"To Click or not to Click": Back to Basic for Experience Sampling for Office Well-being in Shared Office Spaces

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ABSTRACT

Sensors in offices mainly measure environmental data, missing qualitative insights into office workers' perceptions. This opens the opportunity for active individual participation in data collection. To promote reflection on office well-being while overcoming experience sampling challenges in terms of privacy, notification, and display overload, and in-the-moment data collection, we developed Click-IO. Click-IO is a tangible, privacy-sensitive, mobile experience sampling tool that collects contextual information. We evaluated Click-IO for 20-days. The system enabled real-time reflections for office workers, promoting self-awareness of their environment and well-being. Its non-digital design ensured privacy-sensitive feedback collection, while its mobility facilitated in-the-moment feedback. Based on our findings, we identify design recommendations for the development of mobile experience sampling tools. Moreover, the integration of contextual data with environmental sensor data presented a more comprehensive understanding of individuals' experiences. This research contributes to the development of experience sampling tools and sensor integration for understanding office well-being.

CCS CONCEPTS

• **Human-centered computing → Interaction devices**.

KEYWORDS

Experience Sampling, Contextual data, Office well-being

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1 INTRODUCTION

Using sensors in office buildings can help optimize performance and work activities by collecting data for building management, such as measuring occupancy [51, 61] and energy consumption [42, 58]. By measuring environmental factors such as temperature, humidity, and light, these sensors can enhance our understanding of individual and social work habits [1, 7, 19, 43, 60]. While sensor systems are instrumental in measuring the overall workplace condition, they often fail to capture how individual workers experience the environment, giving an incomplete picture of overall well-being in the office [44, 73]. Encouraging people to express their views on their organization, the environment, and their well-being can positively impact workplace dynamics [22]. Furthermore, urging people to reflect on their work environment can facilitate and empower them to embrace healthier work routines and behavioral changes [8, 16]. Our work proposes to involve individuals as active participants in data collection by combining the worker experience with environmental data to improve understanding of overall office well-being [7, 8].

While contextual data collection systems have emerged over the years (e.g., [22, 25, 29, 31, 32, 46, 50]), the common approach to collecting contextual information from office workers is annual surveys [17] focusing on topics such as the office environment [4, 34, 45], well-being [40], and management [23]. Yet, these surveys only ask for employee feedback annually, missing in-the-moment feedback and making follow-up questions difficult [17]. Additionally, a survey can be too limited in scope by addressing only employee satisfaction-related issues or too broad by covering too many topics for management to address effectively in a year [38, 48]. An alternative method commonly used to collect data is mobile experience sampling [73]. Using mobile devices to send notifications eliminates the need for participant memory to reconstruct past events and concentrates data collection on research-relevant events [59, 73]. However, researchers have raised concerns about the potential downsides of using this method. For example, notifications can distract participants and cause an additional burden, particularly for office workers who may be trying to focus on their work [27, 47, 73]. Furthermore, notification overload can lead to display blindness [54] and low content recall [57], and using participants' mobile phones can also pose a risk to data privacy due to the potential collection of personal data without user knowledge [59].

Figure 1: Click-IO: a tangible, mobile, and privacy-sensitive experience sampling tool.

To encourage people to express their views on their well-being, Click-IO (Figure 1) incorporates design principles derived from an analysis of 21 existing public data collection installations and mobile experience sampling (Table 1), while addressing challenges associated with notification overload and display blindness. The foundation of Click-IO rests on key design principles: (i) Privacy Prioritization: By eliminating the need for personal phone or digital identification, Click-IO ensures user privacy. (ii) Tangibility and Unobtrusiveness: Allowing users to opt in and choose when to input data fosters an unobtrusive environment through minimized direct display interactions to address challenges like notification overload and display blindness. (iii) In-the-Moment data collection: Click-IO facilitates instant interactions, allowing individuals to use the system without relying on memory. This is achieved through the utilization of tangible clickers, enabling data input at any location within the office. The mobile aspect of this approach, in contrast to situated public data collection systems, empowers individuals to reflect in situ without being constrained at a specific location [26, 32]. It allows them to track their actions throughout the day giving them the autonomy to decide when and where to vote, while also allowing researchers to analyze spatial variations. (iv) Social visibility: Click-IO comprises a clicker station and data logging agents (clickers). The clicker station, centrally positioned, encourages active user engagement and community discussions throughout data collection. Simultaneously, the mobile data logging agents eliminate the need for users to walk to the main unit, allowing private voting and setting a low threshold for participation. In summary, Click-IO incorporates a privacy-conscious approach, social visibility, user-friendly unobtrusiveness, and the ability to capture data in-the-moment, making it a versatile and efficient system. Furthermore, to study the consequences of the system and approach, we explore how we can combine data from the clickers with environmental data from stationary sensor systems to learn if and how this combination can enhance our understanding of office well-being [73]. We describe the technical details of the artifact and its technical implementation, (ii) evaluate the system in a real-world setting, and (iii) propose design recommendations for the development of mobile experience sampling tools. To evaluate the system, Click-IO was used for 20 days in an office setting, asking individuals to reflect on the office environment and well-being. Based on the findings, we discuss the use and development of tangible and mobile experience sampling tools that enable real-time reflections for office workers, promoting self-awareness regarding their environment and well-being. Additionally, we discuss how the design ensures privacy-sensitive feedback collection, while its portability facilitates the option for in-the-moment feedback. Furthermore, we analyze the integration of contextual data with information from environmental sensors, which presents a more comprehensive understanding of individuals' experiences. Based on these findings, we identify design recommendations for developing these kinds of mobile experience sampling tools. Through Click-IO we contribute a new approach to experience sampling to support the collection of office well-being data.

Name	Ref	Year	Input:	Data collection	Mobility	Form	Localization
"Interactive Opinion Polls"	[2]	2014	Public	Private	Non-Mobile	Digital	Easy
SmallTalk	[21]	2016	Public	Private	Non-Mobile	Tangible	Easy
Mood-Squeezer	[22]	2015	Private	Private	Non-Mobile	Tangible	Hard
Sense-Us	[24]	2015	Public	Public	Non-Mobile	Tangible	Easy
VoxBox	[25]	2015	Public	Private	Non-Mobile	Tangible	Easy
"Kiosk"	[27]	2016	Public	Private	Non-Mobile	Digital	Easy
Umati	[29]	2012	Public	Public	Non-Mobile	Digital	Easy
Bazaar	[31]	2014	Public	Public	Non-Mobile	Digital	Easy
Roam-IO	[32]	2019	Public	Private	Non-Mobile	Digital	Easy
I-Vote	[37]	2004	Private	Private	Mobile	Tangible	Hard
"Everyone Is Talking about It"	[41]	2015	Public	Private	Mobile	Tangible	Hard
Pinsight	[46]	2018	Private	Private	Mobile	Tangible	Easy
FunSquare	[50]	2012	Public	Private	Non-Mobile	Digital	Easy
Moment Machine	[49]	2015	Public	Public	Non-Mobile	Digital	Easy
Madeira Story Generator	[55]	2016	Public	Public	Non-Mobile	Digital	Easy
"People, Content, Location	[65]	2012	Private	Public	Mobile	Digital	Hard
"Vote with your feet"	[68]	2014	Public	Private	Non-Mobile	Tangible	Easy
Viewpoint	[70]	2012	Public	Private	Non-Mobile	Digital	Easy
MYPOSITION	[72]	2014	Public	Private	Non-Mobile	Digital	Easy
PosterVote	[74]	2014	Public	Private	Mobile	Tangible	Easy
VoiceYourView	[75]	2010	Public	Private	Non-Mobile	Tangible	Easy

Public	Private	Private	Public	Mobile	Non-mobile	Digital	Tangible	Easy	Hard
17	4	15	6	5	16	11	10	17	4

Commonly occurring pairs	
Most common	**Amount**
Public Data Input and Easy Localization	16
Non-Mobile and Public Data Input	14
Non-Mobile, Public Data Input and Easy Localization	14
Non-Mobile and Easy Localization	14
Private Data Collection and Public Data Input	13
Private Data Collection and Easy Localization	12
Least common	
Hard Localization, Private Data Collection and Private Data Input	2
Mobile, Private Data Collection and Easy Localization	2
Mobile, Private Data Collection and Private Data Input	2
Hard Localization, Mobile, Private Data Input	2
Mobile, Easy Localization	2
Hard Localization, Mobile, Private Data Collection	2

Table 1: Analysis of public data collection installations, including the level of privacy (public and private for both input and data collection), data localization (easy or hard to localize), form (tangible vs digital), and mobility (mobile vs non-mobile) and most and least common occurring pairs of features used in systems.

2 RELATED WORK

Our study aims to develop a tangible, mobile, and privacy-sensitive approach to collect contextual information from office workers. We examine previous work in the following research areas: (i) contextual data collection systems and (ii) office well-being data collection systems.

