H2Office: A Smartwatch and Water-Gauge System for Facilitating Hydration of Knowledge Workers

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Abstract. Consistent hydration is paramount for health and well-being. For knowledge workers, it also has an impact on overall productivity. Unfortunately, many knowledge workers experience insufficient hydration during busy working hours. We conducted interviews (N=10) to investigate the causes of inconsistent hydration during work and explore the expectations of knowledge workers regarding intervention systems to improve their hydration habits. Based on the results of the interview study we designed the H2Office system, a comprehensive approach comprising a water gauge and a smartwatch app. A comparative field study over 10 days (N=7) of the H2Office system shows its effectiveness in motivating knowledge workers to increase their water intake substantially (by 61%). The combination of auditory and vibration intervention effectively reminded them without causing any work distractions. In the evaluation of H2Office we identify detailed water consumption patterns of users concerning the time of day, sip interval, and sip quantity. Lastly, we found that knowledge workers desired a holistic approach (tracking consumption of other beverages) for delivering hydration interventions.

Keywords: Hydration · Interventions · Auditory icon · Office · Health · Well-being · Knowledge worker

1 Introduction

Water is essential for our day-to-day functioning. It accounts for 60% of an adult body weight [8]. It helps in building material for cells and carriers for tissues [10]. Hydration helps in regulating body temperature, aids brain function, helps to restore fluids, breathing, sweating, and the removal of waste [9]. Irregular hydration leads to a decrease in alertness and concentration, and a significant increase in headaches and tiredness [11,12]. Hence, it is important to have consistent and adequate intake of water during work.

As knowledge workers, individuals invest a significant portion of their daily lives in the workplace, dedicating 8-10 hours each day. They are found across

multiple professions, where they are expected to innovate and solve complex problems in their respective fields [27]. Considering the entirety of our lifespan, work emerges as the second most time-consuming activity after sleep [13]. On average, a working individual located in Europe or the USA allocates 1350-1750 hours per year to working [14]. Given the demands of their busy schedules and workloads, knowledge workers often overlook the importance of maintaining adequate hydration.

Water intake reminders after a regular interval were one of the desired features of work assistance [16]. To overcome dehydration knowledge workers have been relying on various techniques to hydrate themselves regularly. Examples include mobile applications like "Water Minder" [20] and "Water Reminder" [21] as well as smart water bottles like "HidrateSpark" [25]. However, none of the current water intake apps and devices have been specifically designed considering the challenges and requirements of the knowledge workers while at work.

The initial phase of this research involved conducting interviews with 10 knowledge workers, with a specific focus on determining challenges related to regular water intake at the workplace. The objective was to identify the expectations of knowledge workers with regard to a water reminder system. Subsequently, we developed the "H2Office" system, which comprises a water-gauge device and a smartwatch watchface and app. The water-gauge device was designed for precise measurement of water consumption over time, while the smartwatch app aimed to deliver interventions, update the water intake state within the app, set goals, and motivate knowledge workers to achieve their daily hydration targets.

Following the development phase, we executed a 10-day comparative field study involving 7 knowledge workers. The results demonstrate a significant increase in water consumption among knowledge workers when using H2Office in comparison to their baseline (Table 1). The auditory icon of a water-pouring sound was well-suited to a formal office setting, effectively capturing their attention without distracting them or their colleagues. Additionally, feedback from knowledge workers highlighted H2Office effectiveness in increasing daily water intake. Furthermore, the participants gave suggestions for improving the system's design and considering holistic approach for H2Office interventions.

Our contributions can be summarized as follows: (1) We identified the factors associated with the inconsistent hydration of knowledge workers and elicited their expectations with regard to a water reminder system. (2) We designed and developed the H2Office system for office settings to actively promote and support consistent hydration. (3) We conducted an evaluation of H2Office through a field study, determining the system's potential and identifying hydration patterns of knowledge workers.

2 Related Work

Different intervention techniques have been used with the objective of ensuring hydration during work. To increase hydration, intervention techniques can broadly be divided into two approaches: The gamification approach uses points

and penalties in the interface to motivate users to drink more water. Another approach involves group-based motivation strategies, which are based on collective encouragement.

