Co-sleep: Design for workplace based wellness program to raise awareness of sleep deprivation

Bing Zhai
Open Lab
Newcastle University
Newcastle upon Tyne
b.zhai2@newcastle.ac.uk

Yu Guan
Open Lab
Newcastle University
Newcastle upon Tyne
Yu.Guan@newcastle.ac.uk

Kyle Montague
Open Lab
Newcastle University
Newcastle upon Tyne
Kyle.Montague@newcastle.ac.uk

Stuart Nicholson
Open Lab
Newcastle University
Newcastle upon Tyne
S.A.Nicholson1@newcastle.ac.uk

Patrick Olivier
Open Lab
Newcastle University
Newcastle upon Tyne
Patrick.Olivier@newcastle.ac.uk

Jason Ellis
Northumbria University
Newcastle upon Tyne
jason.ellis@northumbria.ac.uk

ABSTRACT
Sleep deprivation is a public health issue. A lack of sleep not only harms our bodies’ immune systems but also degrades their capacity to maintain cognitive skills. Awareness of sleep deprivation has not been widely investigated in work-based wellness programmes. In the study, the project carried out with nine participants from a local manufacture company to raise that awareness. The common causes of sleep deprivation have been identified through the deployment of probes and the interviews. The research generated design concepts of smart IoT workplace to track and share daytime sleep-related activities. Through the bottom up and co-design methods, participants give the points of considering the use of sleep data from different power relationship perspective, includes the unexpected use of sleep for fatigue risk management and evaluation of employee performance.

Author Keywords
Sleep deprivation, wearable sensors, digital civics, digital health, workplace wellness program

INTRODUCTION
Sleep deprivation is a growing public health issue. In the UK, with nearly one third of the population suffer sleep deprivation to varying degrees, according to research by NHS at 2011[8]. The population was trying to survive on six hours or less sleep a night. That went up to almost one in two people in 2017. That compares to only 8% in 1942 [18].

Lack of sleep will significantly impact on work and life quality. Most workers spend almost 30% time at work, another 30% or less time in sleep. The sleep-loss epidemic costs the UK £40 billion annually with 200,000 working days each year due to insufficient sleep, which is equivalent to 1.9% of the GDP[34].

Insufficient long-term sleep negatively impacts on people’s lives bringing daytime drowsiness and impaired cognitive function[24]. Moreover, it can increase the risk of more severe health conditions, such as heart disease, high blood pressure and diabetes[13]. A recent sleep study demonstrated that sleep time below 4 hours a night is similar to the effect of drinking alcohols[55; 65] A chronic sleep deprivation study suggests that when time in bed for sleep is chronically restricted to less than 7 hours per night in healthy adults, the produced cognitive decrement equivalents to what occurs to the individuals who remain awake for 28 – 48 hours [61]. For office workers, this would significantly reduce their efficiency and lead to an increase in work stress due to the lack of capability to catch up on the daily workload [2; 20].

In the past two decades sleep deprivation hasn’t been adequately promoted and people are unaware of it due to lack of visibility of the causes and knowledge of sleep science[3; 14; 36].

Information technology can be used to aid sleep research. Within HCI, the design of systems that support data collection, self-reflection and self-behaviour change has been addressed as personal informatics[38]. Personal informatics tools and mobile applications which support sleep tracking are becoming commonplace [1; 9; 15; 21]. Such as the development of mobile apps to assist people improve their sleep hygiene behaviours based on stage-based model [25; 28; 35] However, when designing for tracking and sharing personal health data, such as in the workplace, these introspective models become questionable. Some of
the fundamental health data challenges included pervasive data capturing, personal privacy and health data sharing.

Researchers have begun to explore the design of personal informatics system for large scale work environments, to encourage behaviour change through workplace based wellness programs [17; 45]. For example, by designing a short-term step-counting campaign in the workplace [12; 32]. However, the design of programs to encourage employees to sleep well are still in their infancy.

The case study lasted for a month with a local manufacturing company. Firstly, the study explored the reasons causing sleep deprivation in manufacturing worker’s life and their willingness to track the activities and contributing factors related with their sleep in the workplace. Secondly, the study contributes the three-stages co-design method for constructing a wellness program. Such as the ideas of an Internet of Things based smart work space to reduce the burden of manually logging the contributing factors in wellness program and identified privacy setting of data sharing. Thirdly, a set of interactive dashboards based on their data as probes were built, then nine interviews were carried out and explored the way people understand and use those shared data. In the interviews, the study also found that sleep data can be used to shape the company’s health and safety policy and discussed the solutions to deal with the conflicts between personal privacy and the wellness program.

BACKGROUND/ RELATED WORK

Sleep deprivation issues in manufacturing sectors
Sleep deprivation has many effects on the manufacturing industry, such as declined productivity, increased defect rate and more importantly, lack of sleep can lead to production accidents. For the manufacturing companies that operate 24 hours a day, the primary factor that causes blue-collar workers to be sleep deprived is the shift pattern. Circadian misalignment is the primary factor that occurs at an adverse circadian phase when the body is programmed to be awake, and most shift workers reported they feel difficult to fall in asleep[37].

