# eDrinking 50+: Designing a User-Centered System to Enhance Hydration in Middle-Aged Adults

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**Abstract.** Adequate water intake is fundamental for the optimal functioning of the human body, impacting vital systems such as the digestive, urinary, and nervous systems. Research has identified that adults aged 50 to 65 (middle-aged adults) exhibit the lowest water intake levels. To address this challenge, "eDrinking 50+" was developed using a user-centered design approach. This system consists of a mobile application and a physical device that facilitates and automates the tracking and recording of daily water intake. The development process included two iterative cycles, resulting in a final design that was successfully evaluated for usability and acceptability by group of users aged 50 to 65, proving to be a tool that could help to improve water intake in this demographic.

**Keywords:** User-Centered Design · Water intake · Middle-aged · App · Water measure gadget · Healthy behavior

## 1 Introduction

Water intake is crucial for the proper functioning of the human body [11]. Deviating from adequate intake can adversely affect mental and physical health [31]. Insufficient water consumption can lead to issues in multiple systems, including the digestive and nervous systems [11, 28]. Specific problems associated with dehydration include cognitive and motor function impairments [16, 10], thermoregulation issues [16], and an increased risk of kidney stones and urinary tract infections [16]. Conversely, excessive water intake can result in central nervous system edema [16, 10], lung congestion, impaired kidney function, hyponatremia, and other health issues.

The body can experience water deficits within a few hours due to reduced intake or increased loss. However, daily fluid consumption, guided by thirst and drinking beverages during meals, helps maintain proper hydration and normal total body water levels. According to the National Institutes of Health (NIH) in the United States [16], the total daily water intake for adults over 19 years old should be 3.7 liters for men and 2.7 liters for women, including drinking water, water in beverages, and water present in food. This translates to approximately 3.0 liters ($\approx$ 13 cups) of total beverages (drinking water and other beverages) for men and 2.2 liters ($\approx$ 9 cups) for women. The European Food Safety Authority

(EFSA) recommends an adequate total water intake of 2.0 liters per day for females and 2.5 liters per day for males [10]. These values are not rigid, as various factors such as physical activity and hot environments can influence the daily required quantity of liquid intake. To maintain optimal hydration, natural water should be the primary liquid consumed [4].

Studies indicate that a significant portion of the adult population in various countries fails to meet adequate water intake levels [11, 22, 20]. This shortfall is due to factors such as forgetfulness, stress, a preference for caffeinated or other beverages [23], confusion about recommended intake levels [13], unhealthy behaviors and attitudes [14], working conditions [2], and social behaviors [24]. These factors often lead individuals to prioritize other activities over proper hydration. As the population ages, maintaining adequate hydration becomes increasingly important for good physical and cognitive health [9, 18, 21, 3, 8]. However, total water intake tends to decrease with age [32], and several studies have found that adults between the ages of 50 and 65 consume less daily water than younger adults or adolescents [12, 27, 14, 32]. Dehydration is a common issue in elderly people that can lead to serious complications and death [7].

Several interactive systems and technologies have emerged to encourage and monitor sufficient water intake among individuals. Nonetheless, there remains a gap in interactive systems tailored specifically for middle-aged adults (aged 50 to 65 years) [7]. This age cohort often experiences cognitive decline [15] and significant lifestyle adjustments [25], underscoring the need for a personalized support system that prioritizes the end user's needs, preferences, and behaviors. Given this research gap, our current study aims to conduct a user-centered design investigation to understand middle-aged adults' needs, preferences, behaviors, and requirements. Subsequently, our goal is to design and develop a system that effectively supports them in improving their daily water intake while ensuring a positive user experience.

## 2 Related Work

Numerous commercial apps and technologies aim to promote and monitor water intake, but their suitability and effectiveness remain unverified. Furthermore, many of these solutions are designed for a broad audience and overlook the specific needs of different age groups, particularly middle-aged adults. In contrast, various academic studies have proposed interactive support systems integrating hardware and software to promote water intake. For instance, SmartOne [30], is a smart water bottle for users under 50 that monitors water consumption and cleanliness using pH and turbidity sensors. It tracks drink events through push button, humidity, and ultrasonic sensors, and a mobile app records water source locations and consumption data. HydrationCheck [26] is another IoT-based smart water bottle that tracks daily fluid intake, calculates average intake, and records the last drink time. It sends reminders every two hours to help users meet hydration goals. SPLASH [19] is an Android app for individuals aged 18 to 45, allowing users to set daily hydration goals and automatically track liquid intake using smartphone NFC technology and NFC-tagged cups. Lastly, the mobile game "Dropdash" [1] sets daily hydration challenges for players, who log their intake by scanning their containers. Challenges are personalized through machine learning. While the developer used a user-centered design approach, they did not specify the target user group's characteristics. The game received a high usability score of 77 on the SUS scale from 5 experts.