2.1 Contextual Data Collection Systems: Privacy, Localization, Input, and Data Collection

Traditional experience sampling methods, like surveys or diaries, are often structured and scheduled. Surveys [53], for instance, prompt recall and reporting of experiences, capturing snapshots of thoughts and emotions in both controlled and natural settings [15, 73]. These methods can be deployed in controlled or natural settings, capturing specific moments or the ongoing flow of experiences over time, and vary from pen-and-paper surveys [15] to mobile apps [73] and technological artifacts [12]. While pen-and-paper surveys can capture complex data, they might lack contextual richness, especially in repeated surveys. Conversely, mobile devices offer flexibility in survey deployment and rich contextual data collection through situated inquiry but raise issues like display and notification overload and privacy concerns [54, 62]. Public data collection installations address these issues, each emphasizing different attributes related to privacy (public and private for both input and data collection), data localization (easy or hard to localize), form (tangible vs digital), and mobility (mobile vs non-mobile). Analyzing 21 systems (Table 1), which we identified by employing "citation chaining" [14] starting with two key papers (Roam-IO [32] and Mood Squeezer [22]), we noted the following trends: most systems (f = 17) have public data input, where data collection is always visible; data logging is typically anonymous (private data collection, f = 15), the system is at a fixed location (non-mobile nature, f = 16), and uses digital notifications to trigger individuals (f = 11). Finally, for most systems (f = 17) it is easy to localize the data input. The most common feature combination is "Public Data Input" and "Easy Localization" (f = 16), with "Non-Mobile" systems frequently using this combination (f = 14). The least common features include "Private Data Collection" with "Mobile" and "Hard Localization" (f = 2).

To understand the strengths and weaknesses of these attributes, we discuss some systems that utilize different combinations. Examples like Pinsight [46], I-Vote [37], and Mood Squeezer [22] offer private input and collection, allowing anonymous participation. Conversely, installations like FunSquare [50] and VoxBox [25] have public input without personal details, while some, such as Twitter-based systems [65], trace data back to individuals via login credentials [31], ID cards [24, 29], or photos [49]. Such systems may allow more advanced data analysis, but could pose privacy concerns. Most installations collect data privately without personal detail traceability; some examples are MyPosition [72] and I-Vote [37]. Considering data localization capabilities, public data collection systems can be non-mobile, situated, or mobile. Non-mobile systems, like Roam-IO [32] and Viewpoint [70], offer easy localization, especially when they have multiple units that allow contextualizing feedback by collecting it at different locations. Mobile systems vary in data localization capabilities, with some like PosterVote [74] and Pinsight [46] localizing data effectively; for example, Pinsight collects artifact location data and displays it using interactive maps.

This analysis shows that public data collection systems vary in privacy, input characteristics, form, mobility, and data localization among public data collection installations. Furthermore, there is a clear contrast between such installations and experience sampling. While data input and collection are typically private in these systems, most public data collection systems use public data input, which may cause distractions in an office environment when the objective is to collect multiple data points daily. Furthermore, experience sampling is nowadays typically mobile [73], while public data collection systems are commonly non-mobile. A particularly uncommon combination is that of private data collection and input, mobile nature, and easy localization.

2.2 Office Well-Being Data Collection Systems

Public data collection installations collect data to understand users' experiences and opinions. While these systems typically do not measure any data on how the environment of office workers could influence their well-being, researchers in the field of office well-being have developed sensor-based systems that could help answer this question [8]. For example, Office Agents [67] collect work-related productivity, environmental factors such as light, sound, and air quality, as well as personal data such as physical activity. Meanwhile, the Break-Time Barometer [39] combines environmental factors such as light level, sound, temperature, and humidity with personal data on break times. However, both artifacts are limited to the user's desk or office environment and do not offer hybrid options for other work locations or home settings.

In contrast, SensorBadge [7] offers a more ego-centric approach to data collection, focusing on human-data interaction to provide personalized insights that promote healthier work styles and environments. This artifact allows personalized data collection and analysis. With SensorBadge, users can gain a better understanding of their office environment and make informed decisions to improve their health and productivity at work. However, mobile sensor systems typically do not include localization mechanisms, which is a disadvantage in terms of tracking responses compared to stationary sensor systems [33, 63]. Hybrid systems, which combine mobile and stationary systems, are a potential solution to overcome this issue [33], but are costly. Additionally, these systems do not collect any contextual information from the user. Therefore, we identify opportunities to combine the strengths of different systems by combining the localization capabilities of stationary sensor systems and tangible, mobile, and privacy-sensitive approaches to collect contextual information about office workers.

3 CLICK-IO

The previous section highlighted the need for a system that combines the strengths of experience sampling, public data collection installations, and office well-being measurement systems: real-time data collection, prevention of notification overload, private data input, preservation of anonymity, mobile or hybrid nature, tangible form, and collection of contextual information. To address this need, our work has the following goal: *to create a tangible, mobile, and privacy-sensitive system designed for shared office environments, where individuals engage in various tasks and work settings for different time periods.* As a response to this goal, we developed Click-IO: an experience sampling system for the collection of office well-being data. Click-IO builds on the principles of experience sampling by providing in-the-moment reflections on well-being, capturing real-time insights without relying on memory. Click-IO also integrates insights from public data collection systems by having a hybrid nature concerning mobility, collecting data anonymously, utilizing tangible clickers for easy interaction, allowing contextual data collection, and allowing private data input through a voluntary opt-in approach. The design principles therefore align with considerations from public data collection installations and mobile experience sampling, addressing challenges related to notification overload and display blindness.

3.1 Design Principles for Click-IO

Click-IO is based on the following design principles focusing on (i) Unobtrusiveness, (ii) In-the-moment data collection, (iii) Privacy Prioritization, and (iv) Social visibility:

D1: Tangibility and Unobtrusiveness: Click-IO is a tangible system, ensuring clear and easy interaction with low learning requirements [32]. The system utilizes clickers to enable straightforward interaction, allowing users to easily press to increase the value or turn a wheel to reset. While the system includes an iPad for presenting the challenges, direct user interaction is minimal, focusing mainly on the tangible clicker experience. This design counters notification overload [22] and display blindness [54] by limiting display interactions to reading the challenge.

D2: In-the-moment Data Collection: Click-IO enables in-the-moment reflection on environment and well-being, capturing real-time workplace insights and avoiding reliance on memory [73]. The small size of the clickers enhances their portability, allowing individuals to carry them easily throughout the day in their pocket or with a belt clip, supporting mobility and adaptability across various work activities [7].

D3: Privacy Prioritization: Click-IO ensures user autonomy in participation with a voluntary opt-in approach [32]. Participants freely choose to join by selecting a clicker and can opt-out by returning it. They can also exclude their data by resetting the clicker. By eliminating the need to use personal mobile devices for data collection, Click-IO addresses privacy concerns related to personal data collection [11, 59], prioritizing user privacy and safeguarding their information.

D4: Social Visibility: The clicker pick-up unit of Click-IO is positioned in a central office location to ensure accessibility and encourage community discussions [32]. Its visibility and public availability enhances social interactions and community building [6, 7, 22], promoting collective reflection on workplace well-being. The data logging agents (clickers) are mobile, minimizing the need to walk to the main unit for data input which might be disruptive in an office environment. The overall approachable design and familiarity with clickers make the system inclusive, facilitating interaction among diverse users.

3.2 The Click-IO system

The Click-IO[1] utilizes clickers, which were chosen as data logging units due to their ability to facilitate tangible, low-threshold interaction and their widespread availability in the market. The system is centered around a clicker station, designed to enable reflection on the environment and well-being. This station comprises a clicker platform, an iPad, an RFID scanner, a return basket, and clickers. Emphasizing approachability, its design incorporates wheels for mobility and a bamboo aesthetic contrasting with a white steel frame. Each station holds 18 clickers on a Perspex platform. Below, a custom-built RFID scanner (Wemos D1 controller linked to an MFRC522 scanner) is powered by a 12000 Mah Lipo battery and housed in a PLA 3D-printed container. The scanner reads tags on the clickers. Additionally, office-placed scanner poles with the same RFID technology (MFRC522) allow clicker check-in to track

[1]Github Click-IO: https://github.com/HansBrombacher/Click-IO.git

Figure 2: From design principles to system features: Overview of Click-IO with stepwise (i) reading the challenge and taking a clicker, (ii) scanning in the clicker at the location poll and, (iii) voting when an event occurring to the challenges occurs.

clicker usage. Data from all scanners, including clicker RFID IDs and timestamps, is stored in the Adafruit-IO Cloud.

Challenges in Click-IO are displayed on an iPad secured in a locked holder, using a website developed in Adobe Portfolio[2]. This holder is centrally positioned on the station for participant visibility. The system uses 4-digit mechanical manual palm clickers, ranging from 0 to 9999, which participants return to a foam-protected base at the station's bottom, safeguarding the clickers against damage. The clickers emitted a "brief clicking" sound upon pressing. However, pilot testing revealed that this noise was not particularly noticeable or disruptive.

3.3 Use of the System

The clicker station of Click-IO is centrally located, such as near a building's entrance, ensuring visibility to those entering. Participants pick up a clicker from the station, view the challenge on the iPad (Figure 2), and then scan their clicker on the RFID scanner. During their workday at the office, they scan their clicker at designated poles in various locations, enabling data localization. If an event corresponding to the challenge occurs, participants use their clicker to increase their value by clicking. At the day's end, participants return and scan their clickers at the station before placing them back in the basket.

3.4 Development of the Challenges

Challenges are displayed on an iPad at the clicker station. The challenges may cover various aspects of office well-being, including Space and Place (e.g., "How often was the temperature too warm in the office?"), and Everyday Interaction (e.g., "How often did you talk to a colleague?"). Additional categories, such as Fun (e.g., "How much coffee did you drink?"), may be added to increase user engagement. Topics, frequency, and degree of repetition can be tailored to the specifics of each study, making the system suitable for both short-term feedback and longitudinal studies to observe changing behaviors over time.