2.1 Intervention and Gamification Approaches for Hydration

Graphical and ambient intervention techniques have been frequently implemented to remind users to drink water. In the 'Mug-Tree' experiment [7], Ko et al. designed a playful mug linking water consumption to nurturing a virtual tree. Similarly, 'WaterCoaster' [5] introduced a virtual fish character in a fish tank, relying on regular water intake for the virtual creature's survival. Another approach, 'GROW' [6], presented an ambient water bottle unveiling a cherry tree silhouette. The act of drinking water determined the visibility of branches and leaves, tracking progress towards the hydration goal. 'MossWater' [17] employed an empathetic approach, with the system performing the action of watering moss to remind users to drink.

'WorkFit' [3] utilized voice interventions techniques for reminding knowledge workers to drink water. Voice interactions were successful in reminding and motivating knowledge workers in drinking water. Moreover, in 'Dual-intervention' [2] strategy Ahire et al. asked knowledge workers to rank their modality preference for nutrition intervention. They ranked vibration, ring, graphical and auditory icon and their preferred mode for primary intervention and followed by voice reminder as secondary mode of intervention.

'Hydroprompt' [19] utilized three approaches within its system: historical information, enabling users to compare their water intake levels; implicit feedback, providing subtle cues to users; and explicit prompting, attempting to remind participants when hydration falls below acceptable levels. Gouko et al.[18] developed a coaster that prompted desk workers to hydrate by emitting periodic sounds. Their investigation revealed that a 15-minute interval was optimal for maximizing work efficiency. Hamatani et al. [26] investigated the use of smartwatch sensors to gauge water intake by analyzing drinking duration. They employed a macro-activity classifier to differentiate drinking from other activities and a micro-activity classifier to identify sequential micro-actions like holding the bottle, drinking, and putting the bottle down.

2.2 Collective Water Consumption

In an effort to promote collective water consumption among office workers, the 'Playful Bottle' study [4] compared a single-user 'Tree' with multi-user 'Forest' strategies for encouraging water intake. Social reminders were found to be more effective than single-user prompts. Additionally, 'Wwall' [15] employed an ambient display to offer individual yet collective feedback in office settings, promoting cooperation and shared goals over individual objectives. Visuals on the wall held significance when all participants achieved their personal objectives. Although prior literature has evaluated multiple approaches, it is essential to investigate

whether proactive autitory interventions can encourage knowledge workers to drink water and, if so, how effective those are.

2.3 Commercial Applications and Devices for Hydration

Knowledge workers are also opting for different water reminder and water intake tracking applications like "Water Minder" [20] and "Water Reminder – Daily Tracker" [21]. However this applications delivers a reminder and requires users to estimate their consumption and update it regularly. Similar these apps, some smartwatches also offer water intake reminding and tracking[1]. However these typically rely on the user for updating the hydration state. Likewise, the HidrateSpark water bottle [25] features an integrated gauge for monitoring water intake. It sends reminders to the user's smartphone and enables water consumption tracking through a dedicated app. All applications and devices are dependent on mobile phones for delivering interventions. This reliance means users must consistently check their phones for updates on their hydration intake, potentially leading to increased screen time and distraction while at work.

3 Interview Study

To gather insight into the hydration behavior of knowledge workers and the associated challenges, we conducted semi-structured interviews. In particular, the aim was to understand the causes of inconsistent hydration during work hours and to gather knowledge workers expectations concerning a hydration reminder system.

3.1 Participants

We conducted interviews with 10 knowledge workers. All the participants were male. The age range of the participants was between 24 and 30. On average the participants worked 7.2 hours per day. They self-reported that during their workday, they drank between 2 to 3.3 cups of water per day. We recruited the participants using snowball sampling and by advertising the study on university forums. Three participants also had experience using water reminder apps such as WaterMinder [20] and Aqualert [24].

3.2 Method

We initiated our interviews by investigating the problems that knowledge workers face in achieving consistent hydration. Following this, we inquired them about their expectation of a system that would support them in achieving consistent hydration.

