U-Sense: Feasibility Study of "Human as a Sensor" in Incident Reporting Systems in a Smart Campus

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Abstract—**The 'Human as a Sensor' paradigm provides a way of leveraging the power of individuals' observations to benefit situational awareness via monitoring, incident detection and reporting potential issues to responsible authorities. Our research explores the feasibility of using this approach to improve situational awareness in a smart campus by prompting building occupants to perform routine checks for potential problems with building facilities. We present a feasibility study of an interactive reporting system prototype named "U-Sense" by conducting a real-world experiment for one month (n=21). Based on responses through the system and interviews with the participants, we assess the potential for this approach and propose a number of design implications for such systems including task-related aspects, human sensor availability preferences and participation motives.**

1. Introduction

Incident responders are teams or people within organisations who handle incidents in various contexts, such as safety and cybersecurity, to minimise the damage. Incidents include accidents, hazards, near misses, IT and cybersecurity incidents, facility faults and errors, and ecological observations. Reporting such incidents is indispensable in public and work places [53]. This falls under the umbrella of situational awareness which simply means having adequate awareness of the existing and shifting condition of a situation or environment [11]. In most built environments, occupants view the facility condition and status as exclusively falling under the responsibility of the building management [33]. Improving situation awareness by real-time condition updates about the building resources' defects or potential incidents (e.g. water dripping, loose door handles, trip hazards, sensors not working affecting lights and temperature) remains a challenge, particularly when dedicated employees may be under-resourced.

With the increasing number of "smart" environments, situation awareness has been improved by the automated collection of data [33], such as passive infrared (PIR) sensors [2] and magnetic reed switches [38] to sense door movements. Still, those sensors only deliver binary information associated with noise, hence are not suitable for precise reading. CCTV cameras are useful to some extent, however they can be considered intrusive and costly [20]. Although they are accurate in detecting human movement [39], defects of resources in facilities may not be detected by current systems. Also, they cannot provide alerts for potential incidents or defects before they happen. For example, a loose door handle condition could worsen by falling off and causing the door to get stuck or locked with people inside the room affecting their security and safety. This issue could not be detected by machine sensors and requires a human that reports the problem.

The 'Human as a Sensor' paradigm provides an attractive solution by utilising individuals' knowledge and observations to benefit situational awareness via monitoring, event/incident detection, reporting potential issues or emergency response [9], [40], [41], [46], [58]. Typically, this has utilised people's contributions through social media channels such as Twitter and blogs. In addition, a wide range of work related to user inclusion with the management of smart environments gives more attention to improving local services by asking for feedback, reviews or complaints rather than asking users to perform tasks [19], [45]. Multiple studies have also been conducted around occupants' comfort and preferences during interaction with the building [12], [13], [18], [42].

However, none of the cases above involve relevant agencies proactively requesting that people perform checks, relying instead on grassroots contributions. There is an opportunity to explore whether organisations could actively prompt building occupants to perform checks and use the "Human as a Sensor" concept to improve the reporting process.

Figure 1 illustrates a high-level model of a typical reporting process, showing how this might be augmented by an interactive reporting system requesting human sensors to perform simple tasks of checking facility condition and report defects. We believe when occupants are included in the process of continuous checks of the building facilities by providing their own observations, they can help improving situational awareness, efficiency and reduce latency and cost. However, there is currently no research exploring the feasibility of this approach in a smart building context or how such requests could be configured to maximise their usefulness. To explore this gap, our research asks:

1) Is it feasible to use human sensors to improve reporting systems in a smart campus?
2) How can we configure the reporting system to improve its usefulness to organisations?

In this paper, we present a feasibility study of an interactive reporting system prototype named "U-Sense". We

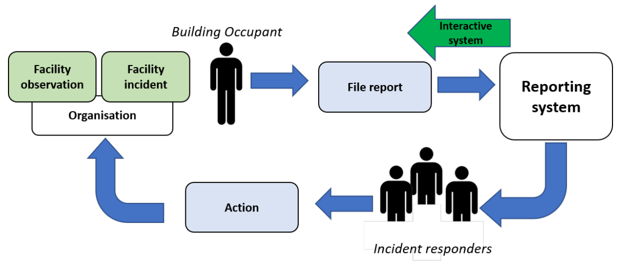

Figure 1. A high level model of a standard reporting system used in work environments and an interactive version (Green Arrow).

conducted a real-world experiment in a newly built (2017) smart university building in the UK over one month, where 21 participants were asked to respond to system requests to check the status of building facilities. Based on these feedback and interviews with the participants, we tested the feasibility of such a system and are able to make recommendations for potential features of reporting systems utilising this premise. We found that such a system is highly feasible and has benefits for the building facilities and community. We analysed the response quality, numbers of responses per task, and individuals' engagement with each incident, as basic factors, in addition to the interviews findings; all indicating promising results. Accordingly, we discuss a number of key implications for such systems including task-related aspects, human sensor availability preferences, participation motives and interface design.

2. Related Work

This section covers related research around incident response and reporting, Human Building Interaction and building management, crowd sourcing applications and motives driving people to engage in incident reporting.

