Using Adaptive Architecture to Probe Attitudes Towards Ubiquitous Monitoring

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Abstract— **The term Ubiquitous Monitoring aims to capture the unprecedented degree to which data collection will occur in the future through ongoing developments in embedded, wireless and sensory technologies. Intelligent buildings represent the most current instantiations of this technology in the form of building management/automation systems. However, there is an emerging field of research called adaptive architecture, which aims to explore more meaningful and direct interactions between occupants and their environments. In this paper, we use the experience of a prototype adaptive/biofeedback architecture called ExoBuilding as a probe to explore user attitudes towards future monitoring systems in buildings. We present results from a semi-structured interview, which encouraged participants to envision future monitoring technologies, making projections based on their real experiences with ExoBuilding.**

Keywords- Adaptive; Architecture; Envisioning; Pervasive; Probe; Monitoring; Surveillance; Ubiquitous.

I. Introduction

In today's society, both monitoring and surveillance are frequently supported by technology. For example, consider the usage of time-attendance systems, closed circuit television cameras [1] and radio-frequency identification tags [2]. These technologies stand to change dramatically with the proliferation in sales of, and on-going developments in, mobile, embedded and sensory technologies. Through this a whole range of new monitoring-based applications and services will become possible. This will be brought about predominately through a newfound ability to collect novel data types on a previously unprecedented scale [3]; a concept referred to as Ubiquitous Monitoring (UM) [4].

The physical environments we live and work in will soon be able to collect data about us, providing a variety of useful applications in domains such as healthcare [5], education [6] and in security/surveillance [7]. This can be achieved by augmenting buildings with electronic monitoring technologies, with the intention of introducing features designed to support their users [8]. These so called 'intelligent buildings' are arguably some of the first incarnations of UM in the real world. However, this is not the first time buildings have been designed to serve the purposes of monitoring. During the 18th century, Jeremy Bentham proposed a prison design called the Panopticon [9], with the specific intention of maximizing its monitoring properties through the physical structure.

Alongside modern developments in intelligent buildings, there is an emerging field of research called adaptive architecture, which seeks to use pervasive technology in built environments in a different way, to return more fundamentally to the architecture itself. Adaptive architecture seeks to physically change the built environment through actuations in a way that can support occupants. They could involve intelligently and physically altering the space based on data collected through sensors or by directly interacting with occupants. This interplay between actuation in a space in response to users and sensors provides an innovative context within which to explore ideas surrounding monitoring and surveillance.

Given that the area is only starting to emerge, there is much to understand and explore regarding any potential social implications surrounding its use. The success of novel pervasive technologies (including ExoBuilding) requires consideration of the desires, concerns, and understanding of the users [10]. For much of the pervasive technologies used in the built environment, speculations about such concerns have been the only option for researchers mainly due to the availability of deployable instances of the technology. This raises the question of *what are user attitudes and concerns in relation to intelligent buildings and adaptive architecture.*

ExoBuilding [11], a prototype biofeedback-based adaptive architecture, uses similar pervasive technologies as those anticipated for use in UM systems. The prototype was developed to explore the use of digital technologies (physiological measures) to respond and adapt to a building's occupants and environment in a highly interactive way. One aspect of this two-way interaction is the collection of data about occupants. Given the availability of the prototype, we were motivated to use it as a means of probing some of the social concerns and desires of users in response to the aspects of adaptive architecture related to monitoring/surveillance.

In this paper, we present selected results from a wider study, where a series of participants directly experienced the types of interaction in adaptive architecture, as we understand it. The intention was to ground participants in this experience, and use it as a part of an *envisionment* technique in HCI that has been proposed for exploring user reactions to future technologies [12]. Our findings suggest that users feel vulnerable about the use of their own physiological data as it is a strong representation of themselves. There are also significantly different 'default' views on monitoring buildings as either being designed to support users, or designed to watch them and coerce specific behaviors.

