AN ERGONOMIC EVALUATION OF THE POTENTIAL IMPACT OF TOUCH-SCREEN TABLETS ON OFFICE WORKERS

Katarzyna Marta Stawarz

Project report submitted in part fulfilment of the requirements for the degree of Master of Science (Human-Computer Interaction with Ergonomics) in the Faculty of Brain Sciences, University College London, 2012.

NOTE BY THE UNIVERSITY

This project report is submitted as an examination paper. No responsibility can be held by London University for the accuracy or completeness of the material therein.

ACKNOWLEDGMENTS

A number of people supported me during the project and the course in general and I would like to thank them all for interesting discussions, difficult questions, and simply being there for me.

However, a few people deserve a special mention, because without them this project would not be possible. I would like to thank in particular:

My supervisor, Professor Rachel Benedyk, for her advice, honest feedback, and kindness;

My personal tutor, Dr. Anna Cox, for insightful questions;

My managers, Amanda Talboys and Robert Frumkin, for their support and flexible working arrangements that made studying possible;

My research participants, for interesting interviews and comments that often challenged my preconceptions;

And Kornel and Rachel, for their love and support.

ABSTRACT

Since Apple introduced the iPad, the popularity of touch-screen tablets has been raising. Initially advertised as entertainment and leisure devices, tablets have now entered into the business world, leading to a need to understand possible ergonomic issues.

To explore the use of touch-screen tablets for office work and to identify ergonomic risks, eleven semi-structured interviews, nine observations and an online questionnaire were conducted. Grounded Theory was applied to identify key themes, possible risks and usage patterns, and REBA (Rapid Entire Body Assessment) was used to analyse the posture of participants using tablets.

Research findings showed that tablets are primarily used in meeting rooms as well as *outside the office*. Regardless of being personal or work-supplied devices, they are used for both work and leisure, blurring the boundary between work and home time. Due to its usage and design limitations, particularly the size and the virtual keyboard, poor posture is encouraged and the risk of developing neck, wrist, finger and back discomfort increases.

This thesis fills the gap in the existing body of knowledge as to date there have been no studies investigating the ergonomic impact of touch-screen tablets usage in an office environment. It explores possible ergonomic risks, offers a number of recommendations for minimising them, and highlights areas that require further research. It also emphasises the lack of relevant health and safety regulations and argues that such regulations may not be needed.

TABLE OF CONTENTS

1 INTRODUCTION

When Apple released the iPad in April 2010, the public opinion was divided: some fell in love with it (Director, 2010), while others found its capabilities too limited (Beaumont, 2010). Fast-forward two years, and tablets are used almost everywhere. While initially advertised as leisure and entertainment devices (Geyer & Felske, 2011), they have now entered the business world.

The entry to the business sphere means that tablets are now used not only comfortably on a sofa, but also in offices and meeting rooms, during commute, at airports and conferences; anywhere with enough space for a tablet. Unfortunately, it also means that people are now hunching in these places over their tablets in postures that make any ergonomist squirm. The design of a tablet – its size, shape, and screen – encourages poor posture, and although tablets are not the only devices that put our posture at risk (laptops and smartphones have been guilty of that for years (Berolo *et al.*, 2011; Gold *et al.*, 2012; Price & Dowell, 1998)), it adds another source of potential musculoskeletal disorders.

This thesis presents an ergonomic evaluation of touch-screen tablets as an office work device and explores related ergonomic issues. Data collected through interviews, observations and an online questionnaire provide an overview of the most common uses and associated health and safety risks. The research suggests ways of minimising those risks and highlights the lack of relevant standards and regulations.

1.1 Project aims

Since tablets in their current form have been around for less than three years, not much academic research has been conducted from an ergonomic perspective or to evaluate their suitability as an office device. While they have plenty of advantages due to their portability and technical capabilities, the size and design encourage poor posture, and a prolonged use could lead to or aggravate health issues.

With this in mind, the office context seems especially interesting, mainly because office work – and computer use in particular – has been thoroughly researched (see Brand (2008) for the review of relevant research) and regulated (e.g. BSI, 1990; HSE, 2003; ISO, 2001). However, while ergonomic issues and risks related to "traditional" computer work (i.e. with desktop computers and laptops) are well known (e.g. Wahlström, 2005), tablets are still a rather unexplored area. Therefore, the aim of this thesis is to answer the following research question:

> *How and why do people use touch-screen tablets for office work and what potential ergonomic issues could arise as a result?*

The answer will help to better understand the context and patterns of use. It could also lead to a creation of guidelines that could be adopted by companies to minimise

identified risks caused by tablets. At the time of writing, such guidelines are not available.

