FloorPlay: Design and evaluation of a system to motivate physical activity in office workers

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Abstract

Office-based workers spend most of their working day sitting down and this sedentary behaviour can impact adversely on their health. By contrast, physical activity can improve health, as well as having short-term cognitive benefits, such as better focus and concentration.

This thesis is about the design, prototyping and evaluation of three of the main components of FloorPlay, a novel interactive system that aims to encourage university staff and students to increase their physical activity at work. FloorPlay offers playful whole-body interaction on a large-scale interactive floor surface as a reward for climbing the stairs.

Using a user-centred design process, this thesis has developed and evaluated solutions to three major challenges: measuring stair climbing activity; tracking and recording participants' stair usage; and providing engaging playful interaction that motivates people to climb the stairs.

We designed and evaluated prototypes to: first, measure stairwell activity; and second, enable users to quickly scan their university ID card whilst climbing the stairs. We also significantly extended an existing floor display from 16 to 216 LED units and integrated commercial IR sensors with the system to track movement across the floor.

Eight activity counters were installed on the landings between the floors of the Malet Place Engineering Building and they reliably collected data for over a month. The design was robust, cost effective and its accuracy was confirmed by an observation study. After several design iterations, the ID card scanners were found to be effective

following a short initial learning stage. Using Wizard of Oz testing we identified properties that made games engaging on the large interactive floor.

Contents

Chapter 1: Introduction

Those who regularly exercise enjoy better health and longer life. Research by the NHS National Institute for Health and Clinical Excellence (2011) shows that fifteen minutes exercise each day can increase overall life expectancy by up to 3 years, and completing as little as ten minutes of exercise throughout the day can produce short-term cognitive benefits resulting in better focus and concentration (Yangisawa, Tsuzuki, Kato, Okamoto, Kyutoku and Soya, 2010). Despite the undeniable benefits of regular exercise, it is suspected that less than 40% of the British adult population meet Department of Health guidelines for physical activity and that 61% are overweight or obese (Department of Health, 2010). Office environments promote sedentary behaviour as most of the day is spent working at a desk. A 2009 study of 131 office and retail workers found that they spent 77 percent of their time at work sitting down. The study also showed that many workers overestimated the amount of physical activity they did (Medibank Private, 2009). A decrease in occupational physical activity has been partially attributed to many of the growing health problems in the US (Church, Thomas, Tudor-Locke, Katzmarzyk, Earnest, Rodarte and Martin, 2011; Gordon-Larsen, Boone-Heinonen, Sidney, Sternfeld, Jacobs and Lewis, 2009) and elsewhere in the world (Owen, Bauman and Brown, 2009; Katzmarzyk, Church, Craig and Bouchard, 2009).

This thesis details the process involved in designing and evaluating the usability of the main parts of a novel system whose purpose is to encourage increased physical activity by the staff and students working in a university building.

The system, FloorPlay, uses the floor of the foyer area on the sixth floor of the Malet Place Engineering Building (MPEB), University College London (UCL), as a large-scale interactive surface. Playful whole-body interaction on the surface is offered as a reward for climbing the stairs in the building. Users climb the stairs in the MPEB throughout the day, scanning their ID card as they go, collecting credits, which they can then redeem at the surface.

We followed a user-centred design process (UCD) to meet three of the main challenges in designing the system: counting stairwell activity, tracking participants' stair use and providing engaging interactions on the surface as a reward for climbing the stairs. We created multiple physical prototypes over a number of iterations to ensure the system was reliable, usable, and, most importantly, encouraged a change in behaviour. Our ActivityCounter and CueCat card scanner designs could be used in many different systems and as a result of our evaluation of the interactive surface we are able to make suggestions on appropriate interactions to reward participants after walking the stairs.

In the second chapter we give an overview of the research that has guided and inspired us in the project. This includes our motivation for the project: the health problems which arise from sedentary behaviour. We also look at previous work promoting behaviour change and motivating physical activity, systems using public and floor displays, and other interactive systems.

The third chapter gives a more detailed introduction to and overview of the system we designed and implemented. Here we detail the constraints placed upon the project, the situation where the system was installed, its major parts and how they are connected to each other.

The fourth chapter concentrates on methods for counting human activity in the stairwells. A measurement of stairwell activity is important to allow us to make a quantitative comparison of stair usage before and after the system was installed so that we can evaluate whether it successfully increased stair usage. We provide an overview of the different methods for counting activity and detail the design and prototyping process we worked through. The ActivityCounters we produced are self-contained and could be used in a number of different situations; they were installed in the stairwells where we were able to observe how people interacted with them and get feedback on the project from occupants of the building.

The fifth chapter details the method used to track and record participants' stair-climbing activity. We produced and evaluated parallel prototypes using Arduinos and CueCat barcode scanners, before carrying out further design and prototyping interactions that were shaped by user feedback. A prototype based on this feedback was then installed in the stairwells for in the wild evaluation (Rogers, 2011), where we gained valuable insights into the usability and appropriate design for the scanner. From this we offer a number of recommendations on the use of CueCat barcode scanners as a component in an interactive system.

The sixth chapter describes work on tracking participant movements across the interactive surface, using infra-red Thermitrack cameras. Four of these cameras mounted above the surface would have allowed us to track whole body movements across it. We evaluated the cameras in the lab, but unfortunately had to rely upon others in the department to install the cameras above the surface. This work was not completed in time, so we were unable to evaluate the system with the cameras installed.

The seventh chapter details the testing and evaluation of the interactive floor. We conducted a Wizard of Oz evaluation of the surface, allowing participants to move across the surface to play "Pong" and other games, whilst we manually tracked their movements. From this evaluation we give recommendations on the types of interaction users enjoyed and which worked well on the interactive floor surface.

Finally, the eighth chapter concludes the thesis, where we reflect on the work carried out and discuss the implications for future work: a long-term study of the effect of the system on encouraging staff and students to use the stairs.

Chapter 2: Literature Review

In the introduction we put forward an argument for encouraging increased physical activity throughout the day in office environments. Here we will give an overview of the previous research and how it has influenced the current project.

We first look into the notion of Nonexercise Activity Thermogenesis (NEAT) activities and ubiquitous computing projects encouraging increased physical activity. We detail their findings and list the design recommendations they make for systems to encourage increased physical activity. We also look at other behaviour change literature, and ideas behind using social norms to change behaviour, and how to publicly display these social norms.

We then look at some projects which have used novel public floor displays to share information or change behaviour. The space and place where interactive systems are installed has a large effect on interactions and engagement, we look at other interactive systems and their findings relating to the space where they are installed.

The process of installing and evaluating a physical system in a working space brings about many challenges of its own. A project similar to ours was undertaken in the Open University, we review a paper documenting the challenges faced and offering a new implementation approach to follow (Hazlewood, Dalton, Marshall, Rogers and Hertrich, 2010). Finally, we look into evaluation and design guidelines.

2.1 Behaviour change and physical activity

Levine (2004) coined the term Nonexercise Activity Thermogenesis (NEAT), to refer to all physical activity undertaken which is not eating, sleeping or "sports-like" exercise. NEAT includes all everyday activities such as cleaning, typing or walking up stairs. NEAT has been the focus of discussion in popular media, increased NEAT activity has been suggested as a lifestyle change for promoting weight loss and healthy living (Saunders 2010). Fujuinki, Kazakos, Puri, Pavlidis, Starren and Levine (2007) explored the use of mobile exergames for increasing NEAT physical activity in a healthcare community. They evaluated a number of games designed to support NEAT in everyday activities, primarily walking. The games were installed on the participants' mobile phones, with a pedometer used to measure the number of steps taken. Users interacted with games based upon the number of steps they made throughout each day.

A four-week study of the games was conducted with a group of colleagues in a medical centre. The number of steps taken by participants, and their usage of the games was recorded throughout the study. This was followed by interviews and a focus group to reveal positive and negative points about the implementation, and to seek to explain the trends spotted in the recorded data. Results were positive, showing an increased number of steps taken by those who used the games most consistently. They suggest that games to support NEAT activities should be simple, informative, discreet and motivational.

In order for exergames to appear attractive to users, Sinclair, Highston and Masek (2007) *s*uggest they should support Csikszentmihalyi's state of Flow, where the user is singularly focused on an activity. Consolvo, McDonald and Landay (2009) stress that lifestyle behaviour change as a long-term activity, and as such principled approach is needed. This project will take the approach of increasing NEAT activities in peoples daily routines; specifically, taking the stairs rather than the lift.

Consolvo has worked on a number of projects using ubiquitous computing to encourage physical activity, and has given a number of design requirements for systems seeking to motivate increased physical activity. Consolvo, Everitt, Smith and Landay (2006) detail the design and evaluation of a pedometer-type application for personal devices, to record and share the number of steps taken each day with a group of friends using the application.

A three-week study with a prototype system was conducted with a group of women who wanted to increase their physical activity. Goals were set for users based upon the number of steps taken in the first week. Quantitative evaluation was carried out based upon the participants recorded step-counts against their goal.

The paper presents four design requirements for systems that increase physical activity: give users proper credit for activities, provide personal awareness of activity level, support social influence, and consider the practical constraints of users' lifestyles.

There are a number of commercial solutions, such as the Nike+ Fuelband[1] and the fitbit[2], which offer pedometer functionality through a 3-axis accelerometer and computer connectivity. The Fitbit Ultra and One even offer tracking of stairs climbed throughout the day, through the inclusion of an altimeter. Using this device in a stair-climbing project such as ours would allow any flights of stairs the participant climbs throughout their day to give them game-time. However the cost of using these

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[1] Nike+ Fuelband. Available from: http://nikeplus.nike.com/plus/products/fuelband, accessed 14/10/12.
[2] Fitbit One Wireless Activity and Sleep Tracker. Available from: http://www.fitbit.com/uk/one, accessed 14/10/12.

devices in the MPEB project would be high, as each user would require their own device.

A project by Schultz, Nolan, Cialdini, Goldstein and Griskevicius (2007) showed households their energy usage in comparison to that of their neighbourhoods. Households using a higher than average amount of energy decreased their usage, whereas households using less energy than average tended to increase their energy consumption, clearly showing the effect of social norms to change behaviour.

2.2 Public Displays

Public displays such as LCD screens can be used to share information or social norms with a community. One problem with standard public displays such as LCD screens is that many people do not see them if they believe their content will not be of value, similarly to how people do not see banner adverts on websites (Müller, Wilmsmann, Exeler, Buzeck, Schmidt, Jay and Krueger, 2009). They suggest in order for information to be viewed that the content of displays should reflect the users expectation. Huang, Koster and Borchers (2008) also studied public use of such screens in a variety of different public settings, and concluded that they were rarely viewed, and when they were it was usually for only a short moment of time. A number of these displays are installed in and around the UCL, including within the MPEB. In his undergraduate project Shah (2012) conducted a study of these screens, and found similar results to Huang: the majority of people ignored them, or only glanced at them very briefly (for less than two seconds). From this we can conclude that LCD screens are not a good medium on which to display social norms, as it is likely that they will largely be ignored.

2.3 Floor Displays

Floor displays have previously been used for advertising (innopixel.com, 2012), wayfinding, as interactive surfaces for play (Wyeth, 2012), and for displaying information to motivate behavioural change. The Piano Staircase (Rolighetsteorin, 2009) took the approach that "something as simple as fun is the easiest way to change people's behaviour for the better". A public staircase in Stockholm was painted to look like a piano, and was made interactive so that as users stood on the steps they would play piano notes. During the study 66% more people than usual climbed the stairs rather than using the adjacent elevator,

Rogers, Hazlewood, Marshall, Dalton and Hertrich (2010) used a public floor display as a nudge to encourage stair usage, along with a physical representation and LCD displays showing stair versus lift usage. The Tidy Street Project (Bird and Rogers, 2010), and more recently Shah's project (2012) have used novel floor displays to visualize information in order to motivate sustainable behaviour.

The Tidy Street Project used a novel public floor display painted onto Tidy Street itself, to increase awareness of energy usage. The average energy usage of the Tidy Street community was compared against the Brighton average, and displayed on the road for everybody to see. The overall energy usage of the community decreased by 15% after three weeks, but after six months many households had reverted back to their previous energy usage.

Previous work studying the use of a floor display in the MPEB was undertaken by Shah, as part of an undergraduate project earlier this year (Shah, 2012). The motivation for this project was to decrease energy consumption by publicly displaying information about energy usage in the building (Figure 2.3.1).

Figure 2.3.1 The floor display used in Shah's study in the MPEB.

The display consisted of 16 LED units and visualized the occupancy (number of lit LED units) and energy usage (green = low, yellow = medium and red = high) on four floors of the computer science department. A study of the system showed that it overcame the display blindness problems that typical LCD screens exhibit, gaining the attention of passers-by who looked at the display for on average 26 seconds.

2.4 Public Interactions

The space and place where interactive systems are installed has a large effect on interactions and engagement. The Collective play Urban Screen Game (O'Hara, Glancy and Robertshaw, 2008), details the installation of three large interactive systems installed in cities in the UK. Each system consisted of a large display screen and a camera facing the floor immediately in front of the screen. The screen showed the image from the camera, a series of bouncing red balls were then overlaid on the image. Users movements across the surface would cause the balls on the screen to move, when two balls collided they would combine to form one ball, when there was only one ball left a point would be scored.

The system was installed over 4-weeks, evaluation of the system consisted of observations and interviews with users. The authors made a number of recommendations for large-screen games in public settings as a result of this study.

It also draws attention to the importance of health and safety issues when designing for shared space games. Collisions with gamers and non-gamers occurred during the study, and the systems interfered with the normal use of the spaces.

In order to play the game more successfully, participants worked in groups, interacting both with people they already knew and strangers. The study also found that having an audience made a difference to users interactions, some participants acted differently, to show off to, or amuse the spectators. After each game a leader board showing the three cities was displayed, this increased use and brought about a championing effect as participants worked for their City to be at the top of the board, this effect could potentially be used within the MPEB project, with participants working to increase the score of their department.

2.5 Interactive system design and installation

Rogers (2011; Marshall et al., 2011) suggests in the wild evaluation can be revealing, and produce different effects to evaluation carried out in the lab. As the devices we are producing will be used in the wild, it makes sense to conduct evaluation with them in situ. The article goes on to speak about the importance of longitudinal studies and suggests that people may appropriate technologies for their own purposes.