Sleep deprivation influences manufacturing admin workers as well. Office work may be repetitive and unengaging. Inadequate and insufficient sleep at home and lack of exercise also accelerate subjective sleepiness and the propensity for sleep. The sleep propensity is usually accompanied by a decrease in alertness which then results in decreased attention to detail, poor judgement, and distraction during complex tasks and loss of awareness in critical situations [37].

For many manufacturing companies, the existing solution is to implement the fatigue management plans to prevent accidents. The methods include observing fatigue by the shift manager, training workers to maximise daytime sleep opportunities, allowing employees to stick to fixed shift pattern rather than rotation shift, and adopting fatigue monitoring technologies to prevent accidents[37]. For office workers, in addition to educating and encouraging employees, many companies adopted a flexible working schedule to support their employees.

Digital Innovation in Sleep deprivation
Choe et al. [16] revealed that people have a strong willingness to track their sleep and the factors related to their sleep in a low burden manner. The study also emphasised that long-term tracking of sleep is also vital for people to identify the trends to assist them to build their desired objectives in sleep pattern.

Building upon those opportunities, and many studies and commercial mobile apps have explored ways of capturing sleep patterns and providing feedback or suggest sleep hygiene related behaviours (e.g. avoid use electronics before going to bed) on aspects that relate to personal sleep health [6; 15; 21; 26]. SleepBate is a mobile app designed to let adolescents record their sleep and lifestyle data (e.g. caffeine, exercise, stress). The application aims to help users to explore possible impacts between their sleep and everyday lives and share them with their families. The subjective sleep quality assessment can give users insight of the impacts of sleep in their daytime life, and thus encourage self-driven behavioural changes towards the realistic goals.

Furthermore, Pina et. al [51] extend the personal informatics system to designing one for family to track and sharing sleep data among family members. A step towards collectively reacting sleep issues. This views digital technology backed systems as a social process where data is shared with family members understand the causes of lack of sleep.

Design for Sleep Personal informatics & Smart Workplace
Personal informatics is a class of tools that help people collect data for self-monitoring in private and public space. Recent HCI research has begun to explore personal tracking experience and meaning in specific social contexts[29]. For instance, people share their personal data through social media integration or in-app friend networks to compare and compete with friends and colleagues[25]. The recent researches have also begun to explore the way to support social sense making by visualising and aggregating personal data to enable individuals to reflect on activities they have shared, which facilitates group sharing, discussing self-tracker data and deriving collective understanding[52].

In Rooksby et al. [56] research, they demonstrate that researchers can configure sociability by designing tools that share information. In this way, self-tracker not only considers themselves but also can focus on other activity trackers to collectively change behaviour.

Moreover, researchers use lived informatics sociability feature to promote shared reflection in the group of trackers where attempts to go beyond behaviour change[7; 29]. These studies extend beyond the behaviour modifier that raises questions about how we should integrate our data into a shared, reflective, and interactive everyday lived experience.
The personal informatics data can be collected by IoTs (Internet of Things) that is the network of physical devices embedded with sensors, software, actuators and electronics that when connected to the internet allows existing computer-based systems to sense the physical world[27]. Deploying IoTs in the workplace can help addressing the public health issues. The Staats et al. [59] study demonstrated that monitor handwashing behaviours would improve hospital caregivers’ compliance with handwashing rules by using RFID based IoTs. IoTs provided effortless opportunities for pervasive data collection. Especially in recent years, with the continuous development of machine learning and IoTs, the technology of tracking subjective feelings through the use of sensors and emotional algorithms is constantly being updated.

**Designing for Health Tracking Workplace Wellness Program**

Workplace health or wellness programs are attracting HCI researcher’s attention in recent years. Today, employee health promotion has become an international trend, and in recent years, the amount of money enterprises invested in employee health has continuing to grow[17]. Many companies provide their employees with discounts on purchasing fitness trackers or reimbursed their gym membership cost to encourage employees to exercise on their own. [30; 45; 64] In Lin et al. [39], the Fish ‘n’ Steps demonstrate an early insight that researchers can encourage behavioural change by means of public display and collective activity tracking. The way of design adopting pseudonymity avatar that dissociated with personal identity and allowing employees take control of sharing their data and privacy. The use of personal data in a social environment poses privacy and security challenges, especially in the workplace. The anonymous or pseudonymous can effectively deal with the negative effects of ubiquitous sensing technologies.

Regarding the company lead wellness program or campaigns, the activity trackers are the most commonly used equipment to collectively encourage behaviour change within the work environment as part of employer health and wellbeing campaigns[17; 31; 32] These projects can be divided into two categories, short-term project and challenges and long-term projects.

Some companies organise short-term events or projects to raise the awareness of healthy behaviour and to motivate their employee to increase levels of physical activity [12; 19; 31; 33]. These projects usually last for one to three months and include incentives such as cash reward or the gift card to encourage employee participating in the events. Sometimes these short-term projects were designed as competitions, and employees can participate as individuals or be a part of the team to win the prizes. Other projects might be designed with pre-defined goals, such as average steps walked per day, or the number of days is cycling to work. Employees who reach the goals will be rewarded accordingly.