1.2 Terminology

Unless stated otherwise, for the purposes of this thesis, touch-screen tablets are referred to simply as "tablets".

"Office work" is defined as a screen-based work conducted primarily in an office environment that could also be carried out by some office workers away from the office.

1.3 Structure of the thesis

The thesis starts with a literature review (Chapter 2) that presents an overview of office ergonomics issues, mainly focusing on musculoskeletal disorders. Then, portable display screen equipment is described with a special focus on laptops and smartphones. The chapter concludes with a brief history of tablets, current usage trends, overview of relevant research and possible ergonomic risks.

Chapters 3-8 focus on studies conducted as a part of this research and their findings. Chapter 3 describes and justifies human factors research methods used in this study (interviews, observations, and an online questionnaire), and discusses considered alternative methods. Chapter 4 outlines the preliminary research conducted to better understand the problem space and aid the design of the main studies. Chapter 5 describes how interviews with tablet owners were planned, conducted, and analysed. Chapter 6 covers observations of tablet users, postural analysis, and risk assessment. Keyboard and typing analysis are also described in detail. Chapter 7 describes the online questionnaire distributed to tablet users. Chapter 8 brings together results from all these studies, presenting the common usage trends and describing in detail identified ergonomic issues.

Findings are then discussed in Chapter 9 in relation to the literature and relevant research, and presents recommendations for minimising identified risks. Limitations of the study are also considered.

Chapter 10 presents conclusions and highlights areas requiring further research.

2 LITERATURE REVIEW

This chapter presents an overview of relevant literature and regulations. It starts with office ergonomics to provide context and outline relevant risk factors. Display screen equipment is described next in more detail, including portable devices. Then, touch-screen tablets are introduced: their history, current usage trends, and relevant research and regulations. The chapter concludes with an overview of possible risks related to tablet use in an office environment and highlights research needs.

2.1 Office ergonomics

Office work is characterised by the use of computers (European Agency for Safety and Health at Work, n.d.), and is regulated by a set of standards. For example, ISO 9241 provides information about the design of office workstations and equipment (ISO, 2001), while BS 3044:1990 focuses on furniture, equipment and environmental factors (BSI, 1990). In addition, as employers are legally obliged to protect health and safety of their staff and minimise risks of work related upper limb disorders (HSE, 2002), several regulations are available to provide guidance, including: Health and Safety at Work etc Act (The Stationery Office, 1974), Workplace (Health, Safety and Welfare) Regulations (HSE, 1992), or Management of Health and Safety at Work Regulations (HSE, 2000). Screen-based office work is regulated by the Health and Safety (Display Screen Equipment) Regulations (HSE, 2003).

As discussed later, none of these documents sufficiently cover tablets, even though they focus on the most common office risks: upper limb disorders, poor posture, keyboard use, and environmental factors.

2.1.1 Work-related upper limb disorders

The term "work-related upper limb disorders" (WRULDs) refers to a set of conditions affecting hands, arms, shoulders, and the neck, that are characteristic of people whose work requires an intense use of hands (Pheasant & Haslegrave, 2006).

Office workers are at risk of developing WRULDs due to the sedentary nature of their work and working postures, workstation setup, repetition of actions, and duration of exposure (HSE, 2002; HSE, 2003; Marcus *et al.*, 2002; Punnett & Webman, 2004; Sillanpää *et al.*, 2003; Straker *et al.*, 2009; Szeto *et al.*, 2002). Awkward[1] or static postures held in a fixed position for longer periods can increase the risk of injury, as they require more muscular effort and cause static loading of muscles and tendons (HSE, 2002; Stock, 1991). Repetitive work requires the use of the same muscle groups and may not allow enough time for recovery, leading to

[1] Awkward posture is characterised by body parts deviated from their neutral position defined as trunk and head upright, arms by the side of the body, forearms hanging straight or at the right angle to the upper arm, and hand in the handshake position (HSE, 2002; ISO, 2007a).

fatigue (HSE, 2002). Non-work activities (e.g. sport or hobbies) or previous injuries can have additional impact (HSE 2003).

Typing in particular can be seen as a risky activity (Gerr *et al.*, 2004). A keyboard fixes the posture and the working position can cause muscle tension (Lundervold, 1958). The design of a keyboard, especially its travel distance, affects muscle activity, wrist posture and wrist extension during typing (Hughes *et al.*, 2011). There are connections between using keyboards with shorter travel distance and perceived fatigue (*op. cit.*), and a greater distance between the activation force and the end of key travel may reduce force exertion and muscle activity (Lee *et al.*, 2009; Radwin & Jeng, 1997).

