Tiny Habits in the Giant Enterprise: Understanding the Dynamics of a Quantified Workplace

Akhil Mathur, Marc Van den Broeck, Geert Vanderhulst, Afra Mashhadi, Fahim Kawsar
Bell Laboratories, Alcatel-Lucent
{firstname.lastname}@alcatel-lucent.com

ABSTRACT
We offer a reflection on the technology usage for workplace quantification through an *in the wild* study. Using a prototype Quantified Workplace system equipped with passive and participatory sensing modalities, we collected and visualized different workplace metrics (noise, color, air quality, self reported mood, and self reported activity) in two European offices of a research organization for a period of 4 months. Next we surveyed 70 employees to understand their engagement experience with the system. We then conducted semi-structured interviews with 20 employees in which they explained which workplace metrics are useful and why, how they engage with the system and what privacy concerns they have. Our findings suggest that sense of inclusion acts as the initial incentive for engagement which gradually translates into a habitual routine. We found that incorporation of an anonymous participatory sensing aspect into the system could lead to sustained user engagement. Compared to past studies we observed a shift in the privacy concerns, due to the trust and transparency of our prototype system. We conclude by providing a set of design principles for building future Quantified Workplace systems.

Author Keywords
Quantified Workplace; Empirical Study; Social Sensing

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

INTRODUCTION
The collective behavior of employees within an organization shapes the organization culture and has proven to play a critical role in an organization's success [19, 35]. Significant effort has been put into understanding how the collective behavior patterns – energy levels, unspoken and implicit signalling, and activity dynamics across employees - can directly affect employees' productivity [6, 36, 37]. Besides, there are environmental factors that influence the productivity of the teams in an organization. For instance, by examining the impact of noise and temperature in the workplace, Mak et al. concluded that low productive employees are easily influenced by background noise [30]. Kuller et al. [25] and Kwallek et al. [24] explored the role of color and light in the workplace and showed how different interior colors influence the mood of the employees, and affect their productivity. These past studies clearly demonstrate that by quantifying collective behavior and various metrics, a reliable and illuminating picture of the hidden workplace dynamics can be uncovered, which in turn can be converted into actionable insights. Some of these insights can immediately be used to change the physical nature of the workplace, or to increase the informal communication level within the organization. Our investigation continues the tradition of past studies examining technology for workplace quantification, however, by carefully applying non-invasive passive and participatory sensing principles.

We had the unique opportunity to deploy a Quantified Workplace (QW) system, as a technology probe to collect and visualize various workplace metrics (noise, color, air quality, self-reported mood, and self-reported activity) in two European offices of a research organization for a period of 4 months, survey 70 employees, and then interview 20 employees in detail about their experience. We sought to understand which workplace metrics are useful and why, how employees engage with the system and what privacy or other concerns they have. Our research questions were:

1. Which metrics in a workplace should be measured that employees would find beneficial for their productivity and awareness? Prior studies have examined the role of environmental factors (noise, temperature, color) [24, 25, 30] or mental well-being (e.g., mood) [21] on employees' productivity. We broaden this focus to understand from participants (both employees and management) which workplace metrics are useful to them and why?

2. How do employees react to data visualization and two different data collection strategies, i.e., passive sensing with sensor infrastructure, and participatory sensing with wilful engagement in a QW system, and how this behavior affect the sustained usage of the system?

3. What privacy concerns do employees have with various workplace metrics? Recent studies on people analytics in an enterprise setting have raised substantial privacy concerns albeit obvious benefits [6, 36]. Focusing on environment factors (noise, color, and air quality) and

UbiComp '15, September 07-11, 2015, Osaka, Japan.
 ISBN 978-1-4503-3574-4/15/09 ...$15.00.
http://dx.doi.org/10.1145/2750858.2807528

anonymous collective behavior (mood, and activity), we wanted to re-examine the privacy space for a QW system.

Our study findings suggest that collective experience of inclusion through anonymous participation acts as an initial incentive for employees to adopt the QW system, however, over time user participation translates into a sustainable *tiny habit* [47]. Our participants showed a preference towards quantification of metrics which are beyond a human's natural sensing capabilities, and also highlighted the negative effects of quantification if users are unable to act on its outputs. Perhaps the most dramatic change from past studies is the shift in privacy concerns – while the idea of the QW strikes some people as a *big brother*, we found that, if approached in the right way with trust and transparency through anonymous data collection and real time visualization, privacy concerns can be addressed in a way that makes everyone comfortable with a QW system.

RELATED WORK

Over the years, there have been various technology interventions in the workplace with varied focuses including improving socialization and collaborations [16], providing connectivity and awareness across remote locations [11], promoting informal lighthearted conversations and playfulness [18]. While these studies and others highlight interesting aspects of technology use in the workplace, most relevant to our study is the research on the rise of the Quantified Self movement and its extension to Quantified Workplace.

Quantified Self Movement

The Quantified Self [39] is a movement that promotes the use of technology for self-tracking various kinds of personal information, such as physical activities, emotions, diet, etc. Due to the potential of self-tracking in promoting intentional behavior change, researchers have looked at incorporating both passive and participatory sensing in designing self-monitoring technology. Past research works have studied many self-tracking technologies in the domain of health and wellness for tracking physical fitness [10, 29], diabetes care [38], sleep [22], diet [31], stress [34] and smoking [2]. Li et al. [28] have characterized self-tracking activity in a five-stage model (preparation, collection, integration, reflection, action) to better explain the psychology behind it. In a recent work, Choe et al. [9] analyzed 52 video recordings of Quantified Self Meetup talks to understand the common pitfalls of *Quantified-Selfers* and concluded that over quantification (i.e., tracking too many metrics resulting in tracking fatigue), ignoring situational context and lack of scientific rigor regarding data interpretation are the primary barriers towards successful adoption, and sustained usage of these technologies. Taking a critical standpoint, Rooksby et al. [44] argued that self-tracking technologies should be considered more social and collaborative, and their evaluation should also consider hope and playful feelings they generate among the users, instead of just evaluating the *improvement* of a certain metric. We build upon these suggestions by exploring the social nature of quantification technologies in the workplace and the impact of playful artefacts in improving user engagement.