II. UBIQUITOUS MONITORING

With advancements in wireless, sensory and embedded technologies, we are soon approaching the pervasive era of computing. This technology stands to fundamentally change the way we interact with and think of computers, where technological complexity is hidden and dedicated interaction is no longer required. Monitoring systems in particular will benefit from this advancement, as data collection will be a core component of future pervasive systems [13]. These new technologies will be unrestricted by physical boundaries and distance and so their capabilities will be significantly greater than existing technologies [14]. This new type of monitoring is referred to as Ubiquitous Monitoring (UM), and is defined as *the use of pervasive or wearable devices for collecting data to provide services and application for users* [4]. There are five main characteristics which differentiate UM from existing forms of monitoring: *Collection Scale, Collection Manner, New Types of Data*, *Collection Motivation and Data Accessibility* [15]

Beyond these characteristics, the technology is being used in an innovative way in *adaptive architecture* to create dynamic physical structures, which react to and interact with their inhabitants. However, to begin to appreciate the relationship between this new field and UM, we must first take a step back in time and examine a point in history where architecture and surveillance merged in an interesting new way.

A. Monitoring through Architecture

Jeremy Bentham's [9] 18^{th} century conceptual prison design was known as the Panopticon (see Figure 1). Guards in the prison were housed in a single central tower, overlooking all of the prison cells, arranged in a circular formation around it. Light from outside of the prison building created clear silhouettes of prisoners that ensured the guards could always see prisoners, while small windows and little illumination in the guard tower prevented prisoners seeing the guards. As a result of this, prisoners would be unaware of when a guard might be watching them, forcing them to act as if they are being watched at all times; allowing the prison to be minimally staffed. This '*panoptic effect'* [16] is caused by the contrast between the visibility of the observed and the invisibility of the observer (which echoes the embedded aspects of pervasive computing). Foucault, as described by Albrechtslund [7], famously reinterpreted the Panopticon as a framework for examining power and disciplinary relationships. This acted as the foundation for the concept of the '*electronic panopticon'* [17] which captures how modern day computing technologies can be used to impose social power.

Similarly, the '*information panopticon'* [18] refers to the idea that only information, without restriction of time and physical space, is needed to create modern *panoptic effects* such as perceptions of privacy invasion, increases in uncertainty and stress [19]. As we approach the "pervasive era" of computing, the metaphorical variants of the panopticon will again no longer be a sufficient means for understanding the characteristics of the surveillance and its effects [20]. The concepts of the "*embedded panopticon*" [20] "*postmodern panopticon"* [7] and "*Überveillance*" [21] are intended to illustrate the impact of pervasive technology when used for surveillance. Surveillance is of course far from the only use of pervasive technology in physical environments, and one way in which this technology currently manifests itself in the context of architecture is in the form of intelligent buildings.

B. Intelligent Buildings

With a number of proposed definitions of an Intelligent Building, it is often unclear what the term actually represents [22]. Typically, the term refers to Building Automation Systems (BAS) [23] and Building Management Systems (BMS) [24]. These systems consist of networks of intelligent electronic devices that monitor and control different aspects of a building, including energy consumption, heating and lighting levels and other operational mechanisms to make the buildings and occupants operate more efficiently and comfortably respectively [25]. They are also used to manage and control the security and surveillance systems (e.g. CCTV, lock mechanisms). Moving beyond these existing systems, there are many instances of research-based living laboratories that utilize wireless and embedded pervasive sensors, in new and exciting ways. For example, the Aware Home [26], the Place Lab [27], and iDorm [8]. These were designed with many different pervasive technologies, and for a variety of different