For systems and technology designed specifically for middle-aged adults, Lee et al. [17] conducted a study to develop a smart water bottle for new seniors. They used Cooper's "goal-directed design" method within User-Centered Design (UCD) for Korean individuals aged 50 to 60. The proposed design remained conceptual, and no user evaluations were conducted to assess its effectiveness or whether it met user needs and requirements. Additionally, other studies focus on estimating water intake in elderly users using methods like sound, smartwatches, inertia sensors, or weight sensors [7]. However, these methods only estimate water intake without helping users track or improve their drinking habits, lacking a comprehensive solution.

In general, based on our review of existing literature, most current apps and technologies are designed for a broad user base and are not tailored to the needs and characteristics of middle-aged adults, nor have they been tested in this age group. This highlights the need for tailored system designs for middle-aged adults and represents a potential gap that could be addressed with a user-centered approach focused on this demographic's specific needs and preferences.

## 3 Methodology

In this project, the RABBIT [29] methodology was employed to emphasize rapid and iterative design cycles with active user participation, optimizing the UCD process by focusing on user needs and feedback, ensuring the final product consistently aligns with user expectations and requirements. The methodology is structured into five iterative steps: 1) researching users (R), 2) assessing the situation (A), 3) balancing the needs (B), 4) building an operative image (BI), and 5) testing the product (T). These steps were implemented through three iterative cycles, enhancing the previous result to generate progressively improved solution prototypes. The first iteration aimed to understand the problem´s needs and propose an initial system prototype to satisfy potential users' requirements. The second iteration focused on refining the system prototype based on direct user feedback. Finally, the third iteration involved further improvements to the system prototype and a final evaluation to assess user usability and acceptability of the proposed system in controlled environments.

### 3.1 First iteration cycle - medium-fidelity prototype and experts' evaluation

The first iteration aimed to understand the problem´s needs and propose an initial system prototype to satisfy potential users' requirements. Following the

RABBIT methodology, this iteration consisted of five steps. Step 1 involved conducting a daily study with 4 participants and 8 semi-structured interviews to understand the user context. Step 2 included 5 semi-structured interviews to identify user requirements, complemented by the earlier comprehensive literature review. Step 3 focused on balancing the needs by analyzing and counterbalancing the results obtained from the previous steps. In Step 4, a medium-fidelity prototype was developed. Finally, Step 5 involved an initial heuristic evaluation of the prototype, conducted with 5 experts from related areas.

To clearly define the target group, we refer to it as individuals of Mexican nationality, aged between 50 and 65 years (inclusive), regardless of work occupation, economic level, or physical activity level. To ensure a focus on the general user, individuals within this demographic with medical conditions that could put them at risk during the experimental process or affect their interaction with the system (such as kidney failure, diabetes, gastrointestinal problems, etc.) were excluded from the study.

During Step 1, a daily study was conducted with 4 participants (2 men and 2 women; average age 54.5 years, std. 4.2) to understand the users' life context. They were asked to keep a diary to document their daily activities, the times they consumed water and an estimate of the quantity consumed. The results indicate that water consumption behaviors vary widely and do not consistently fall within a recommended range. Their current activity and location significantly influence participants é water intake. While they know the importance of staying hydrated, they lack a method to accurately track their daily water intake. Subsequently, semi-structured interviews were conducted with 8 participants (3 men and 5 women; average age 55.375 years, std. 3.11) within the target user group. These interviews aimed to complement the previously gathered information of the users´ life context by exploring challenges, deficiencies, the environment where participants spend most of their time, and their motivations and limitations. The interviews were recorded with the user's consent and later reviewed to note the most important points. Based on the results obtained from these interventions, the characteristics of the target user group revealed two distinct lifestyles: one characterized by a fast-paced routine with inadequate water consumption due to their activities and another characterized by a relaxed lifestyle typically at home, where water intake may either fall below or exceed recommended levels. During these interventions, most participants confirmed owning a smartphone, which they use daily for various activities and carry everywhere. This is consistent with literature indicating that at least 74% of middle-aged adults in México own this type of device [6], supporting the feasibility of implementing a mobile app for the target population.