Hazlewood et al. (2010) detail some of the challenges experienced in building the Clouds and Lights system at the Open University. Similarly, in this project there is the challenge of producing – in particular the time spent writing software and building hardware components – and evaluating the system. To evaluate systems in the wild is resource intensive.

In “The Design of Everyday Things”, Norman (1988) presents six interface design principles: consistency, visibility, affordance, mapping, feedback and constraints. These offer general guidance to the design of not just computer interfaces, but also physical interfaces such as the CueCat Card Scanners and the interactive surface in the FloorPlay system.

2.6 Summary

Lots of work using ubiquitous computing to encourage physical activity has been conducted. This research has indicated that systems to encourage physical activity should be simple, informative discreet and motivational, supporting a state of flow. Consolvo et. al. (2006) suggested the importance of giving users proper credit for their activities, provide personal awareness of activity level, support social influence, and consider the practical constraints of users’ lifestyles. Social norms can also be successfully used to change users behaviour, but the display of these social norms needs to be carefully thought-out.

LCD displays are often used to publicly share information, but a problem with a standard public display of information such as LCD screens is that many people do not see them, similar to how people don’t see website adverts. Novel displays, such as the floor displays used in the Tidy Street project and the Shah’s MPEB have been shown to attract more attention, so offer a good method to publicly display social norms, in our case, stair-climbing activity.

Chapter 3: System Overview

In this chapter we give an overview of the entire FloorPlay system, detailing its design and architecture, location and constraints on the project.

The system is made of four main parts: ActivityCounters to measure stair usage, CueCat Card Readers to track participants' stair climbing activities, a large-scale interactive floor surface to be used as a reward for climbing the stairs, and a back-end database system which ties the components together.

Our main contributions to the FloorPlay system are the design and evaluation of the ActivityCounters, the CueCat Card Readers, and an evaluation of the usability and engaging nature of interactions on the interactive surface. The Thermitrack cameras, used to track participants movements across the interactive surface, and the kiosk for the surface have not yet been installed, however we were able to conduct an evaluation of the surface without them.

3.1 FloorPlay System Schematic

Figure 3.1.1 shows the overall system schematic and the separate parts of the FloorPlay system.

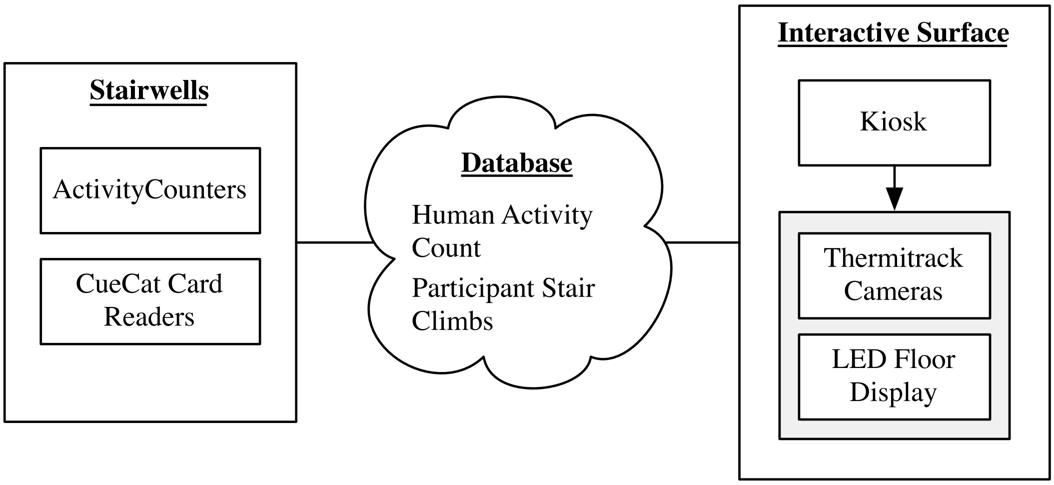

Figure 3.1.1 System Schematic

The ActivityCounters and CueCat Card Readers were installed in the stairwell. The ActivityCounters used a sensor to detect and keep a count of activity in the stairwells, whether a card was scanned or not. CueCat Card Readers were created to record participants' stair activity. Participants' must scan their card as they pass each CueCat Card Reader device. A database is then updated with their climbing activity.

The reward for walking the stairs in the building was the use of a large-scale interactive surface, in the space shown in Figure 3.1.2.

Figure 3.1.2 The foyer of the sixth floor of the MPEB

We installed LED units into the glass wells in the floor. Controlling each unit allowed us to turn the floor surface into a large low-resolution display.

To allow participants to interact with the floor display, plan to track whole-body movement across the surface. Using infra-red thermal imaging cameras mounted on the ceiling we will be able to reliably track participant movements as a heat-source; lighting and other environmental conditions have little effect on the reliability of the tracking. These cameras are often used for tracking and counting customers' movement in shopping environments because they are robust and reliable[3]. They have also been used in a number of public interactive art installations[4].

Unfortunately whilst we were able to get these cameras working in the lab they were not installed above the surface by the network support team, so we could not use them to track participant movements on the surface.

A further scanning device was planned to be adjacent to the interactive surface, allowing participants to be identified before beginning interaction with the surface. After a card is scanned the interaction on the surface will begin running. In our evaluation we carried out this this part of the systems functionality.

Throughout the project we used the Arduino platform to produce physical prototypes and interface with hardware for a number of reasons. Firstly, we already had access to a number of Arduinos for prototyping, meaning fewer pieces of new hardware

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[3] Irisys | People Counting Technical Information, available from: http://www.irisys.co.uk/people-counting/how-it-works/.
[4] Thermitrack- Installations, available from: http://www.thermitrack.com/installations.html.

needed to be purchased, helping lower the overall cost of the project. We had also had previous experience working with Arduinos, having previously created the "feelybean" and attending an Arduino workshop earlier in the year. A large online community of Arduino experts also exists offering support and access to libraries of code, which can be rewritten and recycled.

3.2 Interactive Surface

The FloorPlay interactive surface is made up of two main parts, the Thermitrack IR cameras, and the floor display (Figure 3.2.1).

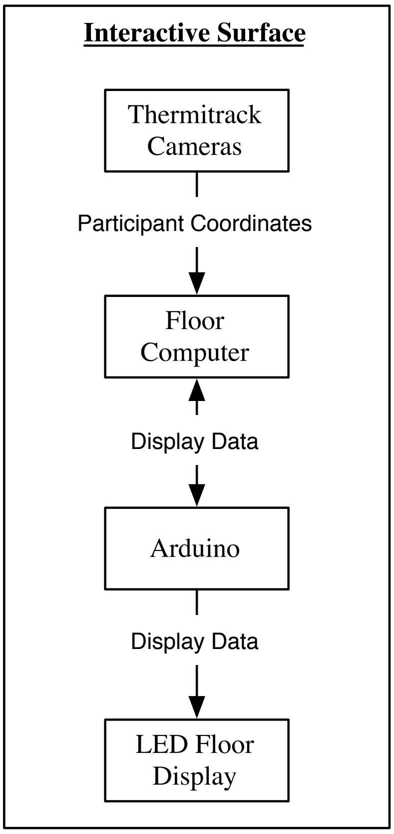

Figure 3.2.1 Interactive Surface Schematic

Each lighting unit comprises four RGB light emitting diodes (LEDs) each capable of displaying over two million colours and a white cardboard diffuser to increase visibility, installed on top of a plastic pipe cap which tightly fits into the light well (Figure 3.2.2).

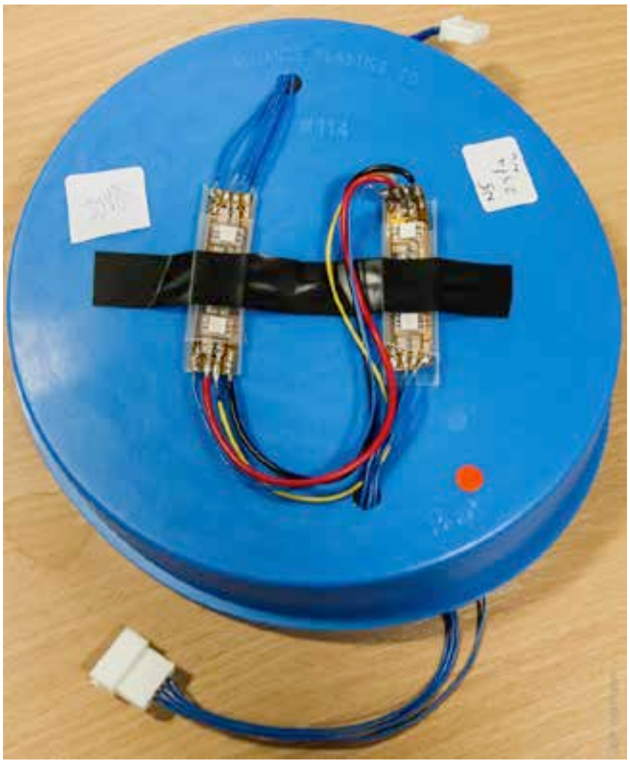

Figure 3.2.2 Lighting Unit

The LEDs in these units are cut from an addressable RGB lighting strip[5] (Figure 3.2.3). An LPD8806 chip is installed between each pair of LEDs on the strip, making it possible for the colour and intensity of each LED to be individually controlled and pairs to be separated and re-joined with just four wires; power, ground, clock and data.

[5] LPD8806 Digital Addressable RGB LED w/ PWM Waterproof Flexistrip http://adafruit.com/products/306, accessed 14/10/12.

Figure 3.2.3 LPD8806 LED Strip

Very long runs of LEDs can be created and controlled by an Arduino. As the Arduino is not capable of providing enough power to long runs of LEDs, the LED strip requires a 5v source so we modified three ATX computer power supplies to provide power to the LEDs (Figure 3.2.4).

Figure 3.2.4 ATX power supply

The hardware for the display was purchased before full-time work was started on the project. Because of the time-consuming nature of building, a UCL alumnus was hired to produce the lighting units for the end of April. The network support staff were due to run power and data cables to the foyer before the end of June, however this work was not completed.

As mentioned in the previous chapter, a project using this surface as a display of energy usage and occupancy in the building was undertaken earlier in the year (Shah, 2012). The current design of the LED units is a result of the evaluation carried out during that project where it was found that four LEDs and a diffuser produced the best compromise between visibility and cost in the lighting units.

Thermitrack infra-red imaging cameras were to be installed above the surface to track participants' movements (Figure 3.2.5). These cameras are used for tracking and tracing movements of people. The co-ordinates are sent over a serial connection, and can be mapped onto the interactive surface. Four of these cameras would provide coverage of the entire surface, giving the potential to create a great number of different whole-body interactions.

Figure 3.2.5 Two Thermitrack cameras

The previous project used 16 (4x4) of the 288 glass wells as a display. This project used 216 of the 288 wells in the concrete floor (Figure 3.2.6). The 72 light wells in the area shaded in red, immediately adjacent to the lifts, were not used to lower the risk of collisions between those interacting on the surface and people exiting and entering the lifts.

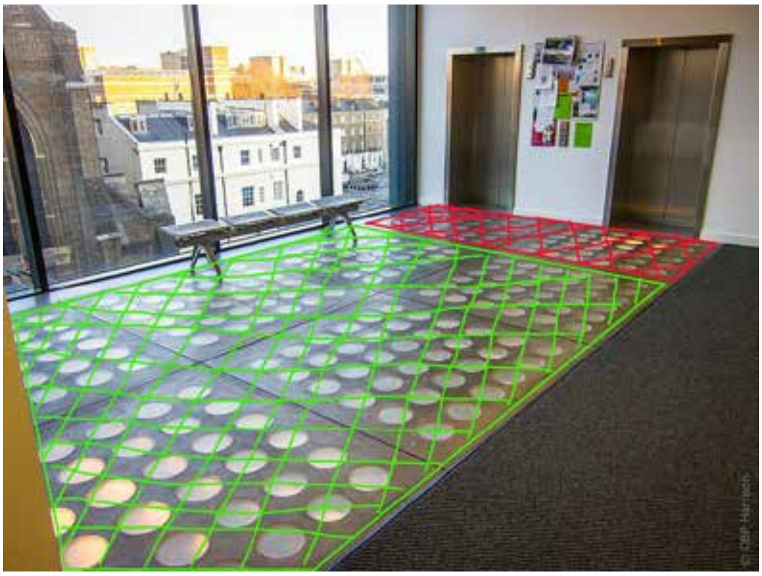

Figure 3.2.6 The surface for the interactive display

The infra-red cameras are connected in a ring network, forwarding co-ordinates from camera to camera, then to a computer running OS X. The computer maps these coordinates to the surface and produces visualisations. Floor display data is sent from the computer to an Arduino, which updates the LEDs in the floor, allowing participants' movements to control what is displayed on the surface (Figure 3.2.7).

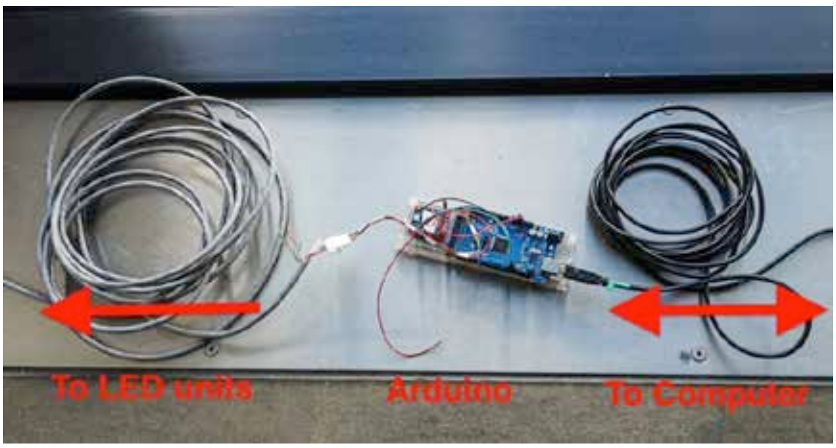

Figure 3.2.7 Floor Control Arduino

3.3 Stairwell Activity

All UCL students and members of staff carry an ID card when on campus. This ID card includes two methods for identifying users: an embedded passive Radio Frequency Identification (RFID) chip, similar to London's Oyster Card system, which works with contactless Near Field Communication (NFC) readers, and a printed barcode on the reverse of the card. Both of these features are unique to each individual, allowing them to be identified from their ID card.