This may be an issue with tablets, as virtual keyboards do not have mechanical keys and therefore have a zero travel distance. Irwin and Sesto (2012) evaluated the force required to operate a kiosk-style touch-screen and found that the average force exerted by participants was 6.2 times required activation force of 0.98N. Moreover, an evaluation of a touch-screen in a desktop computer revealed that touch-screen users reported higher levels of discomfort than physical keyboard users (Shin & Zhu, 2011). This suggests that virtual keyboards may not be optimal for typing and steps should be taken to reduce risks. For example, tablet stands with an external keyboard (Figure 2.1, left) or a screen-top keyboard that adds haptic feedback (Figure 2.1, right) could reduce finger fatigue.

Figure 2.1. Tablet stand with an external keyboard (left) and a screen top keyboard (right)

2.1.2 Environmental factors

Environmental factors relevant to office work include space, temperature, heating and ventilation, and lighting (HSE, 2003). Glare and flickering lights are most relevant to computer work and apply to portable devices – they can distract workers and encourage them to assume poor posture in order to see their screen clearly (HSE, 2002), and glare can lead to visual fatigue and stress (HSE, 2003). Both can be reduced by shielding or repositioning sources of light, rearranging work surfaces, or modifying the colour or reflectance of the work environment; anti-glare filters are also recommended (*op. cit.*). However, as tablets can be used in various

environments and only users themselves (or device designers) can take steps to reduce the glare and reflections, these precautions may not be relevant.

2.2 Display screen equipment

The UK Health and Safety Executive defines display screen equipment (DSE) as *"any alphanumeric or graphic display screen, regardless of the display process involved"* (HSE, 2003, p. 3). Such equipment can be a source of musculoskeletal discomfort, fatigue, stress, eye discomfort or visual fatigue (Bergqvist, 1989; Bergqvist *et al.*, 1995; Hagberg & Sundelin, 1986; HSE, 2003).

While the size of a display screen is not specified, it is stressed that it *"needs to be large enough for the user to do their work comfortably"* (p. 38). The screen also needs to be adjustable: users should be able to change the tilt, height, brightness and contrast. A keyboard *"should allow workers to locate and activate keys quickly, accurately and without discomfort"* (p. 39). When using DSE, a viewing angle and the height of the screen have a significant impact on the neck muscle activity and posture, particularly head tilt, neck angle and trunk rounding, and can lead to fatigue and discomfort (Seghers *et al.*, 2003; Sommerich *et al.*, 2001).

2.2.1 Portable devices

Portable computers are increasingly used by office workers, frequently away from the office (European Commission, 2010). While mobile work and the use of portable DSE allow for greater flexibility and autonomy, help to strengthen family bonds, and tend to increase effectiveness (Hill *et al.*, 1996), there are drawbacks.

Portable DSE are used for both work and personal tasks (European Commission, 2010), and the line between work and leisure time becomes blurred. Mobile workers are reported to work 2 hours per week longer than those working from home and 4 hours per week longer than those working from a regular office (Hill *et al.*, 2003), and since portable devices are associated with an increased risk of musculoskeletal disorders (Heasman *et al.*, 2000), such prolonged use can have negative consequences. The design of portable DSE limits the range of comfortable postures, mainly due to the size of the device and its screen, the fact that the screen and the keyboard cannot be separated, and that portable devices are used for work in situations that encourage poor posture (European Commission, 2010).

However, it must be noted that both Heasman *et al.* and European Commission published their reports before the iPad was released and therefore they do not take into account touch-screen tablets. Extending the work to cover tablets and draw conclusions requires caution. Nevertheless, as discussed later, many highlighted ergonomic issues are relevant.

2.2.2 Laptops

Laptops were originally designed as portable devices for a mobile workforce. However, because of their flexibility and portability they have been adopted by office workers (Price & Dowell, 1998) who seem to ignore their limitations. Because laptops are meant to be portable, they are small and compact. Their screen and keyboard cannot be separated or adjusted independently, which limits the number of possible comfortable postures and can lead to discomfort; neck, back, and wrists in particular are at risk (Gold *et al.*, 2012; Price & Dowell, 1998; Straker *et al.*, 1997; Villanueva *et al.*, 1998).

Laptops can be used both in and outside of an office environment, and the office use is regulated. For example, the DSE Regulations (HSE, 2003) cover laptops in Appendix 3: Work with portable DSE. To minimise ergonomic risks, users are encouraged to use docking stations that allow connection of full size keyboards and monitors on a desk, which changes the portable computer into a desktop machine. The regulations also suggest buying the lightest and smallest device possible to make transportation easier, selecting a model with detachable or height-adjustable screen and tilt-adjustable keyboard, ensuring the device has friction pads underneath to prevent sliding, and selecting a model with a long battery life to avoid carrying chargers. Unfortunately, suggestions in most part are rather impractical given the current trend of the "unibody" laptops that use a single piece of metal for the whole device[2], and therefore have reduced adjustability.