Next, in Step 2, 5 interviews were conducted with participants from the target user group (3 men and 2 women; average age 54.5, std. 2.88) to identify user requirements. These interviews helped identify both general and specific requirements. Notably, individuals previously involved in the interventions from Step 1 expressed similar needs. Based on an analysis of the interviews and complemented by the earlier comprehensive literature review, user requirements were divided into three categories: reminders, historical logging, and miscellaneous needs. In the reminders category, users require loud and soft alarms ranging from every hour to every two hours. They also prefer options to stop reminders either automatically or manually. Regarding historical logging, users require a history spanning from one day to six months. They also need the ability to compare logs with the current day and the option to perform automatic logs. Miscellaneous requirements include a compact, user-friendly system featuring dynamic animations and images related to water consumption. If a physical device is required, it should accommodate various container sizes. Additionally, the system should be fast and easy to use, avoiding the necessity of constantly carrying uncomfortable portable devices.

Based on these results, Step 3 involved refining and integrating the needs according to the most requested user requirements, ensuring they addressed most situations observed in the user´s daily lives.

After balancing these needs, a medium-fidelity prototype was developed in Step 4. The initial system design combined a mobile application and a physical device (Figure 1). The considerations for the mobile application included: 1) a reminder system with configurable alarms, 2) water consumption history tracking, 3) motivational features for the user, and 4) a simple and intuitive interface for ease of use. For the physical device, the considerations were: 1) a system designed to be as simple and automatic as possible, and 2) a non-portable device (not wearable or similar). The physical device was integrated into the system to automatically measure water intake by monitoring the decrease in water in the glass using a weight sensor. This feature aims to accurately track water intake without depending solely on user input via the mobile application, thereby enhancing data accuracy and reducing user effort. Subsequently, a medium-fidelity prototype of the system, encompassing both the mobile app and the physical device, was developed (see Figure 1).

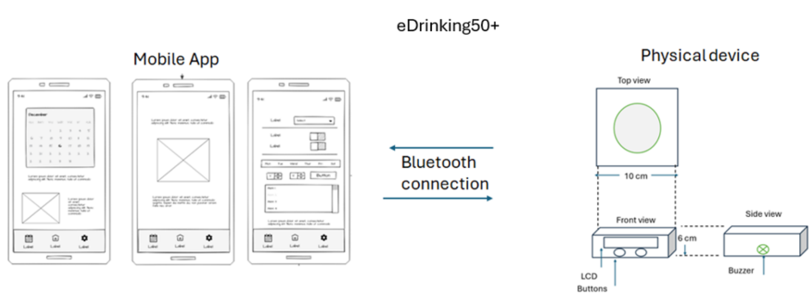


**Fig. 1.** A medium-fidelity prototype of the initial system design, consisting of a combination of a mobile application (left) and a physical device (right).

Finally, Step 5 involved an initial heuristic evaluation of the prototype, conducted with 5 experts from related areas, including 2 from the medical field, 2 mobile developers, and 1 electronics specialist. The heuristic evaluation protocol included presenting the evaluation objectives, outlining the problem context, demonstrating the initial prototype, and conducting interviews to identify areas for improvement. This process ensured that the system designs were tailored to meet users´ characteristics and met the proposed requirements. This evaluation underscored the need to enhance usability by implementing tutorials, clear buttons, and help titles. There was also a strong emphasis on maintaining a seamless connection between the two devices within the same mobile device and improving hardware stability. Experts recommended displaying reminders throughout the day emphasizing the importance of hydration and its benefits. These recommendations aim to enhance user experience and system effectiveness.

### 3.2 Second iteration cycle - high-fidelity prototype and first user evaluation

Based on the results of the first iteration, another development cycle was initiated to implement essential adjustments to enhance the user experience. Since the user information gathered in Steps 1 and 2 from the first iteration cycle remains unchanged, this iteration focused on Steps 3, 4, and 5 of the RABBIT methodology. Step 3 involved refining the system based on feedback and insights gathered from the initial prototype from the first iteration. Step 4 encompassed the development of a high-fidelity system prototype, integrating features such as alarms, reminders, and intake records, and a tutorial within the mobile application. A tangible case was also designed for the physical device (see Figure 2).