Audio recordings of post-study interviews underwent transcription and coding. Codes were devised to encapsulate the essence of the data and convey its

[1] `https://www.youtube.com/watch?v=U8MTy0VV4gc`

concepts and ideas. Inductive thematic analysis was employed to uncover emerging themes. Patterns, similarities, and connections among codes were scrutinized to delineate distinct themes, each of which was described and labeled. To uphold rigor, the first and second author independently cross-checked the identified themes [22].

3.3 Findings: Causes of Inconsistent Hydration

From the interviews, we identified four important causes of inconsistent hydration.

Forgetfulness amidst demanding work routines. Knowledge workers function within tight schedules and engage in challenging and demanding tasks. Participant P4, P6, and P9 highlighted that their heavy workload and deep engagement in tasks often led to forgetfulness regarding water consumption. In some instances, back-to-back meetings consumed their time, causing them to overlook their health needs. The demanding and fully scheduled nature of their work routines resulted in many users forgetting to prioritize and consume an adequate amount of water.

Reduced hydration: consequence of habitual consumption of other beverages. Participants P6, P1, and P7 noted that their habitual consumption of coffee made them less prone to feeling thirsty, resulting in limited water intake each day. The regular consumption of other beverages, such as tea, coffee, and energy drinks, often eliminated their explicit thirst for water. This consistent intake of alternative beverages contributed to a reduced overall consumption of water in their daily routine.

Challenges with existing water reminder apps. Participants P2, P8, and P3, who had prior experience with water reminder apps, expressed their views on the effectiveness of such apps. While acknowledging the utility of reminder and tracking apps, they pointed out a significant drawback – the reliance on users for inputting data. The dependence on users to manually log water intake updates was perceived as tedious and added cognitive load, as it required consistent input each time. Additionally, participants felt that manual logging introduced inaccuracies, making it challenging to estimate their actual water intake. These inaccuracies, in turn, led to demotivation over the long term.

Dilemma of reminder and distractions. Many water reminder applications depend heavily on mobile notifications for hydration reminders. However while working if the mobile device is set aside due to distractions, then there is a risk of forgetting to drink water. However, if the mobile phone is kept nearby, the knowledge worker may face additional distractions from other notifications such as social media notifications. This situation presents users with a dilemma, as

they must choose between being distracted by the phone and receiving water intake notifications, thereby creating a challenging decision-making scenario.

3.4 Requirements: Expectations of the System

In this section, we discuss two essential expectations of the participants concerning the hydration intervention system.

Effortless and automatic In contrast to existing applications, participants suggested a system featuring an automated water measurement mechanism. They proposed that the system would monitor their water intake timing, send notifications at regular intervals, record water consumption, and compile a total of daily water intake. Additionally, participants expressed their desire to establish a daily water intake goal, utilizing the water reminder system to assist them in achieving this objective. *"I do not want to give too much effort every time I use the device or the app. I only want to get notification and motivation."* -P1. Moreover, the participants expressed the desire for the system to send reminders every 45-60 minutes.

Non-disruptive and unobtrusive interventions. Some participants preferred a non-intrusive water reminder in the form of a pop-up rather than an app that requires active opening and tracking. They wished for the water app to be consistently visible on the front of the screen of their smartphone, serving as a subconscious prompt for water intake without distracting them consistently. The app should also automatically display progress in a subtle manner to without breaking their workflow, removing the need to open the app each time to check intake and progress. One participant specifically mentioned his preference to show the information on the front screen, stating, *"I am too busy to open the app and see my progress every time and I might end up forgetting about the app."* -P2 Furthermore, unlike commercial intervention systems that use distractive reminders, participants desired a system that was subtle and non-intrusive.

4 Development and Testing of H2Office

In this section, we explain the development of H2Office, its components, and software for development. Further, we also discuss the process of testing the H2Office water-gauge.

4.1 Water Gauge

The water gauge utilizes a load cell sensor HX711, which functions as an analog-to-digital converter (ADC), primarily employed for object scaling[2]. The primary

[2] `https://www.digikey.com/htmldatasheets/production/1836471/0/0/1/hx711.html`

function of the water gauge is to calculate water consumption after each sip. This involves determining the weight of the bottle or glass both before and after consumption. The water gauge calculates the water quantity by analyzing the difference in bottle weight before and after consumption, converting grams to milliliters (1 g = 1 ml). The HX711 comprises four relevant pins: GND, VCC, DT, and SCK. GND and VCC are responsible for powering the circuit, while communication with the Raspberry Pi is realized via DT and SCK.