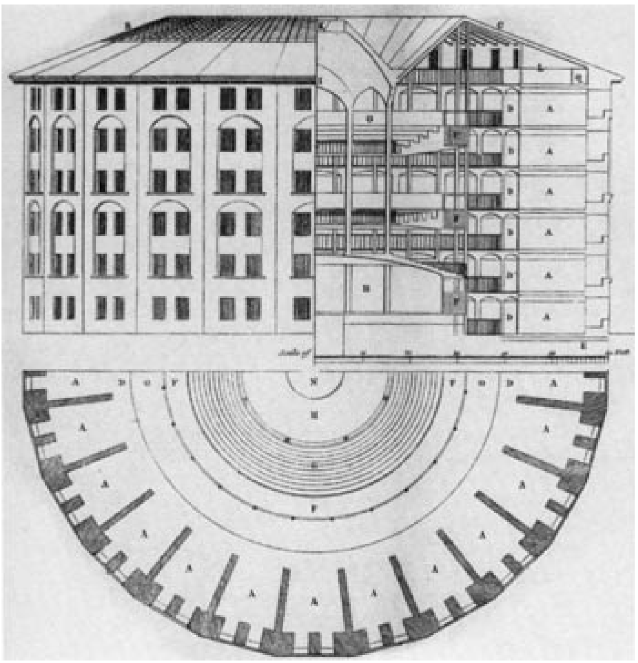

Fig. 1 A schematic of Bentham's Panopticon prison design

purposes including: explorations regarding health, wellbeing sustainability, and an overall intention to improve quality of life [26].

While these environments are useful to explore different aspects of monitoring systems and pervasive technology, their direct relationship to architecture is limited. The laboratories restrict the dynamic aspects of the system to actuations in the forms of changes on display screens, or intelligently turning appliances on and off [8]. In parallel a new field of research and use of technology has emerged offering more impactful dynamics. These dynamics are in the form of novel actuations of the *physical environment* itself in direct response to its inhabitants: this truly interactive relationship is called adaptive architecture.

C. *Adaptive Architecture*

Adaptive architecture is an emerging inter-disciplinary field, which aims to study buildings that are designed to adapt to their inhabitants, objects and their environment [28]. The movement might be said to be 100 years old and includes buildings that are designed to be manually adaptive; and has therefore had an emphasis on interaction. Others in the field take an emphasis on auto-generation, making intelligent buildings a part of adaptive architecture. Architects and architectural research programs have recently started to investigate possibilities, afforded by new technologies, to make architecture itself kinetic in an interactive way, especially through digitally driven actuation devices. More recently, digital technologies have enabled new types of interactive adaptations. An example for this line of investigation into architecture that consists of moving elements and digital data is a project called Open Columns [29]. Open Column used CO2 sensors to detect deterioration of air quality caused by increased human activity or density. The columns would then drop from the ceiling to disperse any group gathering with the intention to improve the air in this location. Another example is called Active Room by Yiannoudes [30], and was designed to increase its size depending on the number of people inhabiting the space. For this to happen, a shell-like structure was developed that would automatically add segments in order to increase building volume and floor plan size.

The examples of kinetic architecture mentioned above show that, because of the increasing utilization of sensor data and software to actuate structures, the research area is located at the intersection between architecture and computer science. What differentiates this strand of adaptive architecture from intelligent buildings is the fundamental working principle of a two-way interaction between user and a technology-enabled environment. Furthermore, the technology does not *necessarily* need to store, process, interpret or collect data in order to adapt to its occupants. There are a significant number of potential benefits to this technology; which are derived from the ability for such environments to automatically be tailored to an individual. However, this is fundamentally a form of monitoring/data collection system (albeit a highly interactive one). While the technology has benefits, it could potentially in the future be adopted as part of a larger surveillance network. While user reactions and responses to monitoring systems have been partly explored in terms of intelligent environments and buildings [31], to date, little work has explored the views of users on the monitoring aspects of adaptive architecture. This motivated our exploration of user attitudes towards future monitoring systems beyond ExoBuilding, but based on the technologies associated with it.

III. Wider Study Design and Probe

This section describes the ExoBuilding prototype in more detail, outlines the design and procedure of the wider study, and presents the specific questions centered on UM systems that are relevant to this paper.

