyday objects for behavior modification without intervention of social power which generated both positive and negative influence. The Playful Tray [19] monitors the eating actions of a child through a mobile weight-sensing tray. The eating actions are then communicated via Bluetooth to a mobile phone and used as input to play a game on the mobile phone. The game is designed to encourage positive eating behaviors by integrating digital play with eating. The UbiFit Garden system [9] encourages physical activities by sensing and detecting physical activities. UbiFit displays user exercise levels on a virtual flower garden shown on a cell phone screen. The UbiGreen project [13] explored the use of personal ambient displays on mobile phones to provide environmental feedbacks to users about their transportation behaviors in order to persuade them to adapt transportation choice with less impact on the environment. Vito (as opposed to TiVo) [21] 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 the 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 [6] is an augmented toothbrush that assists parents and teachers in motivating kindergarten children to learn proper and thorough tooth brushing skills by linking their brushing actions to a game. The Nutrition-aware Kitchen [7] 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 [16] encourages people, whose job requires them to sit for long periods of time, to take breaks more frequently with an ambient display.

This study compares the above two approaches (social persuasion and non-social persuasion) to verify which method to construct an system for encouraging healthy water drinking behaviors is more effective. Both methods enhance the effect of mobile persuasion in the case of guiding and motivating healthy water drinking in university office workers. Furthermore, a group collaborative approach using computer-mediated care-giving and care-receiving is more effective than the non-social system approach alone. According to the studies and experience of the authors, multi-user social persuasion is good match for behavior modification.

CONCLUSION AND FUTURE WORK

This study developed a Playful Bottle system using a mobile phone and an everyday object, i.e., a drinking bottle, to monitor and influence an everyday behavior, i.e., hydration. The Playful Bottle is designed to digitally interface the physical activity of drinking water with an enjoyable game to guide and remind office workers to drink sufficient amounts of water on a regular basis. Two persuasion strategies, computer-automated reminders and computer-mediated social reminders, were implemented and tested. The results of our user study, based on a randomized trial design, suggest that the Playful Bottle improves the amount and regularity of water intake in the examined university office workers. Additionally, the user study results suggest that computer-mediated social persuasion further enhances the effectiveness of the Playful Bottle in comparison to the computer-automated persuasion alone, as measured by the shorter response time of subjects to social reminders than that to system reminders.

Future work will continue our user study with the 3-week posttest phase when the games will be turned off to test the effects of a Playful Bottle system on maintaining long-term

healthy water drinking behavior. We will then conduct pretest-posttest comparisons to assess the learning effectiveness of our Playful Bottle system. Additionally, we will invite all test subjects to participate in the focus group after completing the user study. The focus group will explore qualitatively how the two hydration games influenced the drinking behavior of the subjects.

We believe that there are many potential applications for exploring computer-mediation persuasion framework and mobile phone technology for other collaborative human behavioral changes, such as energy and resource conservation behaviors, household spending habits and school studying habits. We are looking forward to exploring these behavioral domains.

REFERENCES
1. Allen, V.L. Situational factors in conformity. *Advances in Experimental Social Psychology 2*, 1965, 133-170.
2. Arroyo, E., Bonanni, L., and Selker T. Waterbot: exploring feedback and persuasive techniques at the sink. In *Proc. CHI2005*, ACM Press (2005), 631-639.
3. Asch, S.E. Opinions and social pressure. *Scientific American*, 193, 1955, 31-35.
4. Batmanhelidj F. Your Body's Many Cries for Water. *Global Health Solutions 18*, Elsevier (2005), *697-699.*
5. Brady, B. Avoiding Dehydration on the Job. *Nursing. 33*, 2003.
6. Chang, Y.-C., Lo, J.-L., Huang, C.-J., Hsu, N.-Y., Chu, H.-H., Wang, H.-Y., Chi, P.-Y., Hsieh, Y.-L. Playful toothbrush: UbiComp technology for teaching tooth brushing to kindergarten children, In *Proc. CHI 2008*, ACM Press (2008), 363-372.
7. Chi, P.-Y., Chen, J.-H., Chu, H.-H., Lo, J.-L. Enabling calorie-aware cooking in a smart kitchen. In *Proc. PERSUASIVE 2008*, Springer (2008), 116-127.
8. Consolvo, S., Everitt, K., Smith, I. and Landay, J. A. Design requirements for technologies that encourage physical activity. In *Proc. CHI 2006*, ACM Press (2006), 457- 466.
9. Consolvo, S., McDonald, D. W., Toscos, T., Chen, M. Y., Froehlich, J., Harrison, B., Klasnja, P., LaMarca, A., LeGrand, L., Libby, R., Smith, I., and Landay, J. A. Activity sensing in the wild: a field trial of ubifit garden. In *Proc. CHI2008*, ACM Press (2008), 1797-1806.
10. Epley, N., and Gilovich, T. Just going along: nonconscious priming and conformity to social pressure. *Journal of Experimental Social Psychology 35*, 1999, 578-589.
11. F.I.T. http://www.fluidintaketracker.com/.
12. Fogg, B.J. *Persuasive Technology: Using Computers to Change What We Think and Do*. Morgan Kaufmann (2003).
13. Froehlich, J. E., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B. and Landay, J. A. UbiGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits, In *Proc. CHI 2009*, ACM Press (2009), 1043-1052.
14. Gasser, R., Brodbeck, D., Degen M., Luthiger, J., Wyss R., and Reichlin, S. Persuasiveness of a Mobile Lifestyle Coaching Application Using Social Facilitation, In *Proc. PERSUASIVE 2006*, Springer (2008), 27-38.
15. Hydracoach. http://www.hydracoach.com/.
16. Jafarinaimi, N., Forlizzi, J., Hurst, A., Zimmerman, J. Breakaway: An Ambient Display Designed to Change Human Behavior, In *Proc. CHI 2006*, ACM Press (2006), 1945-1948.
17. King, P. and Tester, J. The landscape of persuasive technologies. *Communications of ACM*, 42, 5(1999), 31-38.
18. Lin, J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. Fish'n'Steps: encouraging physical activity with an interactive computer game. In *Proc. UBICOMP2006*, Springer (2006), 261-278.
19. Lo, J.-L., Lin, T.-Y., Chu, H.-H., Chou, H.-C., Chen, J.H., Hsu, Y.-J., Huang, P. Playful tray: adopting Ubiomp and persuasive techniques into play-based occupational therapy for reducing poor eating behavior in young children. In *Proc. UBICOMP2007*, Springer (2007), 38-55.
20. Mamykina, L., Mynatt, E. D., Davidson, P. R., Greenblatt, D. MAHI: Investigation of Social Scaffolding for Reflective Thinking in Diabetes Management, In *Proc. CHI 2008*, ACM Press (2008), 477-486.
21. Nawyn, J., Intille, S. S. and Larson, K. Embedding behavior modification strategies into a consumer electronic device: a case study. In *Proc. UBICOMP* 2006, Springer (2006), 297-314.
22. Nord, W. R. Social exchange theory: an integrative approach to social conformity. *Psychological Bulletin* 71(3), 1969, 174-208.
23. Toscos, T., Faber, A., An, S. Gandhi, M. P. Chick Clique: Persuasive Technology to Motivate Teenage Girls to Exercise In *Proc. CHI 2006 extended abstract* , ACM Press (2006), 1873-1878.
24. Water: How much should you drink every day? http://www.mayoclinic.com/health/water/NU00283.
25. A review of the literature on how important water is to the world's elderly population. International Nursing Review (2004), 159-166.