4.2 Raspberry Pi

A Raspberry Pi serves as the integral component for calculating water intake and for recording date, time, and user identifier. It connects to the Internet via WiFi and uploads the data to a Firebase database.

4.3 Firebase Database

Firebase, a back-end service by Google[3], operates as a real-time database, in which data is stored and retrieved in JSON format. The Firebase database is utilized to store the water intake (in milliliters), date, time, and user identifier. The measurements sent to the database are subsequently forwarded to the H2Office smartwatch app, to update the water intake information. The Firebase database maintains a persistent record of each user's water intake behavior.

4.4 Smartwatch

The smartwatch was chosen as the users interaction device for its close proximity to the user, thereby being effective in capturing attention and delivering voice interventions. The likelihood of users not noticing voice interventions due to focused work is minimized when delivered through a smartwatch. Additionally, smartwatches facilitate multimodal interactions, encompassing graphical, voice, and tactile outputs, enabling users to engage through diverse modes. As found in the interviews (section 3.3) unlike mobile phones, smartwatches do not pose a significant source of distraction for knowledge workers. We used the Samsung Galaxy 4[4] smartwatch for app deployment.

H2Office app. The smartwatch app was created to administer interventions and synchronize user's water intake consumption from the cloud. Users are required to log in to their profile, configure the water intake interval, and set their working hours and working days within the app. Additionally, the app provides a display of weekly statistics (Figure 3) of daily water consumption.

[3] `https://firebase.google.com/`
[4] `https://www.samsung.com/global/galaxy/galaxy-watch4/specs/`

Fig. 1. H2Office watchface: showcasing achieved goal, overall intake target, last water intake timer, and last water consumption

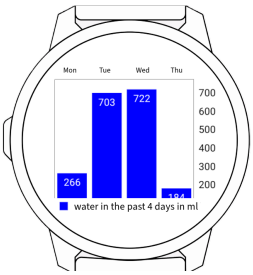

Fig. 2. H2Office app stats page, showing the consumption of last 4 days

Fig. 3. H2Office gauge system at the in-situ settings

H2Office watchface Prior literature has shown that smartwatch users prefer's to update about their activity in glance without consuming more time and is perceivable at the periphery of users attention [1]. Watchface enables users to quickly glance the activity status. Moreover, watchface helps motivating smartwatch users and encourage them in achieving their goals [23]. Therefore, we used a watchface so that the water reminder is always upfront and explicit. This enables users to monitor this information in a short glimpse and not get distracted from the on-going task. The watchface must meet aesthetic requirements and can only display one app at a time due to limited space. Because it must be easy to read at a glance and space is limited, it cannot accommodate a large amount of information. Additionally, it must still allow users to easily read the current time.

As shown in Figure 1, we designed the watchface as an animated water tank. The water level increases after each sip. The watchface also displays the total amount of water that was consumed during the day as well as the goal the user set for the day. It displays the water consumption during the last intake and time (in minutes) since last consumption.

H2Office interventions While designing the interventions for H2Office, we focused on keeping the attention required by the knowledge workers at a minimum in order to prevent distracting them too much. We decided to deliver the intervention using an auditory icon and a vibration. For the auditory icon we selected the sound of pouring water, which can be easily associated with drinking water. Further, the sound of pouring water is subtle and non-intrusive to knowledge workers and their colleagues. The sound of auditory icon[5]. A vibration interven-

[5] `https://drive.google.com/file/d/1tt0TSe0_7HIKTaOQ2YnWfr_cyiO8LYvi/view?usp=sharing`

tion combine with audio can serve as an additional reminder if the audio fails to capture the user's attention or if the smartwatch is set on low volume.

4.5 Testing H2Office

In the testing phase, we assessed the precision of water intake measurements by cross-referencing them with a kitchen weighing scale. To ensure the calibration of the gauge, a known weight was placed on it to establish a reference unit. Subsequently, this value was incorporated into the code. Our calibration process involved using 1 kg food packets, weighing them on a standard scale, and calibrating the gauge accordingly. Through multiple gauge tests, we observed a standard error of $\pm$ 3 grams for every 1 kg. This deviation is deemed acceptable, equating to an error of 0.3%. As a verification step, we utilized a measuring jar to validate the accuracy of the calculated value in milliliters.