Quantification at Work

While the Quantified Self movement has really taken off, the notion of a Quantified Workplace (QW) is in a relatively nascent stage. The technology blog Gigaom [45] envisages QW as an extension of Quantified Self, with the aim of promoting health and wellness at the workplace. In the academic literature, however, there are a number of past studies that have investigated physical quantification at a workplace from a number of different perspectives. In [12], a sociological survey of 274 knowledge workers in the Netherlands shows that the physical and social environment at work do have an impact on the creativity of employees. Kwallek et al. investigated the impact of color on employees' productivity [24]. In that research, 90 workers were treated to three identically furnished, but differently colored offices (red, white, blue/green) and it was reported that red interior has a strong negative impact on moods, while green has a positive impact. In a survey based study with 259 office workers in Hong Kong, Mak et al. found that sound and temperature were the principal environmental factors affecting office productivity [30]. Although interesting, these studies rely on ethnographic observation and surveys, which unfortunately suffer from biased results either because participants adapt their behavior during observation [49] or they tend to provide socially desirable responses [4].

In the UbiComp literature, Efstratiou et al. [14] have explored the benefits and privacy concerns with passive sensing in the workplace in a two week study. They found that comparison of self with others was considered a major benefit of the system, and lack of control over the sensor data collection was a significant privacy concern. A number of works also explored different technology probes to increase group communication either through active sensing or by introducing playful artefacts. Olguin et al. [36] have looked at using wearable electronic badges for measuring face-to-face interaction, conversations and physical proximity. Brown et al. took a similar approach of using wearable badges to track serendipitous interactions in a workplace and evaluate the effect of workers' cultural backgrounds on interaction diversity [6], and to study how the physical design of workplaces combines with organizational structure to shape contact patterns [7]. In [18], Gallacher et al. make use of multicolored squeezy balls to elicit mood inputs from the employees. Arnie [3], a talking beer vending machine, was designed to attract employees into common areas for an opportunity to chat with colleagues. Other studies [23, 43] have looked at deploying persuasive technologies in the workplace aimed at behavior change by providing live feedback. Finally, Mark et al. [33] explored the affect of digital and physical interactions in the workplace on employee mood. Most of these works however were short research studies, focusing on measuring the impact of a particular metric in the workplace. Grounded upon their findings, our work is focused on exploring the design of a *holistic Quantified Workplace system* through a longitudinal deployment, by systematically studying various input and

output modalities, multiple environment and people metrics, and issues of privacy and anonymity.

A PROTOTYPE QUANTIFIED WORKPLACE SYSTEM

The main objective of our technology probe is to explore various aspects of workplace quantification by taking a systematic approach, and to gain deeper insights that would inform future design of QW systems. As such, we looked at the system design from two aspects, i) *Data Dynamics* – which workplace metrics should the system collect and visualize, that would have varying degrees of usefulness, and privacy concerns for the employees and ii) *Engagement Dynamics* – what strategies to follow to collect these metrics, and with what level of engagement from the employees. Our design challenges were to systematically explore these options to build a technology probe that would give us deeper understanding on the user experience, and concerns of workplace quantification technology. In the following, we discuss these design challenges, followed by the explanation of the system implementation and deployment.

Design Challenges

In this section, we first discuss the different workplace metrics that we collect, and the rationale behind them. Next we discuss how these metrics are collected, i.e., what sensing and engagement strategies are used.

Data Dynamics

Past ethnographic studies have looked at various environmental factors, such as noise and color [24, 25, 30] at the workplace and found that these factors do impact workplace productivity as well as increase the awareness of the employees. Similarly, visualizing indoor air quality in the workplace has shown to be useful for the employees [8]. Looking through the privacy lens, the former metrics are comparatively privacy invasive to the latter one due to the data modality, e.g., audio and video data. While there are other environment metrics such as nature and layout of spaces [1], brightness, humidity, etc. that influence organization culture, in this study we limit our environment data collection to noise, color, and air quality as they provide an excellent case study due to the nature of data, their usefulness and complementary privacy sensitivity.

To understand the collective behavior pattern within an organization, past studies have logged face-to-face interaction data [6, 36, 37], mood and stress data [18]. While face-to-face interaction data has been shown to be valuable in understanding organization dynamics, its data collection could raise concerns about employee surveillance at the workplace, particularly in the context of European countries where our study was conducted. On the contrary, a soft metric such as mood, when measured collectively has shown to be less privacy sensitive [18]. We therefore decided to limit the data quantification in this study to the collective moods of employees – to examine its impact from both usefulness and privacy perspectives. In addition, grounded upon the insight of Efstratiou et al. [14] that employees often prefer to compare themselves against others, we decided to gather *work activity* data, again in a collective fashion. These metrics are further discussed below from a utility and privacy standpoint, and summarized in Table 1.

1. Air Quality: We measure the air quality (CO_2 levels) in the office. This information could be considered useful for health and wellness reasons. We hypothesize that air quality measurement would not be considered privacy invasive by employees.