2.1. Incident Reporting and Response Systems

Incident response is the process of detecting alarming events that could affect resources (digital or physical) and then performing the proper planned steps to assess and fix the situation as necessary. Governments and organisations set guidelines, policies and rules to prevent incidents from happening [32]. One of the important aspects of handling incidents is how early they are detected. There are different ways of detecting alarming events such as having monitoring systems, human reports, and combined methods. Incident reporting is considered the first step of this chain. In this context, there is a difference between an 'incident' and an 'accident' [28]. An *accident* is defined as an unexpected action ending with serious injury, illness or property damage. An *incident* is an occurrence that doesn't result in harmful damage yet has the potential to cause harm. In the context of a work place, incidents are more likely to happen. According to the Australian risk management consultancy IPM, accidents cover only 2 percent of the incidents in the workplace [28].

Several studies have focused on analysing the existing reporting systems. For instance, Bach et al. [6] focused on the user side of the reporting tools and analysed 23 incident reporting systems. They studied urban contexts to understand users' insights into incident reporting applications and aspects affecting the user experience [5]. They found that UX dimensions that can be utilised to trigger and motivate users to report incidents in the urban places. Likewise, Winckler et al. [57] explored the user experience of a reporting system app. They reported certain requirements such as presenting reportable items in the app menu to avoid non-specific forms, identification for avoiding fake reports and features for uploading evidence such as pictures and videos. Grant et al. [23] conducted a study to assess the usability of an incident reporting tool by recruiting users to conduct tasks using the prototype tool and then filling Ravden and Johnson's Human Computer Interaction (HCI) checklist.

2.2. Human–Building Interaction (HBI)

When it comes to the "smart agenda" for any environment, research has focused on improving efficiency, sustainability and reducing costs. On the other hand, HBI emphasizes human values, requests and preferences to understand occupants' interactions with such environments. Different building type has its own purposes, needing a number of contextual requirements demanding the expansion of attentive research where the outcomes may have differences and similarities with other contexts [3], [43].

Describing HBI in *Space is the Machine* [30], Bill Hillier said that: "Built environments are a construction of physical elements that create and protect a space. Each of these two aspects, the physical and the spatial, carry a social value: the former by the shaping and decoration of elements (with functional or cultural significance), and the latter by providing spatial patterning of activities and relationships. Designing Human–Building Interaction, in that perspective, consists of providing interactive opportunities for the people to shape the physical, spatial, and social impacts of their built environment." HBI thus focuses on the multifunctional concepts of the building, comprising of three interconnected features of the: physical-material, spatial-configurational, and social-cultural [3].

In addition, some research has gone into the security and privacy concerns of the occupants of smart buildings when used as their work place [24], [25], [48]. They report that the occupants express uncertain understanding of smart buildings as a work place. They extend their concerns to sensors embedded in these buildings and worry about their privacy and lack of transparency in these environments.

In HCI, research conducted by Verma et al. [52] analysed the use of building space based on sensors data. Finnigan et al. [22] also used sensor data in the auditing routine of building managers. Other studies concerned occupants' complaints as an approach for facility supervisors to evaluate their satisfaction of the indoor environment [43]. Clear et al. [12], [13] set their attention on occupant contribution in building assessment and administration. They examine how environmental data can facilitate interactions between building managers and occupants, and propose ways influencing more inclusive and bottom-up building management [12]. Other studies explored the dimensions of comfort around shared places [13]. We recognise that the occupants are involved in the incessant making [42] and appropriation [18] of place. Therefore, we ask how can they engage with management in terms of maintenance and facility conditions.

2.3. Crowdsourcing and Human as a Sensor Paradigm

Increasing connectivity of citizens and the digitalisation of the information systems of governments and businesses have opened ways of sourcing knowledge from residents via internet-based approach e.g. mobile apps [1], [44]. 'Crowdsourcing' is a term initially defined as: *"the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in an open call*" [31]. Other terms were also used describing similar ideas such as 'peer production', 'user-generated content', and 'smart mobs' [17], [26], [55]. Several authorities and organisations have utilised the concept of crowdsourcing in order to gain access to collective insights, skills and ideas from the public [49].

The 'Human as a Sensor' paradigm is one method of performing crowdsourcing. In computer science, human sensors have been used in smart cities to utilise individuals' observations for the authorities to broaden their situational awareness among several fields such as event/incident detection and monitoring and emergency response of natural catastrophes [9], [40], [41], [46], [58]. Bennett et al. [7] used this concept to reduce crimes inside neighbourhoods, while He et al. [27] used analysis of Twitter content to predict traffic and Heartfeild [29] applied the same concept in the field of cyber security threats in social media. Alkhatib et al. [4] applied text mining techniques to Twitter feeds in Arabic to extract reports from the public to help managing incidents and events in smart cities. We can see from these examples that incident reporting is a domain where the Human as a Sensor concept can be applied. Therefore, we aim to leverage the power of human sensors in building reporting and management.

2.4. Incident Reporting Motivations

In order to design engaging incident reporting systems, it is crucial to identify the motives that drive people to participate where there are no obligations to do so [35], [47]. The source of such motivations are either intrinsic or extrinsic [15]. With intrinsic motives, individuals do not expect personal benefit from doing any actions whereas extrinsic drives includes a gain of personal benefit [54]. However, motives may differ significantly based on the user type, the situational context and the system itself.

Katmada et al. [34] have identified 7 motives: learning/personal achievement, altruism, enjoyment/intellectual curiosity, social motives, self-marketing and direct compensation. The first four can be considered as intrinsic motives that are aligned with Maslow's hierarchy of needs [21]. Motivations can also be triggered by some incentive mechanisms. Katmada et al. [34] have presented four basic incentive mechanisms that motivate people to participate: reputations systems, social mechanisms, gamification [16] and fnancial rewards: cause extrinsic motives like vouchers and token rewards.