2.2.3 Smartphones

Ofcom (2012) defines a smartphone as a device *"capable of a range of functions including playing audio and visual media, providing voice and data telecommunications, allowing access to emails, downloading files and applications, viewing websites and surfing the internet*" (p. 222). No wonder then that its capabilities allow it to be used as a work device, and 51% of users (N=654) use their smartphones to access email (*op. cit.*) and stay connected with work. Mobile Workforce Report (iPass, 2011) shows that 95% (N=2,300) of "mobile workers" (i.e. people who use mobile devices for work) use smartphones and 58% of companies (N=1,100) provide smartphones for their employees.

Falaki *et al.* (2010) conducted a study to understand smartphone usage trends, although they did not distinguish between work and personal use. The results were striking: while some users interacted with their smartphones for about 30 minutes per day, heavy users did so for 500 minutes – about eight hours per day. On average, individual users were interacting with their phones 10 to 200 times per day. Communication tools (e.g. email, text messages, instant messaging) accounted for 44% and 49% of all usage for Android and Windows Mobile users respectively (N=255), which confirms Ofcom's findings. Unfortunately, Falaki and colleagues

[2] http://smallbusiness.chron.com/unibody-laptop-28328.html

did not cover iPhone and Blackberry devices that are currently the most popular company phones (iPass, 2011), although usage trends are most likely to be similar.

The fact that people use smartphones for so long is not surprising, although it is still worrying. Berolo *et al.* (2011) found out that 84% of study participants (N=140) reported some sort of pain as a result of using a smartphone, mainly in the base of the thumb, hands, elbows, shoulders, neck and upper back. Since smartphones are often used in addition to laptops, desktop computers and tablets (Karlson *et al.*, 2009), the risk of developing musculoskeletal disorders increases as the discomfort caused by different devices in both work and non-work setting accumulates (Ciccarelli *et al.*, 2011; HSE, 2002).

There are no official standards and guidelines regulating the smartphone use at work. While companies often issue their own policies, they tend to focus on privacy, confidentiality and personal use (Thomas & LaRosa, 2011), rather than health and safety.

2.3 Touch-screen tablets

Apple iPad, released in April 2010, *de facto* defined what a touch-screen tablet is and how it should behave: with only a few exceptions, almost all models released afterwards have replicated the design, functionality and interactions. The definition of a tablet used in this thesis is primarily based on an iPad: it is a flat tablet computer with a virtual keyboard that can be operated by touch gestures (although it is possible to connect external keyboards or other devices); it is small, light, and portable (see Figure 2.2).

Figure 2.2. Touch-screen tablets: Apple iPad (top left), Blackberry Playbook (top right), and Samsung Galaxy Tab 10.1 (bottom)

A tablet's functionality is centred on media and information consumption (Foster, 2012). It offers the portability and responsiveness of a smartphone (i.e. small, light, starts up immediately, long battery life) and capabilities of a laptop (e.g. word processing); it seems to be a perfect note-taking device as it is no bigger or heavier than a paper notebook. However, it has its limitations. It is too big to be carried around everywhere like a smartphone and, unlike a laptop, working with more than one application or a document at a time is not possible (Beaumont, 2010).

Currently, several tablets are available, and the most popular models, based on the OPA report (2012), are presented in Table 2.1. All are similar in terms of functionality, design, and technical specification, although Kindle and Nook are primarily e-book readers with tablet capabilities.

Table 2.1 Tablet models comparison – dimensions

Tablet	Height	Width	Depth	Weight	Display (diagonal)
Apple iPad [3] (3rd generation)	9.50 inches (241.2 mm)	7.31 inches (185.7 mm)	0.37 inches (9.4 mm)	1.44 pounds (652 g) or 1.46 pounds (662 g)	9.7-inch
Kindle Fire [4]	7.5 inches (190 mm)	4.7 inches (120 mm)	0.45 inches (11.4 mm)	1.04 pounds (413 g)	7-inch
Samsung Galaxy Tab 10.1 [5]	6.90 inches (175.3 mm)	10.1 inches (256.7 mm)	0.34 inches (8.6 mm)	1.25 pounds (565 g)	10.1-inch
Barnes & Noble Nook [6]	8.1 inches (206 mm)	5.0 inches (127 mm)	0.48 inches (12.2 mm)	0.875 pounds (397 g)	7-inch
Blackberry Playbook [7]	5.1 inches (130 mm)	7.6 inches (194 mm)	0.40 inches (10 mm)	0.9 pounds (425 g)	7-inch

2.3.1 History

Tablets have been around for decades, but only in recent years they have entered the consumer market. It took over 50 years to move from the initial concept to reach the current status, as advances in supporting technologies – mobile internet, smaller and longer lasting batteries, minimisation of components – were needed first.