The process of designing, selecting and refining the challenges is as follows: The challenges in the Click-IO system are selected through collaborative sessions with relevant stakeholders, including researchers, office workers, and decision-makers. During the collaborative session, stakeholders also rate the generated challenges and add notes considering the following factors:

- **Ease of answering:** Challenges should not demand much mental effort to avoid disrupting work, and the phrasing should not be very ambiguous to avoid misinterpretations.
- **Privacy and ethics:** Challenges should not include topics that are ethically questionable, or might make participants uncomfortable. Any potential negative effects should be considered here, such as making participants too self-conscious about their actions, decreasing their social interaction due to the questions asked, or elevating any prior negative emotions.
- **Informativeness and potential for self-reflection:** Stakeholders here have the opportunity to indicate challenges that could also generate value for them, either through self-reflection during voting or at a follow-up session after the analysis of the results. Potential positive effects of challenges can also be added in this section (e.g. motivating participants to increase their physical activity through questions about sitting patterns).

The researchers conducted a second round of challenge filtering, considering the same factors as well as how the stakeholders rated

[2]https://portfolio.adobe.com

the questions based on these factors in the first round. This two-fold approach leads to the final set of questions, ensuring that the challenges will generate meaningful responses without generating any issues for the participants. The system also allows for questions answerable with counts, binary responses or single-direction (not diverging) scales, so at the final step the researchers adapt the challenges for measurability in Click-IO if needed (e.g., from "I am feeling cold during the day?" to "How many times was the temperature uncomfortable today?").

3.5 Analyzing Click-IO data

The data obtained from the scanned clickers is analyzed to compute the total time participants spent using the clicker, along with the number of clicks per user and per time unit (e.g, minute or hour). The data can be analyzed at different levels depending on the research question (e.g., at a group level or per space based on the localization poles). The placement of localization poles can be reassessed through preliminary data analysis conducted during the data collection phase. For instance, if the data reveals the presence of smaller spatial clusters within a larger area, adjustments to the pole locations may be considered. Additionally, there is an option to incorporate environmental sensor data, either for an overall evaluation of office conditions or per space, depending upon the number and distribution of sensors.

4 METHODOLOGY

To evaluate the use of Click-IO in a real-world setting, we deployed the system in an office environment over a 20-day period. The main goal of the deployment was to understand how users experienced the system and gain insight into the advantages and challenges surrounding mobility, tangibility, and privacy in our system's implementation. Furthermore, we explore how we can combine data from the clickers with environmental data from stationary sensor systems to learn if and how contextual clicker data and sensor-based data can reinforce each other. Click-IO is not designed to replace sensor-based systems used to measure well-being data in office buildings. Instead, we propose a complementary approach: integrating Click-IO data with sensor data when available. By analyzing both datasets together, we aim to obtain a more holistic understanding of well-being.

During the 20 days, the participants were presented with a total of 20 challenges. After the study period, semi-structured interviews were conducted. The study was approved by the university ethics board.

4.1 Challenges

The challenges of the study are based on a brainstorming session following the method described in section 3.4, with six designers working on office well-being, human-data interaction, and industrial design, who have worked in the location of the study. During six three-minute rounds, participants were asked to write challenges on A3 sheets and rotate them, collaboratively building on each other's work. We selected 20 challenges and rephrased those that were unmeasurable by a clicker. Challenges were presented once daily and changed every day. The selected challenges were as follows:

(1) How many times did you drink coffee today?
(2) How many times was the temperature uncomfortable today?
(3) How often did you surround yourself with music/put on headphones?
(4) How many times did you lose your concentration?
(5) How often did you have a walk during work? (change based on weather)
(6) How many times did you open a window?
(7) How many times did you feel energized/motivated?
(8) How often did you need a private working space?
(9) How many times were you distracted due to noise?
(10) How many times did you change the light conditions (blinders, lights, etc.) during work?
(11) How many times did you feel productive?
(12) How often were you in a good mood?
(13) How many times did you enter a room and find it stuffy?
(14) How many times did you drink water today?
(15) How many times did you stare out of the window/daydream?
(16) How often did you work in a standing position/use a bike chair?
(17) How many times was it too bright or too dark at your workplace?
(18) How many times did you take a break?
(19) How many times did you talk to someone?
(20) How many times did you switch tasks?

4.2 Data Collection

Throughout the study, several data sources were collected. First, data from the clickers were collected based on the presented challenges. This data were numeral data points and depended on the number of times the clickers were pressed and the total number of clickers that were used. Data collected from the scanned clickers corresponds to the total time the participants used the clicker to calculate the number of clicks per minute or hour.

Environmental data was collected through the Spacewell workplace app[3]. The Spacewell workplace platform is connected to several environmental sensors (e.g. humidity, CO2, temperature, occupancy, and VOC (Volatile organic compounds)) that are installed in the office. These data from the Spacewell app were combined with four SmartCitizens, which were distributed in the office environment. Smart Citizen [10] is an Arduino-based open hardware sensor kit that enables both outdoor and indoor sensing through a participatory online platform. Individuals can deploy their kit, which is connected over WiFi to an online platform that shares and visualizes sensor data related to the office, including nitrogen dioxide (NO2) and carbon monoxide (CO) gases, sunlight, noise, temperature, and humidity, updated every minute.

After each day, the environmental data were combined with the contextual clicker data to learn if the user experience matches the environmental data. This was evaluated on both the overall environmental level (workplace as a whole) and for specific environments (location of the clicker poles). To analyze this, the collected environmental data was compared to the environmental standards outlined in the report by the Dutch Green Building Council, which

[3]https://spacewell.com/solutions/workplace-solutions/workplace-experience/smart-workplace-app/personal-assistant

Figure 3: Office overview including (i) position of the clicker stations and polls, (ii) placement of the environmental sensors, and (iii) division of the office environment per location.

is a translation of the World Green Building Council's publication on 'Health, Wellbeing, and Productivity in Offices' [13]. These standards aim to ensure a healthy office environment, with specific guidelines for CO2 levels (below 800 ppm), temperature (between 20 and 25 degrees Celsius), light (between 300 and 500 lux), and sound/noise (below 40 dB). This analysis was not conducted as a comparative analysis but rather as an indication of similarities and differences between sensor data and the experience of individuals.

4.2.1 Overview of the Office Setting. The office setting is an existing open office in the Netherlands, comprising 18 sit-stand desks, 1 presentation area, 4 meeting rooms, 2 larger standing tables, 2 phone booths, and several smaller meeting spaces. The office demographics include several startups, graduate students, researchers, and supporting staff. Regarding workflow, individuals work either the whole day or half a day (either morning or afternoon). Office workers mostly have desk-based work behind a computer (based on a clean-desk policy) and occasionally presentations and meetings in dedicated rooms. Click-IO was deployed as follows: we distributed 6 clicker check-in polls, dividing the office space into 6 work locations (Figure 3) - 'standing', 'demo', 'water', 'coffee', 'presentation', and 'meeting'. Two clicker stations, for pick up and check out, were located at the entrance of the building. For environmental data collection, 10 Spacewell sensors and 4 SmartCitizen kits were placed around the office.

4.3 Participants and Procedures

Click-IO was employed for 20 work days (Table 2). In this interval, 292 clickers were deployed, with a daily average of 15 clickers. The range of usage spanned from a minimum of 10 to a maximum of 27 clickers per day. The total desk occupancy, measured in the Spacewell workplace app, during this period was 364 desks (an average of 18.2 desks occupied per day), ranging from a minimum of 10 to a maximum of 35 occupied desks. The system recorded a total of 1574 clicker votes, averaging 79 votes daily, with a day's votes ranging between 7 and 301. These figures were derived from complete data entries that included the clicker's location, start, and end time. Due to partial entries, 16 clickers and 127 votes were excluded. When analyzing location, standing space was predominant with 122 clickers (41.8%) and 726 votes (46.1%). The demo space followed with 55 clickers (18.8%) and 290 votes (18.4%). The water space accounted for 45 clickers (15.4%) and 231 votes (14.7%), while the presentation space accounted for 42 clickers (14.4%) and 229 votes (14.5%). The least frequented were the meeting rooms with 21 clickers (7.2%) and 80 votes (5.1%), and the coffee pantry with 7 clickers (2.4%) and 18 votes (1.1%).

Following the study, semi-structured interviews were conducted with 10 participants (5 male and 5 female, average age of 42.8 (SD = 15.9) and an average participation of 10,1 days) to gather additional information. The participants were recruited using convenience sampling and the criteria that they used Click-IO for a minimum of 5 days. The interview covered the following aspects: (i) introductory information such as age, gender, and the number of days the clicker was used, (ii) general impressions of the clicker; experiences related to the clicker's form and use, including noticeability in the morning and ease of use, as well as mobility, tangibility, privacy, and localization, (iii) opinions on the challenge topics, favorite and least favorite challenges, and any undesired challenges, (iv) how the clicker impacted the ability to provide information about the office environment, or triggered discussions regarding the system and the challenges, and (iv) future preferences and suggestions for system improvements. Follow-up questions were posed based on participants' responses. After obtaining consent, the interviews were recorded, transcribed, and analyzed using a combination of open coding and reflexive thematic analysis [5]. The analysis was done by 2 researchers. The open coding was conducted to understand participants' opinions related to our design principles (subsubsection 5.1.1). For thematic analysis, we followed an inductive approach and selected 96 codes. In the second round of coding, these codes were merged to form 17 themes based on a discussion between the researchers until consensus, which were subsequently merged into four overarching themes. Nine interviews were held in Dutch, the native language of the participants, and one in English. Quotes from the Dutch interviews were translated into English for this paper.