A. *Exobuilding*

ExoBuilding [11] is a single-person, tent-like structure that changes its height, volume, and shape based on its inhabitant's real-time physiological data. ExoBuilding is driven by servomotors that receive signals through a middleware platform. This platform allows data processing and manipulation as well as communication with physical actuators, such as the servomotors. A central spine made from thin aluminum tubing is suspended from two servomotors mounted to a wooden beam, which is attached to the ceiling. The servomotors achieve a motion range of about 30 centimeters between the up and down state. The structure is ca. 1.3-1.6 meters high, about 3.5 meters long and roughly 3.5 meters wide. It is the combination of physical structure, sensing technology, and middleware platform(s) that allows direct physiological interaction between the inhabitant and the environment.

The single inhabitant of ExoBuilding first sits down on a reclining chair, which itself is mounted to a wooden platform equipped with coasters. The experimenter, then, rolls the inhabitant into ExoBuilding, entering the structure from the back.

The inhabitant (participant) sits underneath the stretchable jersey fabric onto which a static, filled circle of blue light is projected for the duration of the experiment. This circle allows the participant to perceive motion of the environment better than sitting in a completely dark space. For the duration of two trials, the ceiling lights are extinct and only minimal residual light coming through the window curtains and the light of the projection illuminates the environment.

Fig. 2. The ExoBuilding prototype adaptive architecture

B. Wider Study Design and Procedure

The work presented in this paper is part of a wider in-progress study, which aimed to explore the relationship between participants and physiological data in the context of adaptive architecture. This involved two separate interactions with ExoBuilding, with a controlled change between a human-driven, and machine-driven, actuation. However for the majority of their experience the environment was human-driven through participant physiological data. Participants (n = 31: 16 Female, 15 Male) were between 18-50 year old university students (undergraduate and postgraduate) of various ethnic backgrounds, the majority being Caucasian (16).

Upon arrival at the lab, participants were fitted with torso-mounted electrodes (electrocardiogram, galvanic skin response, and a respiration belt). In total, participants experienced two 9-minute trials inside ExoBuilding. Prior to the first trial, the experimenter gave a short introduction into the physiological link between the participant and ExoBuilding. Participants were asked to fill out questionnaires before and after each trial - a total of three rounds of questionnaires. Immediately before each trial, participants were asked to walk ca. 45 meters at slightly faster-than-normal speed in order to achieve comparable levels of alertness and physical arousal.

Prior to the first trial, a testing phase was conducted which was not part of the experiment. This testing phase was between two and four minutes long, during which the participant could experience the environment and would receive additional verbal help, if necessary, to make the environment move smoothly and regularly. The experimenter also issued instructions for a particular respiration pattern, as this was vital for the success of the study. To reduce distraction by external noise and to facilitate focus on breathing, each participant received noise-cancelling headphones before each trial. After their experience participants were asked, in addition to filling out the last batch of questionnaires, to draw their experience. This drawing was used as a point of departure for a subsequent semi-structured interview, which lasted approximately ten minutes.

C. Experiential Probe

The semi-structured interview within the procedure is the focus of this paper, and aimed to make use of ExoBuilding as an experiential probe. Building on participants' experience of the environment reflecting their physiological measures, we aimed to surface their views and attitudes towards future monitoring systems similar to ExoBuilding. Their interaction with ExoBuilding was intended to help ground their experiences in something physical and tangible, beyond simply using an idea or hypothetical system e.g. [31]. The following two main questions were asked to participants during the semi-structured interview:

> *What would you think about sharing physiological data with a building you use day-to-day?*
>
> *How do you feel about the idea that buildings in the future will collect data about you?*

These were designed to avoid bias when presenting future monitoring systems, particularly with respect to the use of the word surveillance. They were also deliberately left open ended, to allow participants to express their salient concerns and perceptions. The idea was to initially probe the concept of collecting physiological data in participants' current day-to-day lives, and to then consider their views towards future monitoring systems.

IV. Results

From the interviews with participants a number of factors appear to either positively or negatively influence attitudes toward sharing of physiological data with an entity such as a building. These factors include aspects of usefulness, privacy, context, control, authority, vulnerability, invasiveness and permanency. The results are presented in two sections, each reflecting the two different questions asked.

A. Buildings and Physiological Measures

The following are examples of responses from participants regarding the sharing of physiological data with the built environment in today's society.