In the long-term program, the employees also receive the incentives (e.g. virtual points) based on his own health tracking data to keep participating in the project. These virtual points can be redeemed at the end of the year or operated on an on-going model. Points can be redeemed such as cash rewards, gift cards, or insurance discounts. These projects are commonly carried out in cooperation with third-party companies such as insurance provider.

**The Criticisms of workplace**

In recent years, using tracking technology in workplace wellness program has not gone unnoticed by media. Most reports are critically viewed on the subject. The boundary between life and work is being slowly blurred by technology advancement. Especially whether employees have a choice to participate or coerced into the participation attracting the attention of journalists and researchers [22; 40; 43].

The increasing number of quantification of employees is worrisome as these expanding wellness programs are rarely considered and designed from the employee initiative[42; 54]. These incentive-based health tracking program may lead to implicit disciplining risks for employees who cannot afford to say no, in which disempowering people in the program[58]. In addition, the increasing of concerns for many non-technical employees who fear their data can be de-anonymized for other purposes. As critics remark, tracking devices provide many new ways to monitor employee productivity throughout the day and even expand to breathing, attention and stress levels in different environments[48; 58]. Although employers usually emphasised such programs aim to optimize the workplace by making employees healthier and even adds a little “friendly competition” to improve the morale and productivity, the main purpose still focuses on improving disciplining effects[41; 60].

**PROJECT DESIGN**

There is a lack of research focus on how to empower employees to understand the relationship between sleep deprivation and their daytime life from a personal and collective perspective through a workplace wellness program.

This research aims to empower the employees and to encourage them to construct their wellness program, let them decide which data should be collected and shared. It aims to explore a bottom-up method by co-designing the wellness program to address the sleep deprivation. In particular, our goal was to derive design implications for the system that can be used in the workplace to promote reflection and dialogue about sleep deprivation and encourage employees to improve their sleep collectively. Focusing on employees from a local manufacturing company, the project ran over one month with three stages: 1) design and deploy digital and culture probes for gathering accounts and understanding sleep deprivation issues; 2) organise design workshops for acquiring sleep-related information using Internet of Things technologies in the workplace 3) design sleep data visualisation and conduct
data-driven interview that incorporated of the corporate business social responsibility and ethical issues.

The first phase of the study was to gain an in-depth understanding of the factors that related to people’s sleep through nine interviews of office workers. The second stage used that understanding to undertake an IoT card-based design workshop. There were two purposes of the workshop. The first purpose was to involve the users to join the design of the smart workspace which can automatically collect data by using IoT technology. The second purpose was to let users decided which data should be shared, and in what way to visualise the data.

The third stage was to visualise the data which collected from the previous stage on an interactive dashboard by using the Qtik® [53]toolkits. The dashboards were presented to the users to understand how the users understand and use the data.

**Participant recruitment**
A local medium-size manufacturing company in the North East of England was chosen as being an appropriate case study partner. The main protocol of the study was sent to the company's HR manager and the director, in their strategic plan of last year, the employee's welfare and wellness have been regarded as a major investment and their business social responsibility. Health and safety in the manufacturing environment have been seen as a priority to be addressed.

**STAGE1 UNDERSTANDING CAUSES OF SLEEP DEPRIVATION**
The sleep data profile was akin to a cultural probe. It consisted of thirteen pages, included a standard sleep diary, the log sheets and empty data visualisation charts. The study provided the sleep diary on paper to enable users to record those sleep-related factors at any time. The log sheets allow them to track factors that are not included in the sleep diary. The secondary reason is to include participants who do not want to wear a wristband but want to participate in the study. In addition, using paper-based sleep diary can also reduce the effect of using electronics that impacts their sleep before bed.

**Wearable sensors**
AX3 sensors were akin to digital probe, which was used to collect the unconscious limb movements during the sleep. It’s a tri-axial accelerometer design in OpenLab at Newcastle University. The device is similar to most activity fitness band that can record the acceleration data later on used for human activity recognition. There are many commercial-off-the-shelf products on the market that can collect sleep duration data, such as Fitbit and Jawbone. However, the algorithm accuracy of these products were remain unknown and the actigraph chart couldn’t generated from them, which is widely used in the sleep clinics to present the sleep data to the users and explain how sleep time is calculated. Therefore AX3 (accelerometer) was adopted [5; 23] as our sleep monitoring band for our study.

**Sleep data collection**
Nine participants wear the bands for a week and upload their sleep diary data through an online form for logging purpose. The sleep data were processed by “Estimation of Stationary Sleep-segments”[10] algorithm to generate Actigraphy data which is commonly used for determining sleep patterns and circadian rhythms. Afterwards, nine one-to-one follow-up interviews were conducted. Every participant was given a £25 amazon voucher to compensate their time spend on the study.

There are four purposes of the interview. The first was to gain insights into the user's understanding of sleep quality and duration and the difference between the Actigraphy data analysis result and their sleep diary. The second was to explore the reasons or factors impact on their sleep, as well as the influence of sleep on one's physical and mental health and work efficiency. The third was that the study explored the user’s attitudes and opinions toward tracking the relevant information in the workplace, and the way to collect these information and related barriers. The fourth was to find out what kind of wellness program users want to participate in, what kind of common objectives are there and what they think about sharing their sleep data in the office environment. All interviews were transcribed and thematic analysis were carried out using a Braun & Clarke’s six step process[11].