2. Noise: We measure the ambient noise in the workplace. Intuitively, we expect that employees can utilize the noise information to decide which areas in the workplace are better suited for them to work, e.g., if they prefer to work in a quieter area, they can look at the real-time noise map and choose a suitable area. Noise information could also help the management to plan the workspace layout and sitting arrangements. In terms of privacy, noise measurements may be considered invasive, as employees might fear that the system is capturing audio conversations.

3. Color: Past studies were primarily concerned with the interior colors [1, 24] of a workplace, which in most cases are static. However, studies in color psychology have shown evidence that color of clothes [13, 41], and dynamic color of surroundings [40] also affect an individual's emotions in various contexts. Therefore, we decided to collect the color of clothes worn by the employees, and aggregated them to determine a set of dominant colors in the workplace at any instance of time. In terms of utility for the employees, we hypothesize that they would find it playful to know the dominant color of the workplace, and it may lead to informal conversations and higher engagement with the system. From a privacy perspective, color measurement could be considered highly invasive as it requires capturing a visual image of the employees for color analysis.

4. Mood: Mood inputs are collected with a self reporting approach (see next section for more discussion on engagement). Employees are presented with 8 moods to select the one that reflects best their mood at a point of time. We sampled the moods based on Russell's Circumplex model of affect [20] from the behavior psychology literature. Mood could be beneficial for an employee's self-reflection, and the quantification of mood can provide better workplace awareness. The sharing of mood, a highly personal trait, with the system may be considered privacy invasive.

5. Activity: Activity inputs are collected with a self reporting approach, and employees can select their primary work-related activity in the day from a pre-populated set of 8 activities[1] e.g., meetings, writing, programming, administration. Activity inputs can generate awareness of what is going on in the workplace, and may be considered less privacy invasive.

The final aspect of data dynamics for the QW system is the output modality. Previous studies have reported, insights emerged from workplace quantification has implication

[1]The set of activities selected are hand crafted based on the nature of the workplace, a research organization, in which this study was conducted, as such they should not be considered either complete or generic.

Metric	Type of Sensing	Expected Utility	Expected Privacy Concern
Air Quality	Passive	Health, Wellness	Low
Noise	Passive	Workplace Awareness, Informed Decision	Medium
Color	Passive	Playfulness, Mood Influencer	High
Activity	Participatory	Workplace Awareness, Comparison of Self vs. Others	Low
Mood	Participatory	Self Reflection, Workplace awareness	Medium

Table 1. Description of the Collected Workplace Metrics

to both employees and management [19]. As such, a QW system should explore the preferences of different stakeholders towards visualization of quantified data in a workplace. To achieve this, we deployed two different types of displays for visualizing the quantified data: one was a large screen dashboard which showed detailed visualizations (e.g., various graphs) of the data, while the other was an ambient display inspired by the recent work by Gallacher et al. [18], which changed its color corresponding to the dominant mood (aggregated over time) of the workplace. For mapping mood to a unique color in the RGB spectrum, we followed the guidelines from color psychology [48].

Engagement Dynamics

In the previous section, we described the different workplace metrics that we decided to collect in our prototype QW system. There are multiple ways to gather these metrics: either by passive sensing with dedicated sensor infrastructure (e.g., array of microphones, cameras and physical sensors to measure noise, color, air quality, mood, activity), or by combining infrastructure sensing with explicit user participation (e.g., self reporting). Previous works [6, 7, 14, 36] have mainly looked at passive sensing either using infrastructure or distributed wearable sensors (e.g., RFID badges) as a data collection methodology in a workplace. In this work, we sought to understand employees' perception towards a data collection process that combines both passive sensing (for air quality, noise, and color), and participatory sensing (e.g., self reported mood and activity). By doing so, we could explore if employees have a preference towards a certain way of sensing.

The latter modality i.e., participatory sensing with self reported mood and activity, raises another design question – *should participatory inputs from employees be solicited through a publicly placed device or through an app installed on their phones?* To arrive at this decision, we piloted two versions of the Quantified Workplace system (described in the following paragraphs) in one of the offices: one as a tablet application deployed on publicly installed Samsung Tablets in the workspace, and the other as a personal mobile app. A one month pilot study showed high engagement with the tablets with 57 daily participatory inputs on average. The mobile app, on the contrary, got poor reception with only 4 users downloading it on their phones. Based on this finding, we decided to use publicly deployed tablets for collection of participatory inputs in the rest of the study. As we will discuss later, our exit surveys and interviews also confirm this design decision, with 68% of the users saying that they would not install a Quantified Workplace app on their personal phone.

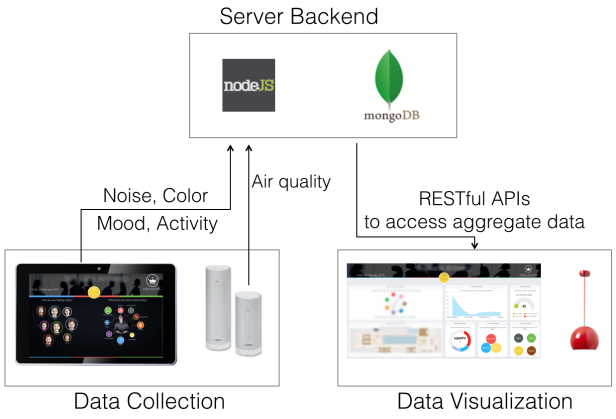

Figure 1. System Architecture

Implementation

We now explain the design architecture of the prototype Quantified Workplace system. Instead of dedicated sensing infrastructure, we wanted to leverage existing commodity hardware in this Quantified Workplace system to keep the deployment costs low with no or minimal maintenance from the management. Our entire setup (for each office) comprising of four commodity Android tablets (used for sensing noise, color, and gathering employees mood and activity data), 1 air quality sensor, 1 Philips Hue Light[2] (used as a color changing abstract display) and 1 LED TV (used as dashboard display) costs around $2000. Furthermore, no maintenance was required from the management, except to provide a power inlet to each device. From a software point of view, as shown in Figure 1, the system consists of three components:

Data Collection: We developed an Android application for passive sensing of noise and color of clothes, and participatory sensing of moods and activities. Using the MediaRecorder class of Android 4.4, we took an audio sample every 15 seconds, which contained the maximum observed audio amplitude near the tablet in the last 15 seconds. For capturing color we used the front-facing camera on the tablet. When we detect a significant change in the reading of ambient light sensor of the tablet, it is assumed that a person was walking by the tablet. At that instant, the

[2]http://www.meethue.com (Last accessed: July 16, 2015)

Figure 2. Tablet Application, Dashboard Display, and Mood Lamp of the Prototype Quantified Workplace System

front camera (passively) took an image of the scene, which was analyzed to find the dominant color in the image while filtering out the background. The front-end user interface of the Android application is used to collect mood and activity inputs (as shown in Figure 2(a)). After each participatory input (mood and activity), we also ask the employees to select the name of the research division to which they belong, e.g., Wireless, Application, etc. Finally, we used the Netatmo weather station[3] to measure the air quality in the office.

Back-end Server: All the collected data (environment metrics and participatory inputs) is immediately sent to a Node.js back-end server. The server stored the data in a MongoDB database and provided RESTful APIs for accessing the aggregated data.

Data Visualization: We employed two display methods to visualize the quantified data. Firstly, a large-screen dashboard application (as shown Figure 2(b)) written in HTML5 showed various charts representing different workplace metrics in real-time – including a noise map of the office, a mood map showing the overall mood of the office, an activity map highlighting different activities of the office, an air quality index, and a color map showing the most popular colors in the office. We also display the name of the research division with the highest number of inputs on a given day. Secondly, we installed an ambient display in the form of a multi-color lamp (Figure 2(c)), which changes its color as per the dominant mood of the workplace. Both the dashboard and mood lamp worked on an active polling strategy with a polling frequency of 30 and 15 seconds respectively – this was done to ease any privacy concerns that users might have with their inputs being immediately reflected on the display.

Deployment

We conducted an in-the-wild deployment [42] of the system in two European offices of a research organization. Albeit situated in two different countries, these two offices share several common interior constructs, e.g., employee lounge, coffee area etc. To be consistent, we placed the tablets in areas that have similar usage in both offices: *coffee area, printer area, employee workspace and in the largest meeting room*. We intentionally placed the tablets close to the coffee machine, and the printer assuming that the activities that occur in these area offer momentary opportunity (e.g., idle time while waiting for coffee, or print) to interact with our system. We have observed interesting facts about these placement choices that we will discuss later. The air quality meter was placed in the *employee cubicles*, while the dashboard and the mood lamp were located in a common area – namely, *employee lounge close to the workplace entrance*.

[3]https://www.netatmo.com (Last accessed: July 16, 2015)

STUDY METHODOLOGY

Our study was conducted from October 2014 to January 2015. We collected data in three steps: i) system usage logs ii) a survey and iii) semi-structured interviews.

System Logs

Over the period of four months, the system passively collected 425,511 noise, 69,159 color, and 46,080 air quality values in 80 working days (excluding weekends and Christmas vacations). It also received 5312 participatory inputs from the users, with an average of 66 inputs per day in a 120 employee workplace (both offices together). Mood inputs accounted for 73% of the total inputs, while activity inputs made up the remaining 27%. Users' preference towards mood inputs was due to the playfulness attached with the mood lamp, and also because mood inputs led to self reflection.

Survey

Four months into the deployment, we e-mailed an anonymous survey to all the employees. The survey comprised of 33 questions. In addition to collecting demographic data, the survey aimed at understanding user experience with the system, including its perceived benefits, trustworthiness,

engagement dynamics, privacy and other concerns. In total, we received 70 responses to the online survey out of 120 employees, with 25.7% of the respondents identifying themselves as managers. In total, 85% respondents mentioned that they have interacted with the Quantified Workplace system.

Semi-Structured Interview

After the survey, we conducted a series of in-depth interviews with 20 employees (9 females) aged between 28 to 43 years. For recruiting, we used stratified sampling with snowball sampling within each stratum. During the recruiting process we identified two primary groups of participants that represent the two main roles in the organization, e.g., employees (including research scientists, research engineers, and admin staff) and management. Also, 6 of these participants were from non-European nationals while 14 were European nationals. The interviews were semi-structured, involved one interviewer and one note taker, and lasted 1 hour each. Similar to the survey, interviews also focused on questions of perceived utility, engagement, privacy, trustworthiness – but with the objective of diving deeper into each aspect. To this end, we followed an interview technique called *laddering* [26], a qualitative research technique which seeks to understand the core values behind the user reactions to any system. Each interview was recorded and later partially transcribed to complete the observer's notes. The participants were compensated for their time with an Amazon voucher.

The results of the survey and the interview together with the quantitive data we extracted form the system logs are presented in the next section.

STUDY RESULTS

The system logs, surveys, and interviews gave us a fascinating view on a number of different aspects for the workplace quantification. We now discuss the study results from these aspects.