1) Purpose and Usefulness

Many participants demonstrated a good foresight, and were able to extrapolate their experience with ExoBuilding to other aspects of life in a positive way:

> *"It's a good idea, the building can adapt to you. If we are able to demonstrate that a certain heart rate means you're sad then the building can adapt and try to make you feel better."*
>
> *"Be quite good because it would be adaptable to you and personal to you. It would help the way you are thinking, acting, operating."*

Other participants were not sure on the direct applicability of physiological data, but showed a willingness to share the data if there was some benefit to them or others:

> *"If it is for a good cause, it is a good idea to share."*
>
> *"I don't mind sharing my data. It would be nice. Not sure how it could be used. Sometimes I am cold in the office and I am not sure if it would help. I would like my building to know that I am cold and make it warm."*

Other participants expressed concerns related to the intentions of those collecting the data (**they**), and the potential for unlawful use of the data:

> *"What's the aim? Are they going to reveal my name? What will they get? Maybe there are advantages; they can improve their building quality."*
>
> *"In some ways it could be useful but at the same time it might be like they were spying."*
>
> *"I don't see any disadvantage unless the data is being misused."*

2) Privacy and Control

Several participants raised questions about data collection and anonymity. Participants revealed a sense of indifference if anonymity could be guaranteed:

> *"Is it going to be identifiable?"*

> *"That would be fine as long as the data is confidential."*

> *"It's fine provided that the recorded data will be kept private."*

Control of access and use of the highly personal physiological data was shown to be an important facet in interacting with adaptive monitoring technologies:

> *"I wouldn't like that. My physiology changes with my mood, I am not sure I would want the building react to my mood/state of mind. Unless it is changing to help, it would be strange. I like to be in control, I would like to have control over things like that."*

> *"The only worry is who has access to that data."*

> *"Is it connected to the internet? If it was separate, I would be happy. But if people could invade, I would be opposed to that."*

Participants also expressed concerns about the temporal aspects of data usage in real-time:

> *"If people can see it not in real-time, it would be okay."*

> *"If they can see it in real-time, it would invade my privacy. Maybe I am nervous about something, but I don't want to talk about it"*

One participant commented on the covert potential of the technology:

> *"I think I would feel like being looked upon because there are people behind screens looking at me saying 'see someone is not feeling well today'."*

3) Invasiveness and Vulnerability

One participant intriguingly explained that through ignorance of data collection, they would accept the technology:

> *"If I wasn't aware, it would probably be okay."*

Others remarked on the obtrusiveness of the physical sensors used during the experience of the ExoBuilding, highlighting the potential physical invasiveness of the technology:

> *"If I have to wear this kind of stuff, then no."*

> *"I don't mind. If it's for a good cause, but it's difficult to wear electrodes."*

Several participants described how physiological data is highly personal, and a strong part of their 'self', creating reservations about the need to share it:

> *"There's not much left that is mine. So I don't want to share that."*

> *"Just something about sharing the entirety of things with a building wouldn't be so nice."*

> *"We already give a lot of information about ourselves with physiological info. It would really be everything about ourselves…"*

> *"We share so many things, we are so exposed, so if there is no draw-back, I would not have a problem."*

Participants also mentioned ideas related to self-preservation and fear, and grounding these in their experiences with existing technologies:

> *"That sounds a bit scary. The building knows you. It's just that something or someone else has your data. Maybe it's my fear of things like Facebook or Google. I am very afraid nowadays that someone has my data"*

> *"I am very willing as long as it doesn't cause any damage to me. Sharing something personal is quite dangerous. I have to be sure that it doesn't cause any damage to me. It's a matter of keeping it private."*

> *"The notion of something collecting all the data about you is a little bit scary"*

4) Context

Two participants explained the different contexts they would and would not accept monitoring of this kind, and actually showed directly opposite opinions:

> *"If it's my office, I wouldn't mind. But in the living room, no. I think it's private. Some things are not meant to be shared with other people. It's like a laptop. You would put private things on a laptop, not on a desktop."*

> *"If it was my house, that would be okay. But at work, I don't know if I was okay with that. Might be uncomfortable with the idea. It feels judg-y. You set up your own home to be comfortable. Your own home should just react you, that would be quite comfortable."*

Other participants also showed conflicting opinions on this information being measured in the workplace:

> *"Employer shouldn't know how stressed I was."*

> *"I don't see why* ***they*** *would want it. In a workplace maybe a manager would want to know if a person came in a good or bad mood."*

B. Buildings and Data in the Future

The following are participant responses to the idea of buildings collecting data in general beyond physiological data in the future.

