WaterCoaster: A Device to Encourage People in a Playful Fashion to Reach Their Daily Water Intake Level

Figure 1: WaterCoaster

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Abstract
In this paper, we present *WaterCoaster*, a mobile device and a mobile application to motivate people to drink beverages more often and more regularly. The *WaterCoaster* measures the amount drunk and reminds the user to consume more, if necessary. The app is designed as a game in which the user needs to take care of a virtual character living in a fish tank, dropping the water level if the user does not consume beverages in a healthy way. We report results of a pilot study (N=17) running three weeks suggesting that our approach is appreciated and subjectively influences participants. Based on the results, we look forward to evaluating the system in a long-term study in the next iteration.

Author Keywords
Persuasion; Gamification; Prototyping; Water Intake

ACM Classification Keywords
H.5.m. [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous

Introduction
Consuming enough water every day is important for our health, as water is a vital nutrient [8]. With insufficient water intake, people can become dehydrated, leading to issues such as weakness, headaches or lower brain activity [16]. However, most people suffer from at least slight forms of

dehydration today [20]. Reminding people to drink more frequently, and a sufficient amount, is therefore a key issue we want to target. A core requirement for reminders is to know the water intake of a user. However, we need to derive this information in an unobtrusive way that does not burden the users. To be able to use such a system in various situations, the following requirements must be fulfilled: (1) the system should be capable of working with different drinking vessels (bottles, cups, etc.); (2) it should be mobile so it is easily carried along; (3) it should be usable without much additional effort and (4) it should be low-cost.

We present the *WaterCoaster* (cf. Figure 1), a coaster which is able to measure the weight of objects and thus can provide the necessary information to derive the water intake. The user is not restricted in the choice of drinking vessels and does not need to make any special effort when drinking. Ambient notifications [6] conveyed via LEDs remind the user that it is time to drink; mobility is achieved through an integrated battery. To further support our goal, we utilize the sensor data in a mobile game. The drinking actions of the user are directly connected to a virtual character living in a fish tank that the user needs to take care of. Besides other game elements, we also use reminder notifications on the smartphone.

Related Work

The playful bottle [3] consists of a gamified app and an instrumented cup. The cup needs to have a graduated scale within view of the smartphone's camera mounted on the cup. The system determines the water intake by analyzing the camera pictures based on the scale. The app features a single-player mode in which each player has a tree that drops leaves if the user does not drink enough, as well as a social mode in which users see others' trees and are able to remind them to drink. A seven-week user study (three weeks baseline, four weeks intervention) showed a significant improvement in water intake. They could also show that the participants in the social mode performed better than those in the single-player mode. We also use a playful approach to encourage healthy drinking, but use a greater variety of game concepts. In contrast to their approach, we will not restrict the user to a certain type of instrumented cup, nor is it necessary to mount the user's smartphone.

MediaCup [1] is capable of measuring the current temperature of beverages. It presents an example of an unobtrusive, mobile augmentation of a cup. Although the MediaCup is not designed to measure water intake nor to motivate an improvement, the concept is interesting as it enhances an everyday object without restricting its use – a goal we also want to accomplish with our system.

To encourage communication in partitioned offices, Nakano et al. [13] introduced the Traveling Café approach. With the help of a pressure sensor, the system is able to calculate the filling level of each cup and notifies other workers when a cup is empty. A two-week pilot study showed that the communication could be improved. Though we have a different goal in mind, we will use a similar measuring approach with the help of a weight sensor.

Butz and Schmitz [2] also used a pressure sensor to detect the presence of a glass on an augmented beer mat to induce pub interaction. The beer mat is equipped with a gravity sensor, a pressure sensor and a radio transmitter. One possible interaction they outlined is a voting process based on the presence of a glass and the orientation of the beer mat. In contrast to their design, we will preprocess data on our coaster and use it for achieving a behavior change.

We also inspected work that did not involve scientific investigations, as can be seen in Sidebar 1.

Vessyl [12] is an augmented cup that is able to measure the water intake of the user and to analyze the cup's contents. The main drawback is that there is only one cup for all sorts of beverages. Also, there is no reminder functionality.

HidrateMe [7] consists of a cup that reminds the user to drink. An app visualizes how far away people are from their goals. Similar to our approach, the app calculates the daily intake levels according to different user-specific aspects. Again, the user has to use the same cup for all beverages.

Water Drink Reminder [14] is an app which allows to track water intake manually. It calculates the daily goal based on weight and reminds people to drink. Since logging every drink manually is very tedious, we provide an automatic approach for this.

Trago [17] integrates its technology into a bottle cap. The idea is to utilize an ultrasonic approach to measure the liquid level and to provide a smartphone app.

In our approach, we combine advantages of the presented systems and enhance them with a playful setting to motivate people further.