Understanding Spatio-Temporal Usage

Figure 3 (left) shows the distribution of participatory inputs over time. In the first week of deployment (excluding weekends), a total of 1184 inputs ($\mu = 236, \sigma = 165.2$) were provided on the tablets. This high number could be attributed to the novelty effect of deploying the system. In the subsequent weeks, the usage became more stable and averaged at 294 inputs/week (daily $\mu = 58.8, \sigma = 23$). For the rest of quantitative analysis in the paper, we only consider the participatory inputs second week onwards.

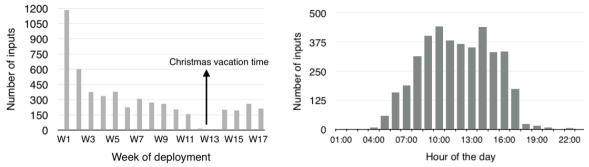

Figure 3. Weekly and hourly distribution of participatory inputs

We found no correlation between day of the week and number of inputs (Spearman's $\rho = 0.2, p = 0.78$). Figure 3 (right) shows the hourly average of participatory inputs into the system. We analysed the inputs to the system during working hours (08:00 to 19:00) and found a weak correlation between hour of the day and number of inputs (Kendall's $\tau = 0.21, p < 0.001$). Our exit survey shows that 60% employees did not have a fixed time for interacting with the system, rather they interacted with the system in an opportunistic manner. In the Figure 3 (right), there are peaks between 10:00 - 11:00 and 14:00 - 15:00; we speculate that these times correspond to breakfast and coffee breaks for employees and hence were opportune interaction times. Although the individual inputs were anonymous, we collected the team/department information after each participatory input. Based on it, we found that 66% of the participatory inputs came from top 4 departments as shown in Figure 4.

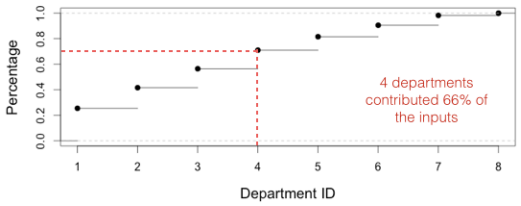

Figure 4. CDF of participatory inputs

The placement of tablets had a significant impact on usage. Based on placement, we classified the tablets in two categories: A) those placed at locations where users may have had some free time (e.g., at coffee area, and at printer area) and B) tablets placed in areas such as meeting rooms and employee workspaces where employees may be busy. With a Welch's t-test, we found a significant effect of tablet placement on the number of participatory inputs ($t(2722) = 20.13, p < 0.0001$, Cohen's $d = 0.55$) with category A tablets receiving 90% of total inputs. Most (n=19) participants agreed to this opportunistic interaction in the interviews, one remark was: *"It's not like I go consciously to the tablet to put my mood. But when I am waiting for my coffee, I have spare time so I always enter my mood and activity..."*

There was another interesting dynamic that influenced user participation – the possibility of seeing the mood lamp from a tablet's location. The tablets from where mood lamp was directly visible received significantly more inputs ($t(4334) = 9.85, p < 0.0001$, Cohen's $d = 0.26$). This result has an interesting implication about integrating playful artefacts in the design of a QW system, which we discuss further in the coming sections.

Understanding Data Dynamics

Of the three environmental metrics we collected, air quality was the most preferred (42% participants found it useful), while noise (21%) and color (13%) were less preferred. Multiple participants commented that while noise and color quantification is informative, both these metrics can also be sensed by bare human senses. On the contrary, air quality is an *invisible* metric and therefore its quantification can be useful.

Our qualitative interviews however reveal that none of the environment quantifications had any behavioral influence on the employees. For color, participants (n=15) commented that it is a *good-to-know* metric and may have an indirect effect on individual moods, however in a workplace setting, completion of professional objectives is a bigger motivation than the physical look and feel (e.g., color) of the workplace. Some participants (n=13) remarked that they need to collaborate with colleagues in the workplace, so even if the quantification shows a certain area as noisy or with a relatively poor air quality, they would still have to go there for collaborations. Few participants (n=4) even highlighted the negative effect of such quantifications: *"Even though noise in my area is very high as compared to other places, I cannot really change my desk ... It is better to not know about the higher noise levels in my area..."*

We believe that this is an interesting finding as it shows that quantification can be considered disadvantageous at times, if users do not have the capacity to act on it. Therefore, system designers should focus on *actionable quantifications* in the workplace, i.e., quantification of those metrics upon which users can act.

The management was more open to passive quantifications, with 33% managers finding color quantification, and 58% finding both noise and air quality quantifications useful. Managers were primarily interested in noise data for desk management e.g., teams which prefer quiet workplaces can be placed in a quieter area of the building (n=3), for understanding the impact of noise on moods and activities of the employees (n=5); air quality data for health and wellness reasons (n=3); and color quantifications to understand if color of the surroundings has any influence on employee's moods and productivity (n=2). As opposed to individual employees, management has more authority to act on the quantified data, which increases its usefulness for them.

Our system quantified two participatory inputs from the users: mood and activity, and both were found more useful than the passively collected metrics. Quantification of mood was found useful by 60% employees and 89% managers. Day-wise log analysis shows that positive mood inputs were significantly higher than negative moods ($t(191) = 2.54$, $p = 0.01$), with positive inputs comprising 59.3% of all mood inputs. In the interview, most participants (n=16) highlighted that they were entering their real moods to the system, with no bias towards projecting a positive mood of the workplace. Many participants (n=14) believed that average mood is a reflection of the vibrancy and long-term performance of their workplace. Furthermore, participants (n=13) considered mood inputting as an opportunity for self expression and self reflection, as remarked by one of the participants: *"You have the feeling that you can communicate your mood and that's a real relief when you are stressed....we should be reflecting on our moods more often, but do we? When I was near the tablets, it gave me a chance to do that..."*

Mood quantification was also used by some participants (n=6) to do a "me vs. rest" comparison, i.e., how is an individual's mood comparing to the rest of the workplace. One remark was: *"Sometimes I see people are stressed at the time of deadlines. But if I am not stressed, I think maybe I should also be stressed..."*

For the management too, mood quantification was highly useful. They mentioned that it would help them to find how different teams are feeling over time, impact of building works on employees' moods, and seasonal impacts on moods. They also felt that it gives an opportunity to employees to freely convey negative emotions about the workplace, which they might not do otherwise, and such openness will lead to a better workplace.