**INTERVIEW FINDINGS**

**Lack of awareness on effective sleep**
Some participants (6 out of 9) did not realise that they had a lack of sleep before participating in this program. They thought they have slept for a long enough time because they count awake time such as on bed drifting time as sleep time. For example, one participant stated: “I think I’ve probably been awake at times when I don’t realise I’ve been awake.”(P2) By comparing Actigraphy data with their sleep diary, many participants realised that their sleep time was less than seven hours.

Five out of nine participants understood the number of hours they needed and the impact on their work. Such as P8 stated: “If everybody was going into work and had a good eight hours’ sleep, I would say that production figures would rise, without a doubt.”

**Family reasons & personal reasons**
Family reasons were one of the most important factors. First of all, some people have a heavy family burden, such as the elderly and children who were sick at home need to be taken care of. P9 said: “My mum’s an alcoholic and she’s got Alzheimer’s. My dad’s 71 and just suffered cancer, just got over cancer.” Stress from the family often affects the quality of their sleep. Still, others were disturbed by their family members during sleep, such as partner or kids. P8: “Whether you like it or not, she wakes you up because she’s noisy when she (wife) comes in.”

Other factors that affect sleep include: “water or caffeine”(P6) intake, “noise”(P4), such as workers outside
the window”(P7) and “light”(P7) interference, proper temperature(P2), the activities of “pets”(P3,P6,P4) or “animals and. All participants went to the toilet at least once per night (or day for night shift worker) which was the top reason for waking up.

Work related issues affect sleep
Three out of nine participants pointed out the work pressure may affect their sleep. These participants worked more than eight hours a day, and some even have to work overtime or take their work home. A variety of work stresses have a significant impact on sleep because they were lying on the bed to recall what happened during work, and even worry about whether they have made any undetected mistakes. Or consider tomorrow’s work, especially the next day if there are some very important jobs. Lewi stated: “I'm just lying there, and that’s when you then begin to reflect on what’s going on during the day, what’s going to be coming tomorrow...Obviously, your mind is just constantly being stimulated by these stressful thoughts.”

Some people checked their work emails from their smart phone before going to bed which affects sleep. P6 stated: “you read that email before you go to bed, then you’re up thinking about the email all night.”

Some employees worked in shifts. The shift pattern has a significant impact on employees’ sleep. Some employees who need to work at six in the morning will fall asleep because they were worried that they have overslept or feeling that they have little sleep time. Also, if a person is working on different shifts within a week, the sleep pattern will make the circadian clock disorder, or the sleep time left be the circadian clock disorder, or the sleep time left be too short. The participant further indicate that it is better for employees to work in a fix shift pattern than to let them rotate to a different shift by reference to a survey result: “People did a follow-up survey and they did say they were sleeping better by doing one shift rather than a rotating three-shift.”(P8) Therefore, he would instead choose to work on night shift than a rotating three-shift pattern.

In addition to some work to be completed within a limited period, such as the end of accounting period. “It will have time pressure, which affects sleep” (P1). Some people who need to “travel” frequently will get a very poor sleep because of the long journey or “staying at the hotel.” (P6) within a different sleeping environment.

Influence of workplace wellness program (Visibility of Data as Evidence)
The company is very concerned about the mental and physical health of employees. P5 stated: “As a company, our objective would be for the welfare of the employees to make sure that they are not stressed...overstretched, and they're working an acceptable number of hours. And, when they leave work, they leave work at work, they don’t take work home with them.” One participant believed that the sleep wellness program could improve their work performance. P6 stated: “It would improve sickness, reduce accidents, improve quality, improve output, and improve morale.”

Secondly, for employees, by looking at the data provided by the program, they can find ways to improve their sleep problems and enhance mental health. And they can see that the company is not just a business entity to make the profit, it shows concern for its employees. P2 stated: “I would say it’s been good that they [the company] doing this.”

However, 4 of 9 participants thought there were privacy issues involved in the health tracking. They expressed their concerns on sharing the data. For example, P2 stated: “sharing sleep data may cause others to question the life of people who sleep less, and then go to hear or guess whether the employee's personal life will be troublesome or mentally ill.”

All participants said that using the sleep diary can help them record behaviour and contributing factors that affect their sleep and the subjective feelings of the next day. All participants believed that manually tracking information was very time consuming and it was unrealistic in long-term. So they are very interested in the machine learning based IoT tracking solution in workplace and recognised that the new technology can make them know themselves better.

STAGE TWO DESIGN WORKSHOP AND DATA VISUALIZATION
Internet of Things, as independent federated services and a type of application architecture, usually completes data in a highly automated mode for data acquisition, event transfer, network connectivity and interoperability[4]. Our IoT design workshop aimed to generate the ideas of tracking sleep-related information (e.g. activities, behaviours and mental state) automatically that can reduce the tracking burden. Besides, it provided an opportunity for people to imagine the experience of living in the environment. The design outcomes expect suitable and acceptable IoT technologies that can be used in the workplace from the employee perspective and the way they want to share their data.