5 RESULTS

The Clicker was evaluated over a period of 20 days. In this section, we report on the analysis of the interviews with the participants and the analysis of the contextual clicker and environmental sensor data collected during the study.

5.1 Interviews

Five overarching themes were defined: (i) Clicker system as an Experience Sampling tool (with subthemes: privacy, localization, mobility, and in-the-moment feedback), (ii) challenges (with subtheme tensions in human-building interaction), (iii) reflection on the office environment (with subtheme environmental vs. Contextual data collection), (iv) social role of Click-IO, and (v) future development of Click-IO.

5.1.1 Clicker System as an Experience Sampling tool. Click-IO was developed as a tangible, mobile, and privacy-sensitive approach to collect contextual information from office workers. To evaluate these design principles, participants were asked how they experienced these principles during the study. Overall, Click-IO was perceived as an easy-to-use and understand tool. P10: *"It was simple, it was easy to use and clear what to do"*, P2: *"I also found the use of the clicker itself very easy and quick to understand"*, and P6: *"The device, it's very easy to use. It's super small and comfortable to carry around and it's very simple. It does one thing and it's clear."*. For some participants, the use of Click-IO became even a part of their daily work routine. P4: *"I really liked that there was a different question every day and I was looking forward to what the question would be today. I almost regretted not being there every day"*, and P5: *"it was just a bit of a habit of oh what's today's question? Okay, grab your clicker."*.

Privacy: The privacy aspect of the clicker was also discussed by the participants. The system was indicated as privacy-safe with almost no possibility of tracing the data back to the user. P4: *"It is extremely privacy safe, so that makes it very suitable [for data collection]"*, and P2: *"You are not connected to the data in any way, so for me, there is no problem at all in terms of privacy."*. The idea of using a privacy-safe system was experienced as pleasant since the participants did not need to be concerned with any privacy infringement. P10: *"I experienced that as pleasant; I had the feeling that it was just very anonymous"*, and P7: *"With this system, you are protected; there is no suspicion of privacy infringement behind it."*.

Localization: For the location of the clickers, 6 scanner poles were installed in the office environment. However, these poles were experienced with mixed reactions in terms of user-friendliness. P2: *"Those poles were quite clear, it was evident what you had to do [scanning the clicker] ... the only difficult part is that you don't hear or see if you've done it correctly"*, P6: *"I think I needed some kind of feedback that it has been scanned because I didn't know and I rotated the clicker around a few times just to make sure that it's scanned."*. This was also caused by the changing work settings of individuals, which required participants to scan in at multiple locations. P3: *"At the beginning of the day, I did it very easily [scanning the clicker], but as the day went on, I sometimes forgot when I moved to a different place"*, P7: *"I occasionally forgot to scan [the poll] when I was in a different zone"*, and P9: *"Sometimes you sit down and then you think, 'Oh, I have to go back to that pole."*.

Mobility: From a mobility perspective, Click-IO offered participants the opportunity to carry their experience sampling tool with them, which remained visible throughout the day. Overall, this device was perceived as user-friendly, allowing participants to conveniently bring it along throughout their day. P3: *"I usually had it in my pocket or something because that metal thing doesn't really click"*, P2: *"It's small and light, and it fits easily in the hand, so it's easy to take it everywhere"*, P8: *"It just sits next to your laptop, and then there was a challenge, and you could easily click and bring it with you"*. P4: *"There was never a problem, so I just put it nicely in my pocket. I can imagine that maybe it could be a problem for people."*. This was confirmed by one of the participants. P10: *"The only thing I didn't find easy is that I couldn't really attach it to my clothes or hang it."*. However, this was experienced by one person only (P9): "*What I found difficult is that you couldn't attach it to your belt or something."*.

In-the-moment feedback: Click-IO offered individuals the opportunity to reflect on their office environment and well-being in real-time. This "in-the-moment" feedback collection was considered a valuable means of providing feedback that was deemed more accurate than conventional methods like annual reviews. P4: *"I have to say, there are definitely questions that you wouldn't be able to answer without such a clicker. For example, how often you opened the window. If you ask me at the end of the day, well, unless it happened recently, you just don't remember."*. The in-the-moment feedback also provided individuals with social cues, where individuals acted based on others using the clicker in-the-moment. P4: *"I actually find it to work well, that you can press it in the moment with very little effort. I also see people around me using it in that way, so that's really positive"*, and P8: *"In the moment seems very valuable because it increases the chance that you have the right conversation with each other. It's an enabler to have a better conversation about what went well or not, so I can imagine that capturing that momentum is valuable."*.

The system was also compared with the currently used annual evaluation surveys, which are often used to evaluate the office environment and well-being of individuals. P5: *"With a clicker, you're also providing feedback, actually. I think it's giving more conscious feedback... those surveys, are more reflective, and now it's really in the moment."*. Individuals indicated that the strengths of the system specifically enable them to reflect in the moment, rather than on an annual basis. P10: *"If you ask people once a year about all the topics from the clicker, they might not remember it at all. At least not the accuracy and depth of the information, because I simply don't remember it and that is super important."*. Participants explained that they are more inclined to address issues due to the system's direct reflection feature. P6: *"With an in-the-moment feedback system, you can actually reflect on the events when they are happening instead of, for example, in the annual survey. I think when I answer a survey, I don't tend to put too many complaints, but with the clicker, it's just a direct reflection."*.

5.1.2 Challenges. Throughout the study, participants were asked to reflect on 20 challenges. These challenges were experienced as a wide variance of topics which enabled users to reflect on their office environment and well-being. P9: *"There is a wide range of different challenges, but they are all things related to office life or work at the office"*, and P6: *"I think it is very useful to have input in this because this also relates to the health of employees."*. The challenges also made individuals reflect on topics that they usually don't discuss. P9: *"But there were also other aspects that you don't usually think about, and it's good to pause and reflect on them. So, I found it really enjoyable to have a varied number of challenges"*, and P5: *"It was quite diverse and also enjoyable because it covered everything from behavior to distractions, interactions with other people, and even changes in lighting, and things like that."*.

However, there were some questions in terms of the interpretation of the challenges. P7: *"Some of the challenges were quite open-ended. Yeah, you really had to think, 'Okay, when should I click and when not"*, and P8: *"There were questions that sometimes made me think they could be interpreted in multiple ways."*. Participants specifically indicated this for challenges around the stuffiness and social interactions. P2: *"We did discuss the issue of stuffiness. Like, when I enter a room, it does feel slightly stuffier than outside, but is it really stuffy or not?"*, and P3: *"I also found some questions to be complicated, like knowing when to click. For example, during a one-hour meeting, if you're talking with someone, do you have to click every time you speak, or is it considered one conversation?"*.

The challenges, however, did have an impact on participants' behavior and, consequently, their well-being. P2: *"The questions did make you immediately aware, so I think it directly influenced your behavior."*. This was particularly evident in standing and water-drinking behaviors. P5: *"The question was, how often do you stand or how often do you go standing? That is behavior I already want to change and am in the process of changing, and it makes you extra aware, which can be a bit confronting"*, and P6: *"To click it when you drink water... it makes me conscious of how much water I am drinking and ensures that I drink enough throughout the day."*.

Tensions in human-building interaction: Click-IO provided participants with the opportunity to reflect on their office well-being. This did however lead to some tensions between the challenge and the environment. An example of this was when participants were asked how often they wanted to change their light settings (e.g., light and blinders). After changing the blinders in the office environment, the building itself overruled the participants. P5: *"The blinds, that's a good example of tension because they kept going down on their own"*, and P6: *"Maybe also the building. I know the building something changes the blinds and that annoys people in a way that it is not necessarily measurable by sensor systems."*. A similar instance occurred when participants were asked about their need for private meeting space. This led to some tension, because of the limited available private meeting spaces. P8: *"You look for a space and at some point, which was one of the questions, and I would often prefer to be in a different room, [which wasn't possible] I can be a little bothered by that."*.

5.1.3 Reflecting on the office environment: Environmental vs Contextual data collection. Click-IO offered participants the opportunity to provide contextual feedback on the building, environment, and their well-being. This ability to provide feedback was considered valuable not only from the perspective of office workers. P3: *"It really provides information on how the space is appreciated and used by people"*, and P6: *"I think it is very useful to have input in this because it also relates to the health of employees."*. Moreover, participants recognized opportunities to use Click-IO as a tool for providing feedback to the building management. P2: *"Especially for those managing the building, it's important to see if many people are not happy with the conditions because then changes can be made."*.

Environmental vs Contextual data collection: Furthermore, participants emphasized the value of combining of sensor data with contextual data from the clicker, as relying solely on sensor data could result in incomplete insights into the office environment. P6: *"I think it is useful because the data we collect in the building don't necessarily represent the experience of the people themselves"*, and P6: *"What people are experiencing and what the building is measuring is not necessarily the same because the sensors in the building are usually located at ceilings or not in ideal locations."*. An example of this was indicated when discussing the temperature in offices. P2: *"A sensor is based on certain standards, but those standards can feel very different for individuals. For example, if you just came in from riding a bike, you already feel warm, so the indoor temperature will also feel warmer"*, and P2: *"I personally experience this when I sit behind my laptop for a long period. Eventually, I started feeling cold even though the temperature is technically the same. So, I think it's a good combination to monitor it with sensors but also consider people's own perceptions."*. Participants also sometimes mistrusted sensor readings. P5: *"It's good not to blindly trust those sensors and to keep looking at them critically, taking into account the experiences of what those sensors cannot measure"*, and P9: *"There can be multiple reasons for experiencing discomfort, so I think if you combine the context, you can extract much more information."*.