5 Field Study

5.1 Participants

The participant group consisted of 6 males and 1 female, all falling within the age range of 24 to 30. This group included both full-time and part-time knowledge workers. All the six male participants had also participated in our interview study. Participants were requested to complete the consent form. To maintain the integrity of the study, we ensured that participants were not utilizing any other intervention system for water intake, and their drinking behavior habits remained uninfluenced.

5.2 Method

The study was conducted for a duration of 10 working days, equivalent to two work weeks. The initial 5 days constituted the baseline condition, followed by the second 5 days dedicated to the evaluation of the H2Office prototype. Throughout the baseline condition, participants were instructed to independently record their daily water intake using measuring jugs and submit the data at the end of each day. In the evaluation phase, participants were requested to use our prototype, which consisted of the H2Office water gauge system and a smartwatch app. It was emphasized that the smartwatch should be consistently worn throughout the study period, as the H2Office app would only deliver interventions when the smartwatch was securely fastened to the wrist.

The study was conducted in the month of May 2023 and all the participants were located in Hannover, Germany. After the field evaluation we conducted interviews with the participants. Post-study interview recordings were transcribed, coded, and analyzed using thematic analysis. Patterns and connections among codes were examined to define distinct themes, cross-checked independently by the second author [22].

6 Results

6.1 Quantitative Findings

Table 1. Mean values of each participant's data, including baseline water consumption, water intake with the H2Office intervention, percentage increase, total number of sips, intake per sip, and sip frequency using H2Office.

Participant	Baseline (ml)	H2Office (ml)	Increase (%)	Total Sips	Intake per Sip (ml)	Sip Interval (minutes)
P1	1080	1196.4	10.8	48	112	42
P2	515	1068.0	107.3	41	126	59
P3	290	494.4	70.4	49	122	44
P4	1350	1708.6	26.6	69	128	50
P5	500	1032.8	106.6	35	71	50
P6	1500	1975.4	31.7	196	51	12
P7	560	980.2	75.0	35	140	63
Mean	828	1208.0	61.2	68	107	46

Overall, the system recorded 473 sips of water by the seven participants. The total number of sips per participant ranged from 35 to 196, with a mean of 68 sips per participant. Similarly, water consumption per sip for participants ranged from 51 to 140 ml, with a mean of 107 ml per sip. During interviews participants desired the sip interval to be 45-60 minutes (Section 3.4). Nevertheless, except for P6 all participants had sip intervals between 42 and 63 minutes. During the baseline condition, participants consumed an average of 827 ml, whereas with the H2Office intervention, the average water consumption increased to 1207 ml, indicating a 61% increase.

In the evaluation we found an average increase in water intake of 61.2%. The smallest increase was by 10.8% for participant P1. The maximum increase was by 107.4% for participant P2. It was unexpected to discover that participants P4 and P6, despite having a substantial baseline intake of 1350 and 1500ml, exhibited notable increases of 26.6% and 31.7%, respectively, in the H2Office condition. A paired t-test showed a significant difference in water consumption between the H2Office condition and the baseline condition ($p < 0.05$).

The comparative bar graph of baseline and H2Office for each participant is presented in Figure 4, revealing a substantial increase in water consumption for each participant. The distribution of water intake for all participants is shown in the histogram in Figure 5. Notably, the frequency of intakes within the 40-80 ml range surpasses that of all other intake values. Additionally, Figure 6 illustrates the overall water intake for each hour. Notably, there is an observed increase in the frequency and water intake amount from 12 pm to 4 pm, indicating higher and more frequent water consumption in the afternoon compared to the morning.