In order to earn game time participants have to use the building's stairs, rather than the lifts, recording their activity by scanning their ID cards at custom built scanners. Each time a user climbs a floor a record is added into a database for that particular user, allowing them to collect a number of credits throughout their working day.

As previously mentioned, including the basement there are nine floors in the building, and two stairwells, making a total of 16 landings where scanners could potentially be positioned. The production and maintenance of 16 scanners is outside the scope of the project, both in terms of time and cost, so we installed eight scanners on the landings in the main stairwell. After some preliminary investigations, we decided to use the printed barcodes to identify user ID cards, rather than the RFID tag. The cost of purchasing eight standard commercially available barcode or NFC readers was prohibitive. An inexpensive barcode scanner was found: the CueCat.

The CueCat (Figure 3.3.1) was a failed venture from US based company Digital Convergence, first introduced in 1999. Many CueCat PS/2 barcode scanners were distributed free-of-charge to households in the US. They were designed to scan small barcodes within a printed advert, similar to a QR code today. After scanning a barcode the page would open up in a web browser on a computer.

Figure 3.3.1 CueCat barcode scanner

The company went bankrupt in 2001 leaving millions of unused CueCats. Given the large numbers that were produced and distributed, CueCats are still available today, at low cost, and can easily be modified for use with the Arduino.

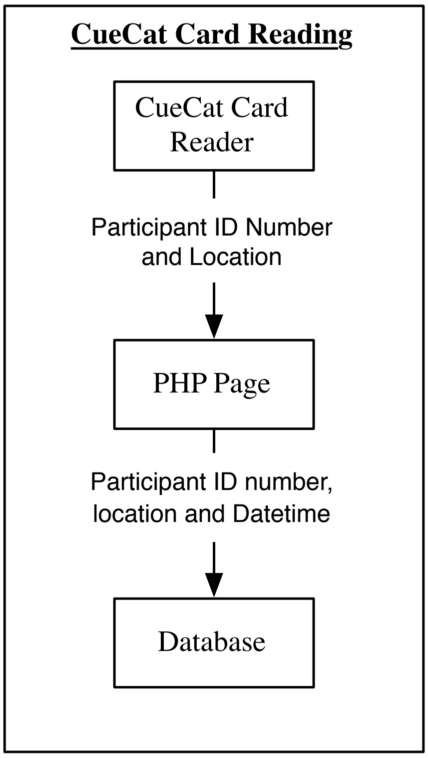

Figure 3.3.2 Scanning Schematic

Each Arduino also includes wireless connectivity, to allow a connection to the Internet over the network. There were no wireless networks with a sufficient signal strength in the stairwells, so a new wireless network was set-up, although was not available until approximately two weeks before the end of the project. An external Apache web server was set-up to host the database, which was updated through a PHP page with which the device communicates (Figure 3.3.2).

3.4 Situation

The system was installed in the MPEB in UCL (Figure 3.4.1). The MPEB itself is located within the main campus of UCL in central London. The nine-floor building provides lecture theatres, labs and offices for students, academic and support staff from the Engineering and Computer Science departments. It contains two main lifts and a smaller service lift, along with two stairwells that run through all floors of the building, and an additional set of stairs between the ground and first floors.

Figure 3.4.1 The MPEB and stairwell shown from Malet Place

A large foyer area is located immediately outside the main lifts on each floor (Figure 3.1.2) with a concrete floor pierced with a grid of 288 light wells, each of which is capped with semi-translucent glass.

This surface is easily accessible from beneath; we took advantage of this design to install individual lighting units into each well from below, to shine through to the floor above.

3.5 Constraints

The main constraints on the project were time and cost. Our work on the project began early in 2012, with full time work starting in June. The system was to be installed, working and evaluated by early September.

Because of logistical and time considerations, a number of decisions relating to hardware had to be made; much of this hardware had to be ordered without evaluating its suitability, or testing alternatives (cf. Hazlewood, et al., (2011). We purchased LPD8806 LED strip to create the floor display, Thermitrack cameras to track participant movements on the surface and CueCat barcode scanners to scan user ID cards before commencing full-time work on the project.

The cost of our part of the project was a large constraint, with just £200 available to cover all costs. Fortunately most of the necessary hardware was purchased as part of a separate project grant, so only costs for hardware not already purchased needed to be covered with our £200 budget.

3.6 Summary

In this section we have given an overview of the entire proposed system, detailing some of the constraints and technical issues. We have justified and outlined some of the choices made early on in the project, such as the use of Arduino microcontrollers as our hardware prototyping platform, CueCats to scan participants' ID cards, and Thermitrack infra-red cameras to track movements across the interactive surface.

The following three chapters will concentrate our main contribution to the project as a whole; the design and evaluation of prototypes created to count stairwell activity, record participants stair usage and that of the reward itself; the interactive surface.

Chapter 4: Counting Stairwell Activity

In order to evaluate the effectiveness of the FloorPlay system to change behaviour it is necessary to perform a measurement of stair usage in the MPEB building before and after it is installed. Many behaviour change systems have a short-term novelty effect. However, in many cases short term changes in behaviour are not sustained in the long term. For example, in the Tidy street project (Bird and Rogers, 2010), where a public display of a community's household energy usage facilitated an initial 15% reduction in electricity consumption, many households reverted back to their previous levels of energy usage after six months.

A system that can reliably and consistently count stairwell activity is essential for the project in order to evaluate whether it encourages more people in MPEB to use the stairs rather than the lifts. In this chapter we present our solution to counting stairwell activity, the ActivityCounter.

4.1 Options

There are many commercial solutions for counting human activity; systems are often used in retail and public environments where an understanding of footfall or customers movements can be useful for analysis and planning layout. Systems in use range from simple trip-sensors, which count the number of times a line-of-sight sensor is broken, to far more sophisticated imaging systems which can be used to record and analyse movement and flow through a physical space. Perhaps the most common method of counting human activity is through manual observations. However, this method is susceptible to human error and a single investigator could not possibly keep an accurate long-term count of activity through a public space.

There are a number of considerations which must be taken into account when choosing the method of counting: the appropriate and safe positioning of the counters; seasonal and other environmental differences such as sunlight and direct heat that can affect sensor systems; ensuring that the system is robust enough to operate autonomously for long periods of time; and finally, providing energy to run the counting system.

A computer imaging solution could have been used by installing cameras in suitable locations and using software to track and count participants. However, in the MPEB multiple cameras would need to be used as there is no vantage point from which a single camera could view all the activity in the stairwell. As we had already made the decision to use Arduino microcontrollers to scan user ID cards, we decided to also use them to count activity between all floors in the stairwells.

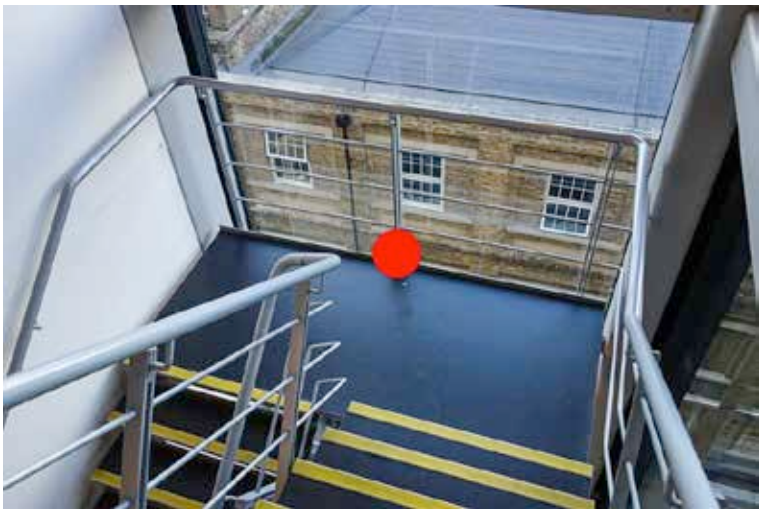

Figure 4.1.1 ActivityCounter position in the stairwell indicated by red circle

We chose a position in the stairwell that could be retained for the entire project (figure 4.1.1), to ensure that the counting was kept consistent throughout.

4.2 Sensor overview

Eight counting units need to be produced and installed to measure the stairwell activity between all the floors in the MPEB building. It was therefore essential that they were low cost, low-energy usage as well as being robust.

Health and safely regulations meant that no power or network cabling could be run into the stairwells; each of the units therefore either needed to be completely self-contained (and store data on an SD card) or use wireless connectivity to log data on a server. Each Arduino includes 1KB of non-volatile memory (EEPROM), which was used to record activity until a wireless network was set-up in the stairwell. The EEPROM can only be written a finite number of times, at least 100,000[6]. To increase the lifetime of each Arduino we updated the EEPROM after ten activations of the sensor, rather than after each activation. No data was lost as until it was stored in EEPROM, the current count is kept in the RAM of the Arduino microcontroller.

A project somewhat similar to ours was carried out at the Open University, using a series of LEDs laid into the carpet of a university building to nudge users towards the stairs, along with public displays comparing lift and stair usage (Rogers, Hazlewood, Marshall, Dalton and Hertrich, 2010). This project used pressure mats laid underneath the carpet tiles, which were used to activate the system as well as counting participants' movement to either the stairs or the lifts. Unfortunately the stairwells in the MPEB are not carpeted, so it was not practical to use pressure mats in our project.

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[6] Arduino Playground- EEPROM FLASH. Available from: http://www.arduino.cc/playground/Code/EEPROM-Flash, accessed 14/10/12.

Another solution could have been to use vibration sensors mounted to each stairwell landing. However this method may have proved to be unreliable as the entire stair system is made from metal and tends to vibrate between floors; calibration would have been a challenge due to differences between participants, and a heavy footed participant may have triggered sensors on multiple floors.

There are a number of light sensors available that could be used for recording when people walk past (figure 4.2.1). Infra-red (IR) Sharp rangefinders have been used in many projects to count passers by, such as the Phantom Railings project (Pollak, personal correspondence, 2012) where people walking past trigger a sound. Rangefinders combine an infra-red light source and sensor in one unit and are triggered when the IR source is reflected back to the sensor. Unfortunately a pilot test indicated that these sensors did not work reliably with non-reflective surfaces, such as dark clothing.

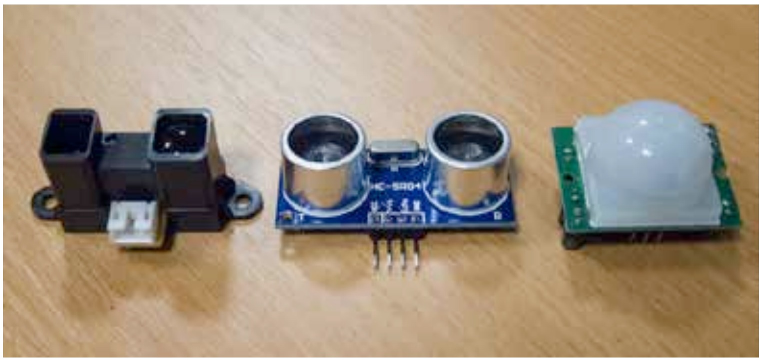

Figure 4.2.1 IR Rangefinder, HC-SR04 and PIR sensor

Ultrasonic rangefinders, such as the HC-SR04, work similarly to the Sharp IR rangefinders, but instead of using IR light they use ultrasound. This means that they respond reliably to a wider range of different surfaces passing close by. However, the sensors place a greater computational load on the Arduino which has to calculate the distance of an object. This could cause problems when the Arduino units add card scanning and wireless functionality along with the human counting.

Passive Infra-red (PIR) sensors are commonly used in security and automated light systems and they work similarly to the Thermitrack cameras we are using to track participants' movements on the interactive surface, detecting the infra-red light/ heat source given off from a human. The PIR sensors have lower power consumption and are self-contained, putting less energetic and computational load onto the Arduino. PIR sensors are available from a number of different manufacturers and for a relatively low cost, from as little as £2.50 per sensor.

4.3 Limitations of the chosen technology

Based upon the limitations and advantages of the different technologies discussed in the previous section, we decided to use the PIR sensor (figure 4.3.1) for counting human activity. The sensor comes as an all-in-one unit controlled by three wires: power, earth and signal. The sensor gives a high output when sensing proximal activity, and a low output when not.

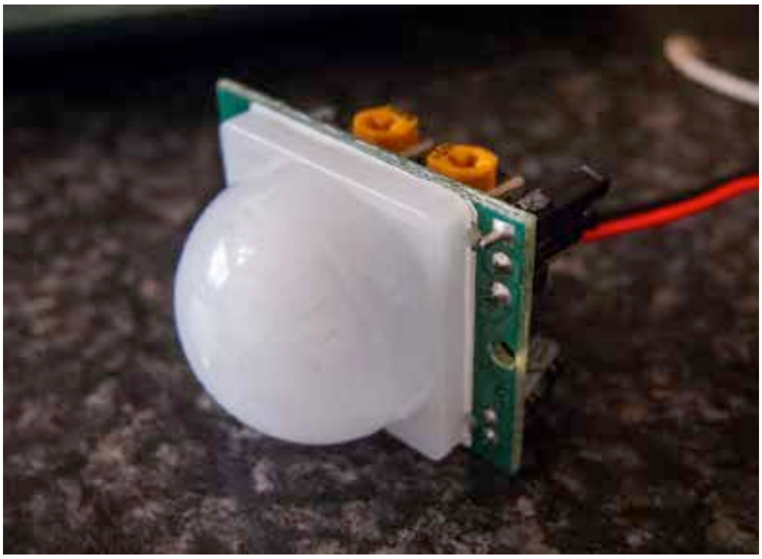

Figure 4.3.1 PIR sensor

One limitation of the counter means we were unable to give a precise count of the number of users who passed each scanner; if two people passed within close proximity they could be counted as one person. This was not a problem for the project, so long as the counting method remained consistent, because the purpose of the ActivityCounter is to measure whether there is any relative change in the stairwell activity once the FloorPlay system is installed.

The sensor has a 120° field-of-view, through the use of a lens over the sensor. This can cause some issues with the design and placement of the counters: passers-by may have activated them as they moved up and down the stairs, rather than as they passed the sensor itself. This meant that the sensor would remain activated for a greater length of time, thereby increasing the chance of multiple people passing by who were not counted and therefore affect the accuracy of the count.

A number of different solutions were tested to limit the view of the sensor, which included removing or modifying the lens and placing additional shielding around it. The solution which proved to be most reliable was to create a circular shield around the original lens of the PIR sensor which limited its field of view. Various materials, diameters and lengths of tube were tested in situ (figure 4.3.2).