1) Usefulness

Participants reiterated their likely acceptance of the technology if it served a useful or beneficial purpose to themselves or others:

> *"If it's to make our lives better, it would be okay. Of course it depends on the data. I think it is interesting. If it improves our quality of life, I would be okay."*
>
> *"If it's good for the general population, I would be for it."*
>
> *"If it's for something good, I wouldn't mind."*
>
> *"If it's to improve the quality of life of people in the building, it should be fine."*

While some participants would accept the technology based on its usefulness, others failed to see even the potential use:

> *"Why would it do that?"*
>
> *"I can't imagine why they would use it."*
>
> *"For what purpose? For me now, it's not preferred. If in the future, the building can indicate that I have a disease, maybe that would be okay."*

2) Data Types

Moving beyond physiological data, participants question the benefits and needs for different types of data:

> *"If it noticed that your favourite colour is green and it changes the walls to be green, I would be all for that. But if it was gathering your heart rate, I am not sure, it might be scary."*
>
> *"I think it is too much. You don't need to know that many details. Maybe just the main points to collect is fine. You have to prioritise which data to collect."*
>
> *"Depends on the data that is being shared. If it is your thoughts, that could be difficult. But just physiological data, should be fine. Data about your position etc. could be sensitive"*

3) Context

Again, participants show mixed responses about the use of monitoring technology in the home and work:

> *"It would be convenient: in the bedroom, if I feel really sleepy, the light just turns off."*
>
> *"I wouldn't want it at home."*
>
> *"I wouldn't want to live in a house that knows everything about me, all my habits etc. It's a bit weird if your building knows exactly how you behave and what your habits are."*
>
> *"At the workplace I would be fine with it. Not at home."*

4) Privacy

Participants voiced concerns over what person's would be given access to what information:

> *"There are advantages (fire w/ location tracking), if it is effective and private it's fine; if privacy is extorted, I would oppose to it."*
>
> *"Maybe I don't want people to know when I am going to the toilet. Or I want meet someone without others knowing."*
>
> *"It's kind of being watched […] I would feel rather uncomfortable."*

5) Authority

Some participants also mentioned ideas around choice and authority. They suggested compliance with instructions from a home monitoring system, reference to "**they**" that monitor, mention of big brother and interestingly the suggestion of an independent negotiator:

> *"I am quite lazy at home, so it couldn't really make it easier at home. If it would suggest to do something differently, I would feel like I have to do that."*
>
> *"I don't really like that. They have information about you but you don't have information about them. It's not balanced."*
>
> *"I think it's possible. They can get your data from everywhere, and the access is really easy and the technology is developing everyday."*
>
> *"That might start being a bit 'big-brother-ish'. I like the idea of getting away from everything. But if it's recording were you are and everything, you cannot get away from it anymore."*
>
> *"I think both collectors on collectees of data need to agree. An independent negotiator needs to solve it."*

6) Permanency

There was much discussion on the permanency of future systems:

> *"Technologically, I am very excited about that idea, but at the same time I am very afraid. What if it falls into the wrong hands? […] That you cannot run away from."*
>
> *"It would be gradual. Already a lot is being recorded, voluntary or not. I would not want to walk into a building tomorrow that does that. But it will be over a longer period of time."*
>
> *"It violates privacy a bit. But if everybody is treated the same way... There would be a conflict in the beginning but after a while, it would be okay."*
>
> *"That's probably the future. We have to get used to it."*

V. DISCUSSION

From the interviews a number of different themes emerged, regarding questions about sharing physiological data now, and the idea of sharing data in general with a building in the future. The following is a discussion of the key recurring themes.