To help non-experts navigate the space of opportunities provided by the IoTs, the IoT tile card toolkits[46] were adopted for our workshop. The workshop used the mission (Theme), things, feedback card, and the sensor cards were created by the researcher. Things card represent daily contact low-tech objects that can be enhanced by technology such as coffee mug, water bottle, etc. in the office environment. Human actions cards describe how the user can trigger a digital input by interacting with the objects. Data cards contain the sleep-related data that used to track and share data, such as caffeine intake, stress level, sleep durations and
quality. The study also designed two personas and four scenarios for the IoT workshop to focus on the common problems mentioned in the previous stage’s interview outcome. Furthermore, these problems were printed on the mission card (themes cards) as divergent thinking that suggested a set of provocative design goals to provide creativity triggers.

Their office floor plan was printed for the workshop. The workshop process of the entire smart workspace is as follows:

1. Users discuss the contents of the mission card and works out how to combine the sensor with the low-tech object to collect data.
2. Mark the location of the relevant IoT devices on the floor plan of the office and factory. And mark the location of dashboard should be installed.
3. Discuss which data should be kept privately or shared by real name or remain anonymously.
4. Depicting graphics to visualize sleep and sleep related data

Findings
The workshops have been audio recorded, transcribed and the thematic analysis were conducted. In the IoT design workshop, the ideas were gathered about the extent to which technology could and should help them gather and reflect up their sleep, daily exercise, type of diet intake, water intake, daily feelings, and stress levels. Participants understood IoT technologies and aware privacy issues caused by using IoTs in the work environment. In the design workshop, the participants made it clear that any application must take care to balance intrusive, privacy, and usefulness. P7 stated: “The whole idea was to discuss what would be the most relevant, what would best suit us, obviously we got different jobs so all the applications of what they actually require will be different, so we thought about which one will be too invasive on your own personal life and which ones would be more ideal and how you could incorporate today’s technology with the things that are happening in your life.”

However, 5 out 9 participants can participate in the design workshop due to their job responsibility prevent them join in the workshop at the same time.

Tracking and sharing the information related with sleep
The user selected the appropriate sensors to complete the task on the mission card and marked out the locations where the sensors should be installed. Table 1 shows the outcomes

Design for tracking daily subjective feelings
Participant firstly discussed the reasons causing the stress and explained how they related to sleep. After that, users pointed out that they can use the desktop cameras to track their daytime feelings, emotions and stress, diet and water intake activity. P2 stated: “If you had your desktop camera it could recognise your face... so it could see how you looked... It picks you up throughout the day...or you get to a point where you feel a little bit more lethargic, it could be your stress levels.”

In terms of tracking the diet, in the second workshop, one participant pointed out the diet can be tracked by the company installed CCTV camera in the canteen. Later, they felt that the way of tracking was too invasive for other employees and the camera view can be blocked by other objects. So they decided tracking the diet through mobile phone app which can automatically recognise the food type.

Privacy of tracking in workplace
From these workshops, the study found that users have different privacy considerations for using IoT tracking personal information. For data sharing, employees have different attitudes toward sharing the data in granularity, and some employees do not want to share emotion data because of they had mental health diseases in the past such as depression. P2 stated: “sometimes it’s easier in the office atmosphere, talking to somebody that you know but doesn’t know your situation too well.”

| Type of data                      | Location & object                      | Type of sensors/ wearables          |
|----------------------------------|----------------------------------------|-------------------------------------|
| Emotion, Stress and Feelings     | Desk, or near Clock in machine         | Camera, Fitness band                 |
|                                  |                                        | (body movement, heart rate)          |
| Caffeine & Water intake          | Desk, Colour coded mug, bottles, toilet| Activity sensor (accelerometer) strip, weight scale pad Bluetooth scanner. Bluetooth mug Token based coffee machine |
| Diet type                        | Office                                 | Mobile phone camera, CCTV camera    |
| Exercise                         | Human body                             | Fitness band, Smart phone           |
| Heart rate & body temperature    | Human body                             | Fitness band                         |

Table 1. The location of sensor installation, data type and sensor type.

Users also pointed out that using the cameras made people feel uncomfortable, because “it’s too invasive, too in your face type of thing and the microphone might be a little bit too invasive of your... private conversations” (P2) Detecting a day’s dehydration can effectively prevent participants from drinking too much water before going to bed, recording the volume of water intake and the number of times went to the toilet is useful but some participants think detecting this value is also a bit intrusive.

Finally, participants designed their wellness program data sharing system that will allow users to set which sleep-related information they want to share with colleagues and companies, and all users believe that sleep time should be shared with the company by default.
Unexpected use of data in workplace

For managers, health and safety are the essential things in the manufacturing industry. Managers believe that sleep not only impacts personal physical and mental health but also causes workplace safety problems. The existing occupational health covers the safety production process. The responsibility was more on the employer’s shoulder for compliance. As one P7 pointed out “if you come in tired you are more likely to do something daft and you are thinking, “Why have I done that for?” The participant came from management then compared our IoT design with Virgin’s[63] wellness program expressed strong positive attitude towards tracking health indicators. More importantly, P6 further pointed out a potential application of these data: “As a manager, if that data was being fed back to you then you know who is likely to have an accident on the shop floor ...How many of them are down to people being tired? ... Is it because he is tired? Is it complacency? Some of them will be tired, won’t they?”