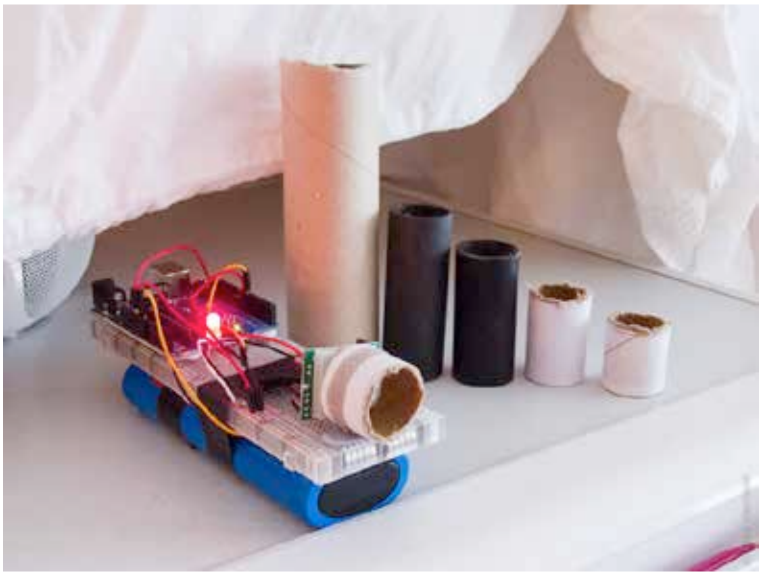

Figure 4.3.2 PIR sensor and various tubes to reduce field of view

The sensor retained greater sensitivity, detecting movement from a short distance and afar, with the wider and shorter tubes but with a wider angle of view; narrower and longer tubes reduced sensitivity but created a more focused spot for tracking heat. The PIR sensor units themselves offer adjustable sensitivity but testing showed that increasing the sensitivity resulted in inconsistent behaviour: the ActivityCounter would sometimes be activated by a distant passer by and at other times it entirely missed a closer heat-source.

The outcome of the testing was a design using a piece of matt black tubing with an inside diameter of approximately 30mm and a length of 25mm to restrict the PIR sensor field of view.

4.4 Design, and initial prototypes

An initial ActivityCounter prototype was created with an Arduino and a PIR sensor on a breadboard. This was tested using a 7.2v Ni-MH battery sourced from a radio-controlled (RC) car (figure 4.4.1). A red LED was used as feedback to show when the sensor was activated and to confirm that the ActivityCounter was functional and the battery charged.

Figure 4.4.1 7.2v RC car batteries

We chose to continue using 7.2v RC car batteries to power the ActivityCounters. The batteries required no building, are relatively compact, offer a large capacity (up to 3700Mah), low price, and are readily available. Using and charging the batteries was safe and inexpensive, the chargers we purchased included an automatic cut-off to prevent overcharging and cost just £5.99 each[7].

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[7] Orion Advantage IQ801 1A Delta Peak Charger, Available from: http://www.modelsport.co.uk/orion-advantage-iq801-1a-delta-peak-charger/rc-car-products/369437. Accessed 15/10/12.

Other battery solutions for providing power were considered, including sealed lead acid batteries, which offer a greater capacity but with a considerably larger size and greater weight, and lithium polymer batteries which offer lower-weight and greater capacity but are more expensive, and can be volatile during charging and discharging[8].

A pair of prototypes were created and tested in a foyer area in the MPEB for approximately four hours and then briefly in the stairwells to ensure they were functional in their intended situation. The prototypes were placed together, where the sensors would detect passers-by, and were then observed to see if they reliably detected activity (figure 4.4.2). A tally of the number of passers was also kept. At the end of the testing period this was compared against the number recorded by the prototype which was deemed to be accurate.

[8] Data safety sheet for LiPo Cells, available from: http://chimaera.usu.edu/attachments/321/vgi_lithium_polymer_msds_v3.pdf. Accessed 15/10/12.

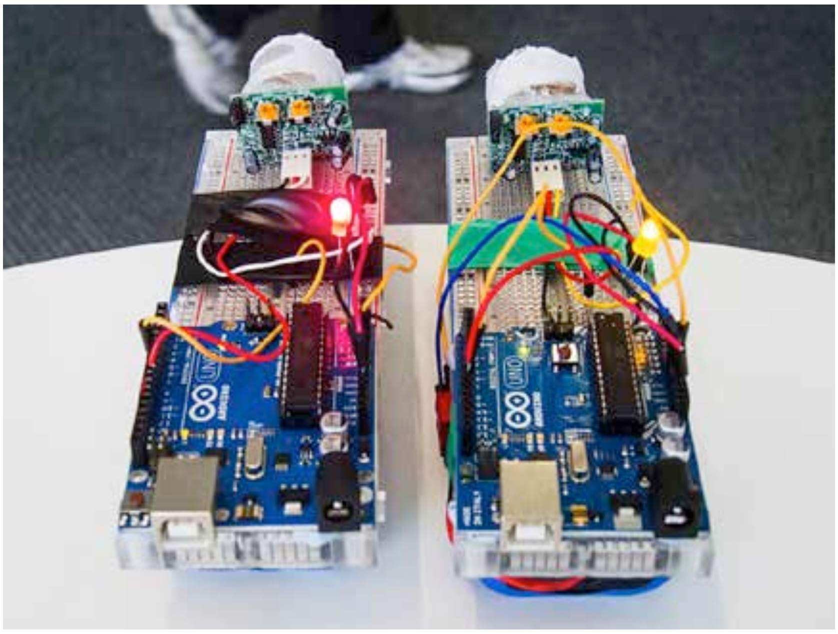
Figure 4.4.2 Arduino prototypes during evaluation

Participants were not recruited for this study, as it was intended to be a technical evaluation of an initial prototype, however, many passers-by commented on the appearance of the prototype, one jokingly commenting that “it looks like a bomb!”. Feedback such as this made it clear that the appearance of the counters was important, that the final units should not have exposed wire and other components and that for many our choice of battery was reminiscent of an explosive device.

The prototype units worked and counted reliably, the sensors activating when expected and not otherwise, so the design was taken forward. Eight units were produced that could be installed in the stairwell on the landings between the floors of the MPEB.

4.5 Building, installing and testing

Each unit was housed in a black material-covered steel sunglass case which was modified to completely hide the battery and electronic components within and create a professional aesthetic look better suited for the environment (figure 4.5.1). A red

LED was retained from the prototype and positioned behind the PIR sensor, to provide feedback that the counters were working and reliably detecting human activity.

Figure 4.5.1 Eight finished counters in housing

Each of the units were installed into the stairwell, along with a small sign that provided information on the counters and the FloorPlay project, along with an URL and QR code linked to a website offering further information (figure 4.5.2).

Figure 4.5.2 Installed ActivityCounter

Once installed the reliability of the counters was assessed by a number of tests. These involved zeroing the counters and then observing and, manually counting the number of participants who passed by. Testing was carried out over three separate occasions, each time observing two counters, during a variety of different weather conditions, and at different times throughout the day to ensure that heat and sunlight did not affect the accuracy of the counting. Because of the infrequent stair usage in the building each test of the counters took between one and two hours to get a large enough number of observations. The data observed and retrieved from the ActivityCounters is displayed in Table 4.5.1.

Observed Count	**Count**
86	80
60	50
44	40
72	70
36	30
41	40

Table 4.5.1 ActivityCounter observation and retreived data

Overall the counters proved to be reliable and consistent in their counting, generally undercounting passers by approximately 5-10%. Up to 9 counts could be lost when the Arduino sketch was restarted. The difference between the observed count and the actual count can be partially attributed to the number of people who passed the sensors in pairs or groups, and partially because any counts (up to a maximum of 9) not stored to the EEPROM of the ActivityCounter were lost when the data was read off of the counter, because this process restarts the Arduino and clears the volatile memory. This means numbers taken read from the ActivityCounters would always be rounded down to the nearest 10, so if the observed count was 19 we would expect to see an actual count of 10.

It is important to note that the PIR sensors would not be suitable to count human activity in an environment where there would be a constant stream of passers-by who move in groups because the sensor would miscount large groups of people as a single person.

One further issue which arose during testing was that the battery life was not as long as had been anticipated, based on calculations of the components' power-draw and the battery life of the original units. It is important that there is a reliable count of activity and this can only occur if the ActivityCounters are provided with a reliable power supply: when the batteries die the units stop counting and there is no way of knowing what data has been missed. A method to get around this problem could be to time-stamp each individual count, this would allow us to see when the battery failed and potentially build-up a model over time to estimate usage, rather than discarding all collected data. However this is not possible using the extremely limited amount of non-volatile memory on the Arduino EEPROM, and would instead require additional hardware, perhaps in the form of a real-time clock and SD card shield. Bearing in mind the future use of the Arduino units for scanning, we did not wish to explore this avenue, due to the increased load put upon the microcontroller.

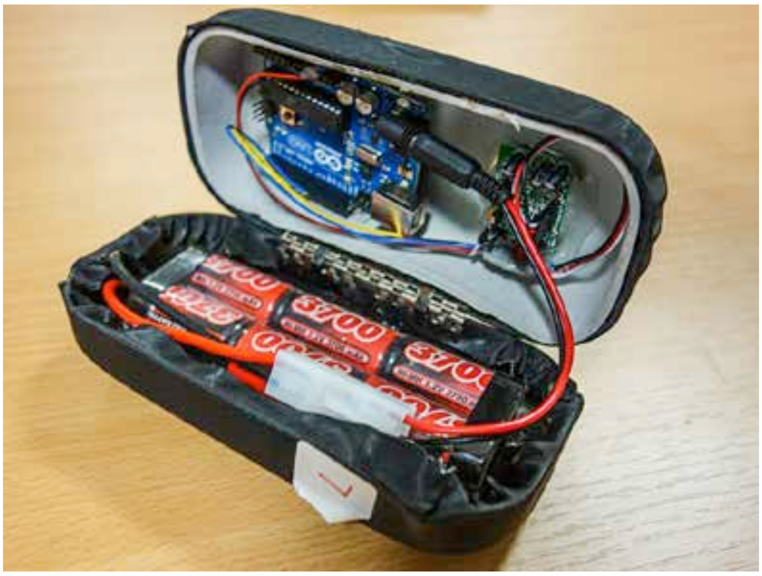

Figure 4.5.3 ActivityCounter with battery installed

The power issue caused problems with the amount of work needed to keep the system counting, with 2400mah batteries the counters were often not lasting much longer than 48 hours before requiring a recharge. To maintain a count we needed to ensure the batteries were never fully depleted, it was not feasible to change the batteries in the counters more frequently than every 48 hours. Higher capacity, 3700mah, batteries were purchased (Figure 4.5.3), which meant that they needed to be replaced every 3-4 days rather than every 2 days, and code was implemented to send the Arduino to sleep for a short-amount of time each time the code looped. These changes gave a notable increase to the length of time each battery lasted.

4.6 User Feedback

Whilst evaluating the ActivityCounters ability to reliably count, a large number of unexpected observations of people interacting with the counters were observed.

The process of installing the ActivityCounters in the stairwells brought about much interest in the technology and the project itself. This effect was expected, however, the number of interactions with the ActivityCounters was less so. During the first few weeks after installation people were observed stopping and photographing the ActivityCounters, bringing their friends and colleagues into the stairwells to discuss them, standing alongside them and "testing" them by waving their hands in front of the sensor to watch the LED light up, and a group of students were even observed carefully "stepping over" the line of sight of the sensors so that they would not be counted!

All of these interactions clearly had an effect on the count produced for the first few weeks after their installation, however after a number of weeks their novelty appeared to wear off as they blended into the background. It could be argued that a more subtle installation would have caused fewer issues, however the bare nature of the environment means that any sensor technologies would be immediately noticeable.

We had expected that there would be some concerns about privacy, and what the units were for, but other than one passer-by muttering about being in a "surveillance state" no concerns about privacy were mentioned. However, a conversation with a PhD student in the MPEB a number of weeks after the installation brought to light some issues. She had been initially concerned that the counters were monitoring her individual activity in the building, for example, when she was arriving and leaving, and how many breaks she was having throughout the day. We asked if this may have encouraged her to avoid the stairs, to which she replied no, and said that she had since forgotten that the counters were there.

She also suggested a reason why the count was unexpectedly high between certain floors in the building, in particular between the 6^{th} and 7^{th} floors, suggesting this may be related to the positioning of toilets on each of the floors, and that climbing the stairs to a toilet on a different floor may be a shorter overall journey than walking to the toilet on the opposite side of the same floor.

4.7 Data

The counters were run for three weeks over the summer, with the number of counts read at the end of each week. After these three weeks some parts of the ActivityCounters were used in prototypes of our CueCat Card Readers.

The first two weeks of this count coincided with the Olympic sporting event held in London. During this time there were noticeably fewer people on-campus at UCL, and as this was outside of term time there were also very few students in attendance. The table 4.9.1 shows the total number of sensor activations of each counter, over each week during the study. It also gives an average for the number of activations from each counter, and from each week in the study.

	Week 1	Week 2	Week 3	Average
Floor 1	1640	1820	2890	2167
Floor 2	1860	3940	4650	3483
Floor 3	1540	2660	2990	2397
Floor 4	280	440	510	410
Floor 5	770	1610	2550	1540
Floor 6	1320	2380	2810	2170
Floor 7	1250	3430	3850	2843
Floor 8	840	1590	2030	1487
Average	1188	2234	2746	2056

Table 4.9.1 Floor Count Data

The data shows a general increase in stair activity as time went on, with the first week in particular having particularly low usage. This is opposite to what we would have expected based on our observations, however we believe this effect was because of the number of people avoiding the MPEB over the Olympic period, and then returning to work during the second week of the Olympics, and after they finished.

The number of people in University and the MPEB in particular changes throughout the year, with many students only present on campus for lectures and labs 20 weeks each year. Comparisons against such a small data set would not allow a good evaluation of a change in stair activity after the project was installed, a baseline of stair activity would need to be collected for a much longer time period.

4.8 Summary

We can conclude that when coupled with an Arduino microcontroller board, PIR sensors provide an inexpensive and reliable solution to measuring stairwell activity. When positioned appropriately the ActivityCounters would reliably keep a record of activity. Whilst this would not represent an absolute value of the number of people who have walked in the stairwells, because of people moving in groups, it provides a reliable and robust solution to record and compare overall activity for a very low cost. The accuracy of the count is sufficient for our needs, as it can show a relative change in activity over time.