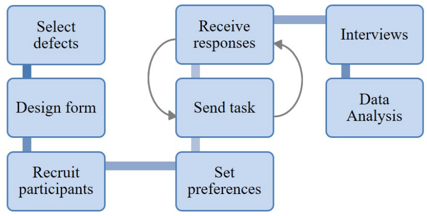

Figure 2. Our experiments' steps and flow.

Although previous research has extensively studied the citizen reporting (e.g. [36], [44]) and user experience of reporting systems [5], [14], [37], there is very little research on user motivation to engage in reporting incidents and observations at work environments. In other contexts such as citizen reporting, previous research show that such motivations may be different across contexts and demographics [1], [56]. Wijnhoven et al. [56] found that the demographic factors such as the socio-economic characteristics does not affect the participants' choices in open government projects, but motives such as enjoyment and learning were relevant in the study. A follow-up work [1] applied an empirical study on participants of a Swiss reporting initiative and found out that self-concern or other orientation are major motives for their engagement.

3. Methodology

Our study includes prototyping an Incident Reporting System (U-Sense) utilising the "Human as a Sensor" concept, testing it in a real-world setup with the occupants (n=21) of a smart university building, and interviewing the participants for more in-depth feedback. Figure 2 illustrates the steps of the study starting from the design phase till the analysis.

3.1. Form Design

Prior the experiment, we designed a mock system to test the feasibility of the proposed idea. A simple Microsoft Office Form was designed, where each form represents a "check request" dedicated for one task. It contained one required question and four optional ones. The questions are structured as follow:

- The main question asks the participant to check the condition of a certain facility. The answers are always multiple choices of: yes, no, not sure, or I can't check it. It also contained a photo of the facility for clarification.
- A question that allows users to upload media such as photos or videos as supporting evidence for their answers.
- A text box to add comments related to the task.
- A 3-star rating question for the user to rate the difficulty of the task.
- An extra comment box for participants to add any information regarding the experiment or their availability (e.g. being busy or not in the building).

A screenshot of a sample task is presented in Figure 3. Figure 4.

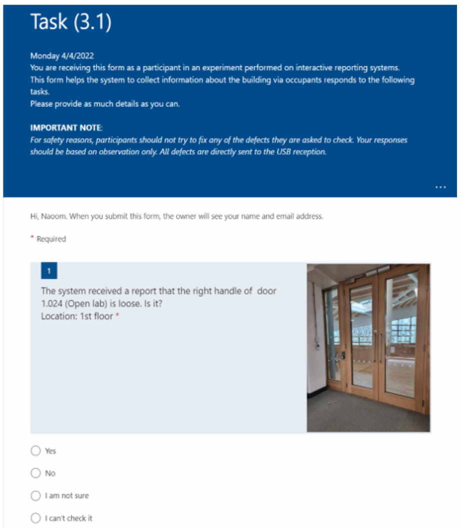

Figure 3. Task Sample (a)

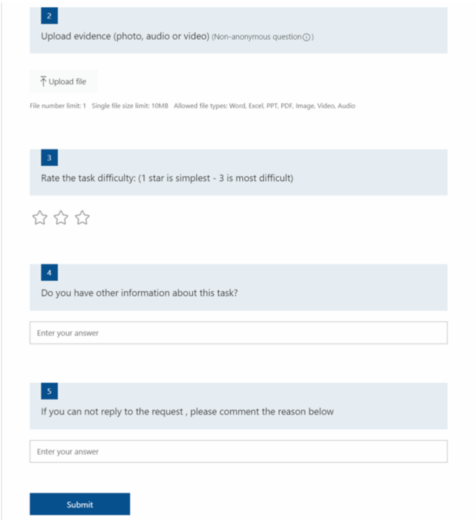

Figure 4. Task Sample (b)

3.2. Participants

Table 1 presents the demographic data of the 21 recruited participants as occupants in the smart building where the trial system was running. A recruiting email was sent to all occupants to invite them for this study. For those who accepted, they filled out a pre-screening questionnaire for demographic data collection as well as some questions about their preferences, including available days and times, and preferred platform for contact (email or Microsoft Teams). Each participant had a minimum of two weeks to participate in the testing of our system. Each participant was compensated with £20 for their engagement with this system and a final feedback interview.

The experiment was conducted in-the-wild for one month in a smart university building in the UK. The participants received a link to a task called a "check request", asking them to check a facility condition in the building (e.g. whether a light is working, or a door is locked). Participants had a full day to respond to these requests, and the choice whether to respond to the request

TABLE 1. PARTICIPANTS' DEMOGRAPHIC DATA

Gender		**Age**	
Male	8	Under 20 years	6
Female	12	20-30 years	8
Non binary	1	30-40 years	4
		40-50 years	2
		50+	1
Nationality		**Role**	
Outside of the UK/EU	5	Professional support	5
EU	2	PhD student	7
UK	14	Undergraduate	9
Location			
1st floor	2		
2nd floor	4		
3rd floor	10		
4th floor	2		
5th floor	1		
6th floor	2		

or ignore it for any reason. The lead author led an orientation session explaining the system to the participants. For safety reasons, the participants were advised not try to fix any of the defects they are asked to check and only respond based on their observations. All defects were directly sent to the building's maintenance team in order to be fixed by responsible personnel.