Sidebar 1: Non-scientific work

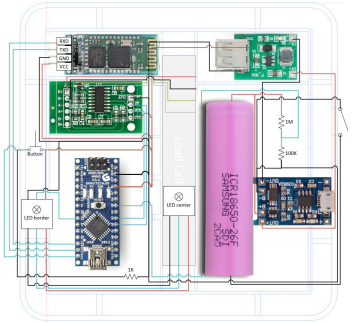

Figure 2: Circuit diagram

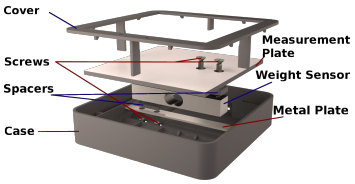

Figure 3: Exploded view

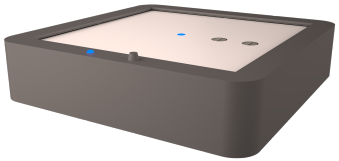

Figure 4: Assembled system

In contrast to the presented work, we contribute a system design that overcomes the drawbacks mentioned: It is portable, able to track the water intake with low effort (i.e. without augmenting/instrumenting a cup or manually logging every drink) and uses gamification and reminder functionalities to induce behavior change. Additionally, many of the presented systems have not been investigated scientifically (or at least do not report studies). With the presented pilot study and the upcoming long-term evaluation, we want to address that situation as well.

Hardware prototype

The hardware prototype consists of electronic components built into a 3D-printed case (see Figures 2–4).

The central part is a load cell mounted between the bottom of the case and a measurement plate (see Figures 2 and 3). We had to stabilize the bottom part of the case by means of a steel plate, as the sensor measures via bending and thus causes a leverage effect. The analog load cell is connected to the Arduino with an intermediate analog-to-digital converter (HX711). Our prototype further includes a Bluetooth module (HC-06), a lithium-ion battery (3.7 V; 2600 mAh) together with the charging electronics as its power supply, two RGB LEDs for feedback, a voltmeter, a push button and an on-off switch. The battery facilitates the necessary mobility for the outlined scenario and allows for flexible use due to a Micro-USB charging plug. For the current revision of our prototype, the user has to push a button to notify the system that there is a new beverage. If the calculation of the current intake level drops below 70%, the smartphone triggers blue flashing of the LEDs. Moreover, both LEDs convey information independent of the smartphone, i.e. they blink green to indicate a successful measurement, yellow to show that the button press was recognized and red if the battery state is low. The developed prototype costs around 26 Euro (or roughly US $29) and can thus be seen as a low-cost device, especially when it is considered for mass production, which would typically further reduce the costs. On the Arduino, we continuously gather weight data from the load cell and perform some smoothing on it. As soon as a considerable change is observed (more than 10 g), the new value is enqueued to be sent to the smartphone app via Bluetooth. Thus, a value is kept in the queue until the app confirms the transmission. We chose this protocol to prolong the battery runtime. In addition, we reduced the LED feedback to 200 ms flashes to save energy. In total, the battery lasts for 31 hours at a stretch, when the *WaterCoaster* is continuously connected to a mobile device and is used once per hour on average.

Software prototype

We pursued three goals with the mobile app:

G1 Establishing a channel to notify the user that he needs to drink something to reach a healthy water intake level.

G2 Using gamification elements to motivate the user to use our system and to optimize his drinking behavior.

G3 Executing expensive calculations to save energy on the coaster, improving its mobility.

The calculation of the water demand of a user is important (cf. **G3**) and related to several individual factors, e.g. age, body weight and activity [4, 5, 19]. Our algorithm calculates the water demand with age and weight as input based on the reference table provided by [4]. We increase the required intake by an estimated fluid loss caused by sweating, which depends on the air temperature and the user's activity level [19]. Based on the received value and the amount of time per day when the user is awake, we calculate the frequency and amount for a healthy water intake. These serve as triggers for reminders, maintaining **G1**.

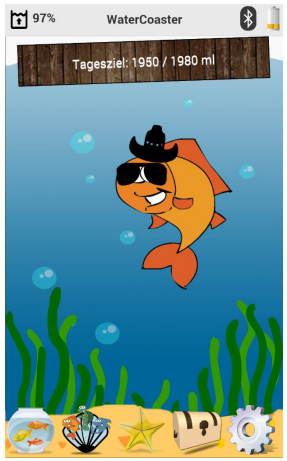

Figure 5: Dressed avatar

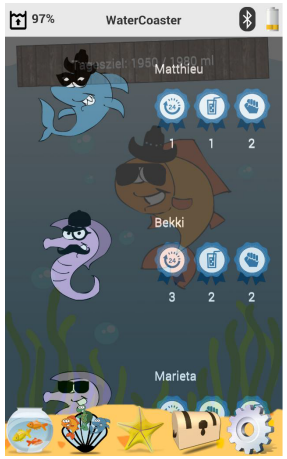

Figure 6: Social view

We also integrated elements to make the experience game-like (cf. **G2**), and the interactions with the application more fun and potentially more motivating to follow advice to drink more frequently and a sufficient amount.