**Fig. 2.** High-fidelity prototype of eDrinking 50+. Selected screens from mobile app (left) and physical device (right).

Subsequently, during Step 5, a user evaluation was conducted to evaluate the high-level prototype with 6 participants (3 men and 3 women; mean age: 59.5 years, std.: 2.43) from the target user group. The evaluation focused on usability, user satisfaction, and validating user needs. The primary objectives included evaluating the design of the prototype, identifying usability challenges, evaluating the intuitiveness of the historical section, evaluating the clarity of displayed information, and gauging the overall acceptability of the system. Participants were first informed about the project´s basic information and objectives. Following this, they were equipped with mobile devices containing the installed application and connection to the physical device to perform a set of four activities: 1) checking the water consumption for the current day, 2) manually adding a record of water consumption using the application, 3) setting a new reminder and returning to the Home tab, and 4) checking the water consumption for a day of the user's choice. This set of activities was performed twice, with a 10-minute interval between each set. Finally, interviews were conducted to gather user opinions and feedback. The evaluation utilized the See, Say, Do method, where observers recorded user expressions and sessions for later review. User feedback was gathered using the think-aloud technique and semi-structured interviews.

Overall, users found the application useful and believed it would help promote a healthy lifestyle: *"I think this would help a lot of people when it's finished because it's really helpful to have something capable of reminding you to drink water"* [P1]. The evaluation highlighted the application's memorability: *"It's easy to use the second time because I remember what they do"* [P2], and its efficiency: "It's very easy to do once you get used to it"[P4]. Additionally, there were recommendations to improve information visualization and the initial tutorial: "I think that explaining all the components in more detail would make it easier to understand it the first time"[P1].

The evaluation results underscored the importance of an intuitive interface and a clear user experience. Users expressed overall satisfaction with the proposed system and showed interest in a future deployment to incorporate it into their daily routines. Recommendations for improvement from users included enhancing the initial tutorial, increasing contrast for elements, adjusting element sizes for better usability, and adding clearer titles to enhance understanding. These suggestions aim to boost user satisfaction and encourage long-term engagement with the system, focused on enhancing the application's functionality. Most recommendations focused on less critical elements, such as colors and typography, highlighting a balanced prioritization of essential requirements in the previous iteration. This approach has streamlined the process, indicating that only one final iteration is necessary to refine these details.

## 4 Final Design of eDrinking 50+

With the results from the second iteration, a third and final iteration implemented necessary modifications to the high-level system prototype, followed by a final user evaluation. The final version of the eDrinking 50+ system includes a mobile app for Android 11+ developed using Android Studio with Java (see figure 3, left) and a physical device made of wood (see figure 3, right). The device features a pressure sensor to measure water intake and an LCD display for relevant information and is programmed on an ESP32 with Bluetooth. It provides manual calibration instructions, alerts the user with a buzzer, and displays prompts to drink water. Additionally, the device detects if the glass is removed from its base and not replaced within one minute, issuing a reminder to return the glass. It calculates the weight difference when water is consumed and updates the data on the LCD screen and the app. Users can monitor their water intake on the screen.