3.3. Building Description

The experiment was conducted in the Urban Sciences Building (USB) in Newcastle University, Newcastle upon Tyne, UK. It is a newly built (2017) smart university building comprising around 134,500 sq ft. It consists of six floors designed for teaching, laboratory research, events and testing real-time smart technologies for urban sustainability. The building is considered to be "smart" due to its data gathering system used by facilities supervisors to support problem analysis and to regulate energy consumption, joined with a BMS (Building Management System) that adjusts comfort settings, such as the temperature and lighting. Its residents are diverse, including academic and professional support staff, research staff and undergraduate and postgraduates students. Its spaces include individual and open plan offices, computer labs, seminar rooms, and lecture theatres [43]. Residents have differing levels of access and this was taken into account when setting tasks.

3.4. Incident Selection

In order to make the experiment realistic, we followed a procedure of selecting incidents. The first step was to analyse a defect log file provided by the building reception and maintenance of all the reported incidents and defects in the years 2019–2020. We analysed the 1161 logs to calculate the most occurring and reporting incidents. This approach was used in previous research (e.g. [5], [51]) when examining the user experience and usability of their proposed incident reporting system. We also used live incidents reported to us by the building reception, who are the first point of contact used to receive reports.

Tasks used in this experiment met the following criteria: 1) they should be based on most reported incidents and defects in the building; 2) tasks should be safe and secure for both occupants and facilities; 3) some restrictions were applied for privacy reasons, for example, all incidents were issues in public places excluding personal offices or any other access restricted areas. Table 2 shows the facilities included in the trial, and the final tasks used are shown in Table 4.

TABLE 2. FACILITIES INCLUDED IN THE SYSTEM TRIAL.

Facility Type	Number of requests
Door handle	2
Wet floor	1
Window	2
Computer cable	1
Screen display	2
Lifts	1
Lights/motion sensors	2
Temperature	2
Smartcard readers	2
Intermittent noise	2
Table	1
Sink	1
Dripping water fountain	1

3.5. Data Collection and Analysis

At the end of the trial, we gathered both quantitative and qualitative data. Quantitative results related to the responses such as correctness, duration, number of replies, comments and difficulty ranking of the task. The qualitative results were obtained by two approaches. The first was post-trial interviews that lasted around 30 minutes asking users about their experience. The second approach was based on the Experience Sampling Method (ESM). In ESM studies, participants are instructed to report some information about their actions, emotions, or other elements related to the study during the day. These self-reports are delivered by responding to some short questions when receiving a notification (e.g., the task request from the reporting system) [50]. The optional questions added to the task form descried above were used for this reason. Although the questions were optional in the task, it helped understanding the underlying issues with each task and any other situation.

We report the feasibility of (U-Sense) via measuring three aspects of human sensors engagement in the system (the accuracy of the results, duration and number of replies) as well as user comments or other supporting data, and their reported difficulty in responding to the assigned tasks. We conducted post-study structured interviews with participants for around 30 minutes each to talk about their experience in acting as a human sensor and we recorded these interviews. This included five parts: experience, feelings, preferences, tasks and interface design. A thematic analysis was applied on the answers where the main themes were extracted [8], [10].

3.6. Ethics

This study has received an ethical approval from the Ethics committee of Newcastle University, UK. The participants consented to take part in this study and could withdraw from it at any point. We recorded our interviews and saved them anonymously on a password-protected file.

4. Results

In this section, we present the engagement level of our participants working with our trial system as well as their feedback via the interviews and self-reporting forms.

4.1. Feasibility Assessment

Before deciding whether the system is feasible or not, we set criteria for success. This included three main measures: 1) quality of human sensor response; 2) time duration to receive a useful reply; 3) number of replies indicating that occupants are willing to contribute to the system.

Quality of Replies: Across the one-month experiment, we sent a total number of 143 requests thorough the system. It is crucial to evaluate the quality of received information. This is an important characteristic to decide the trustworthiness of the human sensor concept when utilised in an incident reporting system. To evaluate the response quality, the first author performed a check on the facility condition before and after the request was sent for each individual request. Accordingly, we we identified an incon in the reported assessment of the incident, we talked to the participants about any inaccurate answers during the feedback interview to understand the reasons behind it.

Among 143 responses, there were only 8 inaccurate responses, split across 4 tasks (shown in Table 3). We revisited each of these answers to see whether the participants were confident about their replies or not. When looking at the replies, we noticed that 6 responses were based on lack of understanding of the task and may have been more successful if there was more detailed description (as suggested by participants in the feedback interviews). For example, a request to check the temperature in a room was not clear for some of the participant who did not notice the thermostat placement in the room. In another case, where the participants were asked to check a broken lock on a window, the participants thought that if it closed that means it was fine, despite the handle not locking. When asking the participants, we noticed that three of the inaccurate responses to the tasks could have been avoided by providing more details. Only two responses out of 143 were inaccurate due to misreading or misinterpretation from the participant side (i.e., tasks 2 and 4 in Table 3).

Two tasks received a “not sure” answer in relation to an intermittent noise and a wobbly table. Although the participants did not select a yes or no answer, they did provide a clear explanation of the facility condition in the comment section and the evidence section. The first task was expected since the noise was intermittent not clear all the time. The wobbly table received an explanation that it was wobbly to some extent but not a problem to be reported. We can see here the ability of the human sensors to understand and provide insights on subjective situations.