In our game, the user can choose one out of five characters (a fish, a turtle, a shark, a seahorse and an eel) and has the goal to care for it. By doing this, we wanted to invoke the feeling of empathy to create an immersive game experience [18]. The character lives in a fish tank in which the water level changes based on the drinking behavior of the user. The more frequently the user drinks a healthy amount of water, the higher the tank is filled. We used this metaphor as it was already successfully utilized in the health domain to encourage a behavior change [11] and to additionally motivate people. Moreover, we use facial expressions to support the feeling of empathy and responsibility, ranging from very sad to very happy (cf. Figure 7), depending on the amount of water available. In addition to these dynamic feedback mechanisms, we also display the overall amount of water that should be drunk today, together with how much the user has drunk so far.

Moreover, we use achievements [9] rewarding healthy drinking and/or continuous use of the application. For example, an achievement is unlocked when a user reaches his daily water intake level once, or achieves this for several consecutive days. Besides a badge, with every achievement the user has an additional chance to get an item such as a hat, glasses, a beard or other accessories which can be worn (cf. Figure 5) to provide feedback about the users' hydration behavior and increase motivation [18]. As seeing the engagement of other users can motivate similar behavior [18], we also integrated a view in which characters of other users can be seen (cf. Figure 6).

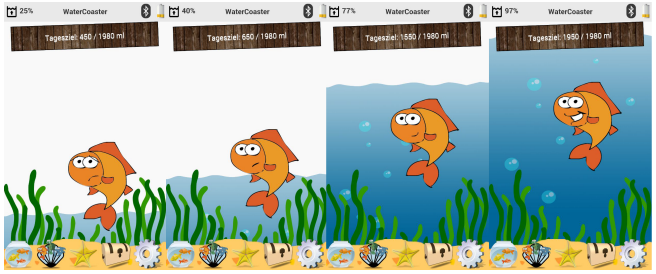

Figure 7: Different water levels and emotions

Pilot Study

We plan to conduct a long-term study in which we will measure the daily water intake and frequency over several months, to rule out novelty effects and to ensure that the system can also influence the behavior sustainably. To this end, we conducted a pilot study (three weeks) with 20 participants (11 females; age: 18-25: 2, 26-35: 11, 36-45: 1, 46-55: 4, 56-65: 2) that has revealed important aspects, showing that they appreciate the concept and that there is a good chance that they would use it on a long-term basis. The goals of the pilot study can be found in Sidebar 2.

Method

For this first study, we decided to rule out confounding variables by restricting the use of our components to office workers only, who reported having a consistent daily routine, have experience with smartphones and are primarily doing activities that are cognitive in nature. Additionally, they were asked to use our system only during their work hours. Thereby we wanted to ensure that in the relatively small time frame of three weeks, participants' activities remained similar. The first week was a baseline phase in which we handed out the *WaterCoaster* and asked participants to use it, but disabled all reminder functions and did not provide access to the game itself. In the following two

Q1 Are there technical problems or usability issues in our prototype?

Q2 How are gamification elements perceived?

Q3 How is the overall concept of our prototype perceived?

Q4 Are there already short-term effects regarding either the actual water intake or the subjective feeling of drinking a sufficient amount of water?

Q5 Are there differences concerning water intake or perception of the prototype when using different feedback configurations?

Sidebar 2: Goals of the pilot study

weeks, we split the participants into three groups: group 1 only received reminders from the hardware prototype (*LED-only*); group 2 used our mobile game app with the hardware prototype but without receiving feedback on the hardware side (*Game-only*) and group 3 received LED feedback and used the game (*Combined*). We provided pre- and post-study questionnaires, with the goal to receive insights into drinking behavior and, from the latter, how the system is perceived. For the questionnaires, we used a mix of free text questions and questions to be answered on a 4- or 5-point scale (depending on the question and whether or not we wanted to force a choice). We had to exclude three participants: one had not filled out the post-questionnaire, one dropped out for several days due to illness and one had severe technical problems with his smartphone, resulting in 17 participants overall.

Results

In the pre-questionnaire, we asked questions about participants' water intake: only four reported that their behavior was healthy or nearly healthy, six thought it was sufficient and seven thought it was at least moderately unhealthy. This corresponds to the reported (estimated) amount of water they drink during working hours: seven reported drinking less than one liter, six drink between one and one and a half liters and four reported drinking more. In an 8 hour shift an amount of 1.2 liters can be considered healthy [5]. Only two participants reported drinking on a regular basis during work. It seems that the *WaterCoaster* could help most of our participants to reach their water intake level and to encourage them to drink more frequently.