Data sharing and depicting data visualisation

In the final part of the workshop, the study focused on sharing the data in the workplace making sleep deprivation more visible. Participants try to maintain the boundary between private life and work as clear as possible. In data sharing discussion, the participants discussed the meaning of each data card and drew the boundaries of data sharing on paper and presents a manuscript map of potential data visualization. The details can be seen in Figure 1.

Figure 1. The outcome of workshop, the top picture is the metadata sharing level (anonymous, real name, private) regarding different granularity, the bottom picture is the sensor locations user marked on floor plan.

Figure 2. Examples of IoT Cards

STAGE 3 DESIGN DASHBOARD PROBE

After the design workshop, the first stage collected sleep data were used with Qlik® sense tool developed three sets of the interactive dashboard. Qlik is an agile and data-driven tool which allows the designer to build and deploy interactive analytic apps in a short time. It let the end user easily filter the data as they needed in the dashboard.
The first set of dashboards focused on personal sleep information, including effective sleep time, total time lay on bed and woke up times, daytime feelings, etc. The second set of dashboards focused on the last night group-sleep data. It shows the participants’ sleep data and their subjective feelings anonymously. The third set of the dashboards presented the sleep patterns and subjective feelings of everyone in the past week. Some participants’ data were selectively removed due to their unwillingness of sharing, the dashboards only retained their subjective feelings as they don’t want to share it. The example dashboards can be seen in Figure 2

**Interview Findings**

After the dashboards were designed, nine one to one interview were carried out and selectively transcript every interviews and thematic analyses were conducted, each interview last 30 minutes to one hour depends on their available time. Every participants were given £10 amazon voucher to compensate their time. Each participant asked to go through the dashboard first. Then a set of questions were designed to ask them to provide their understanding and insights about the design and data. For understanding data some open questions were used in interviews, such as “Could you please pick up one or two of the charts and explain what you think they are telling you?”

**Engage with data, discover knowledge, behaviour change**

All participants saw the sleep data in a visible format as more compelling evidence of existing sleep problems in their study group than their thought. The visualized data keeps them be accountable to themselves: “I think it’s helpful to see things in black and white in front of you.” (P9) Sharing sleep data in a work environment will allow reflect on the group’s data as P8 stated: “wow, I know people don’t get enough sleep, but that is pretty bad.” Some participants compared his own data with the group sleep data and found that the sleep tracking data kept them accountable to the group scores. P3 stated: “I think it’s me pulling the group average down.”

Sharing data in an interactive way can let users find some general rules more accurately and helping them learn from other’s data by discovering pattern. P7 stated: “large scale you can find a more accurate pattern.” For example, one user found the relationship between sleep and type of dinner intake by using interactive data filtering function P4 stated: “A heavy meal means that they are sleeping less [hours] ... The light meal where you can clearly see that people are sleeping a lot better.” In a busy working environment, the analytics function can let users discover interesting things, so “different people will take different things out of it, but that’s definitely useful” (P8).

Since the program begins, some users have started to notice their daily water intake and started to track these changes. For example, “not having a coffee in the night now and trying to manage the level of the fluid I get” (P6), to reduce the times of woke up and times went to the toilet during the night.

Overall, the one-to-one workshop found that many participants feel accountable to themselves. The research finding is similar to [17].

**Fostering care for colleagues, and perceive care from colleague and the employer**

The way of sharing data can potentially enhance the communication between people, Such as for shift workers, each shift is a team, “you could be working with somebody who’s getting no sleep ... If you get this information […] maybe you’ve got to have a bit more patience with him.” (P8)

In addition, for some introverted employees if they choose sharing their data that can trigger them to be cared by other colleagues as the P3 stated: “I think it’s quite good if I made that public ... I am prompting people then to try and talk about my issue of lack of sleep.”

By organizing the wellness program, the company not only benefits the physical and mental health of employees, but also makes employees think that the company is really cared about them. As P8 believed that “things like this can only improve to what companies consider to being their responsibility.”

However, not all participants thought that sharing sleep data will certainly make them take the initiative to care about other people’s lives, because after all, “sleep quality and sleep time is a very private topic.” (P3). For the colleagues whose relationship is not very close, asking for someone else’s private affairs will make them feel like they are forced to expand their private space. “It's not work related... but close colleagues I think I would probably question that” (P3)

The willingness of staffs to form a new relationship is consistent with [17] finding.

**The dilemma of sharing personal data in workplace, and data ownership**

In many people’s lives, there are clear boundaries that separate work and life. Sleep is a thing outside of working hours. Among the participants in our design workshop, 4 of 5 participants had no issues to share their sleep data. But when our participants see the dashboard, the users have been asked what they thought about the data such as: “Do you think that it is right for the company to have access to this
information because it is private data?” Some participants slightly changed their attitude, especially for sharing it with their managers. P9 stated: “Only share if you have a good eight hours sleep... You've got nothing to hide, but if you did have a bad night's sleep, would you want your boss knowing? “

But 7 out 9 participants still maintained a positive attitude for sharing the data, they believe “company is going to take full responsibility for it, and want to help, then it's good. If they're just going to use it as a weapon against people, then this would obviously be an ethical issue. but I don’t think I would be too bothered if the company knew.” (P7)

For many people, weekend life belongs to their own, people will want to go out to socialize, relax, or accompany their families. In our interview, employees have shown that they do not want company record their weekend sleep data apart from Sunday night: “which will mean they [company] are not thinking about your personal life” (P3) However, the participants from management think that to make this project works well, the weekend's sleep data should be included in the sleep deprivation project to educate people to maintain stable sleep pattern.