From observations made whilst evaluating the accuracy of the ActivityCounters it was clear that the data collected during the first few weeks after installation would not give true representation of the general stair activity, as many people interacted with the counting units. However, the novelty of the counters soon wore off, as they began to blend into the background and fewer people took notice of them.

Feedback indicated that the appearance of the units was important: units should look professional with all electronic components hidden, to look and ensure that they are not mistaken for a suspect device. The design produced could reliably be used elsewhere, in different situations. The design and code was published on the Internet[9] and a member of Scion Research, a New Zealand institute developing science and technology for forestry applications, approached us to use the ActivityCounters to count mountain biking activity on trails in the forest.

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[9] Counting Human Activity with an Arduino, Part 1. Available from: http://www.dbpharrison.com/projects/interactivefloor/arduinopeoplecounter1/. Accessed 15/10/12.

Chapter 5: Counting participant stair usage

To collect game-time on the interactive surface, users of FloorPlay must use the stairs to walk between floors, scanning their ID card at scanners, adding a record into a database, allowing them to collect credits throughout their working day.

The UCL ID card includes two methods for identifying users: an embedded passive Radio Frequency Identification (RFID) chip and a printed barcode. Both are unique to each individual, allowing them to be identified. After preliminary investigation, we decided to use the printed barcodes to identify user ID cards. An inexpensive barcode scanner in the form of the CueCat was found.

In this chapter we describe the user centred design process followed to develop and evaluate the CueCat Card Readers, a device to scan UCL ID cards with a CueCat.

We first discuss the positioning of the Reader within the stairwells, highlighting a suitable place to position the scanner. We then detail the results of an initial evaluation, from which we decided to build the CueCat into a device to constrain the user into using the correct scanning technique.

We then conducted parallel physical prototyping and evaluation of these prototypes in the lab. After this we produced an iteration based on user feedback, which we installed in situ in the stairwells, to get in the wild feedback. Finally, we analyse our results and give findings.

5.1 Positioning

To prevent participants from scanning their card without walking the stairs the scanners must be positioned on the platforms between the stairwells, so participants must always walk an entire flight of stairs to scan their ID card.

There are limited safe mounting options for the scanners on these platforms. The vertical beam (Figure 5.1.1) was chosen as the most appropriate location, as it offers some flexibility in mounting height, does not interfere with the flow of people, and if a participant drops their card from this position it is unlikely to fall down the entire stairwell.

Figure 5.1.1 Mounting position highlighted in red

The maximum possible mounting height in this position is approximately 105cm, although at this height the handrail may begin to obscure the device for some users.

The ergonomics and positioning of the scanner are an important consideration (Gill, 2000). The appropriate height for installation depends somewhat on the design of the scanner, the ideal height was ascertained through a combination of analysis of anthropometric data (Pheasant, 2005) for the population and a fitting trial conducted alongside user testing.

5.2 Initial testing

We created an initial prototype to assess: i) how well CueCats could scan ID cards; and ii) how a naive user may expect to scan a barcode using a CueCat. These initial tests were carried out in the Interaction Research Lab in MPEB. Testing was carried out initially by lab members and then by six potential users. Users were asked to complete a walk up and use test, to scan their UCL ID card without being offered any additional instruction.

Figure 5.2.1 CueCat barcode scanner

Our initial tests highlighted a number of issues that had to be solved for a walk up and use system without instruction. Firstly, none of our participants used the correct technique when attempting to scan a barcode with a CueCat. The CueCat scanners need to be manually moved across the barcode, at a constant speed and with the "nose" of the cat in contact with the barcode at all times. Each of our participants initially tried to scan a barcode from a distance, pointing the cat towards their card and often looking for a "trigger" to start the scan, similar to what might be done with a laser barcode scanner. After this approach failed, participants would often try a more appropriate technique, but whilst attempting to scan at an inconsistent or inappropriate speed, or from too great a distance, still failing to scan the barcode.

We also discovered that many users carry their ID card in either a wallet, purse, or lanyard holder which do not prevent the RFID chip in the card working but do stop CueCats effectively reading the barcode. ID cards needed to be removed from any holders before they could be scanned.

It was clear that the CueCat would need to be built into a device to guide users into removing their cards from holders and using the correct scanning technique. This left different options for the design of scanning units. A number of sketches of ideas were drawn, but many of the designs explored were too costly and difficult to produce. One design in particular was put forward as suitable to produce for a reasonable cost, and was further explored. The design encourages the user to remove their card from any holders as the card passes through a slot across the face of the CueCat (Figure 5.2.2).

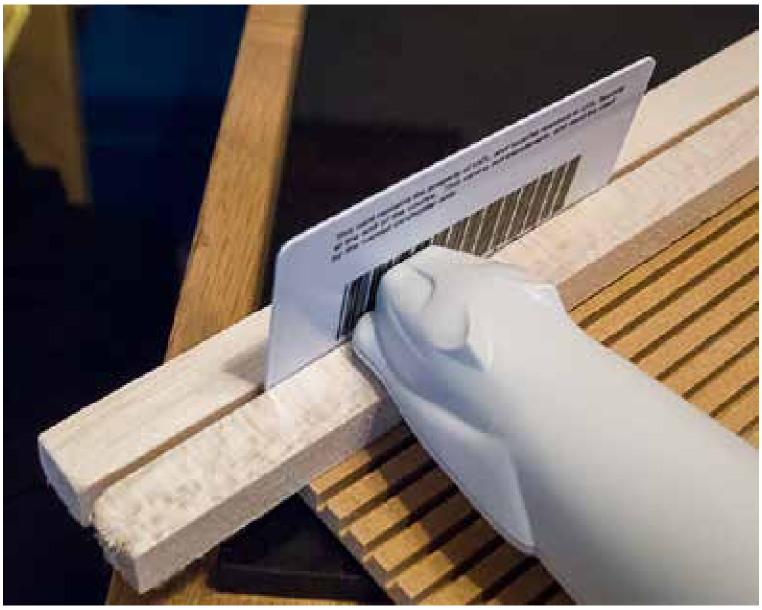

Figure 5.2.2 Prototype of a slot for scanning barcodes with a CueCat

5.3 Physical Prototyping

Parallel physical prototyping of two variants of the CueCat Card Readers was carried out. Parallel prototyping offers a number of benefits: creating and showing multiple prototypes to users helps get more honest feedback: users may give negative feedback when reviewing multiple prototypes where they might not if only reviewing a single prototype (Dow, Glassco, Kass, Schwarz, Schwartz, and Klemmer, 2010). In addition to the benefits it brings to user-feedback, the process of creating multiple prototypes helped us be more creative when designing scanners, and aided identification of flaws with our designs. This allowed us to make appropriate changes as we had not become attached to any particular design.

Two complete hi-lo tech prototypes (Rogers et al., 2011) were created (figures 5.3.1 and 5.3.2), with a number of differences between the two (table 5.3.1). In addition, a standalone CueCat without the platform was also on hand for user evaluation.


Image 5.3.1 Prototype 1

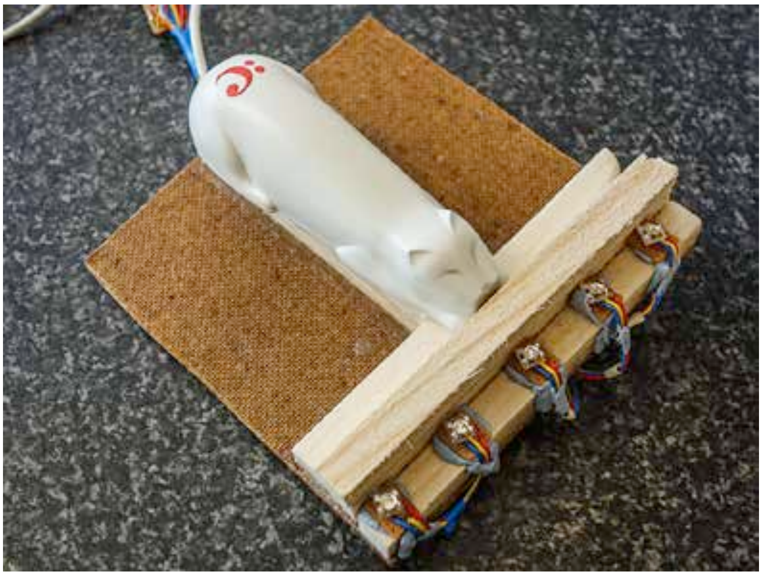
Image 5.3.2 Prototype 2

The two main prototypes were designed to explore a number of contrasting design options for the scanners and to receive user feedback.

Prototype 1	**Prototype 2**
15cm long card slot.	12cm long card slot.
"Funnel" slot design to aid when swiping card.	No funnel design.
PIR activated scrolling red LEDs mounted above slot to suggest position, direction and speed of card scan.	No scrolling LEDs.
Scrolling LEDs light green after a successful scan, red after an unsuccessful scan.	Feedback LEDs, positioned separately light green after a successful scan and red after an unsuccessful scan.
No audible feedback.	Piezo buzzer for audible feedback.

Table 5.3.1 Prototype Differences

In addition, a further prototype was created to evaluate different noises that could be used as feedback after a successful or unsuccessful scan. A number of different feedback sounds were created. Two replicated the feedback noises used in the door entrance system in the MPEB, two used a musical arrangement, and finally two single tone noises were used.

All prototypes offered complete functionality, but were constructed out of balsa-wood, which gave a lo-fi appearance. They were designed to be flexible and allow different design options to be explored during user-testing. Parts were loosely held together with blue-tack so they could be repositioned; all code for the scanners could be manipulated if necessary. In addition the scanners were held onto a plinth with blu-tack, to allow a fitting trial of different heights of the prototypes to be explored (figure 5.3.3).

Figure 5.3.3 The lab evaluation set-up

5.4 User testing

Two main methods were used to evaluate the scanners: a focus group with six participants, and individual user testing with eight participants, using think aloud and semi-structured interviews.

Participants were recruited through social networks. None of the participants were involved in the initial evaluation of the CueCats, and none of them were familiar with the method used to count participant activity. Not all participants had their own UCL ID cards and were provided with a card to use. Participants were not rewarded.

The focus-group session was undertaken in an informal setting, away from the university. The six participants, aged 23-27, were given a general explanation of the FloorPlay system, and the reason for tracking users. Participants were fully briefed with details of the FloorPlay system before beginning the study, and were given an information sheet and a consent form to sign. The prototypes were given to the group of users, who were asked to imagine that the units were installed in the stairwells and that they wanted to scan their ID card. The participants were asked to think-aloud as they were interacting with the units, and to point out any issues or thoughts they might have. The session was semi-structured, with discussion led by the investigator, but allowed to propagate between group members, where a number of useful suggestions were made, such as moving the scrolling LEDs closer to the slot, and increasing the height of the slot to better support the card when scanning. The session lasted approximately 45 minutes.

Eight participants were recruited for individual user testing, which was carried out in the Interaction Research Lab in MPEB as a wireless connection was not yet available in the stairwells. Participants were fully briefed about the FloorPlay project and the evaluation at the beginning of the study, and were given an information sheet and a consent form to sign. Participants were told that they were free to leave at any time. They were first given an explanation of the FloorPlay system and shown where the scanning prototypes would be installed, before heading to the lab to conduct a think aloud session with the prototypes. This session was followed by a short semi-structured interview. Sessions lasted no longer than 30 minutes.

To negate any preference or learning effects from using one prototype before the other, half of the participants were shown prototype 1 first, and then prototype 2; the other half of the participants were first shown prototype 2, and then prototype 1. The prototypes were attached to a wooden plinth approximately 85cm height, which allowed the prototypes to be positioned at the full available height of 105cm. The prototypes were initially placed with the card slot 85cm from the ground based on anthropometric guidelines (Pheasant, 2006; Gill, 2000). The aim was that all able-bodied users would be able to reach the CueCat Card Reader without needing to stoop or reach. The prototypes were attached to plinths using blu-tack, to allow them to easily be positioned higher or lower, based on a user's preference.

The plinth was physically rearranged so that participants were only able to see one prototype when they entered the lab. A script for the user-testing sessions is included in the Appendix, along with sample information sheets and consent forms.

5.5 Feedback

In this section we summarise the feedback received that influenced the design of the CueCat Card Readers.

Generally, the design of the prototypes was a success, most users in our focus group and lab testing understood the units to be barcode scanners, and immediately used the correct technique to scan their cards. Two participants who first saw prototype two, without the scrolling LEDs, initially thought the cat was a contactless reader. Both of these participants hovered their card over the cat, but then soon saw the slot and LED shining from the "nose" of the CueCat and realised the intended use. A passing user in the stairs may not be so patient. It is important to note here that both the area where we ran our focus group and our lab are fairly dark environments, and that the red LED shining from the CueCat was clearly visible in both situations. We believe that the visibility of the LED and therefore the barcode scanner was one of the reasons that users were able to quickly identify how to use it. The slot and scrolling LEDs aided with constraining the user and afforded a swiping action, but only combined with the visibility of the barcode reader, as without this the slot was not obvious.

Thirteen of the 14 participants liked the scrolling LEDs on prototype one and felt that they should be included in the design, but they preferred having the LEDs for feedback separate from the main scanning device, as on the second prototype. This seemed to be so there was clear separation between the red scrolling LEDs and the feedback LEDs, and because the feedback LED in the second prototype was aimed towards the participants eye-level, increasing its visibility to them.

A number of participants interacting with prototype one thought that the unit looked "dead" when the LEDs stopped scrolling, and concluded that they couldn't scan their card at this point. This is not the case- the LEDs simply stop scrolling when no activity is detected by the PIR sensor. This situation would rarely arise when actually in use in the stairwells, and was mostly apparent because of the design and layout of the environment where we were testing the units. It does go to show that during this testing the LEDs

Figure 5.5.1 Particpant scanning their ID card with prototype 2.

The largest and most apparent issue was that of missing feedback after an unsuccessful scan. This is because of the way that the CueCats themselves work: in normal operation they only send data after a barcode has been successfully scanned. We implemented code in the prototypes so that negative feedback would result if an incomplete barcode was sent. However, there was no method in hardware to detect a user unsuccessfully scanning their card. This meant that during testing many users would unsuccessfully swipe their card through the device, and receive no feedback, often then thinking they had either successfully scanned their card when they had not, or being left confused and unsure if the prototype was working. As suggested by Norman (1989), feedback is essential for the usability of interfaces.

