Designing for Inaccessible People and Places

Judy Bowen and Annika Hinze

The University of Waikato, Hamilton, New Zealand,
jbowen@waikato.ac.nz, hinze@waikato.ac.nz

Abstract. New Zealand forestry has the highest number of accident and fatalities than any other NZ industry. Worker fatigue, work environment and worker demographics all contribute to these high numbers. We have been investigating ways of tackling these problems using wearable and sensor-based technology. Two of the challenges faced by this project are: the personal nature of data collected by wearable technology and the lack of regular access to workers to take part in user-centred design activities. In this paper we describe the use of Lean UX methods with proxy participants and proxy technology to explore key aspects of a proposed technical solution. We show that from these experimental studies we were able to draw appropriate conclusions on which to base the development of a prototype designed to support forestry worker safety.

1 Introduction

The forestry industry is one of the most dangerous industries in New Zealand [22]. One of the main contributors to accidents is worker *fatigue* [2] which may be caused by the physical nature of the work as well as the cognitive load required when operating dangerous equipment. It may also be caused by workers taking insufficient breaks due to poor self-evaluation and expected performance [21]. We have been conducting research on the use of wearable technology that can be used to monitor workers for fatigue via personal metrics such as heart-rate variability(HRV) and galvanic skin response (GSR)[4]. Once the data is gathered and analysed, the next step is to investigate how to use this data to inform workers and encourage them to take breaks when they are fatigued. This is challenging due to the demographic of NZ forestry workers – predominantly male (96%) and below the age of 50 (65%) [8]. The work culture means that workers can be described as having a 'staunch kiwi male' attitude, which can lead to a minimising of potential risks and a desire to not appear weak in front of workmates. In addition, the use of personal monitoring in work environments can be controversial due to its invasiveness, without worker buy-in this can lead to deliberate undermining of the technology [1, 3]. We have previously undertaken participatory design sessions to determine what types of technology and data collection/use is acceptable to forestry workers. However, time one can spend with groups of forestry workers is limited due to: the remote location of forestry work-sites; reluctance of forestry managers to give workers time to take part in research activities; long working days in forestry which makes end-of-day sessions unappealing. As such, we can typically only work with groups of forestry workers for three or four days a year and the rest of the time we have to rely on other design methods.

To report fatigue to workers and encourage them to take breaks, we propose the use of a 'Buddy System' (described below). Given the limited access to workers, we needed to use appropriate methods to investigate the key parts of our proposed buddy system before beginning participatory design which would make use of our limited access to the forestry workers. Taking inspiration from the ideas of Lean HCI and minimal viable product design (MVP) [10] we propose the use of proxies to investigate key attributes of the solution we wish to develop. During design, it is common to use personas as proxies for users to remind the design team of key characteristics of their users [18]. Here, we propose using both proxy participants and proxy technology. *Proxy participants* used in studies are different from the target user group but have characteristics that are relevant for the study. *Proxy technology* is used to investigate a crucial attribute of a system outside of its context (i.e. not in the form it will be implemented). Within our studies we distil the central underlying ideas of the proposed technology to study and use proxy technology within the studies which use proxy participants.

2 Background and Related Work

Fatigue in the Workplace. A study by Lilley et al. investigated the role that rest and recovery play in accidents and injury of forestry workers [14] and found that 78% of participants reported experiencing fatigue at work at least some of the time. They concluded that impairment due to fatigue constituted a significant risk factor within the industry. To identify fatigue in the workplace, an understanding of physiological markers and how they might be measured using wearable technology is required. Many studies investigated heart-rate and heart-rate variability as indicators of physical and mental stress (see for example [13, 17, 16]. These have formed the basis for investigations into the use of wearable technologies to detect and manage stress and fatigue in athletes [20], manufacturing operators [23], miners [15] etc. For our work, we combine heart-rate variability and galvanic skin response with contextual factors, such as temperature and terrain, to understand changes which represent the onset of fatigue [2].