5.1.4 Social role of Click-IO. Click-IO and the daily challenge created a social and common topic in the office environment to talk about. Participants talked about the challenge topics and reflected on their environment. P5: *"Everyone becomes aware of the same* *behavior, and that's where you find each other"*, P8: *"I see it as an enabler to have more conversations with each other [on the office environment]"*, and P10: *"I think it also gave rise to discussing things, so that was fun. Like, 'Hey, how many times have you clicked already?' Yeah, it brings a sense of positive social interaction."*. Additionally, the use of Click-IO itself was discussed in the office with individuals reminding each other to click. P7: *"You helped each other remember. So, when you had contact with someone, you would say to that person, 'Yeah, now you have to click too,' and it created those kinds of enjoyable moments"*, and P1: *"It's interesting to see for myself, like am I going to click for that? What are others maybe going to click for? Sometimes we have conversations about that."*.

5.1.5 Future development of Click-IO. Participants also reflected on the future development of the system. The future development of Click-IO includes the improvement of the system and communication of the data back to users. To improve the system, participants indicated that the check-in polls could be replaced by an automatic, internal check-in system (e.g., via Bluetooth). P1: *"Maybe an automatic check could be implemented, where it measures as soon as you enter a certain space"*, and P3: *"In principle, you can also measure those things wirelessly, where they are located."*. Additionally, it was recommended to include a time stamp per click: P3: *"I can imagine that you would want to know, for example, the timing of your clicks."*.

The current version of Click-IO is developed as an input system. However, the data from the system could be communicated back to the user to make them reflect on the overall well-being of the office. P2: *"I think it would definitely add value if you communicate the data back, like seeing the average when there are multiple people in the room"*, P7: *"I would have liked it if the information from the previous week or day, for example, was available regularly"*, P5: *"I would be curious to see how I scored overall in terms of distraction, for example"*, and P6: *"I think it would be interesting to compare myself with the average, it would be useful to know."*. One participant even opted for the idea of making an IoT device of the clicker, linking the input for the clicker with, for example, the light. P3:*"The feedback should actually be that when I click, the lights get brighter, that would be fun."*.

5.2 Similarities and Differences in Sensor and Contextual data

Next to studying how users experienced the use of Click-IO, the study aimed to learn how the contextual data collected from the sensor systems and environmental data could reinforce each other. When analyzing the overall responses per category, 5 challenges fell under "Fun", 7 under "Space and Place", and 8 under "Everyday Interaction". Overall, the "Everyday Interaction" challenges received the most votes, averaging 8.7 votes each (125 clickers used and a total of 1091 votes). The challenges in the "Space and Place" category received the fewest votes on average, with an average of 2.2 votes per challenge (92 clickers used and a total of 200 votes). The "Fun" category, despite having fewer used total clickers than the "Space and Place" category, received a higher average of 3.7 votes per challenge (with 75 clickers and a total of 280 votes).

During the study, an average of 5.4 votes were recorded daily. However, certain days (4, 11, 14, 19, and 20) stood out with higher overall averages (Table 2). This higher average was mainly seen

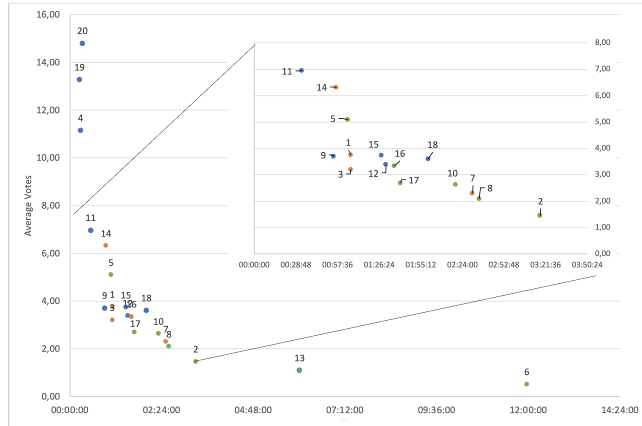

Figure 4: Cluster analysis of the challenges with Green: Space and Place, Blue: Everyday interaction, and Orange: Fun. The graph includes the overview and a zoomed-in version of the clustered data. The numbers in the graph indicate the number of the challenge.

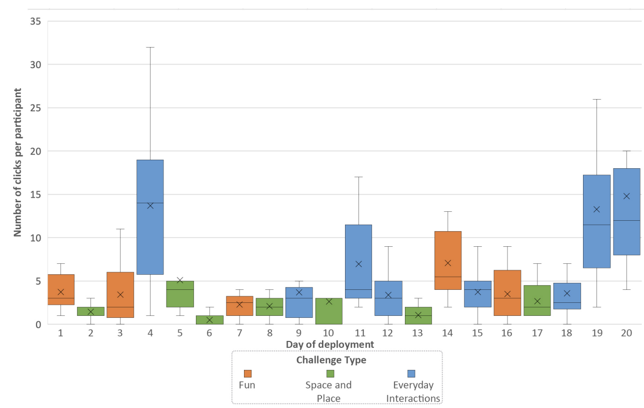

Figure 5: Box plot displaying the distribution of the number of clicks per challenge (minimum, first quartile [Q1], median, third quartile [Q3] and maximum).

in the "Everyday Interaction" challenges (Figure 4). Participants reported an average loss of concentration every 16 minutes, equivalent to 11.5 clicks per person. Task-switching occurred every 19 minutes on average, with 14.8 clicks per person. Additionally, conversations with others happened roughly every 15 minutes on average, with 13.3 clicks per person. On the contrary, there were instances of lower averages (Table 2) observed on days 2, 6, and 13. The lower averages are mostly seen in the "Space and Place" challenges (Figure 4). The frequency of opening windows averaged every 11 hours and 57 minutes and 0.5 clicks per person. Participants reported discomfort due to temperature roughly every 3 hours and 17 minutes, with 1.45 clicks per person. Lastly, participants experienced stuffiness in a room every 6 hours on average, with 1.1 clicks per person.

Day	Users vs (Occupied desks)	Challenge Topic	Challenge category	Sensor Data	Sensor value	Clicker data	Click/Person	Time/Click
1	12 (17)	Coffee	Fun	Coffee machine	72	45	3,75	01:06
2	11 (15)	Temperature	Space and Place	Temperature	Between 18,7 and 20,3	16	1,45	03:17
3	15 (18)	Using headphones	Fun	Sound	Between 36,6 and 39,3	51	3,4	01:06
4	27 (35)	Concentration	Everyday Interaction	CO_2 Sound Temperature	Between 622 and 925 Between 37,4 and 41,6 Between 21, 6 and 21,4	301	11,5	00:16
5	11 (14)	Walking	Space and Place	-	-	56	5,1	01:04
6	15 (16)	Opening windows	Space and Place	Temperature CO_2	Between 22,9 and 24,3 Between 527 and 587	7	0,5	11:57
7	10 (14)	Feeling energized	Fun	Temperature CO_2	Between 22,8 and 23,5 Between 535 and 571	23	2,3	02:31
8	11 (13)	Private space	Space and Place	-	-	23	2,1	02:35
9	10 (12)	Noise	Everyday Interaction	Noise	Between 32,8 and 36,5	37	3,7	00:54
10	16 (18)	Light	Space and Place	Light	Between 568 and 2744	42	2,6	02:19
11	26 (32)	Productive	Everyday Interaction	CO_2 Sound Temperature	Between 595 and 669 Between 37,2 and 45,0 Between 22,0 and 24,1	174	7	00:32
12	13 (17)	Mood	Everyday Interaction	CO_2 Sound Temperature	Between 533 and 580 Between 36,1 and 36,6 Between 22,0 and 22,5	44	3,4	01:31
13	12 (16)	Stuffiness	Space and Place	CO_2 Temperature	Between 317 and 580 Between 22,1 and 22,5	13	1,1	06:01
14	20 (25)	Drinking water	Fun	Temperature	Between 22,1 and 23,6	101	6,31	00:56
15	11 (16)	Daydreaming	Everyday Interaction	CO_2 Sound Temperature	Between 537 and 629 Between 25,7 and 36,5 Between 20,8 and 22,9	41	3,7	01:28
16	18 (21)	Bike chair	Fun	-	-	60	3,3	01:36
17	16 (18)	To bright of dark	Space and Place	Light	Between 732 and 3920	43	2,7	01:41
18	10 (10)	Breaks	Everyday Interaction	-	-	36	3,6	02:00
19	18 (19)	Talk to someone	Everyday Interaction	Sound	Between 35,6 and 43,0	239	13,3	00:15
20	15 (18)	Switching tasks	Everyday Interaction	CO_2 Sound Temperature	Between 542 and 584 Between 37,5 and 41,3 Between 22,4 and 23,6	222	14,8	00:19

Table 2: Overview of the data of the study: number of used clickers and occupied desks that day, challenge topic, and category, the environmental sensor and contextual clicker data, average clicks per person, and time for a person to use the clicker.