Activity analysis shows that Programming (20.1%) and Meeting (13.5%) were the top two activities reported to the system. A limitation of our study was that all activity options were work-related (e.g., programming, paper writing) and there were no options for 'relaxing' or 'taking a break' as a result, we cannot answer if employees had a bias for work-related activities over leisurely ones.

Activity quantification was found useful by 58% employees and 63% managers. Employees found it useful to get an overview of the various activities happening in the workplace and to compare it with their own activities. Furthermore, participants considered this input as an effective tool to give feedback to the management about the activities happening in the workplace. We received a similar feedback from the managers that activity quantification provides coarse level awareness about the workplace on a regular basis.

User reactions on our two data visualization methods revealed an interesting picture. Most employees (n=11) did not consider the dashboard useful, partly because they had less interest in the passively collected data. But more importantly, they felt that it takes time and effort to understand the graphs on the dashboard, and requires them to purposely stop by the display. On the contrary, management (n=4) showed more enthusiasm towards the dashboard and various data visualizations shown on it. They asked for more details to be included such as historic trends of data.

The mood lamp was well received by both employees and management (n=19). They found the concept of mood lamp easy to understand and liked that its output could be interpreted immediately, without requiring users to purposely come near it. One participant commented, *"The mood lamp is easy to explain. Everyone understands it....technical and non-technical people...."*. Another user comment, although negative, reflects the potential of the mood lamp to alter user behavior. *"Yes, I'm concerned about approaching the mood lamp with visitors. I was always worried that the it may show a negative mood....I want the mood lamp to give our visitors a positive feeling about the company."*

These observations advocate that user engagement with a QW system could be increased by using a simple, intuitive and playful artefact (e.g., a mood lamp) as an output modality.

Understanding User Engagement

We found that initially user engagement with the system was driven by a collective behavior trait. In particular, it

was triggered by a feeling of inclusion. Participants (n=14) felt that the outputs of the system are a reflection on their colleagues, and that they should be part of it to get an accurate reflection of the workplace. One participant said: *"I believe the outputs are reliable only if everybody is participating in the system, else it gets biased. I do my part regularly...."*

Some participants (n=4) also highlighted that they want to give a positive impression about their work activities, which led to their engagement with the system. An interesting remark was: *"..at times when the mood lamp was showing a red color (associated with 'Stressed' mood), I purposely went and inputted a positive mood, in order to change the color of mood lamp to reflect a happy mood..."*

These findings suggest that the motivation to contribute to such participatory QW systems comes from the desire of expressing a positive behavior collectively.

Participants (n=19) mentioned that they engaged with the system primarily in an opportunistic manner, i.e., when they were near a coffee machine (or a printer), and waiting for a coffee (or a printout), they would often provide inputs into the tablets. Interestingly, many participants (n=14) reported that over time, engaging with the system at such opportune places became a habit for them. One participant mentioned: *"I always do it in the morning. I come to office, go for a coffee alone or sometimes with others. While I am waiting for my coffee, I just put my mood..."*. Analysis of the system logs also confirms this user behavior: we found that the tablets placed near coffee machines, elevators received significantly more inputs ($t(2722) = 20.13, p < 0.0001$, Cohen's $d = 0.55$) than other tablets. We also found a correlation between time of the day and user inputs on such tablets (Kendall's $\tau = 0.1, p < 0.0001$) with peaks around 10am, 11:30am, 1pm, 3pm, and 5pm. These times correspond to usual food or coffee breaks for many employees and arguably, became their preferred times for interaction with the system.

This is an intriguing finding – it suggests that opportune placement of input terminals and rapid interaction time can lead to formation of a *tiny habit* [47] to engage with the system. Fogg's *tiny habit* guidelines include three steps: i) *pick a small task*, ii) *incorporate it in your daily routine*, and iii) *celebrate task completion immediately*. Our results clearly suggest that, while in the beginning user engagement was informed by a collective sense of inclusion, over time it translated into a *tiny habit*.

Previous research [18] has shown the presence of honeypot effect [5] in the technology initiatives deployed in a workplace, however our findings suggest an opposite behavior. 92% of the survey respondents mentioned that they used the tablet only when they were alone. This behavior was attributed to the fact that one's moods and activity inputs are private in nature, and participants did not want to reveal it to their colleagues, more so when their mood was on extreme negative side. However, they were happy to share their true mood with the system as the data was collected in an anonymous manner. We believe that the corporate setting (the previous study was conducted in an academic environment), and its workplace dynamics might have led to such a contrasting result in our study.

We also analysed our survey data through a gender lens to determine any effect of gender on the data dynamics. A Fisher's Exact test reveal no significant effect of gender on preferences for noise, air quality, mood or activity (all $p > 0.05$). However, for color quantification, there was a significant effect of gender ($p < 0.05$) with female participants preferring it more than their male counterparts.