The first device that recognised gestures was the RAND tablet developed in the 1960s (Myers, 1998) and throughout the 1970s gesture-recognition was used commercially in CAD (Computer Aided Design) systems (*op. cit.*). However, those were not touch gestures – the devices worked with pen-like controllers. Touch-screen technology was first developed and patented in the early 1970s (Atkinson, 2008) and the first tablet that combined the pen interface and a touch-screen was built in 1987 (*op. cit.*). Touch-screens were being developed and studied throughout the 1980s, and in the early 1990s Apple Newton, the first touch-screen PDA[8]

[3] http://www.apple.com/ipad/specs/
[4] http://www.amazon.com/gp/product/B0051VVOB2
[5] http://www.samsung.com/global/microsite/galaxytab/10.1/spec.html
[6] http://www.barnesandnoble.com/p/nook-tablet-barnes-noble/1104687969
[7] http://us.blackberry.com/playbook-tablet/tablet-specs.html
[8] PDA is a personal information manager with the size and functionality of a smartphone that cannot make phone calls.

(Personal Digital Assistant), was introduced to the consumer market (Myers, 1998; Viken, 2009).

In 2001 Sony released the Pen Tablet PC. Unfortunately, due to low sales it was discontinued a year later (Atkinson, 2008). It seemed that there was no market for tablet computers or touch-screens until Apple introduced the iPhone in 2007. The idea of a device with *"a glass* [and] *a multi-touch display you could type on"* initially referred to a tablet (Mobile Review, 2010) and Apple worked on a prototype around 2002, but it had to be shelved as touch-screens were too expensive at the time (Arthur, 2012). However, since the technology could also be used for a smartphone, the iPhone was born a few years later (Mobile Review, 2010). It has been a huge success (as of June 2012, Apple has sold 250 million iPhones (Vu, 2012)) and familiarised the consumer market with the concept of a touch-screen device.

When the iPad arrived soon after, consumers were already used to portable personal computing (laptops) and Internet access on the go (smartphones). The tablet positioned itself between these two types of devices.

2.3.2 Current trends

Currently there are an estimated 74 million tablet users in the US alone (OPA, 2012) and in the UK one in ten (11%) adults own a tablet computer (Ofcom, 2012). Apple's three generations of iPads together account for 52% of US market share (OPA, 2012).

According to the OPA's report, tablets are used daily by 74% of their research respondents (N=724), usually in the evenings. The majority of people use them at home (67%, N=1,592), although as many as 15% use them at work or school. Tablets are mainly used for accessing content (online and documents) and checking email. A third of research participants reported reading newspapers (32%, N=710), a quarter accessing reference materials (26%) and financial information (25%), and getting stock market and business information (18%), which suggests that tablets are used for some aspects of work. The findings are supported by the Ofcom data.

Forty-seven percent of people said an iPad was their primary computer (Business Insider, 2012), which is not surprising given that the Ofcom report shows that tablet owners tend to have a strong relationship with their devices – 34% respondents (N=500) agreed that they *"couldn't live without my tablet computer"*.

2.3.3 Relevant research

While there are plenty of articles describing tablets as an office work tool, e.g. Foster (2012), Geyer & Felske (2011), Nugyen & Chaparro (2011), and market research focusing on business use is available (e.g. Gartner, 2011 or iPass, 2011), not much academic research has been conducted to date, especially in the office setting.

The study by Hess and Jung (2012) seems to be the only one currently available that evaluates the use of iPads in an office environment. To investigate suitability of tablets as business devices (i.e. their benefits, drawbacks, and influence on productivity), they provided pre-configured iPads to 12 employees from their company. Participants were encouraged to use tablets in their daily work and were interviewed later. Identified usage benefits included: mobility, assistance with note taking, ability to respond to huge amounts of emails faster and to work in between meetings or other tasks. Participants also liked the discreet nature of the device, as it did not form a visual barrier between people during meetings and took only as much space as a paper notepad. The study uncovered problems as well: lack of proper integration with company infrastructure, lack of haptic feedback during typing, glare and reflections on the screen, and various usability problems related to software and functionality. Unfortunately, since the study focused on productivity, it did not cover other ergonomic factors such as posture, workstation design or environment, nor presented suggestions for dealing with identified problems.