The purpose and intention behind the collection of both physiological, and other types of data were important to participants in terms of their view of the technology (**Usefulness**). For example, many participants understood the benefits of sharing data as it could help the building be more adaptable and customizable to the individual. This understanding left the participants content with sharing the information. This may be attributed to a more open attitude to sharing data as a result of day-to-day use of cloud services or social networks. Those who did not fully appreciate the potential uses of the data acknowledged that provided it was used for a good cause, then it was acceptable for them to share it. This is consistent with previous findings that perceived usefulness can influence acceptance of technology, particularly if the benefits outweigh the risks [10, 32]. However, some participants questioned the need for a building to collect information about them, adopting a different perspective to others related to the negative '*why am I being watched*' versus the more positive '*if it helps...*' viewpoint.

Sharing the data for the intent of a good cause is one thing, but some participants expressed concerns about who should have access to the variety of data (**Privacy**). Perceived privacy invasion is known to influence acceptance of technology [33], and in light of this, anonymity was viewed as a key point of personal protection in these types of monitoring systems. Different degrees of control of the data's use and access were also seen as important to individuals.

Beyond physiological data, participants started to consider the use of different types of data together (**Data Types**). This was seen as problematic for some, where it was described as simply being "*too much*", and that "*priorities should be made*" about what data is being used. This highlights the way users assigned different degrees of value to different types of data, which has been shown to influence perceptions of privacy invasion [34].

Related to these values are the senses of exposure the data types make (**Vulnerability**). Participants intriguingly viewed physiological data as a particularly accurate representation of themselves. This may be related to the ways in which one (or a system) can attempt to infer mood and emotions from these measures. In this way, a truly physical and social boundary is crossed, where participants cannot protect and hide aspects of themselves that they ordinarily could. This may contribute to participants' sense of fear and the perception that there is potentially personally damaging repercussions associated with the sharing of this information. This type of fear and mistrust also emerged as themes in previous research [35].

Any sense of vulnerability and fear is likely to change depending on the situation and environment within which the monitoring takes place (**Context**). Views on whether this type of technology is acceptable in the workplace or at home differed significantly, reinforcing the knowledge that context is only one moderator of usefulness [36].

This may be related to the default position that participants took on the technology as a tool to help and support themselves, or as a tool for employers or other institutions to coerce, manage and survey. Interestingly biofeedback has been readily established as a means of reducing stress in the workplace [38]. It may also be related to perceptions of ownership of the technology and data. Expectations of privacy depends on the context, e.g. consider a hospital versus a workplace [39], one can more easily be justified in the collection of physiological data than the other, and hence is more likely to be perceived as useful and a benefit. This finding was consistent across views of both physiological data and other types.

Participants also discussed aspects of persuasion and coercion in these future environments (**Authority**). There was discussion of how instructions received from a system in the home would be followed through persuasive techniques. Beyond this, particularly in the workplace, there was mention of "they" (with negative connotations) who collect the data. The use of the word suggests that a group or institution are collecting the data, and given the negative tone, with the intention to coerce users into specific behaviors. Other research exploring bio-data also revealed concerns related to government/authoritarian control and conspiracy [35]. The big-brother concept was also mentioned, implying a negative reaction toward the technology.

Interestingly, one participant mentioned the idea of an independent negotiator to manage the relationship between the observer and the observed. This demonstrates the ways in which people use principles that work in current practices and apply them to the future.

One participant referred to a built environment as *"a house that knows everything about me*". This differs from a work environment such as an office where there will be specific people who own and manage the data collected. This interestingly highlights the agency that the participant has attributed to the environment, raising question of how the data is processed and how/where is it shared?

The temporal aspects of these systems were also viewed as an important consideration for participants (**Permanency**). Ideas surrounding habituation, and the gradual introduction of technology were discussed, with the outcome of simply having to accept that things will change, and be a certain way. This is an interesting consideration, particularly as the technology involved in ExoBuilding does not retain any data about participants.