Most participants believe that data should be controlled by someone who is impartial. It could be either the IT or HR department. The participants from management considered from the perspective of law and policy and noted that the HR department should have data control and the program terms and conditions should have opt-in and opt-out options.

**Unexpected and problematical use of the wellness data**

When the participants have been asked if the company would try to use data to treat their employees differently, P8 think sleep is indeed outside the company’s jurisdiction. It is “an individual’s responsibility to turn up to work in a fit healthy state of mind” (P8). But this does not mean that the company has no responsibility at all, the company launch wellness program, and then they should consider themselves “as the whole umbrella...employee’s welfare is a company responsibility.” (P8)

The sleep data has a greater impact on work than the other health data such as exercise. One participant is a manager who found the data can be used to prevent accidents. He also mentioned it in the design workshop. The main ideas is if the employees suffered acute sleep deprivation for one night such as slept less than two or three hours then “if it's a genuine reason then it would just be part of your sickness policy” (P6). The employee could be sent home to have more sleep to prevent the accident. The participant argued that the serious sleep deprived effects would be same with taken alcohol and drug. P6 also further stated: “it is difficult to determine how many hours of sleep are enough” Another participant also noted that workers “had to be certain alertness to operate the machine...it's health and safety...it should be done.” (P7)

Furthermore, P6 explained from employer perspective: “seriously [you] have to look at your policies, but the first one will be education and the second one on there will be support. You wouldn't look to discipline your staff if somebody has a genuine issue”. P6 further given another example, some employees who have just had children will have sleep problems. In addition to the national maternity leave, the company will consider adopting flexible working pattern to support employees.

Another participant also said that using sleep data can effectively protect the interests of employees and “go against the company... when There’s no way really that they are going to be getting the average seven hours sleep” (P7)

One of our participants is a company director who mentioned people may potential “forge the sleep figures” (P5) and to make their daily feelings looks they slept well, therefore she will check the figures on a quarterly basis to see if their sleep have actually improved. Another participant also pointed out the system should prevent people take advantage of wellness data such as "I want a day off... not have much sleep just so I can get sent home early” (P7) The finding here is similar to Gorm and Shlkover [32] research with moral concerns about how accuracy of the data.

One participant mentioned a potential solution to address the unexpected use of the sleep data in designing wellness program, “you should consider consulting with the staff in policy making, and it is best for the management staff to train them separately. The best practice on [using those data], stay away of any workplace bullying...people need to be informed.”(P1) The participant also said the privacy policy should be in place, “make sure the data is not being negatively used.”(P1) Furthermore, P1 think the policy should be “in place to have some sort of steps and have an opt-in, opt-out options as well... have the flexibility to back out, if the things aren’t benefiting to the person or the company.”

**DISCUSSIONS AND DESIGN RECOMMENDATIONS**

Using digital technology as part of raising sleep deprivation awareness is a laudable goal, and our study demonstrated that even narrowly focused short-term research can get people aware the factors influence their sleep and the importance of quality and duration of sleep. The research attempts to understand the complexities of design consideration to engage employees in sleep wellness program to raising awareness of sleep deprivation in manufacturing sectors. Our study highlights three specific points for discussion.

Firstly, the study discussed the issues encountered in design process. Secondly, the sleep tracking techniques and the sleep hours needed to be classified as sleep deprivation were discussed. The ownership of data and privacy issues were discussed as well. Finally, the potential use of sleep data in company health & safety policy was discussed, and the way of design wellness program if the companies want to use
sleep data as a part of occupational health policy in a long-term wellness program has been also discussed.

In the first stage of study, the research discovered the sleep deprivation is a complex social problem. The companies are willing to support employees by various methods to improve the situation if the problems caused by personal reasons, such as providing flexible working pattern. If the problem is a work related factors then the company can better arrange the work schedule for employees who need to travel, and optimise the shift pattern to improve their wellness.

In our second stage, the design workshop, the study found the machine learning technology back IoTs are relatively new to many non-technical background users, and the lack of example of use made participants hardly to anticipate the potentials of the technology and their use, even potential applications have been labelled on each sensor card. To address these problems, the scenarios were prepared for users to get familiar with these technologies as a provocative design which demonstrate that the card is working better with scenarios rather than persons in a new and sophisticated technology design workshop. This indicates that future studies should consider adopting the scenario or fiction to stimulate participants in future technology design workshop.

Another challenging question is the amount of sleep hours needed. The study use seven hours as the sleep deprivation criteria where recommended by Public Health England[62]. Some participants pointed out that the hours of sleep needed may be different by people, some participants said they don’t need seven hours and they don’t feel fatigue. Therefore, wellness program designs should consider the individual variance on the needs of sleep and should give participants the options to set up their own goals.

Besides, 4 out of 8 participants noted that wearing the band causing them discomfort during sleep. Therefore, the development of non-invasive sleep monitoring technology could benefit long-term sleep wellness program. This research suggested that companies try to organize sleep-related wellness programs should consider providing flexible options for employees instead of just using wristbands.