Persuasive Technologies Our proposed buddy system is related to persuasive technology and of most relevance for our work are persuasive technologies that focus on health-related behaviour. Halko and Kientz describe eight persuasive strategies that are commonly seen within this research field [11]. Our project is similar to their concept of a "neutral agent, such as a friend or peer to encourage the user to meet their goals" along with co-operative feedback. One of the issues we wish to address is the problem of workers not recognising that they are fatigued, or not responding to prompts to take breaks, because they are not concerned about potential impacts to their own health and safety. This can be seen in the following quote from a forestry workers: "You think you're bulletproof in the forest". Persuasive technology often utilises the ideas of peer support and external motivation. Peer support within technology has been shown to provide positive benefits, for example by motivating healthier lifestyles for people with diabetes [19] or encouraging behaviour change for young offenders [7]. We describe such systems as *'Buddy Systems'* as they build on the practice used in scuba diving where people are paired together for safety and support and monitor each others' well-being throughout the dive. Based on our experiences of working with forestry workers, where a strong team culture is encouraged, it seems likely that such a buddy system would be an appropriate persuasive mechanism for providing fatigue notifications and motivating workers to take breaks. Once wearable technology identifies fatigue, we must notify the worker so that they are aware they need to take a break. If they do not stop working, then their buddy is also notified. However, before we design and develop such a system we need to understand how the workers would feel about their fatigue status being shared with others (their work buddy or buddies) and the use of technology as an intervention.

3 Design Exploration with Proxy Participants

With limited access to the forestry workers, we needed to investigate the intrusiveness of our proposed system, and understand the effect on the users before we started developing a prototype for the buddy system. We identified four key features of our proposed buddy system with the potential to make workers feel uncomfortable: public display of fatigue status; technology providing prompts to take a break; notifications to take a rest occurring in a group setting; being prompted by a work buddy to take a break. To evaluate these features outside of a forestry context we followed an approach motivated by Lean UX [9], which uses rapid iterations to explore the experience being designed, rather than the final deliverable. We conducted our experiments with *proxy participants* (not forestry workers) which allowed us to investigate the conceptual aspects of the system separately from the real-world context of use. Proxy participants have been proposed in other contexts, primarily in work where participants may have limited communication abilities [5, 12]. In these works the proxy participants are closely associated with the target users, medical personnel who work with the end users [5] or parents and teachers [12] and are intended to provide realistic observations about the suitability of the proposed technologies through their understanding of the needs of the end-users. In our experiments, however, rather than trying to use proxies in this way, we instead take the approach of investigating the central concepts of our technology (rather than the technology itself) by understanding its impacts on the general population. We describe each of these experiments next.

3.1 Experiment 1: Displaying Emotions Publicly

The buddy system relies on notifications that signal a worker's status (e.g. fatigue) for others to see (i.e. the buddy) to ensure that appropriate action is taken. Our first study was, therefore, designed to investigate how people react when their feelings or health status are made visible and when others comment on this. This was important to explore because people who are uncomfortable with aspects of personal monitoring will find ways to avoid the technology [6]. The study was conducted by a single researcher (R1), the proxy participant, over a four day period. For several hours each day, the researcher would wear one of four different labels describing feelings taped to their back, whilst in a public setting. They noted their own feelings both about this public display and about comments people in the environment made to them. Most of the people they would encounter were people they knew, which replicates the exposing of fatigue status

Emotion Label	Reactions to Comments	Feelings About the Label
"I am Angry"	I feel annoyed that someone would interject with advice; I like that somebody cares that I am feeling angry; I feel annoyed that they were questioning my anger;	This was a very uncomfortable feeling for me to show because it was like showing them that I was secretly angry. This made me feel unsettled.
"I am Hungry"	I felt appreciated; I felt cared about; I was frustrated at a lack of empathy; This made me laugh.	Overall, I was happy to show this feeling as it was almost nice to hear advice about how to fix my hunger. I was comfortable with all responses.
"I am Tired"	I felt confused, and slightly exposed; I appreciated the concern; Grateful for a suggestion; I felt belittled.	I didn't feel tired, so some responses felt unjustified. I appreciated hearing the concern. It was comfortable to display that I was tired.
"I am Bored"	This response felt unproductive and lacking empathy; I didn't appreciate the advice given;	I had hoped for more constructive and involved responses, but this feeling was not uncomfortable to display.