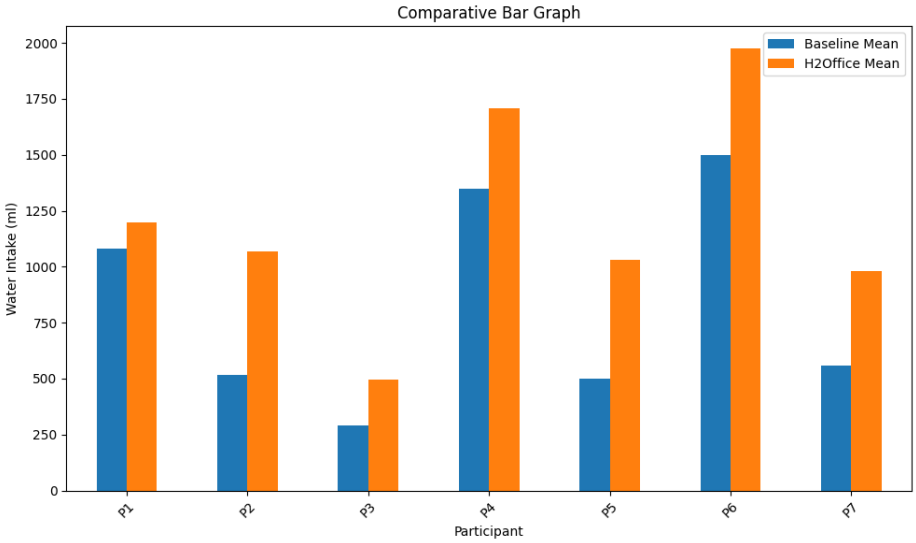

Fig. 4. Means water intake under the baseline condition (blue) and the H2Office condition (orange) for each participant. The intervention leads to a clear increase in average water intake.

As the results show, H2Office substantially increases the water consumption of the participants during the work hours. Thus H2Office is an effective intervention for achieving higher water intake among the participants. This outcome underscores the positive impact of H2Office on encouraging individuals to consume more water, which can have important implications for overall health and well-being.

6.2 Qualitative Findings

Auditory icons and vibrations proved to be effective Several participants stated that auditory intervention combined with vibration was well-suited for the formal office setting. It was able to effectively catch their attention but at the same time did not distract them significantly from work. As the intervention was an auditory icon of pouring water, they could easily distinguish the H2Office notification from the other notifications. Furthermore, the auditory intervention was not extensively loud and did not capture the attention of neighboring colleagues. Because of the smartwatch's proximity to the user, they could distinctly feel the vibration during the intervention. As a result, the combination of both modalities effectively reminded them to stay hydrated.

Count-up timer serves as a hydration reminder Several participants expressed that the count-up timer (Figure 1, line 2), which shows the time since

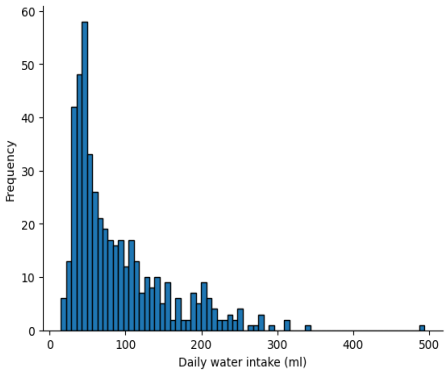

Fig. 5. Distribution of intake amounts (in ml).

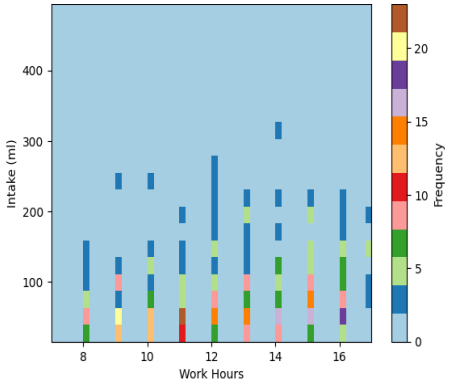

Fig. 6. Overall water intake for each hour and frequency of intake per hour.

the last water intake was effective in motivating them to consume water. Participant 1 specifically stated, *"The count-up timer was more helpful than the notification"* emphasizing that observing the time elapsed since the last water intake proved beneficial. Often, participants did not wait for the interventions, but drank water after having a glimpse at the last intake time. In the interview, P6 stated *"I didn't receive so many notifications to drink water, as I looked at the count-up timer and frequently drank water."*