Several health risk warnings associated with tablets were published since the launch of the iPad, but they were not based on academic research. The device was reported to encourage poor posture and cause repetitive strain injury (RSI), neck problems, and eye strain (Adams, 2012; Jafri, 2010; McCauley, 2011; Tessler, 2012). The lack of research backing is not surprising though: at the time of writing, only Young *et al.* (2012) have evaluated the posture of tablet users. They analysed the head and neck flexion of 15 users who used a tablet in four configurations: on the lap with and without a cover used to prop it at an angle, on a table with a cover, and on a table in the landscape mode for watching movies. Their results showed that the head and neck flexion was 15 to 25 degrees beyond the "neutral posture"[9] for all configurations except the movie watching condition where the tablet was almost vertical and on the same height as a user's face. They suggest that the flexion could be reduced by avoiding the use of a tablet at lap level and using the cover to allow optimal viewing angle. It must be noted though, that tasks used during the study reflected the leisure use: Internet browsing, playing games, reading and responding to emails, and watching movies. These activities are predominantly visual and therefore the neck angle relates to visual requirements, whereas the office usage might involve more extensive keyboard use, which could lead to more constrained postures of the hands and arms. In addition, the suggested avoidance of the lap-level location seems difficult to apply as tablets are used away from the office where the lap is often the only surface.

To evaluate interactions with tablets and their impact on musculoskeletal systems, Lozano, Jindrich, and Kahol (2011) focused on eight multi-touch gestures: rotating to the right and left, zooming in and out, panning with the index finger in four directions. Their experiment showed that these interactions affect the entire shoulder system and gestures involving two fingers can increase muscle activation levels, which may lead to developing musculoskeletal disorders. However, this study

[9] Head tilt: 7.7° above horizontal, head/neck: 43.7°– as defined by Ankrum & Nemeth (2000).

focused on occasional gesture input, which, in terms of ergonomic risks, differs from the direct text input and findings cannot be related to typing.

While these studies evaluate posture to some extent, they do not cover all relevant body areas. Moreover, they do not focus on office work *per se*, but on a wider tablet use. Therefore, an investigation of a full body posture, ideally supported by postural analysis, and a better understanding of how office workers use tablets is needed.

2.3.4 Standards and regulations

There are no standards or regulations explicitly focusing on touch-screen tablets. ISO-9241 (ISO, 2001) covers only drawing tablets that can be used with a stylus and do not have a touch-screen. There is a section focusing on touch-sensitive screens (ISO, 2007a), although it does not apply to portable devices. Therefore, only the DSE Regulations (HSE, 2003) could be applied to tablets as their definition of DSE covers displays used in *"flat-panel screens, touchscreens and other emerging technologies"* (p. 3). As the document already applies to portable devices *("laptop and handheld computers, personal digital assistant devices and some portable communication devices"* (p. 8) in prolonged use, it should be relevant to tablets as well. However, due to lack of research and understanding of tablet-specific risks, the regulations are too general. While the information about the environment factors (lighting, glare, noise, heat) and the interface between a computer and a user can be directly related to tablets, the information about the workstation, displays, keyboards and furniture must be more specific to be considered useful.

Workstation guidelines are limited to a desk and the portable DSE section focuses mainly on laptops and notebooks. The publication recognises that some paragraphs cannot be complied with by portable DSE and acknowledges the design compromising the use of portable devices can lead to health and safety issues. Therefore, avoiding prolonged use and using docking stations are suggested, which are only partly relevant to tablets. While tablet docking stations and covers supporting typing are available, it is not clear what setup is the best and should be recommended. There is a danger that badly set up tablet stands or covers used for typing could still lead to poor posture caused by a small screen and a virtual keyboard. In addition, such measures can reduce the portability, and – as a result – the desirability and usefulness of the device.

Moreover, the DSE Regulations cannot be applied to a virtual keyboard, as the document states explicitly that the keyboard *"shall be (...) separate from the screen"* (p. 33), which, in case of tablets, is impossible by design. In addition, *"the symbols on the keys shall be adequately contrasted and legible from the design working position"* (p. 34), but it is not clear what is meant by the "working position", how it applies to tablets, and whether such position could be specified at all.

The touch-screen itself is also not sufficiently covered. While Appendix 4 of the DSE Regulations focuses on touch-screens, those are of a different kind: built into a

display (e.g. ticket kiosks) or stand-alone keyboard-like devices (e.g. touch-screen telephone switchboards); portable touch-screens are not described. Therefore, the context of use, functionality and technology are different and cannot be related to tablets, further reducing the relevancy of the publication.

2.4 Summary

Tablets are becoming increasingly popular as a work device and the need to better understand related ergonomic issues arises. While the office environment is a well-regulated area in terms of health and safety, existing standards and regulations do not apply to tablets. It could be argued that the DSE Regulations (HSE, 2003) do apply, but the information is too general to be of practical use: it does not specify what docking stations or stands are required to ensure a good posture is maintained and it does not cover virtual keyboards. In addition, while it does cover touch-screens as input devices, the information does not apply to portable devices and current technologies.