Understanding Privacy and Trustworthiness

Privacy concerns among employees can prove to be a showstopper for Quantified Workplace systems as reported by past studies [6, 36]. In our deployment, we collected various metrics, some of which may be considered privacy invasive as discussed earlier in the paper. In the exit survey, we asked the participants to rate their privacy perception of the system on a scale of 1-5 (with 1 being *not at all concerned* and 5 being *very concerned*).

We found that 50.5% of the participants had little to no concern with the system, 21.5% users were neutral, 24% were somewhat concerned, and only 3% were very concerned. The primary reason for the low privacy concerns, as mentioned by the participants (n=17), was that the system collected data in an anonymous manner, and none of the metric could be tied to an individual. 68% of the participants remarked that if the data collection was carried by a mobile application (using on-device sensors for collecting environmental metrics, and self reporting for mood and activity) they would not use it. In the exit interviews, participants (n=12) expressed an apprehension that the inputs on personalized devices could be tied to their name, and used by the management for performance evaluation. One participant mentioned: *"On my phone, I would be hesitant to give mood and activity inputs. It's a very personal thing and I don't want the inputs linked to my name"*. In a similar spirit, another participant said: *"If management has access to this data I feel I won't be inputting my mood because I want to be judged on the quality of my work, not by my feelings..."* . This finding suggests that for a QW system to work, designers should focus on anonymous collection of workplace metrics so as to instil confidence in employees that their inputs will not be misused.

As for the various data we collected, 50.5% users reported that none of the data was privacy invasive, while mood (26.15% users), color (23.08% users), and activity (21.5% users) were found privacy invasive by some users. Noise (9.23%) and air quality (1.54%) were perceived as privacy invasive by the least number of users. This is counter intuitive, in that we initially hypothesized that noise, color and mood would be considered privacy invasive due to nature of the data, and also the data collection modalities (i.e., use of microphone and camera). However, it turned out to be not true, and again users attributed this behavior to the anonymity provided by the system. Even the minor privacy concerns reported by users were linked to the possible loss of anonymity. A participant said: *"I work in a very small*

team. Because of the dedicated nature of my activities, it is very easy to trace back any inputs from my team to me[4]*..."*

This result emphasizes the need to design a QW system by incorporating the principles of *k-anonymity* proposed by Sweeney [46], to ensure that all users are hidden in a sufficiently large group of 'k' people, and it becomes infeasible to link a participatory input to a specific user.

In addition, participants (n=12) mentioned that the real-time feedback and immediate reflection of their inputs in the dashboard and mood lamp, also helped easing their privacy concerns, as they could clearly see what data is collected and how it is used visually. We did not see any evidence of participants (n=0) being concerned with immediate visualization of their inputs, likely due to the 30 second and 15 second delay in visualization introduced by our active polling strategy. Further, the mood lamp worked on a majority-voting scheme, wherein the most popular mood of the workplace was reflected and an individual's input may not have affected it directly.

We also probed the users about their perceived trustworthiness of the system. Do they feel that the quantification outputs shown by the system are genuine? Do they fear that an anonymous participatory system is prone to misuse in the workplace? The results are mixed in nature. About 53% users felt that the outputs are not trustworthy. This mistrust was primarily caused due to the initial engagement dynamics of users with the system. At the beginning of the deployment, participants observed many users playing with the system, in some cases they were providing repeated mood inputs one after another, to change the color of the mood lamp. We confirmed this behavior by analysing the system log, and marking inputs as *repeated* if we observe two or more participatory inputs of same type (e.g., two mood inputs) on a tablet within a span of 10 seconds. We found that the number of repeated inputs was considerably high in Week 1, with such inputs accounting for 44.1% of the total inputs – this negatively influenced the trust perception of the system (n=8) – one participant commented: *'Sometimes I wonder if there is a guy who plays with the system to cheat it, to set a wrong mood. It was a pity that people played with the system and misused it initially..."*

This behavior however subdued in the coming weeks, with repeated inputs falling to 13% of the total inputs in the last week of the deployment – and users felt that the system became more trustworthy. One manager commented: *"Yes, in the beginning some people gave false inputs. And as management this caused me to worry. But now I think the data is levelled out. The system can provide a means for anonymous venting, which is a pity. We must be cautious to prevent misuse..."*

To conclude, while in the beginning the system was partially abused, over time participants started using the system more honestly. In addition, the anonymous data collection with transparent realtime reflection of data helped in alleviating any privacy concerns. This can be considered as one of the most important findings of out study, as it clearly advocates that if designed with adequate transparency and by preserving anonymity, the acceptance of a QW system will increase substantially.

[4]Recall that we asked the users to provide their department name after each participatory input

IMPLICATIONS

In this section, we discuss the implications that emerged from our study, which we found most compelling.

Design for Participation

With advancements in our sensing capabilities, it is becoming feasible to automatically sense data such as moods and physical activities, without relying on user participation. Our findings however caution the designers against this urge of automating the entire data collection process. We found that the participatory nature of our system interested users the most – it gave them an opportunity of self expression, and at times led them to reflect on their own mood and activity. Participatory inputs also led to several conversations about the system in the employee community, which increased the popularity of the system and drove the initial wave of user engagement. It is important to emphasize that we are not advocating against passive sensing in the workplace. Past research has clearly demonstrated its benefits, e.g., Brown et al. [6] learned hidden interpersonal dynamics in a workplace by analyzing passively collected mobility traces. What we are advocating is to have a balance of passive and participatory sensing in a Quantified Workplace system, which will lead to a sustained user engagement.