Finally, one participant explained that through ignorance of data collection happening, they would accept the technology. This supports the hypothesis that behavior changes only occur, in terms of a monitoring system, when a person is aware that there are being observed [4]; in some ways a *reverse* panoptic effect.

VI. CONTRIBUTIONS

The main contribution of this work is to move beyond metaphors and outside intelligent environments to explore a new type of interaction/sharing of data between people and buildings. Allowing participants to experience a brief interactive 'relationship' with an environment facilitated the effective probing of ideas of future monitoring systems. The experience allowed them to project themselves forward, and better appreciate how they might interact with technology grounded in their personal experiences. This gave rise to a series of themes important to them, and which designers of such systems should consider.

These monitoring based themes coincide with those identified by Moran and Nakata [40], which reaffirm their importance in monitoring systems. The similarity suggests that users may perceive ExoBuilding as a similar class of device to other monitoring systems such as wearable tags. However, two additional unconsidered themes emerged related to emotional aspects of fear, and personal damage, and also ideas of authority; which differs from simply giving access to others, as they have power to act upon what it accessed. Key findings from this work highlight user's perception of vulnerability, openness and sense of self associated with physiological data. Anonymity is an important component for protecting privacy, and that most concerns can be outweighed if the system is well justified and serves a noble purpose. Finally, aspects of agency, intention and authority were presented as arguments against the introduction of the technology.

The main limitations of the study are related to the work being only a first step toward an understanding of the monitoring implications of built environments. The work was intended to be exploratory due to the novelty of adaptive architecture, and this is reflected in the results.

From the initial findings, we can begin to consider the design of UM environments more generally, factoring in the way, for example, in which these systems are first introduced/presented to prospective users: the system should be justified, with its intended purpose explicitly stated. Furthermore, users appear to value anonymity, which may resolve issues surrounding privacy invasion, vulnerability in relation to over exposure of personal data, and the foreboding sense of an authority figure(s). This work opens for discussion the implications of this new technology and research area in the context of monitoring systems. This work also contributes towards part of a wider question regarding the ethical implications of collecting bio-data about users [37]**.** In addition, this work raises important questions regarding the use of physiological data as a means of truth [35].

VII. CONCLUSIONS AND FUTURE WORK

In this paper, we aimed to explore user attitudes toward future ubiquitous monitoring systems. To achieve this, we used a prototype adaptive architecture called ExoBuilding as a probe, to ground participants in an experience with real technology and then project this forward to consider more futuristic systems. The results revealed a number of key considerations from a user's perspective, related to perceived *Usefulness*, *Privacy*, *Data Types*, *Vulnerability*, *Context*, *Authority* and *Permanency*.

Of particular interest was the way participants viewed their physiological data as a significant representation of themselves, and that sharing this information was an invasion of their last bastion for personal privacy. In many ways, physiological information is even hidden from the participants themselves, and ExoBuilding progressively surfaced it; revealing it not only to participants, but also to the experimenter and other researchers involved in the study.

With respect to future work, there are many different avenues to explore in this relatively unstudied area and technology. For example, there are several questions related to the implications of a physical environment representing the internal cognitions of a person. Moreover, there are questions related to the sharing of such environments, where such personal actuations may directly influence another person. The implications of this in the surveillance and persuasion research communities are significant.

In terms of extending this work directly, on-going research will seek to explore the implications of further iterations of the ExoBuilding prototype and similar technologies. There are a number of more specific questions to be asked related to the context and justification of use, and to explore applications of the technology in real world settings. Furthermore, it will be useful to more widely examine and compare the literature on related monitoring technologies in order to more accurately position adaptive architecture as a field of research in its own right. It would also be interesting to investigate the effects of large scale information sharing in the form of social networks, and how attitudes towards these technologies may influence the sharing of information within adaptive architecture.

In conclusion, if the views of people are not fully understood and incorporated into the design and implementation of this novel technology, the systems may fail both technically and socially when fully deployed in the future.

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