Table 1: Researcher Reactions to Each Label and Reactions

among groups of co-workers. The labels worn by the researcher display emotions rather than a single fatigue status, this was a deliberate decision in order to understand if there were different reactions to *types* of status that was made visible.

At the start of the first day the researcher felt nervous about displaying the labels. They were unsure as to how people would react, and this was unsettling to them. Once the experiment was underway, however, the researcher felt more at ease, but it depended on the label they were displaying. Table 1 details the observations and reactions to comments made based on different labels. The experiment showed that displaying some feelings was more comfortable than others. For example, displaying anger was unpleasant but broadcasting boredom was emotionally easier to do. As the focus of the buddy system is about displaying fatigue and health status, it was reassuring that reactions to displaying "I am tired" were mostly positive, and the researcher felt comfortable with the display. However, as the researcher self-assigned the labels each day, it was not a true representation of how the worker notifications will function. Therefore, while this first experiment gave some insight into how it might feel when external parties comment on fatigue status, it did not show how it might feel when the display is driven by technology. This led to the second experiment, described next.

3.2 Experiment 2: Responding to Technology-Driven Interruptions

The aim of the buddy system is to provide notifications when a worker is fatigued – firstly to the worker, aiming to prompt them to take a break from what they are doing. If they continue working or continue to be identified as fatigued, notifications will be provided to their buddy who should then take action to encourage rest. The second experiment, therefore, investigated how it feels to be interrupted by technology at uncontrolled intervals while engaged in an activity you wish to finish. This experiment was conducted by R1 as well as a second member of the research team, R2.

Regular interruptions. We started with interruptions at fixed intervals to see how the researcher reacted when receiving notifications telling them to rest. The experiment

Interruption Time	Researcher Observations
32 minutes	I had just finished a mission when this notification came through telling me to stop so it felt almost natural to take a break. The 10-minute break did feel quite long however.
34 minutes	I was in the middle of exploring a new area when this notification came through so that was slightly annoying.
31 minutes	This notification came when I was halfway through an in-game mission. It was annoying to have to stop but once I did, I felt myself being more tired than I had expected. However, I did find myself watching the timer as to when I was able to start playing again.
34 minutes	This notification came at the most annoying time. I was in the middle of a big fight and stopping was the last thing I wanted to do. I really watched the clock as to when I could start playing again. I did not feel that tired, this may have been due to the high intensity of the game play.

Table 2: Researcher Reactions to Technology-Driven Interruptions

was run while the researcher (R2) worked on their laptop during the day. The Windows Task scheduler was programmed to generate notifications every 30 mins. The researcher took notes about how often they took breaks, the break duration and the emotions felt when told to rest by the notifications. Over an 8 hour work day, 15 prompts were made to take breaks. The researcher took 13 breaks (3 to 19 min long), and missed only one notified break. Once, in the afternoon, they wished for a break before being notified, but tried to hold out until the alert. The two longest breaks were 8 and 19 minutes. The researcher reported spending longer away from their desk than intended, without feelings of frustration. They felt it was easier to spend time taking a break for someone else's sake (i.e. the system) than for their own well-being.

However, they reported that many breaks felt like "token efforts" as they did not feel fatigued. Being told to rest before being aware of fatigue caused frustration, especially when being interrupted from a task that needed concentration. While the researcher felt most noticeably fatigued during the final half-hour of the day, they still did not want to follow the direction to rest but rather wanted to finish the work for the day. Their study diary reports four instances of frustration and annoyance. At the end of the day, the researcher felt both "tired and grumpy". The feelings of frustration about the alerts seemed to accumulate. Potential issues that were identified were: frustrations due to a mismatch between not feeling fatigued and the system's interruption (which is likely because fatigue often occurs before it is felt), and discouragement of user initiative and self-management of fatigue. The use of fixed-time intervals provided an interesting finding regarding the potential loss of self-regulating (not paying attention to actual feelings of fatigue). However, it is unclear it this would also be the case with less structured notifications. We therefore also ran a variation of the study under different conditions.