In the post-questionnaire, only three participants reported drinking less than one liter, showing that participants either recognized that they drink more or were explicitly encouraged to do so. A change in subjective judgment could also be found in the frequency, as now nine participants reported drinking on a regular basis. Subjectively, 12 participants reported that their drinking behavior was influenced (seven stated that their drinking behavior was slightly influenced, five that it was strongly influenced) and ten would continue to use our system in their daily life. Nine of them would buy the system if it cost no more than 25 Euro, one would pay up to 50 Euro and one would pay up to 100 Euro (roughly equals US $27.50/55/110, while the remaining six would not buy it). These findings show both that subjectively, the *WaterCoaster* may have had an effect (cf. **Q4**) and that participants liked the concept and idea behind the prototype (cf. **Q3**). Considering the different aspects of our system, the virtual character was perceived as motivational to improve behavior (only one participant disagreed with that); achievements were perceived as helpful by half of the participants. The social feature was only appreciated by two participants; a reason for this could be that the participants did not know each other. Thus, answering **Q2**, the game elements used were perceived as motivational overall. Considering the coaster itself, only two people stated that it did not help them to drink more.

From an objective standpoint (i.e. the measurements), we recognized problems with the hardware prototype (cf. **Q1**), some of which were also verbalized in the post-session questionnaire. Participants seemed to overlook the warning that the Bluetooth connection was not established, leading to data loss (when the device remained disconnected for a long time). For the next cycle, we will also indicate a missing data connection via the coaster directly and not only via the app. Another issue was that although we strengthened the bottom of the case with a steel plate, some devices had too much play, leading to measuring errors depending on the size of the vessel and the position on the coaster. Mounting a wider steel plate and further stabi-

lization should prevent this in the next iteration. Finally, it seemed that moving the coaster, without turning it off, could also result in false recognitions of a drinking activity; integrating a gyroscope will help here. All these issues led to several days we needed to remove from the dataset in the end, and showed that the hardware prototype itself needs to be revised in future work. After filtering out users with too few data points remaining, we compared 14 participants in the quantitative analysis (*LED-only*: 4, *Game-only*: 5, *Combined*: 5), but were not able to find any significant differences, which might be caused by the problems mentioned, participants that interacted only rarely with the game and the small number of participants per group. Thus, **Q5** needs further investigation as the actual water intake could not reliably be determined.

Discussion

Q4 and **Q5** can only be answered partially because of the reported measurement issues. Differences in the conditions (cf. **Q5**) are also limited in their expressiveness, as the participant count was relatively low in each condition. It must also be considered that the use of gamification alone may have no effect, as the intrinsic motivation to drink is high enough and a reminder functionality is sufficient. Moreover, the technical problems may have influenced the subjective perception negatively, so these results may be underestimated. However, keeping in mind that the goal of this study was to reveal whether people are inclined to use our system over the course of several weeks, we see this as fulfilled: despite the mentioned issues, the majority of the participants reported they would continue to use the system in their daily life and would even pay for it. Thus, it seems that after improving the prototype (see above), a long-term evaluation can be conducted. An interesting effect this study has revealed is that the setting changes the way people perceive their drinking behavior. Future research is necessary on whether this effect was achieved by the experimental setting, by the mere presence of a device measuring water intake, or by the actual usage of the *WaterCoaster*.

Conclusion and Future Work

We presented *WaterCoaster*, a mobile, portable and low-cost device that is capable of measuring personal water intake without instrumenting any drinking vessel. Together with a mobile game, it aims to motivate people to reach their daily water intake goal in a playful way. We provided the reasoning behind the hardware and the software part as well as the gamification concept of our prototype. Moreover, we presented the results of a three-week-long pilot study in which we learned not only aspects we can improve, but also found out that people appreciated our idea and subjectively had the feeling of drinking more. Furthermore, participants stated that they would continue to use our system in their daily life, which indicates that there is a good chance that they would use it on a long-term basis.

In the next iteration, we will fix the aforementioned hardware problems and revise our prototype as described. As soon as there is a stable version of our system, we plan to investigate to what extent the *WaterCoaster* is able to change behavior towards healthy drinking, and the impacts of gamification on this, in a long-term study with a sufficient number of participants over several months. Here, we will prolong the baseline phase and will additionally integrate a control group that will not receive a *WaterCoaster*, but will answer questionnaires regarding their drinking behavior on a regular basis. It will also be interesting to use a more tailored gamification strategy as described in [10, 15], to examine its effects on water intake. In addition, it is important to investigate whether gamification is needed at all; potentially the reminder alone is sufficient. This will also be a research direction, we will follow.

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