Building trust: importance of accuracy in water intake Participants observed that precision of H2Office during water consumption was particularly intriguing. H2Office demonstrated proficiency in calculating water intake, providing updates in milliliters that were not rounded off to conventional values like 50 ml or 100 ml. Instead, the displayed measurements were precise, such as 58 ml or 67 ml, aligning closely with the actual amount of water consumed with each sip. This non-rounded approach contributed to participant's trusting the device's calculations, leading them to take their water intake more seriously. As one participant, P6, expressed, *"I was skeptical at first: Does the device really measure the amount of water? I drank from the glass and estimated the water intake, then compared it with the given result on the watchface. It is really doing its job."* This firsthand verification highlighted the accuracy of the device and reinforced the participants' confidence in its functionality.

Holistic approach: extending beyond water Some participants suggested adopting a holistic approach that involves tracking the intake of beverages (such as coffee, tea, soft drinks, and juices) and subsequently recommending water intake. The interest in tracking these beverages stemmed from their habitual consumption of these drinks, unlike water, which often required external triggers and motivation. Participants, however, were concerned about the health

implications of their habitual consumption of beverages containing caffeine and sugar. Since these beverages also contribute to overall fluid intake, participants proposed incorporating a comprehensive approach to hydration recommendations. Additionally, participants pointed out specific times during the workday, such as the start and post-lunch period, when coffee and tea intake was crucial for functioning and integral to their daily routine. They suggested H2Office to consider these factors before recommending water intake to align with their established beverage consumption patterns.

Recommending water intake goal based on a health issue Few participants recommended taking into account individual health considerations related to dehydration. They emphasized the importance of recognizing the critical role of consistent water consumption, acknowledging that while it might be a routine for some, for others, it is crucial for maintaining their health. One participant, P2, expressed a desire for the H2Office to not only monitor but also to recommend a goal based on health issues related to hydration. *"I want it [H2Office] to determine the needed amount of water based on health issue."* This suggestion illustrates the participants' interest in personalized health monitoring and the potential role of technology in addressing individual hydration needs.

Desire for gamification based on points and penalties Most Participants expressed a desire for a more gamified experience to enhance their interest and engagement. Participants suggested incorporating gamification elements such as earning coins or points daily upon achieving the set water intake goals.

This approach was seen as a potential means to encourage consistency in daily water consumption and increase overall participant engagement. Additionally, the idea of rewarding them for the goal completion and penalizing if them for not consistently hydrating them was considered valuable fostering a more serious approach. Participant P7 highlighted this sentiment, stating, *"I think the amount of water that I have consumed was enough, but I need to mention that I would like to have more games if it is possible."* Participant 5 echoed this sentiment, expressing, *"The idea is great, but I need more games. Water tank alone is good, but I need something more, like coins to buy something in the game."*

Optimized design and aesthetic of the device. Some participants recommended optimizing the design of H2Office, noting its current size was somewhat bulky for placing on a desk. They proposed a redesign, emphasizing the need to consider the clutter typically found on desks. Specifically, the participants suggested shaping the prototype to resemble a coaster in terms of size and thickness.

In addition, participants advised taking into account the average empty space available on desks during the design process. One participant, P3, commented, *"The idea and the device itself are well designed, but I don't have enough space on my desk, although I can find some space for it."* Another participant, P5, highlighted the significance of the device's shape and design, stating, *"The device shape and design are very important to me, as the office is a formal setting."*

These statements underscored the participants emphasis on practicality, aesthetics, and the integration of the device into their professional work environment.

7 Discussion

As knowledge workers have a busy schedule, it was important to find a balance between attention seeking, interventions, and distractions. Users expected our H2Office system to be non-intrusive and not distracting. In H2Office, we implemented a technique involving auditory interventions, GUI notifications, and vibration. Using this combination, users felt that the intervention was not distracting. Users highlighted that the "last intake timer" feature increased their awareness of their drinking habits and made them more attentive to their hydration behavior.