Random interruptions. The researcher (R1) spent a period of three hours playing a video game. During that time an app would schedule a notification some time between 30 and 40 minutes, advising them to stop and take a break. Once the notification was acknowledged a ten-minute timer started to countdown indicating the length of the break. At each break the researcher recorded their observations about being interrupted, see Table

2 for results. This experiment yielded interesting results. For each of the four interruptions in the experiment the researcher felt differing levels of inconvenience, suggesting that current task may play a part in how willing people are to adhere to such notifications (e.g. forestry workers may respond differently to fatigue notifications depending on what they are doing). For the researcher it was hardest to take a break when they were in the middle of a battle, while a forestry worker might find it hardest to listen to a notification while in the middle of a time-dependent task, such as planting a seedling box that must be completed by the end of the day. However, at the third break, symptoms of fatigue were felt after starting the rest period. This is a promising sign that when taking a recommended break as suggested, a worker may realise they are tired and take the rest they need. This will in turn build trust in the system.

3.3 Experiment 3: Notifications within a group

For the buddy system there will be multiple workers engaged in both solo and collaborative activities. Our next experiment, therefore, considered the impact of different people being notified to take a break whilst engaged in a collaborative group activity. We recruited six volunteers from a group of University undergraduate students for the experiment, which took place outside on a sports field. They were split into two teams to play a game of 'Rob the Nest'. At random intervals during the game, a participant would receive a phone call or text message from the researcher telling them to slow down to a walking pace. If they did not comply, they would receive another call or message instructing them to stop and sit at the side of the playing field until instructed to rejoin the game. The game was run for eight minutes. The researcher recorded how long it took participants to respond and whether or not they followed instructions given.

It was observed that some of the participants, when told to stop and rest by phone, would argue that they wanted to continue and had to be persuaded to rest. For this experiment, the use of a phone call meant that the researcher could directly respond to the participants creating a dialogue, which enabled them to convince the participants to follow the commands. In a one-way notification system it is possible that users will ignore instructions. For the buddy system to work, the users must either respond to notifications to rest, or be persuaded by their buddy. Our next study, therefore, considered notifications to both the individual concerned as well as to a buddy, in order to understand what impact this might have.

3.4 Experiment 4: Prompting by buddies

This study explored how people react when notified that either they or their buddy needs to rest. We were interested in how people react to their buddy seeing their fatigue status, and how people react when prompted to tell others to rest. We recruited four participants, who were all University undergraduate students, and paired them up. In this study, the system interactions were simulated through a researcher sending text messages. Participants were further able to interact with their buddy by sending and receiving text messages. Possible interactions in this study were: system-generated messages to report on buddy status, check on buddy or respond to check in, and communication between participants which are unprompted. Participants were also encouraged to voluntarily check on their buddy. The researcher observed the time since the last check, and after a pre-defined interval, prompted participants to check on their buddy.

Pairs of participants were designated as each others' buddies, and each participant was instructed to carry out computer-based work for about 1.5 hours. This work was required to be something that participants were motivated to complete, such as university work. The participants worked while sitting across from each other at a table, each working on their laptop; the facilitator sat at the head of the same table. The facilitator recorded the participants states as *working* (interacting with their laptop), *slowing down* (distracted, frustrated, or fatigued), or *taking a break* (disengaging from their work). The facilitator used a silent timer for each participant with a random interval between 10 and 20 minutes (reset after checking in with their buddy). They also collected data on how many prompts each participant acted on. The study was followed by an interview of each pair of participants together. The study and following interview led to a number of observations:

- Shared Information: Participants gave positive feedback and did not find it intrusive that their buddy could see if they were working or resting, or their level of fatigue.
- Fatigue status: Participants showed mixed responses to seeing their buddy's fatigue status. Knowing their buddy was taking a break made them more aware of their own breaks. It was observed (and confirmed by participants) that they did not always truthfully report on their fatigue status.
- Prompts and Interactions: Most participants were willing to act when prompted, even if they felt frustration with the prompt. Participants raised the issue of *prompt fatigue*: wanting to take initiative in checking on their buddy but being prompted so often that they were unable to do this effectively. All participants found the system prompts excessive and reported frustration about the frequency and number of texts.

Frequency of notification and prompts was identified as the key issue. While these caused frustration, participants still checked on their buddy after receiving them.

3.5 Summary of Experiments

Analysis of the four experiments yielded a number of insights. In the first experiment, we observed some discomfort about self-disclosure which was somewhat mitigated by positive or caring reactions. However, the disclosure was driven by, and with full knowledge of, the participant. Experiment two looked into interruptions that were driven by technology. We observed frustration about the interruptions as the participant did not feel fatigued, even though they sometimes noticed their fatigue when they took the break. Willingness to take the recommended break depended on the task. It is a concern that the participant felt discouraged to self-regulate and self-manage fatigue and relied on the system. Experiment three explored interaction in a group setting, we encountered again the participant frustration about being interrupted and an unwillingness to rest. Discussion that ensued between participants and the researcher emphasise the importance of the human-human interaction which supports the technology in a buddy system. Experiment four used notifications to both buddies to see if participants could be persuaded to rest. The feeling of annoyance when interrupted (as observed in all studies) seemed to be mitigated by the involvement of a buddy, and the more low-key enquiry (vs claims of fatigue). When being prompted too often, the care turned into prompt fatigue. While participants were not concerned about the information shared (which was high level), some participants tried to hide feelings of fatigue from their buddy. We observed that participants became self-conscious about the breaks they took, and began to self-censor (e.g. by only taking breaks if their partner had a break).

4 Discussion and Conclusions

This paper described experiments using proxy participants to investigate key attributes of a proposed buddy system for forestry workers. We found that using both automated notifications to the fatigued person along with human intervention by a buddy was more acceptable to participants than technology alone. This suggests that the choice of a buddy system is the right approach, it's not just about the redundancy of a second prompt when the worker ignores the first one, but more about the human contact. However, we also identify the following dichotomies that need to be explored with the buddy system in situ (forestry workers in their place of work):

- Frustration about frequent prompts vs. reduced self-regulation and engagement
- Disclosure of personal data vs. lying about fatigue
- Interaction with buddy vs. one-upmanship (harder work, less breaks)

For these three identified aspects, we believe that personal preferences should play a role in the final system. We considered whether we can successfully investigate the user impacts of technical solutions without access to the actual workers and work places, using proxy participants in studies. We were interested in how useful these studies would be wrt. proxy participants and proxy technology. We found that our approach provided a workable solution under the constraints of the project. Using proxy participants in situations that would create similar incentives and tensions worked well to expose certain behaviours. However, for the next stages of the project, proxies cannot act as a replacement for user studies with forestry workers in situ. It enabled us, however, to explore design ideas without exhausting the time and good-will of our project partners, not to mention the potential day-long travel to remote forestry locations. Through this method, the design progressed far enough to now be able to develop a working prototype for evaluation in a real-world setting with forestry workers. This will enable us to evaluate further considerations regarding ordering of notifications, escalation and understanding of how the wearer reacts in a real situation.

This paper described a mixed-methods approach to designing software for a real-world context in which access to future users and places was restricted. We hope that our example encourages researchers and software developers to not forgo design explorations for real-world problems with challenging settings, but rather use a method that remains true to the underlying issues without resorting to lab-based design only. This paper contributes to the ongoing discourse about transferring theory to the messy practice of real-world projects.

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