A surprising finding of our study was that the opportune placement of tablets and quick interaction time with the system, promoted a *tiny habit* [47] of providing participatory inputs. As such, we advocate that designers of future Quantified Workplace systems should pay particular attention to consider such habitual routines while devising their data collection strategies to guarantee a sustained usage. We also suggest exploring the third step of Tiny Habits, namely 'celebration of task completion' in more detail. In our implementation, it was done by showing the winning department on the screen, however future studies could look at more empathic designs, e.g., if a negative mood is inputted, a sound could be played cheering up the user.

Focus on Actionable Quantification

Perhaps the most important consideration in the design of a Quantified Workplace system is to identify the metrics to quantify and the associated end-user services. While the exact metrics and services will depend on the goals of each system, and the potential stakeholders, our results offer some general insights in this regard. We found that sensing and visualization of raw noise, color and air quality metrics was not found useful by the majority of the employees, primarily because they felt they had little power to act on the results of the quantification. Some employees even highlighted the negative aspects of knowing about non-actionable quantifications. However, to the management, these metrics were useful for informed decision making. This suggests that a Quantified Workplace system should focus on

actionable quantification such that its stakeholders can act on the metrics and the associated services. For example, building managers might be interested in viewing raw environment metrics (e.g., noise) from a historical perspective to make decisions about seating layouts. However, for employees, this kind of visualization offers little value and a better approach might be to provide them a 'recommendation service' which guides them to the quietest space in the workplace at any time.

Design with Playfulness

A workplace has traditionally been perceived as a serious setting, and playfulness in the office is viewed more as a distraction. However, Lamm et al. [27] found that this perception is changing: while those born between 1941 and 1960 often regard fun as counter-productive, the new generation of workers (born between 1981 and 2000) view it as an important enabler for building social connections and trust with colleagues. Our study findings concur that incorporating a playful artifact such as the mood lamp can increase user engagement with a Quantified Workplace system. The changing color of mood lamp led to many informal conversations about the system in the employee community, and had a significant effect on user participation. Gallacher et al. [18] recently explored the role of playful interactions to encourage openness and social interactions in a workplace. Similarly, our findings provide another example of how playful artifacts can increase user engagement with a technology system in a workplace setting.

Design with Openness

A system like Quantified Workplace is geared more towards community-level benefits than individual benefits, which is often not perceived by the target user group. In our study, we observed that a user tried to hide the camera on the tablet with a spoon, perhaps due to his privacy concerns. We also witnessed a high number of repeated negative inputs to influence the color of the mood lamp, which decreased trustworthiness of the system in the beginning. Our key suggestion here is that designers should be cognizant of the possibility of these phenomena, and attempt to mitigate it by building user trust. We suggest three design principles to increase user trust: anonymity, transparency and inclusion.

Anonymity: Our prototype system provided team-level anonymity to the users, and a vast majority of the users felt comfortable with it. On the contrary, 68% of the users mentioned that they would be concerned with using the system, if it were a personalized app on their phones. Thus, we argue that anonymity is a key design element that can mitigate users' privacy concerns with a QW system meant to be deployed in a public setting. Although an anonymous system may be susceptible to misuse initially, our results show that over time, anonymity built user trust and led to less misuse. That said, we do recognize that there are use cases where anonymous data collection is not feasible (e.g., [7]) – in such cases, we suggest that to promote user trust, they should be provided full control over data sharing, e.g., users could prefer to keep their data private, or share with immediate colleagues or the entire workplace.

Transparency: Next, we argue that transparency is a very important design principle for long term sustainability of the system. We visualized the results of quantification in near real-time on the dashboard and mood lamp, which showed the users that the data is not manipulated on the backend and gave them confidence in the system. They appreciated that negative quantifications (e.g., bored, stressed, etc.) about the workplace are not hidden by the system and this led to increased user trust.

Inclusion: Finally, we emphasize the importance of Inclusion in designing community-oriented systems. The inclusiveness and democratic nature of publicly placed tablets ensured that *any* employee could interact with them, and let his/her opinion count. If we had deployed the QW system through a personal mobile application, this sense of inclusion might not be so prominent as many of the users would hesitate to engage due to privacy concerns, which in turn would have reduced the trust in outputs of the system.

CONCLUDING REMARKS

This paper aims to explore the space of workplace quantification. Through the deployment of a prototype Quantified Workplace system in two European offices of a research organization, we found that user engagement with the system was initially driven by community behavior, and over time it translated into a *tiny habit* due to the participatory aspects of the system and opportune placement of input terminals. Users showed a preference towards quantification of those metrics which are beyond human sensing, and also stressed the need to focus on *actionable quantifications*. While the idea of a quantification system at workplace may strike as a *big brother* to some people, we found that if designed in the right way with trust and transparency through anonymous data collection and real-time visualization, such a system may have wide acceptance among employees. Our results and proposed design implications could drive future research in the domain of workplace quantification, and also assist UbiComp practitioners aiming to design such systems.

Certainly, the results presented here must be interpreted in the context of the culture in which they were collected. We expect our results to be most appropriate for designers of future workplace technology in Europe or countries with similar cultures, privacy sensitivies and levels of technology adoption. Another limitation of this study is that we did not evaluate the effect of variations in spatial arrangement of technology artefacts on user participation. It needs to be studied whether user participation would have been different had the mood lamp or tablets been placed in other locations of the workplace.

An exploration on how to systematically incorporate *Tiny Habits* in the design of Quantified Workplace systems could also be a fascinating topic for future work. From a visualization perspective, use of other kinds of ambient displays [32] can be explored for visualizing quantified workplace metrics. While our work was focused primarily on quantification design, researchers should also investigate how to generate and present actionable insights from the quantification to users in a workplace.

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