When analyzing the overall agreement, the median value, along with the interquartile range (iqr), was calculated. A narrow interquartile range indicates that participants had similar opinions regarding a response to a challenge. The higher agreement is mostly seen in the “Space and Place” challenges (Figure 5) as can be seen when asking participants about the temperature was uncomfortable (Median (Mdn) = 1 and iqr = 1), times a room was stuffy (Mdn = 1 and iqr = 2), opening window (Mdn = 0 and iqr = 1), and how often a room was too light or dark (Mdn = 2 and iqr = 3.5). The “Fun” challenges showed less of an overall agreement with higher scores in the interquartile range, drinking coffee (Mdn = 3 and iqr = 3.5), surrounding with music (Mdn = 2 and iqr = 5.25), drinking water (Mdn = 5.5 and iqr = 6.75), and using standing chair and/or bike chair (Mdn = 3 and iqr = 5.25). The “Everyday interaction” challenges (Figure 5) showed the lowest level of agreement with higher interquartile scores. Challenges asking individuals about losing concentration (Mdn = 14 and iqr = 13.25), feeling productive (Mdn = 5 and iqr = 8.5), talking to someone (Mdn = 11.5 and iqr = 10.75) and switching tasks (Mdn = 12 and iqr = 10) showed a higher number of different responses. However, the category also showed lower interquartile scores when individuals were asked about being distracted due to noise (Mdn = 3 and iqr = 3.5), taking a break (Mdn = 2.5 and iqr = 3) and daydreaming (Mdn = 4 and iqr = 3).

5.2.1 Differences in Sensor data and Contextual data. Several occurrences were seen where the environment data and the clicker data could strengthen each other. These instances showed a difference in the quality of the office environment in terms of measured data and how participants were experiencing the environment. The most prominent example of this, was seen on the day office workers were asked to indicate the amount of times they lost their concentration (Figure 6). Based on the environmental data, favorable conditions were observed in terms of CO_2 levels (ranging between 622 and 925), sound/noise levels (ranging between 37.4 and 41.6), and temperature (ranging between 21.6 and 21.4), which would typically be expected to enhance individuals’ concentration. However, the clicker data shows a loss in concentration, on average, every 16 minutes.

The opposite occurred when participants were questioned about their experience of uncomfortable temperatures (Figure 6). Throughout the day, based on the environmental sensor readings, the temperature in the office was not within the ideal standards (ranging from 18.7 to 20.3 degrees Celsius). However, the clicker data revealed that individuals rarely encountered any discomfort due to the temperature, with an average response indicating such discomfort occurring only once every 3 hours and 17 minutes.

Furthermore, there was also a difference observed in the perception of light within the office (Figure 6). Environmental measurements indicated high levels of light, surpassing the comfort zone threshold of 500 lux, ranging from 732 to 3920 lux. However, individuals did not report experiencing this level of discomfort when providing feedback through Click-IO. Participants indicated experiencing light-related discomfort only a few times, on average once every 1 hour and 41 minutes, over an extended period.

In the introduction to Click-IO, participants were asked to report the number of coffees they consumed throughout the day (Figure 6).

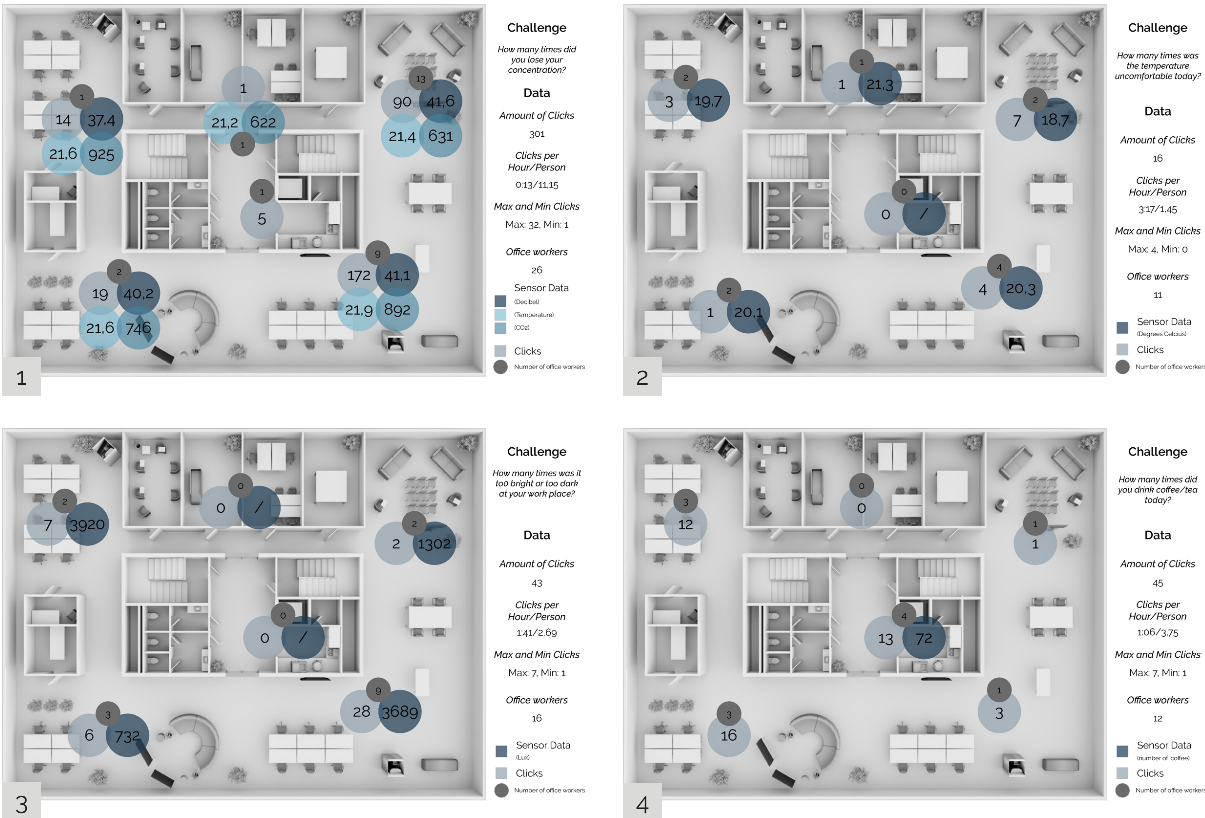

Figure 6: Differences in Sensor data and Contextual data. The 4 visuals include clicker and sensor data related to (i) concentration, (ii) temperature, (iii) light levels, and (iv) number of coffees drunk.

According to their responses, participants indicated a total of 45 cups of coffee consumed. However, data retrieved from the coffee machine indicated a total of 72 coffees being dispensed. The difference can be explained due to the fact that not everyone in the office setting uses a clicker. Nevertheless, this scenario highlights the importance of not relying solely on a single data source, as it can potentially provide a misleading perspective.

5.2.2 *Similarities in Sensor data and Contextual data.*

The data from the clickers and the environmental sensors also complemented each other in several occurrences. In these situations, the data from both the sensors and clickers showed similar patterns in terms of data and experiences of participants. For example, when participants were asked to indicate moments of productivity, they reported experiencing a productive moment every 32 minutes (Figure 7). Likewise, the environmental data reveals that favorable conditions for a productive workstyle were observed, including CO2 levels ranging between 595 and 669, sound/noise levels between 37.2 and 45.0, and temperature between 22.0 and 24.1.

A similarity in the data was also observed when participants were asked to assess the level of stuffiness in their office (Figure 7). Participants reported almost no discomfort regarding stuffiness, which was only mentioned every 6 hours and 1 minute. The sensor measurements showed similar data, with CO2 levels ranging between 317 and 580, and the temperature ranging between 22.1 and 22.5, both falling within the comfortable standard.

A similar pattern emerges when analyzing the sound/noise data in relation to the number of social conversations among office workers (Figure 7). The sensor data collected indicates a higher level of sound, ranging between 35.6 and 43.0 decibels. The contextual data from the clicker also show a high frequency of social conversations, occurring every 15 minutes. This increase in decibel levels is particularly evident in areas where individuals engage in the most conversations.

Finally, a similar effect on both sensor and contextual data was observed when participants were asked to indicate the frequency of daydreaming (Figure 7). Daydreaming, often associated with a loss of concentration, was not indicated as an event occurring frequently. Participants reported it happening only occasionally, once every hour and 41 minutes. Similar conditions are seen in the environmental data, which could affect concentration and, consequently, the occurrence of daydreaming. The CO2 levels ranged between 537 and 629, noise levels ranged between 25.7 and 36.5, and temperature levels ranged between 20.8 and 22.9.