All but two of the participants thought that both visual and audible feedback after a scan was necessary. The participant who didn't think audible feedback was necessary was concerned about feeling awkward when drawing attention to themselves in the stairwells after scanning their card. This participant was strongly against the volume and musical feedback tone, and suggested that the negative tone alone would be enough to put them off of attempting to rescan their card. Other users felt that a strong negative tone was necessary to gain the user's attention to ensure that they rescanned the card.

The decision on the preferred type of audible feedback itself split the majority of participants. None of the participants preferred the single-tone feedback, suggesting that it was difficult to be sure if it was a positive or negative tone when heard alone. There was a slight preference for the tone used by the MPEB entrance system to indicate a successful scan, and the musical tone for an unsuccessful scan. The general reasons behind this choice seemed to be that the more subtle nature of the positive tone was enough to notify the participant, but if the card had not been scanned correctly that the user would want something more noticeable in order to get them to attempt the scan again. This also agrees with feedback received from other participants, who were concerned that the musical tones would bring too much attention to their scanning activities in the stairwells.

Generally, users felt that the shorter card slot on prototype one was sufficient, but that the funnel on prototype two was useful in guiding the card into the slot. One participant suggested that increasing the height of the slot would hold the card more securely, helping prevent the fore-aft movement of the card which often caused unsuccessful scans of the barcode.

5.6 Iteration

Based on this user feedback a further iteration of the prototype was created. Further parallel prototyping at this stage could have been useful. However, due to time constraints and the useful feedback received from the previous prototype we decided that this was not necessary, and instead a single, refined prototype was created (Figure 5.6.1).

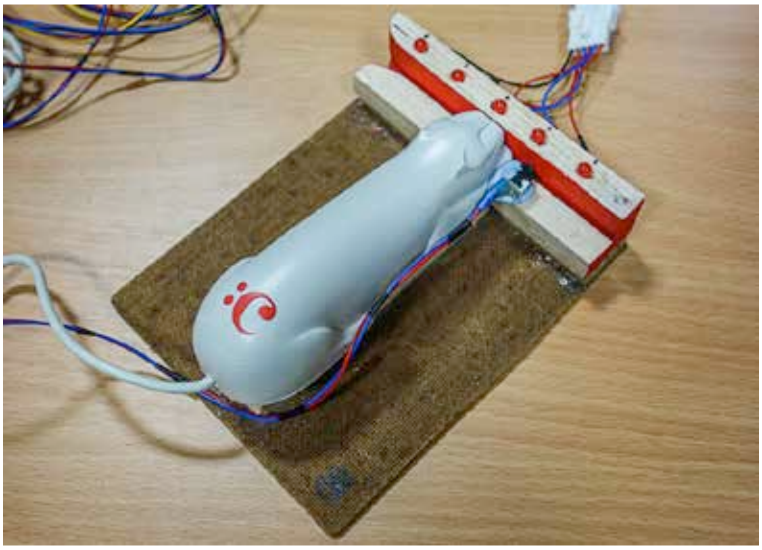

Figure 5.6.1 Refined prototype

A number of design enhancements were made to the design. A solution to the biggest issue, the lack of feedback after an unsuccessful scan, was found in the form of a simple modified push-to-make switch from an old computer case. Careful positioning of this switch means that the Arduino can sense when a card is present inside the slot of the prototype, so if the CueCat does not send a barcode within 250ms after the card is removed then the unsuccessful scan feedback can be played. Additionally, the positioning of the switch within the prototype brought about an additional benefit to the overall usability of the device, helping steady the card as it ran through the slot (Figure 5.6.2).

Figure 5.6.2 Switch to detect card in slot

Based on feedback we decided that both audio and visual feedback after a scan was necessary, and decided to use the audible feedback the majority of participants in our lab study preferred: the musical tone after an unsuccessful scan, and the shorter, more subtle two tone noise after a successful scan.

Ergonomic guidelines (Gill, 2000) recommend the use of a flashing light to guide users to a card entry slot and we found that participants appreciated the scrolling LEDs as a nudge to scan, as well as helping with the direction and speed. The scrolling LEDs were therefore retained in the iteration. We were initially concerned that the red colour of the scrolling LEDs may have caused confusion for some users because of the common association between the colour red and failure, and our use of red LEDs to indicate a failed scan. However this was not the case for any of our participants. However, users did generally prefer the red and green feedback LEDs to be kept separate from the main scanning device, so we moved the scroll LEDs closer to the card slot and separated the LEDs and buzzer similarly to as implemented in prototype one, to allow the LEDs to be aimed towards the user's eye-level.

We thought that the longer card runner of prototype one might encourage users to swipe their cards at a more consistent speed but we did not find this. Rather, users tended to lift their card from the slot before reaching the end. However, the funnel design in prototype one did aid entry into the slot, so this was used with a shorter, 12cm, channel. We also experimented with increasing the height of the slot to increase support for the card. In the user evaluation we found that this not only increased steadiness of the card, but also had the advantage of blocking some external light from the "nose" of the CueCat, which itself improved the scanning reliability. Along with this enhancement, the inside of the card slot itself was painted red, in order to achieve a greater contrast with the natural wood of the rest of the prototype (Figure 5.6.1).

The completion of this design iteration coincided with the installation of the wireless network in the stairwell. This meant that in the wild testing of completed prototypes could be carried out for further evaluation.

Three copies of version 5 of the prototype were built, complete with a functional wireless connection. One of these prototypes was installed on the landing between the sixth and seventh floors of the MPEB. This was the first time CueCat Card Reader was installed in situation in the stairwells. One concern with the close proximity of the scanners to the PIR sensor of the ActivityCounter was that the amount of activity counted would artificially increase because of the participants' movements within the sensors' field of view whilst scanning their ID. Fresh observations of the counters in use alongside the scanners would allow a comparison of their accuracy compared to the previously recorded numbers to be made.

5.7 In The Wild Evaluation

The CueCat Card Reader prototype was installed in the stairwell of the building where it was subject to some further testing (Figure 5.7.1). A PHP page and MySQL database were set-up for this study. After a successful scan, the card ID number, a timestamp and the location of the scanner were sent via Wi-Fi to a MySQL database running on a server.

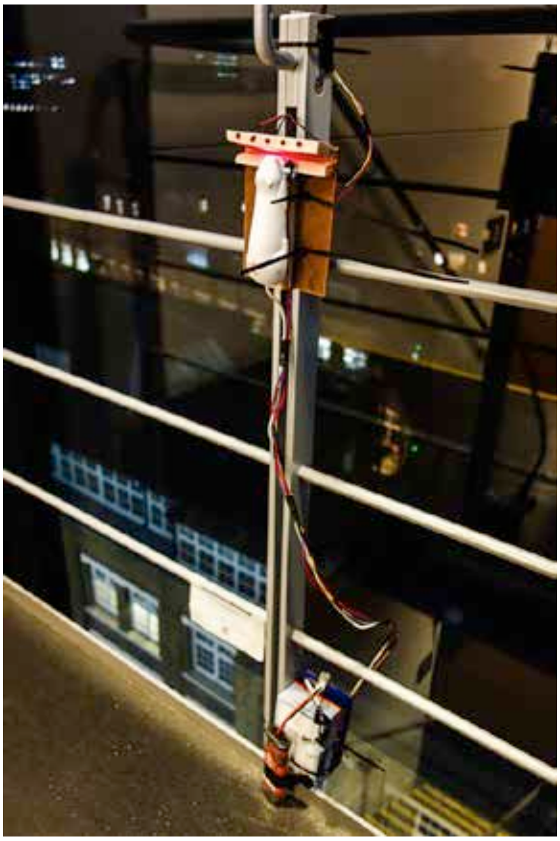

Figure 5.7.1 Scanner installed in the stairwell

Participants were recruited through social networks. They were invited to visit the MPEB to interact with the FloorPlay system. A number of passers-by in the building also joined in with the evaluation, as they were curious about the project and the prototypes installed in the building. We ran the study over two evenings, where in total 16 participants interacted with the CueCat Card Scanners in the stairwells, 12 of these participants had not previously interacted with the prototypes, so were completely new to the CueCat Card Scanners.

When participants arrived they were briefed about the FloorPlay system and told that use of the interactive surface would be offered as a reward for climbing the stairs in the building and scanning their UCL ID card. Participants were not rewarded for taking part in the study, and were told that they could leave at any point. Participants were given information sheets and consent forms to sign, including permission to allow us to photograph their interactions.

Participants were asked to scan their card using the prototype, whilst speaking through their thoughts. Evaluation with our first participants started at approximately 4pm, whilst it was still light outside. Our first participants were taken into the stairwell and had great difficulty with using the prototypes: none who attempted to use the scanners during daylight identified the CueCat itself as a barcode scanner, or saw the slot for the card to be scanned. Each of these participants initially expected the device to use contactless technology, and placed their ID card on different parts of the prototype, expecting it to be read.

Even after participants asked how to scan their card and were told the prototype used a barcode scanner they didn't swipe their card in the slot. The red scrolling LEDs confused some users, who thought that these were the barcode scanning mechanism. These participants held the barcode of their card against the LEDs, hoping this would scan. A number of participants tried multiple angles and even tried running their ID card along the row of LEDs in order to attempt to scan their ID card in this fashion.

Figure 5.7.2 Scanning card in CueCat Card Reader in the evening

As our testing moved further into the evening and the stairwell environment darkened the number of participants who were able to walk up to the CueCat Card Reader and successfully scan their card began to increase (Figure 5.7.2).

We believe that the differences in lighting between the lab and the stairwells may have contributed to the differences we saw in our evaluation. Both the lab testing and our focus group were conducted in considerably darker environments than the stairwells during the daytime, which are completely constructed of glass on two of the four walls (Figure 3.4.1). During the daytime this means that the red light shining into the slot on the scanner is all but invisible. In a darker environment the slot is more obvious, the LED in the scanner helps highlight the slot for users. When asked, one of the participants who tested the barcode scanner in the evening said, “Well it’s obviously a barcode scanner, you can see the red light”.

This highlights an important reason to begin in the wild testing as early as possible; if we had tested our initial prototypes in the stairwells then this issue may have been more obvious to begin with. This also highlights the importance of visibility in the usability of physical systems.

Participants suggested that mounting the entire unit closer to eye-level would have aided in visibility. However, there are limited options for mounting the scanner at a greater height in the stairwell, the only appropriate location is closer to the glass. If a participant dropped their card whilst scanning from this location it's likely to fall to the bottom of the stairwells, possibly colliding with objects and other people on the way down. If a user drops their card whilst scanning at the current location the card is more likely to drop onto the floor of the platform, not causing any significant issues.

Once participants had been shown the correct technique they were able to quickly, easily and reliably scan their cards in the CueCat Card Readers. We observed that even after people had learnt how to scan their card, and could do so reliably, that they would activate the PIR sensor in the ActivityCounter twice, causing a false count. We believed that this effect would lessen over time, as participants become quicker at scanning their card, but the limitations of scanning with the CueCat mean that faster scans are not possible. As a solution to this problem we suggest that each time a card is scanned at a device that a PIR count for that location is removed. Further tests to ensure this solution works reliably under different environmental conditions would need to be made.

5.8 Summary

The user evaluations described in this chapter show that re-purposed CueCat barcode scanners can offer an inexpensive and usable method of scanning ID cards, provided they are built into a device which appropriately constrains and guides the user, as suggested by Norman's (1989) design principles. The scanners must offer visibility of use, constrain the user and afford the correct swiping motion. The units must also offer appropriate feedback after successful and unsuccessful scanning attempts.

Whilst our prototypes worked well in the lab environment, this was not true when we moved them into the stairwells. This in the wild testing found that during daytime the scanners did not work as a walk-up and use system, the bright and open environment stops visibility, and the scrolling LEDs caused confusion. Earlier evaluation of the prototypes in the wild would have identified this visibility problem and a different design may have been created. However, despite this lack of walk-up-and-use usability, the cats can still be robust and work well once the user has first learnt the technique for a successful scan. This is similar to what Cooper, Reimann and Cronin (2007), describe as an idiom: a method which is not completely intuitive but once learnt is simple to use and difficult to forget. Idioms are often used in interface design, and once learnt do not cause usability problems.

An entirely different approach to identifying participants with their ID cards could have been taken, perhaps by taking advantage of the passive RFID chip embedded in the UCL ID card to identify participants. Whilst many of the usability challenges relating to the use of CueCat barcode scanners in a walk up and use system have been overcome with our design, there are still many issues which we could not address.

One issue apparent from our user testing was that many people carry their cards in holders or wallets- in order to use our scanning devices they must remove the card, changing their general activity. A contactless NFC reader would allow the Arduino to use the RFID tag embedded in the UCL card, without the need to remove from any holders, and would be more similar to how participants use their ID cards in the

MPEB and elsewhere in UCL. In addition, ergonomic guidelines (Gill, 2000) suggest that many users who would struggle to guide a card along the card runner would have little difficulty when using a contactless technology. However, the energy usage of many RFID readers is higher than that of the CueCats, which draw approximately 31ma, and NFC shields for the Arduino cost approximately £25 each, far higher than the cost of repurposed CueCats.

Chapter 6: Thermitrack Cameras

This chapter shows the work we completed on our method to track participant movements across the interactive surface, Thermitrack infrared cameras. Four of these cameras mounted above the surface would allow us to track whole body movements across it.

We built hardware and software to get an output from a series of four networked cameras and update an LED display. We then user-evaluated a single camera connected to a 4x4 LED display which tracks the participants movement.

6.1 Camera Overview

The Thermitrack infrared thermal imaging cameras reliably track participant movements as a heat-source; lighting and other environmental conditions have little effect on the reliability of the tracking. These types of camera are often used for tracking and counting customers' movement in shopping environments because of their robust and reliable nature, they have also been used in a number of public interactive art installations, where they have been used to track single and multiple individuals across public spaces.

6.1 Hardware and Software Challenges

Whilst the Thermitrack cameras have been used in a variety of projects before, a very limited amount of code was available for non Windows environments. Our first issue was that there was no OS X driver available for the Thermitrack serial interface, so we wrote this to enable the Operating System to receive data from the cameras. The packaged driver is available from the FloorPlay section of the authors website[10]. We also created a cable to connect power and data to each of the four cameras, as the included cables were only suitable for one camera (figure 6.1.1).