Time Duration of Replies: In this trial, the participants were told that they had a full work day to respond to the check requests. To test the duration of each response we calculate the duration between the task sending time

TABLE 3. Inaccurate responses during the study

	Task	Response	Reason	Inaccurate responses
1)	Temperature	Thermometer placement	Description	2
2)	Motion sensor/ sink	Checked lights instead		1
3)	Window	Closes but not lock	Description	3
4)	Window	Checked wrong window		1
5)	Smart card / door	Wrong door	Description	1

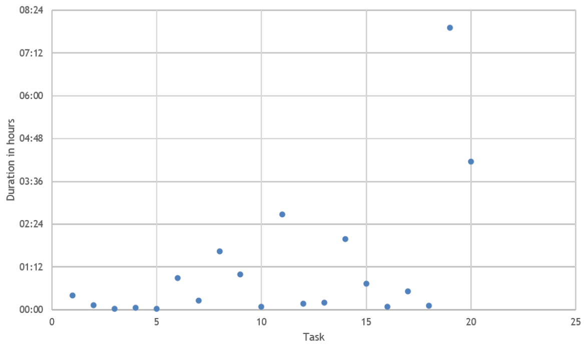

Figure 5. Time to receive one response for each task request.

for each participant and the time of receiving the response. Any declined responses were excluded. We performed these calculations on the first accurate responses received by the system, as this would be the point at which the system administrators received useful data.

As illustrated in Figure 5, the majority of tasks received replies in less than an hour, with the quickest taking only two minutes. However, there were some exceptions, with two tasks taking longer than expected and reaching 4 and 8 hours. This might be expected given that these tasks took place on Thursday and Friday, which were the days when fewest participants were available. This shows the importance of understanding the availability of human sensors in order to predict if replies will be rapid. In addition, it is important to note that the job role and culture of the work building may have a significant affect on the human sensor collaboration and availability. For instance, our case study was a university building comprising professional staff with offices, teaching staff with lectures, and students with lectures and exams. We think that the timing of the experiment had an effect on the duration and number of replies where students were preparing for their exams and not attending every day.

Number of Replies: During the month of the experiment, 20 task requests were sent. A promising finding is that the all of the tasks received replies. The majority of tasks (70 percent) received responses from more than half of the participants, regardless of the place or type of task.

4.2. Further Responses

Apart from assessing the incident, we also asked our participants to report further comments, provide more information (e.g. a photo) and rate the difficulty level that they experienced with each assigned task. We report our findings here.

User Comments: In our trial system, for each task, besides the required question in the check request, two optional text boxes were available for occupants to add any comments regarding the task or their ability to do it. During the month trial, around 117 responses included additional information.

41 comments contained explanatory content. These descriptions could be as simple as reiterating their main answer to the response, e.g. stating that a window is working, or that it could not close. The other 13 comments included clarifying difficulty such as sensors placement, finding room location, access restrictions and room availability/occupation. Furthermore, 17 notes included participants providing their point of view. We noticed expressions of subjective opinions such as describing the level of defect (e.g. “slightly wobbly”, “slight noise won’t consider it banging”, “might drip intermittently”, “long time to wait for drips”, “placement of sensor might affect the defect report”, “temperature shows 20 but it feels cold”). Other useful answers included raising further information (e.g “other door handle is loose as well”, “noise related to another separate room”, “lights turned on by control panel but not by sensor”, “I am sure it is working”). We also received around 33 notes of occupant cancelling the task because they were not inside the building for different reasons such as working from home, illness, travel, or simply being busy and forgetting to reply.

Task Difficulty Rating: Our participants had an option to rank the difficulty of the received tasks. As presented in Figure 6, the majority of votes stated that the tasks were simple. Around eight tasks were ranked as moderate by one or two participants and around six tasks received a complex rating describing some challenges while checking the place. To understand the causes of difficulty, we checked the participants’ difficulty ratings in the form and asking them about this during the interviews. Answers associated with the temperature, intermittent noise and motion sensors were the most commonly rated as difficult. This might be affected by the number of participants available on the days we distributed these tasks. However, we were able to find common aspects of some tasks that makes them more difficult than others as they stated in participants’ comments: (1) Lack of familiarity with facilities (“I wasn’t sure where the temperature meter was”, “I don’t know what is meant by ‘does it show 17 degrees’. Does what show 17 degrees?”). (2) Difficulty reaching the location (“It was hard to find the door as the room takes up half of the first floor and there are many entrances”). (3) Subjective possibilities of answers (“Thermostat shows 20.8 but room does feel cold”, “Definite temperature drop when I went into 2.022 compared to other rooms on the floor”). (4) Access control over facility (“doors won’t unlock for me”, ‘The room is occupied”). (5) Time taken to perform the task (“I kept waiting for the right lift to arrive to be able to check it”, “took me a while to find the correct desk”).

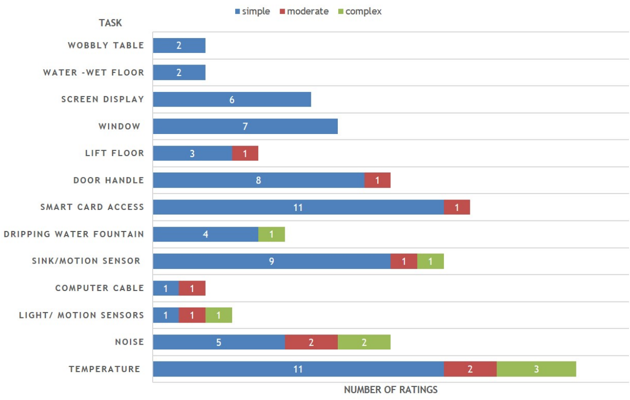

Figure 6. Task difficulty rating.