Privacy concerns of sharing personal data
As much published literature has noted, wellness program may cause privacy concerns when sharing personal data in workplace [17; 31; 57]. In addition, many news on the Internet about workplace monitoring, but most of them are casting negative opinions. These reports covered sleep and fatigue monitoring, and also people’s subjective feelings [22; 44; 49]

In terms of sharing the data, our research found that if we involve employees in the project that sharing private data in work place for their health purposes, such design approach allows users to discover privacy issues in the project design stage. Then the privacy issues can be addressed by co-design method. For example, in the design workshop, the system design will allow users to set sharing permissions for the meta-data. In this way, the users’ attitude towards the privacy issues will be a secondary concerns. This stands in contrast with recent concerns of both researchers and media. [42; 47; 54] Only 4 out 9 participants think there are privacy issues when the questions have been asked explicitly, the rest participants are open to shared and stated the privacy of sharing personal sleep related data isn’t an issue. The finding is similar to previous research [17] The research suggests that the company initiated wellness program such as health tracking program should include employees in the data collecting and sharing design process to better communicate with each other to make solutions that benefit for both ends.

In terms of privacy concerns for deployment of IoTs in work space, all participants are positively open to tracking the contributing factors that related with sleep even monitoring emotion and stress. They believed that such a wellness program can maintain mental health for individuals and improve productivity for the company. Again, our study adopted the bottom-up and co-design method may consider as the reason of the difference. Besides, through the interactive visualisation dashboard, the research finds that such technology applications could enhance communication between people. Through the sleep health dashboard, people can be cared or care for others through seeing the data, especially for some employees who are less introverted. Moreover, the dashboard provided a learning platform for employees to find out useful information by querying the data. It created a collective interacting environment let employees improve their sleep through a peer support and self-driven manner which is similar to Digital Civics’s relational services[50].

Possible and unexpected use of sleep data
In the design workshop and data visualisation interview, the participants from management noticed the data can be used in fatigue risk management. Comparing with other wellness programs such as physical exercise, the quality of sleep directly affects the efficiency and safety of the next day work, and even affects safe production. According to the sleep medicine study result, acute sleep deprivation effect is similar to the alcohol intake[55; 65]. For LGV driver, the sleeping hours has been included in the UK diving regulation. The company has already put the policy in place to stop (consider as sickness) employees who operate machines come to work under alcohol or drug influence as the reduced alertness may result in permanent damage or loss of limb lead to disability. And the sleep data could be used as an evidence.

The way of using sleep data properly is a debatable topic. The study summarise the following potential solutions that could benefit to both sides if the company want to use the sleep data in their health & safety policy, the wellness program needs to consider consulting the work council and employees with respect of their opinions, such as confirming the hours of sleep needed to come to work and the
countermeasure to prevent abuse use of sleep data. For example, the company may misuse the data to force people out of work. Or the employees can also use the sleep data for the long-term absence. This will reduce the user's suspicion of the project, thereby increasing employees' trust and confidence to buy in the project. Companies should consider providing flexible choices to employees rather than set the rigid rules for whom suffered acute sleep deprivation due to the non-intentioned reasons. For example, provide employees with flexible working hours, or allow employees to work from home or switch to a different shift temporarily. The wellness program should also consider empowering employees who can use the data to protect themselves to have enough sleep, especially for shift workers. At the same time, companies should also carefully consider the people who have sleep disorders to ensure their privacy is not compromised and their right to work.

All participants in our study appreciated employer interested in their health-related measures. They all acknowledged that the wellness program should progress to implementation stage without doubt. We urge companies to consider the following points in their design of sleep wellness program:

- The wellness program should have a flexible monitoring mechanism so that employees don't feel that their sleep is subject to company management. Such as if they will receive incentives if they achieve certain days of good sleep above 7 hours. Regarding weekend sleep, the companies should set non-work related nights into private records and will not use the data for any purpose by default other than provide incentives to support weekend behaviour change [17; 31].
- The companies should include the sleep in other wellness program as not everyone has sleep deprivation, the wellness program should be beneficial to every employee.
- If the company found some of their employees have significant sleep deprivation issues, their top priority is to educate and support employees, rather than trying to use data as a discipline tool.

Furthermore, for companies who wants to use the data to evaluate their employee work performance, the company should consult employees to confirm which terms should be included in the terms & conditions before the wellness program begins. The T&C needs to be flexible towards good will rather than disciplinary directions.

CONCLUSION
This work contributed the empirical study of adopting bottom-up and co-design method to construct a wellness program in workplace to raising sleep deprivation from a collective perspective manner.

The research has found that the potential privacy and unexpected use of personal health data in workspace environment can be effectively explored by the method of bottom-up co-design. Through the three stage design process, the paper explored the possibility for design wellness program through employee-led approaches and privacy-related data governance with policy considerations for future use of sleep data in the workplace. This method can also be used to increase citizen science initiatives in collective attempts to generate data and gain insights into health behaviour. Through empowering users on the data sharing control, we could build up a collective data sharing platform to promote sociability and interaction between employees around their personal data in workplace.

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