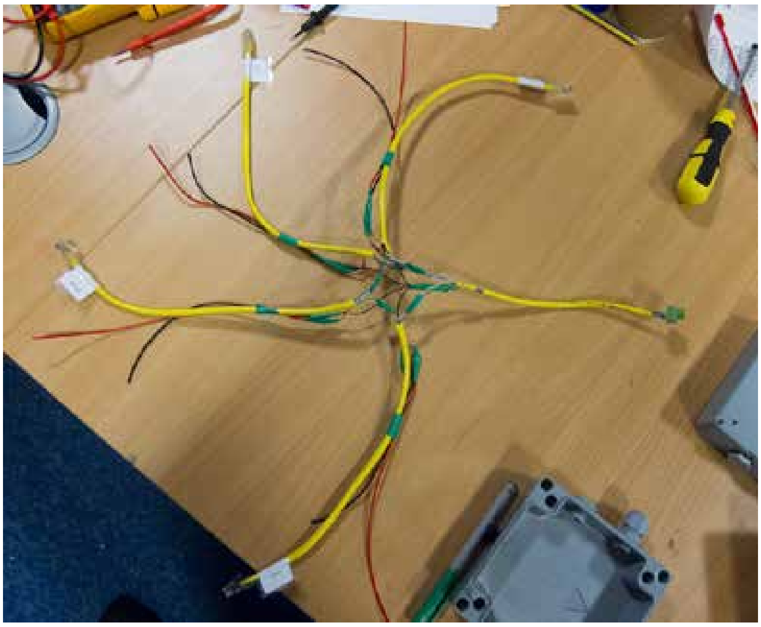

Figure 6.1.1 Star Network cable for thermitrack infra-red cameras

We then modified an existing OpenFrameworks library from Chris O'Shea[11], to allow us to view output coordinates from the each of the four Thermitrack cameras on a computer display (Figure 6.1.2).

[10] Mac OS X Thermitrack Drivers. Available from: http://www.dbpharrison.com/general/thermitrackdriver/
[11] ofxThermitrack- Github. Available from: https://github.com/chrisoshea/ofxThermitrack.

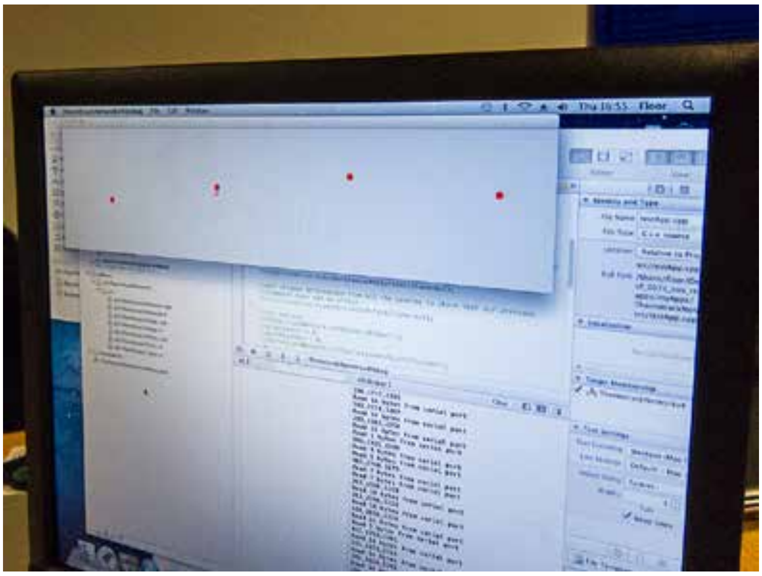

Figure 6.1.2 Thermitrack camera output

Our next step was to output the co-ordinates from the Thermitrack cameras onto part of the floor display. We used a single camera to output to a display of 6x6 lighting units.

6.2 Evaluation

Two visitors to the lab were used as participants to review this set-up, moving within the field of view of the camera to control the display.

Figure 6.2.1 Participant evaluating the Thermitracks with a 6x6 LED display

The hardware proved to be reliable throughout our testing. This was as far as we could work with the Thermitrack cameras from within the lab, we needed the cameras to be properly mounted and access to the floor entire floor display to move any further with the cameras. Unfortunately we had to rely upon others in the department to complete this work, it was not finished so we were unable to evaluate the system with the cameras installed.

6.3 Summary

We have built all of the necessary hardware and software to interface with the Thermitrack cameras, once the network support group have installed the cameras above the surface they will be ready to track participants movements across the interactive surface.

Chapter 7: Interactive Surface

The interactive surface is used as a reward for climbing the stairs in the building, this chapter gives an overview of the process we went through to implement the floor surface, and then design and evaluate interactions on it.

We initially spoke to users about the types of interaction they wanted to use on the surface, showing them a mocked up photograph of what the surface might look like with the LED units installed. We list the ideas of types of interactions and games participants suggested, and took forward one of these games to evaluate on the surface.

A previous floor display using 16 units had been created; we detail the work we completed in enlarging the size of this display to 216 units. Once the floor display was running we conducted user-evaluation with it, using a Wizard of Oz process where we manually tracked participant movements across the surface. Finally, we make recommendations on the use of the interactive surface for a future study of the FloorPlay system.

7.1 Initial Interviews

During the early design phase, potential users were interviewed to collect initial ideas for usage of the surface. Six participants were recruited from staff and students from the Human-Computer Interaction and Ergonomics course at UCL, all of who were already familiar with the design of the floor in the building. Participants were shown a mock-up photograph of what the surface might look like with the LEDs fitted, and asked to suggest types of interaction they would wish to use on the surface as a reward for climbing the stairs in the building. Many participants suggested games such as Twister, where players must place hands and feet on coloured circles on a floor mat, and dancing games similar to Konami's "Dance Dance Revolution". A number of participants also suggested classic games such as Pong and Space Invaders, from an era when lower resolution computer displays were commonplace. All participants suggested they would like to play games on the surface.

Based on our user interviews we suggest the game Pong as a suitable initial interaction to use on the surface, with participants moving from side to side to control the position of the paddles and play the game.

7.2 Installation

All necessary work to the building was due to have been completed before full-time work on the project began, however delays with the network support team completing necessary work to meant that we were unable to install the units into the floor until August, much later than anticipated.

The lighting units were built by a UCL Alumnus and were ready to be installed, we individually tested each unit to ensure the LEDs were displaying correctly and all joints were properly soldered. A number of fixes were made, and then the units were ready for installation in the floor. Installing the floor took three two days, two other people were recruited to assist with this process, with each lighting unit held into the floor with duct-tape to prevent falling.

Three modified ATX power supplies were then installed into an adjacent room, to provide power to the surface. A cable was run from the LED surface to the floor above, to allow us to easily see the surface whilst debugging and writing code and running the Wizard of Oz studies.

Further technical challenges appeared when we began to use the surface, additional ground and power wires had to be installed to produce uniform brightness across the display and we were unable to control the entire display with the code written to control 36 units. We tracked the problem to an issue with a serial buffer over-filling, so our software was rewritten to ensure the buffer would never be over-filled.

Once the floor was installed software was written on the Arduino to cycle through a number of demonstrations, to ensure the units were all working correctly. We removed and replaced three more light units because of problems with their reliability.

7.3 Notable Issues

Shah's (2012) undergraduate project was conducted earlier in the year, and used part of the surface not adjacent to the windows, so the display was in a darker environment. We installed and tested the floor system in August, when the environment outside was particularly bright. A problem with a lack of visibility from a distance was immediately apparent when looking at the surface during strong sunlight. The LEDs are mounted quite low in the light wells and rely upon reflection off of a white cardboard reflector to be visible from an angle (Figure 7.3.1). Other light sources also reflect off of this reflector, so when the environment is bright the LEDs are less visible.

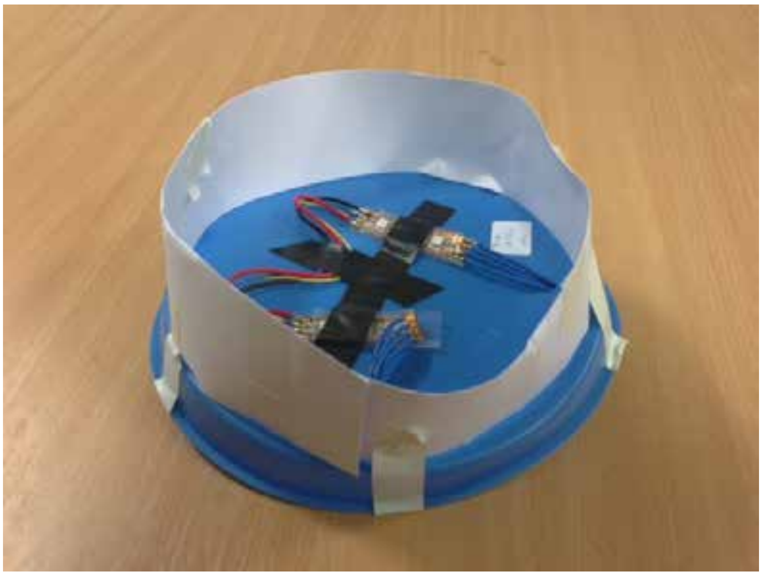

Figure 7.3.1 Image of lighting unit with cardboard reflector

This meant that the visibility of the floor was considerably better in the evenings and at night, when the environment was darker. Under these conditions lighting units could easily be seen from anywhere within the foyer area, their brightness and contrast was significantly improved, during testing many passers-by stopped to look at the floor and even attempted to interact with the surface. During our testing we also ensured the lights over the surfaces remained switched off, to increase visibility (figure 7.3.2).

Figure 7.3.2 The floor display shown at night

A further solution, which we chose to not explore during the project, was to install curtains over the window, do decrease the amount of ambient light in the area during daylight hours.

7.4 Wizard of Oz Evaluation

Work to allow us to install the Thermitrack cameras was not carried out by the network support team, so we were unable to fully implement the interactive surface. However, testing with the floor was important, so we decided to run a Wizard of Oz (WOZ) evaluation with participants.

Initially, we wrote the game "Pong" for WOZ evaluation on the surface. The game was implemented to allow a single player, who would effectively be playing the game against the wall in the foyer. The players paddle would be controlled by the investigator using a visualisation on a computer (Figure 7.4.1), mirroring their movements across the surface. This gave the participant the illusion that their movements were controlling the surface (Figure 7.4.2).

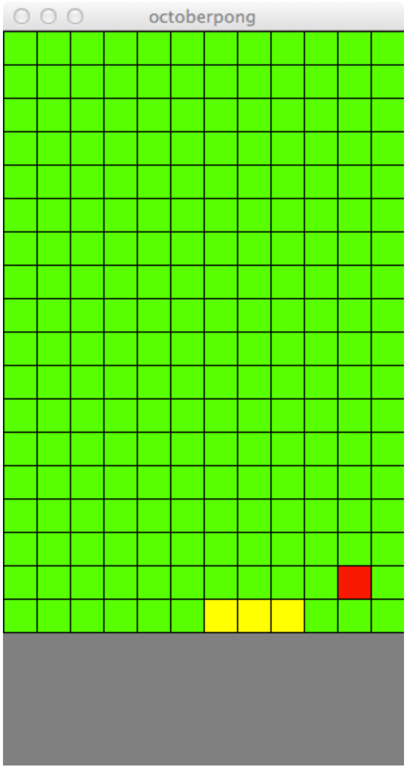

Figure 7.4.1 Visualisation of "pong" on computer


Figure 7.4.2 Participant playing Pong on the surface

A second game “CatNipFun” was also written, after a participant in our pilot study wanted an interaction with more physical activity. In CatNipFun the participant would chase a lit LED around the surface, when the participant reached the target unit another would light up, they would then need to move to this unit. Users were given three seconds to reach the next unit, if they did not reach the unit in this time the game would finish. Participants were given visual feedback of how long they had left to reach the unit with a traffic light sequence of colours, the colour of the unit changing each second until either the participant reached the unit, or lost the game. The software chose target units randomly, often requiring participants to make large movements across the surface. CatNipFun offered no competition, the time to reach the next unit always remains the same; it was purely a test of endurance.

Participants for this evaluation were recruited through word of mouth and posts on social networks, where they were invited to visit the MPEB to interact with the FloorPlay system. A number of passers-by in the building also joined in with the evaluation, as they were curious about the project and the prototypes installed in the building. We ran the study over two evenings, in total 20 participants interacted with the floor surface.

When participants arrived they were briefed about the FloorPlay system and told that use of the interactive surface would be offered as a reward for climbing the stairs in the building and scanning their UCL ID card. Participants were not rewarded for taking part in the study, and were told that they could leave at any point. Participants were given information sheets and consent forms to sign, including permission to allow us to photograph their interactions.

Testing was carried out in the afternoons and evenings, as the darker environment increased visibility of the floor. Participants had the opportunity to interact with the floor surface for as long as they wanted.

7.5 Feedback

In this section we will aim to summarise some of the interesting findings from our WOZ evaluation of the surface.

We expected that most users would be familiar with the game Pong, however, our evaluation showed this was not the case. Despite this, many participants understood the games similarity with "ping pong", and quickly got the idea of bouncing the red pixel against the wall. Several participants said that they did not find this to be a particularly engaging activity, either wishing to have an interaction which required a greater amount of physical activity, or where they were able to compete against other players. The majority of participants only wanted to play Pong once before wanting to try something different.

We believe that this could partially be attributed to our implementation of the game and partially to our WOZ evaluation. Because of the proximity between the evaluator and the participants many were aware that we were controlling the game, rather than the system itself. This often caused the participant to blame the evaluator for missing a ball. Many participants also suggested that the game would be more engaging if they were competing against another person or a computer controlled player. Two player Pong would have been particularly difficult to implement in a WOZ study with one person running the game, highlighting another limitation of conducting a WOZ evaluation of the surface.

Many participants also expressed the wish to have a leader board, perhaps as part of the proposed kiosk where users would scan their card and chose the interaction. They also felt that a stronger consequence of losing a game was necessary, perhaps including some sort of audible signal that the game was over, along with a fresh display on the surface.

Participants preferred quite different amounts of physical activity in their interactions, highlighting the need to have a choice of different games on the floor. One participant in particular was happy to scan his card in the stairwell and speak to us about the project, but did not wish to interact with the surface at all- he felt self-conscious about moving around the surface. He said he would have been happy with a "Kinect like" interaction, where he would be able to make smaller body movements, such as moving his arms or leaning. Other participants showed a strong preference to either interactions which required relatively little physical activity, to those which involved lots of running around.