(6) Intermittent defects that can not be easily detected ("stayed in 3.032 for 5 mins, heard nothing", "it might be dripping slightly intermittently, but I was by it for like a minute and didn't notice any dripping").

Regarding the participants differences, we noticed a correlation between the the participants' demographics data and the task difficulty rating. For instance, the undergraduate students were more likely to rate a task as complex, whereas postgraduates and professional support staff more often rated tasks as moderately difficult. We guess that an undergraduate student is less likely to be unfamiliar with some parts of the building and less confident entering an inhabited room and explaining why they are there. For example, a number of young participants voted "complex" if they could not do the task due to the place being occupied or used by some one. Other occupants who have jobs and spend a longer time in the building expressed more confidence and knowledge regarding the smart building. Professional support in particular had the least votes for moderate or complex difficulty. This suggests that the job type and role in the building might influence the occupant familiarity with tasks relating to the building itself.

Providing Supporting Data: Our participants had an optional choice of providing any supportive information that benefits their reports. They could upload any media file whether it is photo, audio or video. During the experiment, the system received 46 supportive files, which were either photos and videos. In general, among the 20 tasks, 14 tasks received evidence backing up their responses while 6 others did not. Overall, we observed that the number of available participants in a day has an effect on the quantity of received evidence: for example, weeks 3 and 4 had more available human sensors that week 1 and 2, and hence we received more supporting data in those weeks.

We observed that the highest number of the supportive files submitted to the system were associated with the tasks with the highest complexity rank. By observing these photos, we found that the temperature check task was supported with a proof of a thermostat photo (to remove any subjective opinion on the temperature). The second task was associated with motion detection sensors. Although the participants' comments did contain some explanations of the situation, they also tried to support their claims with the recordings.

Another point to mention is the type of supportive media files. The majority of tasks received photos taken by users. In some particular tasks, such as the ones requiring human interaction to check the condition, participants decided to evidence their answers with recordings of their attempts. This was evident in tasks including checking a loose door handle, testing motion sensors on a sink, a dripping water fountain and smart card access to a room. We recommend that this type of supportive data can improve the quality of responses as descriptive recordings of the situation can clarify the condition of the facility. In some cases, it might be beneficial to make supportive media compulsory.

4.3. Interview Results

In this section, we provide the results of our interviews in a few parts: human as a sensor experience and feelings, user motivations for engaging with U-Sense, and their views on the assigned tasks.

Human Sensor Experience: When asking our participants about their experience during the study, simplicity emerged as one of the most common themes. 14 participants described the **simplicity** of the interactive reporting system as one of its main positive features. They mentioned the ease of task requests, way of receiving the tasks and that it did not require a long time. 12 answers emphasized on the points of no urgency or stress. For instance, one participant said: *"Because it is based on preferences, I feel free to decline"*. The **flexibility** of the requests also appeared to be a positive factor, as highlighted by 12 interviewees who said that there was no urgency or pressure to do the task in a certain time. The option to opt out and set their own preferences to receive requests was highly appreciated by participants. Another theme emerging from the interviews was **obligation**. Participants described feeling such as: *" I liked being included to help maintaining the new building"*, while another answer explained *"when I received the tasks, it felt like a manager's order"*. Five occupants of the building enjoyed the **excitement** in being a human sensor where they see it as a chance to break the routine. Expressions like *"It was fun walking around, like a treasure hunt!"* emerged among the answers. **Concerns** from participants included *"what about people performing duplicate tasks?"*. Also, Finding and accessing a room or facility was a concern especially to those who are not familiar with the building. Few explained their concerns by mentioning: *" What if I am not granted access to the place?"*. This suggests that similar systems might add an alert or disable the task when it is already fulfilled correctly and no further help is needed. Regarding the restricted access, some solutions can be implemented such as: cluster occupant groups based on their access rights, or provide the volunteers with a special pass.

A significant positive theme raised among the answers where interviewees reported increasing levels of **awareness and familiarity** of the building and its facilities. Most of the participants (15) pointed to improvements in their knowledge: *"I became more observant"*, *"I explored new places in the building and noticed new features like thermometers"*, *"I paid attention to issues I've never notice before, I guess I'm used to issues being there!"*, *"Ï* *knew my way around"*. However, five of the participants did not report any difference, as their job role already required that they deal with facility defect reports.

Feelings: The second question explored how it feels to act as a human sensor when receiving check requests. A sense of feeling **helpful and belonging** was raised by 7 participants, mentioning: *"I felt important and involved by adding value to the community*". Some liked the feeling of being helpful: *"It is a rewarding feeling to collaborate preserving better environment"*

At the same time, participating as a human sensor brought a sense of obligation and **responsibility** (*"I had this sense of obligation because I signed up for it, so I had to",It is similar to my job"*). While acting as a human sensor for the first time, participants reported feelings of **vigilance and prudence** by doing things that they are not used to doing. At the beginning, some participants described feelings of discomfort (*"I felt strange when checking things", "I felt weird doing something not my responsibility"*). However, participants felt more **neutral** once the requests became expected (*"well, it was expected", "it was fine, I did not feel pushed"*). Some mentioned that they felt interrupted sometimes: *"I did not mind, however sometimes it feels inconvenient and interrupting, especially when I am busy"*

Motives: This topic explored the intrinsic or extrinsic [15] motivations for participating. Starting with a general question, we asked participants if they would continue working with the new interactive reporting system. 12 of them agreed they would continue using it with no external incentives. Four agreed with some conditions such as assigning tasks places close to their offices. The remaining four required external incentives. Regarding incentives and motivations, we asked another question asking what would motivate them if there were incentives.