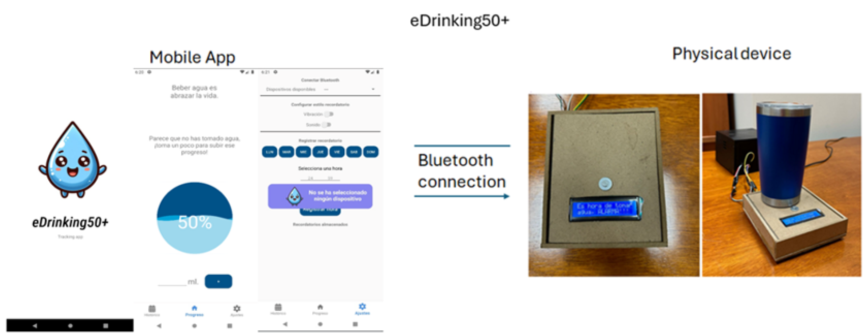


**Fig. 3.** The final version of the eDrinking 50+ system. Mobile application (left) and physical device (right).

## 5 User Evaluation

After developing the final system, we conducted a user evaluation to assess usability and acceptability, guided by MEELS principles: memorability, efficiency, errors, learnability, and satisfaction [29]. The evaluation involved 5 participants (3 women and 2 men) aged 57-61 (mean 59.4, std. 1.36) who consented to participate. The procedure included explaining the project, conducting activities with the system (using the app's tutorial and completing two rounds of four activities), gathering feedback through semi-structured interviews, and administering the System Usability Scale (SUS) questionnaire [5]. Initially, each participant received a project context explanation using a structured script for consistency. Participants then followed the app's tutorial to familiarize themselves with its features, evaluated by completion time and number of interactions (taps). After the tutorial, participants performed two rounds of four activities: 1) checking the current day's water consumption, 2) manually adding a water consumption record, 3) setting a new reminder, and 4) checking water consumption for a chosen day. In the first round, they could consult the facilitator; in the second round, they completed activities independently to assess the system's memorability. The evaluation also included assessing the physical device, where participants interacted with it, read the screen, drank water in response to the alarm, and observed the automatic consumption record in the app. All sessions, including audio and phone screen recordings, were recorded while maintaining participant anonymity. Three aspects were measured from the recordings to assess the efficiency and identify errors using MEELS principles: 1) the average number of taps to complete each activity, 2) the average time taken, and 3) the total number of errors. After completing the activity rounds, participants underwent a semi-structured interview and the SUS questionnaire. The interview focused on learnability, satisfaction, and user acceptance, aiming to gather iterative process requirements. The SUS questionnaire assessed overall system usability, featuring 10 items on a 5-point Likert scale (1 to 5). Data were analyzed per [5], with scores interpreted: above 68 as "acceptable", 50-68 as "marginal", and below 50 as "inacceptable".

## 6 Results

This section details the user evaluation results, including app usability (errors, efficiency, and tutorial effectiveness), physical device usability, user acceptability ratings, and findings from the SUS questionnaire.

### 6.1 App usability results

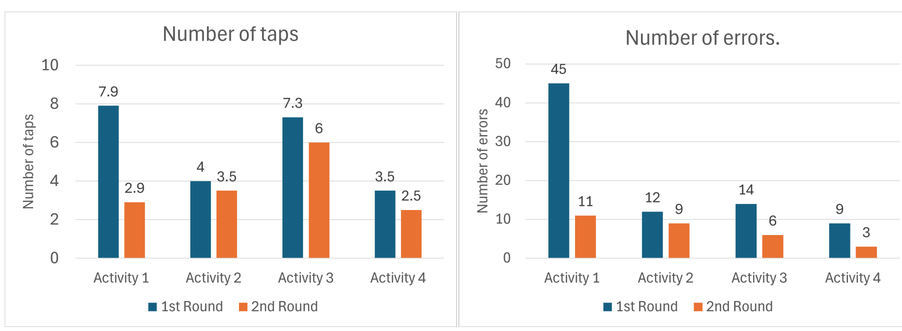


**Fig. 4.** Number of taps and errors in first users evaluation

To evaluate the usability, we analyzed the number of errors and the average number of taps (Figure 4) required to complete each activity. Results show that Activity 1 (check today's water intake) was initially the most challenging, with the highest number of errors in the first round. However, it significantly improved in the second round, indicating good memorability. For Activity 2 (manually recording water intake), the results indicate that it showed the least improvement compared to the second round. While the number of errors decreased in the second round, it exhibited less improvement compared to the first round. Nevertheless, the average number of taps suggests that the participants made relatively few mistakes and were close to the ideal number of 3 taps per activity. According to the results, Activity 3 (adding a new reminder) took the second longest to complete, requiring a significantly higher number of taps. Despite this, Activity 3 showed the second-most improvement compared to the first round, with a notable reduction in errors made by all participants. Notably, although it was the longest activity, Activity 3 had the second-fewest errors by the end of the second round. Participants also demonstrated reduced errors during Activity 4 (checking the intake of one day of the month). Notably, this activity and Activity 2 averaged closest to the ideal number of taps (2 taps), with an average of 0.5. The decrease in errors from 9 in the first round to 3 in the second round indicates that Activity 4 was the easiest activity for participants to perform. Figure 5 illustrates participants spent between 132 seconds (2 minutes and 10 seconds) and 208 seconds (3 minutes and 28 seconds) completing the tutorial, with the number of taps during the tutorial ranging from 18 to 26 taps. The difference in the number of taps is notably smaller than the time invested. Comparing these two aspects, it's noticeable that the participants who took longer to complete the tutorial (P2 and P3) made fewer errors overall during round 1, with 6 and 5 errors, respectively.