5.2.3 *Contextual sensor data.*

A third category can be identified in challenges where only contextual information is collected, without

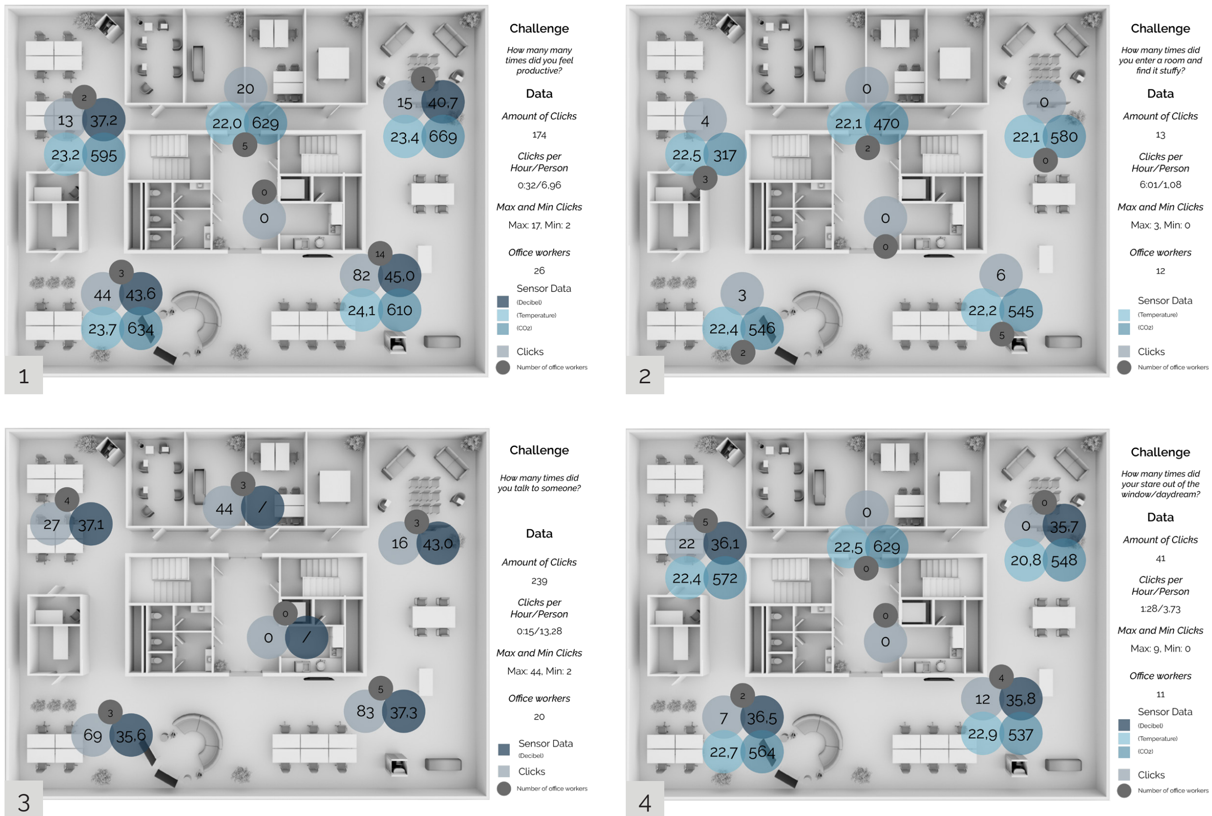

Figure 7: Similarities in Sensor data Contextual data. The 4 visuals include clicker and sensor data related to (i) productivity, (ii) rooms begin stuffy, (iii) social conversations, and (iv) daydreaming.

any environmental sensor data (Figure 8). These topics are not measurable using environmental sensors. Examples of such challenges include aspects like taking breaks, using a sit-standing desk, or needing a private workspace. The data obtained from these challenges indicates that participants prioritized their well-being by taking breaks, on average, every 2 hours, utilizing standing desks every 1 hour and 36 minutes, and incorporating walks into their work routine every 1 hour and 4 minutes. These challenges provide valuable insights into the contextual information concerning the well-being of office workers, which cannot be measured using environmental sensors.

6 DISCUSSION

Our work aimed to develop a tangible, mobile, and privacy-sensitive experience sampling tool to collect contextual information on office well-being. We presented Click-IO and evaluated it to explore the consequences of the system, also examining how the combination of clicker data and environmental data from stationary sensor systems could mutually reinforce each other. In the discussion, we identify design recommendations for developing mobile experience sampling tools. Additionally, we discuss (i) Click-IO system in the environment including, tensions, discussions, and social role, (ii) contextual and sensor collected data, (iii) visualizing clicker data for office well-being, and (iv) limitations and future work.

6.1 Design Recommendations for Mobile Experience sampling tools

Click-IO was developed as a tangible, mobile, and privacy-sensitive experience sampling tool. Considering (i) participants’ experiences related to our design principles, (ii) challenges related to materializing these principles during technical design and system deployment, (iii) other possible system enhancements based on participants’ feedback, and (iv) relevant literature, we provide the following design recommendations for mobile experience sampling tools.

D1: In-the-Moment Feedback and Privacy: The in-the-moment feedback aspect of Click-IO provided individuals with the option to reflect when an event occurred, therefore not distracting them with notifications or being demanding in terms of remembering events, which participants appreciated. The tangible, non-digital aspect of the system provided individuals with the ability to give feedback in a privacy-safe way without having to use their own mobile devices. Our findings highlight opportunities for future work towards the development of systems that adopt these principles:

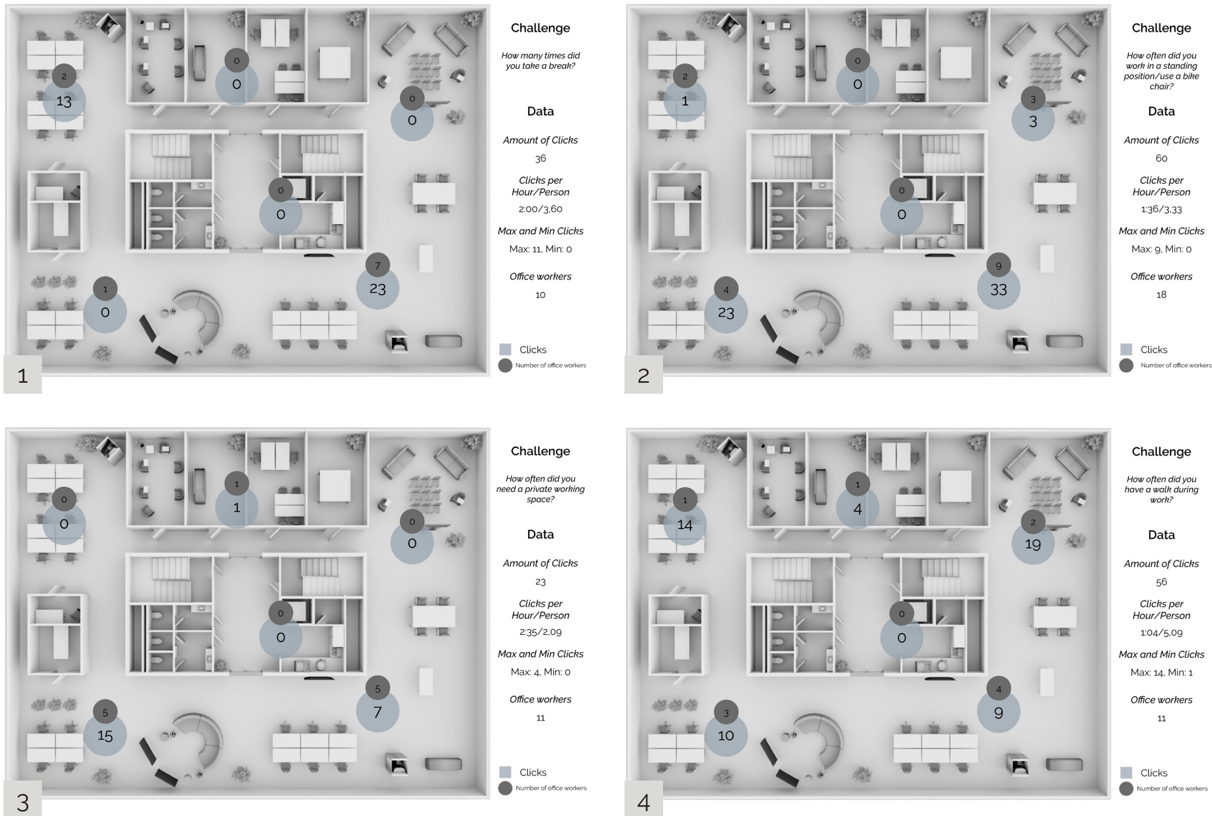

Figure 8: Contextual data, only measurable via the clickers. The 4 visuals include (i) taking breaks, (ii) using standing desks, (iii) the need for private working spaces, and (iv) taking a walk at work.

– *D1.1. In-the-Moment Reflection:* Mobile Experience sampling tools should prioritize in-the-moment feedback to enable users to reflect on events as they occur, reducing the reliance on memory [73]. This can be achieved by allowing users to log their experiences or insights immediately when they happen, ensuring more accurate and timely data collection.

– *D1.2. Tangible and Non-Digital Interaction:* Mobile Experience sampling tools should maintain the tangible, non-digital aspect allowing individuals to provide feedback in a privacy-sensitive manner without relying on their personal mobile devices [11, 59]. This tactile interaction can enhance user engagement and preserve privacy.

– *D1.3. Non-Intrusive Notifications:* Mobile Experience sampling tools should not distract users during work, prompting reflection when a specific event takes place rather than sending intrusive notifications [22, 27, 47, 73]. This design choice helps in maintaining workplace productivity and user focus.

– *D1.4. Privacy and Data Quality:* Consider the trade-offs between privacy and data quality. Click-IO's emphasis on privacy prevents tracking the behavior of individual users over time, which can be a limitation of Click-IO in repeated measures studies. The system also does not allow knowing if the same person uses multiple different clickers in one day, which could be an issue in contexts where there is low trust in participants' behaviors. While these aspects lower data quality, participants appreciate Click-IO's high privacy levels, as shown in the user feedback. A middle ground could be achieved by implementing the ability to assign a randomly generated code to first-time users and allow them to log it each time they use the clicker.