When considering tablets as office devices, a number of currently unaddressed questions arise. The overview of ergonomic issues relevant to the office, especially related to the use of portable DSE, shows that the use of tablets could lead to musculoskeletal disorders; existing tablet research, albeit sparse, already confirms that this may be the case. However, the degree of risks is unknown and needs to be assessed. In addition, an understanding of the context of use, motivations and reasons of adapting a *de facto* leisure device for office work are needed, especially in focusing on long-term impact, WRULDs, changes in the work practice, and the relevance of existing standards and regulations.

3 RESEARCH METHODS

This chapter describes methods used during the study to investigate how people use tablets in an office environment for work purposes, and provides a justification for each method. It then concludes with an overview of alternative research methods considered and explains why they were not selected.

3.1 Selecting methods

Research on ergonomic issues caused by tablets or their impact on office work is sparse. Therefore, to better understand the problem space and supplement limited information, an exploratory study combining interviews, observations and an online questionnaire was designed. Triangulating research methods was important to ensure that findings are supported by data from diverse sources for increased accuracy and reliability (Richardson, 1996). As MacLeod and colleagues (2000) noted, the triangulation *"give*[s] *substance and rigour to the results of ergonomic investigations"*, especially when research is done *"*[under] *time constraints and using only a few test subjects"* (p. 245).

Interviews, observations, and an online questionnaire were selected for this study as they supplement each other. This section describes each method in more detail.

3.1.1 Interviews

As investigating the reasons for using tablets and answering a series of "why?" questions were the core part of the study, interviews were seen as the best approach. According to Oppenheim (1992), the purpose of an exploratory interview is *"to develop ideas and research hypotheses"* (p. 67); in other words: to explore the topic and build understanding. Interviews help to gather detailed information and – especially with a semi-structured approach – identify themes that were not thought of when planning the questions (Cairns & Cox, 2008).

While valuable, interviews still have their weaknesses: the outcome depends on the questions, selected user sample, and the interviewer's experience and their personal biases. In addition, disadvantages of any self-reporting technique apply as well: participants may not remember everything and responses may be incomplete (Rieman, 1996), making the findings less reliable. Therefore, interviews should be supported by other methods.

3.1.2 Observations

By observing users in their natural setting, researchers are able to better understand the behaviour, tasks, goals and the context. Observations help to identify trends and habits users are not aware of, and provide rich data on how people interact with the environment (Sharp *et al.*, 2009).

However, there are a few drawbacks. Observations require time and resources, and often the outcome depends on the location (laboratory vs. "in the wild" studies). The act of the observation itself can have an impact on the behaviour of research participants, especially when the observer in any way interferes with the environment (Oborne, 1995; Stanton *et al*., 2005). These disadvantages can be offset by carefully planning the observations in advance and determining what activities should be observed, ensuring the observed behaviours are representative (Stanton *et al*., 2005), and validating the findings with data gathered using other methods.

In this study, observations were conducted primarily for the purpose of postural analysis i.e. the evaluation of the impact of the workplace design and tools on the worker's posture and the risk assessment related to musculoskeletal disorders (Stanton *et al.*, 2005), and therefore time and resources were not an issue.

3.1.3 Online questionnaire

Questionnaires can be used to validate findings from exploratory studies. They are cheaper and provide access to a large number of participants (Cairns & Cox, 2008), often spread across a larger area, and therefore ideal to reach participants from different industries owning different tablet models. However, they need to be designed with care to ensure they ask the right questions and the results are accurate, relevant, and can be generalised for the wider population (Kuniavsky, 2003; Oppenheim, 1992). Designing a questionnaire after a thorough literature review and preliminary research, and pilot testing it can help to reduce biases and overcome these issues (Oppenheim, 1992).

The target audience can be a problem: with online questionnaires it is difficult to control who the respondents are (Sharp *et al.*, 2009) and qualifying questions are needed to ensure the right people are submitting the answers; distribution channels for the questionnaire should be selected with care.

3.2 Other methods considered

Contextual inquiry and diary studies were considered during the planning stage of the study, but due to practical constraints they had to be rejected. However, they may be appropriate for follow-up studies to investigate specific issues uncovered in this study.

3.2.1 Contextual inquiry

Contextual inquiry is a technique that helps to understand users and their behaviour by observing them in their environment and adopting a master/apprentice model to learn from them about their tasks (Beyer & Holtzblatt, 1998). This approach lets the researcher uncover behaviours that would not otherwise be mentioned during the interviews, and learn more about habits and motivations.