7.6 Future Work

Participants came up with a number of ideas for future interactions for the surface, many participants suggested that creative interactions, such as an “etch-a-sketch” system where they could move around the surface to draw images could be engaging.

Many participants suggested they would be more motivated by games where they were either directly competing against another player, or where their score would appear on a leader board.

We also mentioned the idea of running workshops to allow members of the community in the MPEB to create their own interactions on the surface, many participants felt that this was a good idea as they had many ideas for usage of the surface, but were often less interested in actually writing the code. It was suggested that we look towards the societies in the computer science (CS) department, as a resource for CS students who like gaming and are able to write code.

7.7 Summary

We have completed work in increasing the size of the surface in the building from 16, to 216 LED units, and overcame technical challenges along the way.

We evaluated two games on the surface, Pong, where participants conducted little physical activity, moving from side to side to bounce a pixel against the wall, and "CatNipFun", where participants made large physical movements, chasing an LED around the surface.

Our evaluation and user feedback highlighted the importance presenting a choice of interactions on the surface. Different participants wanted quite different interactions, some participants were engaged by interactions which required large amounts of physical activity such as running across the surface, whilst others preferred games where they would need to move around less, but could compete against others.

Chapter 8: Conclusion

This final chapter discusses the project and results, focusing on the challenges and difficulties of producing interactive systems for in the wild research.

We then summarise our findings, and discuss their impact on the future of the FloorPlay system.

8.1 Discussion

Hazelwood et. al (2010) paper, document the challenges of installing and evaluating a related interactive system at the Open University. In the wild research is inherently challenging. However, we argue that it is a necessary part of understanding how novel technologies will function and be understood in real world environments (cf. Rogers, 2011; Marshall et al., 2011).

The greatest implementation issue we faced was the amount of time taken to investigate potential hardware designs, order and purchase hardware, write and debug software, and produce prototypes before any user evaluations could be carried out. Without developing the necessary technical infrastructure however, it would be impossible to study situated uses of ambient displays (cf. Hazlewood et al., 2011).

Reliance upon other groups of people in UCL caused many problems and delays throughout the project. From the process of ordering and receiving an appropriate ladder from an approved supplier, to the necessary reliance upon the network support team to drill holes and lay trunking in the foyer area so we could install the interactive display. This goes beyond the discussions with expert "consultants" described by

Hazlewood et al. (2011) and highlights the necessary engagement with bureaucracy in fitting a system to an existing building.

There were also a number of technical challenges: while Rogers (2011) emphasises the benefits of prototyping toolkits such as Arduino in developing systems in the wild, this is still far from being ‘plug and play’. One of the greatest challenges we faced was installing and controlling the floor display. We hoped that we would be able to reuse parts of the code from the previous project in the MPEB. However in up-scaling the display from 16 to 216 LED units we discovered limits in the hardware we were using. Much time was spent debugging and finding solutions to unexpected hardware problems.

Unfortunately, in order to evaluate the surface process we needed complete these activities. We could have worked on alternative methods such as running a full Wizard of Oz study on the floor, perhaps replicating the surface with a projector. Whilst this would have been a quicker and easier method it would have also lacked validity. For example, a projected representation would not have allowed issues with the visibility of the LED units to be identified.

8.2 Summary

During this project we have made a large contribution to the development of FloorPlay, an interactive system to encourage increased physical activity in the sedentary community of the MPEB in UCL.

We have followed a UCD process, making a number of physical prototypes to produce solutions to counting stairwell activity and tracking participants stair climbing activities. We have enlarged the floor display from 16 to 216 light units, and made steps towards making the surface interactive by creating the hardware and software to allow Thermitrack cameras to track full-body movement over the interactive surface. Although we have not been able to evaluate the Thermitrack cameras in the wild, as work out of our hands has not been completed, we believe that once installed these will work reliably with the system to track participants movements.

During the project we have solved the major technical issues related to the FloorPlay system as a whole, once the Thermitrack cameras are installed to allow participants movements on the surface to be tracked the system will be ready for a longitudinal study of its effectiveness to motivate the community to walk the stairs more can be carried out.

We produced ActivityCounters, which, with a PIR and Arduino microcontroller board which provide an inexpensive and reliable solution to measure stairwell activity. Whilst they do not give absolute value of the number of people who have walked in the stairwells, because of people moving in groups, they provides a reliable and robust solution to record and compare overall activity. The accuracy of the count is sufficient for our needs, as it can show a relative change over time.

CueCat Card Readers were our solution for tracking participant activity in the stairwells, re-purposed CueCat barcode scanners can offer an inexpensive and usable method of scanning ID cards, provided they are built into a device which appropriately constrains and guides the user. Our in the wild testing found that during daytime the scanners did not work as a walk-up and use system, however, despite this lack of walk-up-and-use usability, the cats can still be robust and work well once the user has first learnt the technique for a successful scan.

From our user evaluation with the interactive floor we suggest that a number of different interactions need to be available for users, in our testing different participants were motivated by different interactions

8.3 Future Work

We suggest that once the system is up and running with an initial interaction, that members of the community will create their own interactions to run on the surface. We hope that this possibility will maintain interest in the system, and that keeping the interactions fresh will promote a longer-term change in behaviour.

The recommendations made and designs evaluated could easily be put forward into production to run a full study in the building, to evaluate the effectiveness of the system to change behaviour and increase physical activity in the building.

We have designed, built and evaluated units for both counting general activity in the stairwells, as well as participants scanning their cards, and have shown these to work reliably in a short study in the MPEB. A baseline of current stair-usage which is currently being recorded will be a valuable resource in comparing the previous stair usage to that which may change in the future quantitative study.

We have been able to make recommendations on the types of interaction which could be written for the surface.

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10. Appendices

10.1 Code

All code written for the system is available from the authors website, at the following address: http://www.dbpharrison.com/projects/interactivefloor/code/.

10.2 Plan for the testing parallel scanner prototypes

Meet and greet participant, explain that the purpose of the study is to evaluate parts of a system to encourage increased physical activity in the community in the building.

Hand out information sheet, and consent forms

Mention potential recording of photographs and video (if applicable), and that these may be published on the Internet, in papers and in the dissertation. It is fine if the participant is not willing for photographs and video to be taken- ensure the appropriate consent form is signed.

Allow time for participant to read information sheet, and to fill out consent form

Collect consent form

Explain that users of the system would collect games on the interactive surface by climbing the stairs and scanning their UCL ID card in purpose built scanners on the platforms between each level of the building.

Explain that after collecting games by using the stairs they would scan their ID card when approaching the interactive surface, in order to redeem their collected games.

Explain the concept of think-aloud- ask the participant to speak through what they're doing and thinking as they're interacting with the system. Explain that the system is being tested, NOT them, and that they can't do anything wrong. Explain that any data collected will be anonymised, and they will not be identifiable from their answers, other than photographs and video if they have given consent.

Take the participant to the stairwells

Show the participant the position where the scanners are to be installed, using the platform between the 6th and 7th floors as an example. Clearly show the situation and positioning of the scanners. Explain that this study will be carried out a lab environment, but a final system would be used in the stairwells.

Show the participant the PIR counter, explain that it is used for counting activity in the stairwells, demonstrate the sensor lighting when it senses movement. If the participant doesn't bring anything up, ask if they've any thoughts on the counters. Explain that the PIR counters will continue to be used whilst the system is running.

Ask the participant to imagine that they would have the opportunity to either walk the stairs or use the lifts multiple times throughout their day.

Walk back to the lab, stop at the card access door on the sixth floor

Show the participant the existing access system in the building, showing the different feedback received when scanning a card that does or does not allow access. If they are not familiar with this system, ask them to imagine that they are.

Move through the door, and enter the lab

Half of the participants see condition 1 first, half see condition 2 first. Plinth should be physically repositioned so that participants see only the appropriate prototype.

<u>Condition 1</u>

RGB LED for feedback (Green for successful, red for failed scan)
Piezo buzzer with ascending (successful scan)/ descending (failed scan) notes
Red LED mounted adjacent to PIR sensor
Shorter card channel
NO funnel for card channel.
NO scrolling LED's near runner

<u>Condition 2</u>

Red scrolling RGB LED's, activated with PIR.
Scrolling LED's flash either green (success) or red (fail) with scan
NO separate feedback LED's
NO audible feedback
Longer card runner
Funnel on card runner

Ask the user to conduct a think aloud whilst attempting to scan their card on the unit.

If participant is from UCL and has their own ID card then give them the opportunity to use this, otherwise give them a UCL ID card with which to test the system.

Once both conditions have been tested, along with testing a standalone CueCat if necessary or requested, give the user a chance to ask questions.

Conduct a semi-structured interview, questions dependent on the information gained in the think-aloud session.

- Was the method of scanning acceptable?
- Did you notice the scrolling LEDs on condition 2? What did you think they were for?
- Did you find the funnel-design on condition 2 better or worse than the lack of a funnel on condition 1?
- Did you notice the difference in the length of the card runners? Was either runner better than the other?
- How did you find the height of the scanner?

    - Possibility to change scanner height, within marked constraints, and test.
- Did you understand the feedback given after a scan?
- Did you understand what the red and green LED's meant?
- What about the audible feedback?
- Which did you think was most useful?

<Move to prototype for testing noises>

Tell the user that you are going to play them a variety of noises, which could be used for feedback on the devices. Ask them to say weather they think the noise is suitable for feedback after a positive or negative scan, after each noise is played.

Play each noise

After the noises have been played, ask which noises they think are most appropriate for the situation, and what their preferences are.

Thank the participant for coming, let them know that they were very helpful and the feedback they gave will help influence the final design of the scanning unit. Ask if they wish to be involved in any further testing, and if they do ask when they may be free and how they could best be contacted.

10.3 Information Sheets and Consent forms

Information sheet for study into usability of scanners

Evaluation of parts of a system to encourage physical activity in a university building

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018.

We would like to invite you to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, please read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you would like more information.

This project explores the effectiveness of parts of a system to be installed in the Malet Place Engineering Building in UCL, to motivate members of the computer science department community to conduct regular physical activity.

You will be asked to interact with a number of prototypes, whilst "thinking aloud". During this, notes may be taken, and if you give specific consent, video may be recorded. The information you give will help inform the design of the system installed in the building. You will be asked to "think aloud" whilst evaluating the parts of the system, it is important to note that the system that is being evaluated, and not you.

If you give permission, photographs and video may be taken during your interaction with the system, these may be published on the Internet. You can read further information about the project at www.dbpharrison.com.

It is up to you to decide whether or not to take part. If you choose not to participate, you won't incur any penalties or lose any benefits to which you might have been entitled. However, if you do decide to take part, you will be given this information sheet to keep and asked to sign a consent form. Even after agreeing to take part, you can still withdraw at any time and without giving a reason.

All data will be collected and stored in accordance with the Data Protection Act 1998.

Informed Consent Form for Participants (with photograph/ video consent)

Motivating a Community to Exercise Through a Public Interactive Floor Surface

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018

Participant's Statement

I ………………………………………….. agree that I have

Read the information sheet and/or the project has been explained to me orally;

Had the opportunity to ask questions and discuss the study; and have

Received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.

I understand that my participation will be photographed or video recorded, and I am aware of, and consent to, any use you intend to make of the recordings after the end of the project.

I understand that the information I have submitted will be published as a report. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any publications.

I understand that I am free to withdraw from the study without penalty if I so wish, and I consent to the processing of my personal information for the purposes of this study only and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed: Date:

Investigator's Statement

I, Danny Harrison confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signed: Date:

Informed Consent Form for Participants

Motivating a Community to Exercise Through a Public Interactive Floor Surface

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018

Participant's Statement

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Had the opportunity to ask questions and discuss the study; and have

Received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.

I understand that the information I have given may be published as part of a report. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any such publications.

I understand that I am free to withdraw from the study without penalty if I so wish, and I consent to the processing of my personal information for the purposes of this study only and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed: Date:

Investigator's Statement

I, Danny Harrison confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signed: Date:

Information sheet for study of interactive surface

Design and evaluation of a system to motivate physical activity in office workers

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018.

We would like to invite you to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, please read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you would like more information.

This project explores the effectiveness of parts of a system to be installed in the Malet Place Engineering Building in UCL, to motivate members of the computer science department community to conduct regular physical activity.

This study relates to the use of scanners to record participant stair usage. We have installed three prototype-scanning devices on the stairwells between the 5^{th} and 8^{th} floors of the MPEB. You may record your stair usage with these devices and your UCL ID card. You will then be able to see how your daily stair usage compares to others by following the link: http://www.dbpharrison.com/projects/interactivefloor/stairstudy/.

There is evidence that for some people, suddenly taking up exercise can have consequences for their health. By taking part in this study you confirm that there are no health reasons why you should not participate.

If you give permission, photographs and video may be taken during your interaction with the system, these may be published on the Internet. You can read further information about the project at www.dbpharrison.com.

It is up to you to decide whether or not to take part. If you choose not to participate, you won't incur any penalties or lose any benefits to which you might have been entitled. However, if you do decide to take part, you will be given this information sheet to keep and asked to sign a consent form. Even after agreeing to take part, you can still withdraw at any time and without giving a reason.

All data will be collected and stored in accordance with the Data Protection Act 1998.

Informed Consent Form for Participants (with photograph/ video consent)

Motivating a Community to Exercise Through a Public Interactive Floor Surface

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018

Participant's Statement

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Had the opportunity to ask questions and discuss the study; and have

Received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.

I understand that by signing this form I confirm that there is no reason why I should not be involved in a study where I conduct physical activity.

I understand that my participation will be photographed or video recorded, and I am aware of, and consent to, any use you intend to make of the recordings after the end of the project.

I understand that the information I have submitted will be published as a report. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any publications.

I understand that I am free to withdraw from the study without penalty if I so wish, and I consent to the processing of my personal information for the purposes of this study only and that it will not be used for any other purpose. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed: Date:

Investigator's Statement

I, Danny Harrison confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signed: Date:

Informed Consent Form for Participants

Motivating a Community to Exercise Through a Public Interactive Floor Surface

This study has been approved by the UCL Research Ethics Committee as Project ID Number: MSc/1112/018

Participant's Statement

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Received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.

I understand that by signing this form I confirm that there is no reason why I should not be involved in a study where I conduct physical activity.

I understand that the information I have given may be published as part of a report. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any such publications.

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