D2: Mobility and Social Visibility: The mobility of the clicker offered individuals the choice to carry it along, ensuring convenient usage and improving social visibility, leading to it becoming a topic of conversation in the office. Furthermore, it allowed users to capture their experiences on the go, regardless of where they were located within the office environment. To maintain the mobility and social engagement of Click-IO within the office environment, consider the following recommendations:

– *D2.1. Portable Design:* Ensure that the tool is easy to carry ensuring convenient usage and improves social visibility. This can be achieved through a lightweight and ergonomic design, making it effortless for users to have the clicker with them at all times.

– *D2.2. Capture on the Go:* Enable users to capture experiences on the go, regardless of their location within the office environment [7]. This feature empowers users to provide insights from various office spaces, contributing to a comprehensive understanding of their work environment.

D3: Technical Enhancements and Challenges: Based on the limitations of Click-IO, the following technical enhancements are recommended.

– *D3.1. Localization Integration:* To address issues with localization polls, the system should integrate localization capabilities within the experience sampling tool itself, for instance, through Bluetooth localization [69]. This feature enhances the accuracy of location-based data collection.

– *D3.2. Timestamp Recording:* Include a timestamp feature to record when participants vote, potentially using a microcontroller. Timestamps add precision to data analysis, aiding in understanding the timing of various events and experiences.

– *D3.3. Technical Requirements:* Address technical challenges by ensuring the clicker remains small, lightweight, and user-friendly, with a reasonable battery life and data storage capabilities [7, 28, 30]. A user-friendly design is essential to encourage consistent use of the clicker.

D4: Challenge considerations: To address considerations related to data quality and challenge topic relevance, we provide the following recommendations:

– *D4.1. Flexibility in Challenge Design:* Introduce a more flexible system that allows for personalized daily challenges. This customization should accommodate a broader range of well-being concerns expressed by participants.

– *D4.2. Challenge Variance:* Aim for repeating challenges to increase data quality by tracking behavior consistency over time - aligning with recommendations from Scollon et al. [66] - while also retaining some variance to ensure challenge anticipation and user enjoyment.

D5: Balancing Data Accuracy, Usability, and Costs: Mobile experience sampling tools should focus on achieving a balance between data accuracy, usability, and financial costs. Opportunities for enriching participant context by integrating external devices and networks should be explored, reducing reliance on the input device for context construction [73]. This balance should be struck by carefully considering the technical aspects and user experience to ensure that data collection is accurate and user-friendly without significantly increasing costs.

6.2 Click-IO in the Environment: Tensions, Discussions, and Social Role

Click-IO not only offered insight into individual experiences, but also played a social role within the office. Examples of this were seen during the study where: (i) tensions in the human-building interaction were revealed, (ii) individuals reflected on changing behavior, and (iii) a social environment was created where individuals discussed the challenges and system. These findings suggest that Click-IO impacted the office environment by encouraging people in the office to discuss and reflect on various aspects of the organization, the building, and their work [22]. When asked about certain challenges (e.g., light or private room), participants experienced tensions because they could not act upon the challenge due to the limitations of the building. Employee control over their physical work environment is crucial in improving health and well-being [7, 64]. However, it remains a challenge for individuals to have control over their work environment, particularly in open offices [7, 64]. To promote the overall well-being of office workers, the office environment should allow individuals to have control over factors such as lighting, ventilation, and office setting [3, 7, 64]. However, the level of control poses a challenge for future research, as conflicts can arise if individuals have different preferences.

Our findings showed that these types of systems could also create a social environment in which people discuss challenges. The study revealed that some participants reported actively reflecting on their behavior and well-being. The system provides a platform for individuals to discuss challenges and reflect on their environment and overall office well-being [22]. However, organizations must be open to feedback and data from these systems, proactively addressing identified issues and improving the office environment [22, 56]. Organizations can gain deeper insight into factors influencing employee experiences and well-being by analyzing data from Click-IO-like systems.

6.3 Contextual and Environmental sensor data

The distribution of the data collected from the clickers showed different levels of agreement. The more objective challenges "Space and Place" (e.g., how often did I open a window?) had a higher level of agreement, compared to the more subjective, "Everyday Interaction" challenges (e.g., how often did I lose concentration?). The larger spread in the more subjective challenges results in a high degree of uncertainty or variability in the data, and high agreement in public data collection systems is crucial for enhancing data reliability, quality, and decision-making by minimizing errors and ambiguity. To overcome this uncertainty, the clicker data could be combined with additional subjective data (e.g., interviews [35]) or environmental data (as demonstrated in this study). The variability in subjective challenges arises from individual interpretation and subjectivity in assessing office well-being, highlighting the importance of using multiple data sources for a comprehensive understanding [8, 73].

Current office sensor systems treat people as passive data subjects and are a "black box" with no input into the sensing and data collection process [7, 52, 76]. These systems collect data about the environment of office workers but do not reveal how office workers are experiencing the environment. The study combined the environmental data from the environmental sensors with contextual data from clickers to learn how these could strengthen each other. The data analysis showed instances where the environmental data and the clicker data reinforced one another. These instances occurred when there were disparities between user experiences and the measured sensor data. The combined data sources also offered complementary insights in cases where user experiences aligned with the measured sensor data. These findings show the importance of combining both sensor and contextual data sources to create richer and more comprehensive insights [73]. The combination of contextual data and sensor data presents an opportunity to gather complementary insights about how individuals experience the office environment [44]. Integrating these two types of data makes it possible to address the challenges that arise when each approach is used independently. These challenges include experience sample bias towards positive experiences [2], capturing data at a level of detail and accuracy that surpasses human memory [73], and overcoming the lack of subjective feedback from the sensors [20]. By combining contextual and sensor data, a more comprehensive and nuanced understanding of individuals' experiences can be achieved, surpassing the limitations of each individual approach.

Click-IO provides researchers with the opportunity to measure the experience of individuals for all kinds of events, including events that are not measurable with environmental sensors such as the frequency of individuals taking breaks or using sit-stand desks [8, 16]. Additionally, it creates the possibility to measure events that are not directly correlated to environmental sensors such as feeling energized or losing concentration. Systems like the Click-IO open up new opportunities for researchers to measure individuals' experiences and assess various aspects of individuals' well-being within environments, beyond what traditional environmental sensors can capture.

6.4 Visualizing Clicker data for Office Well-being

Click-IO was developed as an input system that collects data on the experience of office workers. However, the system does not translate the data back to the user. Participants indicated that they would like to learn from the data to improve their well-being. To make individuals reflect on both the environment and their well-being, they must be able to learn from the data. However, understanding and interpreting the data pose challenges for novice users [7, 9, 18, 63, 71]. Therefore, it becomes essential to classify and present the data in a manner that is easily understandable for novice users and is privacy-safe. Fields such as data visualization and data physicalization offer understandable ways of presenting data. Data physicalization helps to translate digital data into a human-readable format [36]. This approach helps novice users understand the various types of data measured in their environment [36]. Physicalization of clicker data is a promising direction for future work to improve the well-being of office workers.

6.5 Limitations and Future Work

During the study, not all individuals opted to use a clicker, and some attended only single events or meetings. Non-participants influenced environmental sensor data, affecting challenges like the coffee and noise challenges. Data inaccuracies also arose from participants' autonomy in using the clicker, possible voting without corresponding events, and occasional failure to scan at localization poles. There are also limitations in directly linking challenges to environmental factors, like correlating noise levels with headphone use, or daydreaming with CO2 or temperature changes. While the statistical analysis of this correlation was not the main focus of our evaluation study, future research should focus on this correlation, examining the direct relationship between clicker data and sensor data to overcome these limitations and deepen our understanding of their combined impact on office worker well-being.

Click-IO was implemented in a shared office environment already equipped with sensors, supplemented by four SmartCitizen kits. Recognizing that not all environments are sensor-equipped, Click-IO is also viable as a standalone system for understanding user experiences. The study's setting and audience, specific to one office type, indicate that Click-IO's effectiveness might vary in other environments. For instance, workers in closed offices may experience more environmental control but less social interaction. Extended deployment is crucial to evaluate Click-IO's long-term applications and its impact on worker well-being, also assessing if initial engagement was novelty-driven. Future research should include longer, diverse studies in different office settings and with various audiences to gauge Click-IO's overall impact. Interest in Click-IO, particularly for its privacy-safe approach, has been expressed across sectors. A government representative noted: *"There are also different groups that showed interest. If I look at the government, they are very privacy conscious and do not want to be tracked. However, with this approach, they had no objection to using it."* Future work should explore Click-IO's application in various contexts and challenges, further developing it as an experience sampling tool.

7 CONCLUSION

To gain a deeper understanding of the office setting and the well-being of office workers, it is important to tackle the issues that arise in experience sampling tools in areas like privacy, mobile experience sampling, notification management, display overload, and in-the-moment data collection. We present Click-IO, a system implementing a tangible, mobile, and privacy-sensitive approach to collect contextual information about office workers. Through our system evaluation study, we gain insight into the advantages and challenges surrounding mobility, tangibility, and privacy in experience sampling tools. Furthermore, we discuss how contextual data can be enhanced when combined with environmental sensor data, presenting a more comprehensive understanding of individuals' experiences.

With our research, we contribute to the field of Human-Computer Interaction (HCI) by providing design recommendations for the development of mobile experience sampling tools. The produced knowledge is relevant for research setups on the timely topic of environmental and contextual data collection for office well-being.

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