Figure 7 shows the types of motive that were apparent in the interviews. Altruism and intrinsic motives presented in the concepts of "helping the community, having better environment" was found to be the highest with 10 participants. Followed by the desire of adding a factor of enjoyment and competition, around 5 occupants suggested having a point system such as scores or ranking lists with winners announcements. Related to that, participants recommended that if winners were to be given rewards or compensation, it should be simple amount like vouchers or university credits for long time users only. Finally, some participants preferred to be recognised and counted as members in a specified group at work.

Tasks: One of our research questions is to see whether the system is feasible when running it in a smart environment (i.e. smart campus). Therefore, it was inevitable to include check requests to the smart features associated with it that requires interaction and observation. As illustrated in Table 4, some check requests asked the users to check if sensors for lights, temperature or sinks were operating correctly, or smart cards and smart card readers providing proper access.

Participants were asked if they found any differences in checking tasks related to smart buildings or traditional ones. Around 11 responders raised some differences in some aspects. One aspect of this was **complexity** of performing checks (*"technology is always harder to check, interaction is not like observing", "Tasks were simple and basic but it's about not knowing how it meant to work"*). This was also linked to them seeing it as an **interconnected system** where the defect of something might affect the other. Participants explained that in order to check/report a smart feature problem, there are several related variables to consider affecting the quality of the response such as *"the way of interaction, sensor placement, and a person's level of knowledge and familiarity of the building"*. Similarly, the background and **level of experience** theme was raised as an important factor affecting the quality of the report. Factors including the amount of time spent in the building and the role such as being a maintenance staff or field researcher of smart buildings may affect the level of observation and quality of reports (*"it depends on user experience, others might need more time—it is not complex or technical for me"*) where others were unaware of sensors in the building. Occupants who had no experience mentioned that is *"new and interesting"* to explore these aspects of the building. Some professional support that have experience in receiving these type of reports mentioned that the building's smart features can be **temperamental** (*"goes on and off occasionally"*). Other interviewees noticed that there were some tasks that could have two answers in terms of a facility working either **automatically or manually**. This was raised in requests to check lights where they could be switched on manually yet not automatically when entering the room. This can also be reasoned to the movement and sensor placement in the room. On the other hand, 8 participants did not find it different due to the simple observation requests they were required to do, mentioning that they did not require any technical understanding.

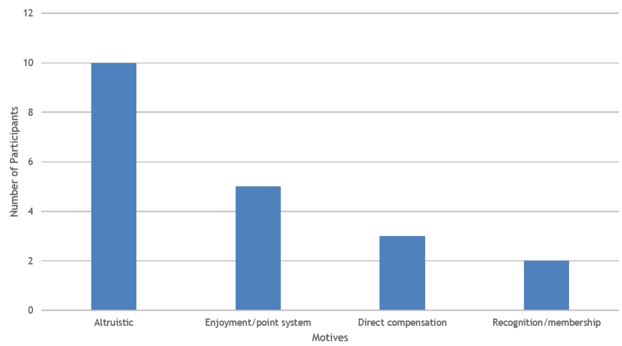

Figure 7. Participant preferred incentives for contributing in the interactive reporting system.

5. Discussion

This paper presented a feasibility study of the leveraging the Human Sensor concept through an interactive reporting system named U-sense in a smart campus. The proposed prototype was intended to inform the deployment of an actual system by obtaining insights into the opportunities and challenges of this approach. In the presented case study, the environment was a medium-sized smart university campus. With 21 participants, the concept proved effective in gathering reports on the state of facilities in the building, suggesting the possibility of more permanent use in a wide range of places. Human sensors might play a role in spaces such as a university

TABLE 4. CHECK REQUEST TASKS SENT THROUGHOUT THE EXPERIMENT.