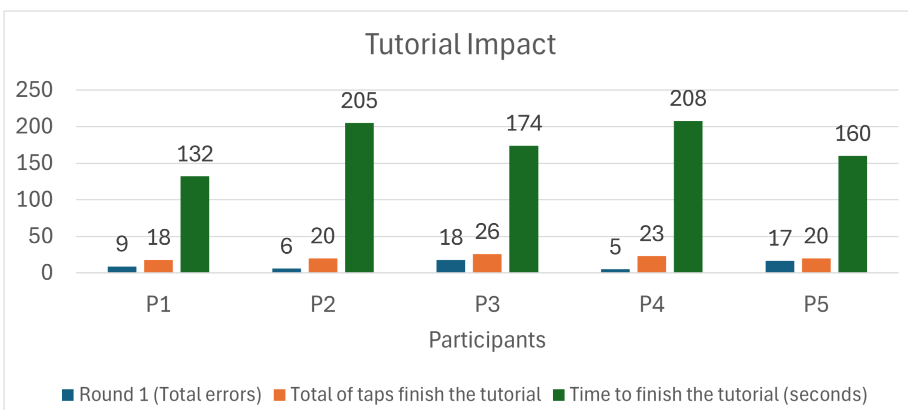


**Fig. 5.** Participants interaction data during the tutorial: number of taps, time taken to complete, and total errors in all first-round activities.

### 6.2 Analysis of physical device acceptability and usability

The analysis of the physical device´s acceptability and usability revealed error-free operation during its use in the activity. Participants expressed that the physical device was remarkably easy to use. One participant noted, *"...it's easier for me here because I don't have to handle the device... it's very automatic"* [P2], while another mentioned, *"I found it easier because you have better control and it's more automatic"* [P5]. From the previous comments, it was found that the messages displayed on the LCD screen were clear in terms of their instructions and clearly showed the user's water intake. According to participants' feedback, this activity was rated the easiest during the evaluation, primarily due to its automatic operation.

### 6.3 eDrinking 50+ acceptability and usability results

During the semi-structured interview, participants were asked to rate the system on a scale from 1 to 10 to assess its acceptability. The average rating across all responses was 8.4 (std. 2.87), ranging from 7 to 10. These results indicate that participants find the system highly acceptable and consider it a viable solution. Additionally, as discussed in previous sections, the usability of the complete system was evaluated using the SUS questionnaire. The average SUS score obtained was 81, indicating acceptable usability between "Good" and "Excellent". Notably, no participant scored below 70, demonstrating uniformly positive perceptions of the system's usability across all participants.

## 7 Discussion

This study used a user-centered design to address low water consumption in a specific population. Positive feedback from evaluation iterations indicates that the solution is useful and appealing to target users. Involving experts and end-users in iterative design cycles helped identify key features that enhanced the usability and acceptability of eDrinking 50+. However, further aspects of these results should be considered. The study confirmed the need for tools to promote adequate water intake in the target population, as current market products are insufficient. A tailored system was developed by integrating key user requirements, resulting in positive feedback. Users reported that the solution could improve their hydration habits with customizable reminders fitting into their daily routines. However, further studies are needed to assess the system's suitability for individuals older than 65, who were not included in the evaluation. An important aspect to consider is the technological proficiency of the target population. The tests showed that users identified their needs from a non-technological perspective. Those more familiar with technology adapted better, while users with less common devices faced difficulties and were less receptive. For example, some found the app easier to use due to familiarity with other apps or higher smartphone usage, which was not initially considered. These proficiency issues are likely more pronounced in the older population. The results showed good memorability and high acceptability and usability among participants. However, future work should include a larger study to confirm these findings. Increasing the number of participants and conducting longer tests in realistic environments would provide more relevant feedback. Further evaluation is needed to determine if eDrinking 50+ effectively promotes adequate water intake in the target population.

## 8 Conclussion

Adequate water intake is crucial for health, yet many struggle to meet recommended levels. This research highlights the challenge of low water consumption among those aged 50 to 65 due to work conditions and social behaviors. To address this, we developed the eDrinking 50+ system using a user-centered design approach, incorporating user needs through research, interviews, and iterative design. The system includes a mobile app and a physical device. The app features reminders, consumption tracking, and motivational elements, while the coaster-like device uses a weight sensor to track intake and syncs with the app via Bluetooth. The evaluation showed high usability and acceptability among the target population. However, further research is needed to determine the system's effectiveness in improving water intake.

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