We found that hydration interventions proved beneficial to the users and were able to significantly increase the water intake in comparison to their baseline. We uncovered drinking patterns of the users by considering their time intervals between sips and amount of water consumption. We found that water intake was higher in the period between noon and 4 pm than in the period between 8 am and noon. There can be multiple reasons for this. Knowledge workers generally consume coffee or tea in the morning, which may lead to the less water intake in the early morning. Another reason could be weather conditions, since the study was conducted in the month of May, in which the temperature rises after noon, which may lead to higher consumption. During the afternoon, knowledge workers may demonstrate an increased awareness of water consumption compared to the morning, resulting in a rise in the frequency of intake and overall consumption.

In the WorkFit study [3], proactive voice interventions in office environments faced challenges such as lack of agency, privacy concerns, and intrusiveness to colleagues. However, in our study, auditory interventions proved advantageous by delivering subtle audio cues audible only to the users, ensuring they were non-intrusive to their colleagues. Moreover, the use of auditory icons did not raise privacy or agency concerns among knowledge workers in a formal office setting. In 'Dual-Intervention' [2] study, vibration was ranked as most preferred modality for nutritional intervention, similarly we found vibration modality provide beneficial for delivering hydration intervention in work setting.

In previous studies, penalties were implemented using various methods such as a tree wilting [7], moss drying up [17], and in the "Water Coaster" system [5], the water level in the fish tank decreased when there was insufficient water intake, potentially endangering the fish. Although we built an interactive system for water intake, H2Office does not have a provision for assigning penalties for missing the water intake. Like the collective water consumption and drinking techniques [4,15], participants expressed a desire for gamification and for inculcating a competitive approach for achieving their daily goals. This could encourage users to compete and achieve their goals with more dedication.

While HidrateSpark [25] employs a similar approach, its limitations include dependency on the HidrateSpark water bottle exclusively for tracking and re-

minders of water consumption. Moreover, it carries a hefty price tag, ranging from $54–$79 per bottle, and requires meticulous care in both cleaning and usage. In contrast, H2Office users have the flexibility to use day-to-day items like glasses, water bottles, or cups according to their needs. Additionally, Hidrate-Spark water bottles and intervention are not specifically designed and developed for office settings and knowledge workers.

Accuracy was judged as an important feature of H2Office. Accuracy of the amount of water consumed helped in building trust and maintain the participants' interest towards H2Office. Further, users were also impressed that H2Office not only delivered interventions, but that it also delivered and calculated their consumption automatically. An average working day of a knowledge workers comprises various drinks, such as water, coffee, juice, and tea. Beverages like coffee and tea were judged as essential for their work day productivity. Furthermore, for some knowledge workers who were habitual to drinking coffee, this was also a growing concern for them. These knowledge workers desired to minimize their coffee intake during their work day. They requested to also measure their coffee consumption and to help them to minimize it and increase their water intake.

7.1 Limitations and Future Work

We would like to discuss the limitations of our paper. Our sample size is highly dominated by male participants. However, we do not think that this invalidates the results of the study. As the study was conducted in the month of May in Hannover, Germany, the drinking patterns are affected by the location, duration, and weather during the study. In the future, we would like to develop a model that provides recommendations to knowledge workers based on weather, gender, age and health conditions. Further, we aim to implement a holistic approach to monitor the intake of other beverages and help knowledge workers to limit them. Also, we would like to optimize and improve the design of H2Office with respect to the size and available place on the knowledge worker's desk. Lastly, since the users appreciated the ability to quickly glance at the watch to see the time interval size the last sip, we would like to improve the visualization of the time interval to enable glanceability [1].

8 Conclusion

We commenced our research by examining the factors contributing to inconsistent hydration among knowledge workers. Our findings highlight that demanding work schedules, habitual consumption of other beverages and challenges with distractions and reminders in existing apps were key contributors to dehydration. In exploring our participant's expectations, we identified a preference for a device that is effortless, performs automated calculations and interventions, and sustains their interest in the long term. In response to these insights, we developed the H2Office system, comprising a water gauge and a smartwatch watchface and

app. We used auditory icon as an intervention for hydration reminder. Results of the field study indicate that H2Office effectively reminds knowledge workers to consistently rehydrate during work. Notably, H2Office substantially enhanced hydration levels compared to the baseline (by 61%). Importantly, we identified the drinking patterns of knowledge workers and in particular quantified the water intake intervals, consumption in milliliters and hourly consumption.

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