Week 1 Tasks	
2.1	The system received a report that the window in lab 4.022 - left corner- is not closing well?
2.2	An intermittent banging heard above room 3.032 and 3.033 coming from the heating pipes in the ceiling. Do you hear the banging noise?
2.3	The system received a report that water is spilled on the floor of lab (4.022). Please check the floor between 2nd and 3rd lines of computers from the left near the window. Is the floor wet in that place?
2.4	The system received a report that the smart card reader (Chubb) is flashing and not granting access in room 2.037. Can you access with your smart card?
2.5	The system received a complaint that room 2.022 is very cold (reading is 17 degrees) - Is the room cold?
Week 2 Tasks	
3.1	The system received a report that the right handle of door 1.024 (Open lab) is loose. Is it?
3.2	Can you check if the timetable screen for room (USB.3.018) is displaying today's timetable?
3.3	The system received a report that lift 145 is slightly higher than the floor when it stops on the 3rd floor. Is it?
3.4	The system received a report that light sensors are not working. They never come on on their own, on request either, or dim over time. Is that true?
3.5	The system received a report that a cable tube hanging from the ceiling - Do you see a cable hanging?
Week 3 Tasks	
4.1	The system received a report that the left handle of door 1.024 (from the inside) is a bit loose . - Is it loose?
4.2	The system received a complaint that room 2.022 is very cold (reading is 17 degrees) - Does it show 17 degrees?
4.3	The system received a report that the motion senor is not detecting hand movement in the sink of the disabled toilet. - Is it working?
4.4	The system received a report that the sink in the student refreshment area is constantly dripping. - Is it still dripping ?
4.5	Is the timetable screen for room 3.018 displaying today's timetable (Friday 13th)?
Week 4 Tasks	
5.1	Does your smart card grant you access to room 3.018?
5.2	The system received a report that there is an intermittent banging heard above room 3.032 coming from the heating pipes in the ceiling.- Do you hear the banging noise?
5.3	The system received a report that the window in lab 4.022 is not closing - closer broken. - Can the window be closed ?
5.4	The system received a report that light sensors are not working. They never come on on their own, on request either, or dim over time.
5.5	Is the small round table of the meeting space (3.029) wobbly?

campuses, airports, train stations, etc. However, each environment has its own characteristics in terms of dynamic, culture, size, occupants' demographic differences. Thus, we recommend studying the specific characteristics for each environment.

Response Quality: We recommend that tasks are stated consistently and clearly, describing the location and the placement of the facility and how to reach it. Highlighting the level of importance and urgency for the received task may also assist users to fit them in their daily schedule. For extra clarification, we suggest providing a method of communication with administrators (e.g., chat button). One of the main challenges that occupants faced is in receiving directions to locate a room or facility. One solution might be to provide guidance around the building, such as a map or descriptive figure, or posting a QR code to scan and shows the location precisely. Furthermore, occupants can be grouped based on zones thus receiving tasks in places near to them.

We also concluded that simplicity is key. Participants would like to feel free and can easily opt-out if they do not have time or simply do not want to do it, so system might add ignore button or a reminder option to resend task at another suitable time. For newly deployed systems, having a rating scale to rate the task difficulty could be useful for deciding what tasks are possible for participants and for assigning points for tasks.

Motivational Mechanisms: This also has an impact in what type of motivational mechanisms that should be implemented. Being in a university, our study raised an interest in altruistic motives in terms of being in a community and having a newly constructed building also elevated the participants interest in maintaining their campus in best condition. Furthermore, we found that contributing to such systems raised occupants' awareness of their environment where they became more observant of the resources and their functionality. We recommend displaying a thank you message that appears when submitting an answer acknowledging their contribution.

Another desired incentive was fun factor, where participants expressed their enjoyment of the "treasure hunt" and of moving around. Being in a work/study place, people may like to get out from their offices and walk around nearby places. This can be leveraged by providing a routine break that includes doing something useful at the same time. This can be taken into account when designing the system by displaying statistics of user's accomplished as encouragement to track their contributions. Listing top highest scores can provide a competition flavour as an enjoyment incentive where participants are rewarded when achieving the highest replies score. Also, when a user responds first, they could be notified that they were the first to reply. Scores can be associated with winning and receiving simple university prizes such mugs or badges.

In general, we believe that incentives do have an impact in participation count and quality. The type of incentive may differ in other environments and different user demographics.

Contextual Responses: Our experiments showed the opportunities of running such systems for real-world applications. The collaboration with human sensors gives a valuable level of subjectiveness that can clarify whether it is a real problem or not. For example, looking at the comments and explanations provided by participants, there are noticeable amounts of useful information such as the cases of temperature checks. We also found that the other related questions such as adding comments and supportive data, rises a proposition to include them to support the responses leading to more reliable and trusted reply. Also, we recommend that adding supportive data can be signed as required in some tasks. So therefore, an option for system administrators to assign the question as required.

Resilient Systems: For future use of similar systems, we recommend collecting long term data and attempting to find noticeable patterns of issues. This will help to build a more resilient and trustworthy incident response system. For instance, getting a repetitive reply about a facility defect in certain times of the year. Similarly, certain timings may affect the availability of human sensors as well such as holidays. Other proposition is to utilise a form of GPS tracking or checking into the building systems. This can offer higher accuracy in knowing the number of available occupants. Although this may increase some privacy and anonymity concerns by occupants. Another suggestion is to find a solution to merge human and machine sensors data to provide more efficiency. All of these could be areas to be explored as future work.

6. Conclusion

The paper explored the feasibility of leveraging the human sensor observations in an interactive reporting system prototype to improve situational awareness in a smart campus. A real-world experiment was conducted for one month by sending tasks to participants to check facilities conditions for potential incidents. 21 occupants of a smart building participated in this study. In order to reduce the number of ignored tasks, we asked the participants to fill in their day and time preferences to receive their check tasks. After completing the experiment, we interviewed the participants to collect their feedback about their experience as contributors to the system.

Our findings showed positive feedback in terms of number of responses, quality of provided information from human sensor and the time duration of receiving responses. We found that the quality of the received replies requires a clear description of the task and the facility location (especially smart devices such as sensors) since this may confuse the participant if not provided clearly.

Finally, the paper lists some design implications and future recommendations for the systems in terms of selecting tasks, occupants availability preferences, and motivation mechanisms to encourage long-term contribution.

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