To be effective, however, contextual inquiry requires time, and longer sessions with users would not be possible during this study. As the literature review showed, tablets are often used on the move or at meetings, and therefore following research participants would be problematic and could make them feel self-conscious. Moreover, in case of senior management, following them to meetings could expose the researcher to confidential company information, making it necessary to deal with various Non-Disclosure Agreements, which would increase administration and planning workload.

3.2.2 Diary studies

Diary studies are a great source of information about participants' daily activities: how frequently they use various tools and how much time they spend on them (Rieman, 1993); in general, they help to understand users' behaviour and identify common patterns (Kuniavsky, 2003). However, to be effective, they must be maintained for a longer period of time and participants need to be regularly encouraged to prevent resignations throughout the study (*op. cit.*).

While diary studies could provide rich data about tablet use, in particular about tasks, frequency and duration of use, observations and interviews would still have to be conducted to gather information about the posture and environment. The additional workload they would add to the study did not justify the inclusion of yet another research method. In addition, encouraging senior staff to participate in a study for a couple of weeks could be challenging, as often scheduling a short interview session was difficult and required a fair amount of planning.

4 PRELIMINARY RESEARCH

This chapter describes steps that were taken to better understand the problem space before designing and conducting research. It starts with a description of a mind mapping exercise and then moves on to preliminary research that fed into the Hexagon-Spindle Matrix (Benedyk *et al.*, 2009). The Matrix was used to identify questions that would be explored further during the interviews with tablet users.

4.1 Mind mapping

Mind mapping is a technique that allows taking notes in a quick and efficient way (Buzan, 1974), and can be used to explore the problem space to identify characteristics and issues related to a selected topic (Buzan, 2006).

Based on the researcher's knowledge and personal experience with an iPad, the map exploring potential reasons to use a tablet in an office environment, information accessed that way, office equipment, purchasing, commuting, and related issues was created. Next, a separate mind map was drawn focusing purely on potential usage issues (see Figure 4.1).

Figure 4.1 Mind map: iPad usage issues

Both maps helped to identify possible problematic areas that would need to be investigated further during research. Areas included:

- Ergonomics, e.g. posture, design of the device
- Security, e.g. "shoulder surfing"
- People, e.g. device as a status symbol, trust issues, envy
- Usage, e.g. typing (small keys), reading (glare)
- Workspace, e.g. desk setup, lighting
- Infrastructure, e.g. Internet access
- Manufacturers' policies, e.g. lack of compatibility with bespoke software

Next, these areas were validated during informal interviews with tablet users.

4.2 Informal interviews

To validate areas identified during the mind mapping exercise, informal discussions and observations were conducted. The researcher spoke to incidental contacts (four people) about their tablets (iPads only), context of use and any problems they encountered. They all mentioned typing as the main issue, but otherwise were happy with the device. However, none of them used the tablet specifically for work.

Therefore, a short informal interview was later conducted with a hairdresser who used an iPad only for work. She had bought her tablet as *"a Filofax replacement"* and was using it to manage appointments and monitor her work bank account. Even though she found it easy to use, small and compact, she was not entirely satisfied with the tablet: the keyboard was *"a bit annoying, especially* [when] *switching between letters and numbers"*.

4.3 Hexagon-Spindle analysis

Insights from preliminary interviews were used to create a Hexagon-Spindle table. The Hexagon-Spindle Model is a framework that can be used to identify possible ergonomic issues within the broad context of use (Benedyk *et al.*, 2009). It helps to evaluate how a user interacts with technology at all levels: their workstation, the workplace, and the wider work setting; it also includes any external factors that may have impact on the task and takes into account organisational, contextual and personal factors. The Spindle part of the framework allows the analysis of change over time or comparison of tasks to identify different factors between them (*op. cit.*). The outcome of the analysis is an Action Table specifying steps that need to be taken to reduce or eliminate identified ergonomic issues.

At this stage of the study the Hexagon-Spindle Model was used to help with the analysis of preliminary research data and to identify areas that would be explored later; hence the lack of an Action Table. The use of the Model as a starting point helped to ensure that a holistic approach was taken and all aspects of workplace ergonomics were considered when planning the data gathering stage. Instead of an Action Table, the result of the Hexagon-Spindle analysis was a set of questions that informed the design of the interview plan (see Table 4.1). A matrix for laptops from Benedyk & Hadjisimou (2008) was used as an inspiration, as some laptop issues could be relevant for tablets.

Table 4.1. Hexagon analysis table for the use of tablets work tasks in an office environment

	Organisational sector		**Contextual sector**		**Personal sector**	
Tablet	**Task environment, management sector**	**Task environment, infrastructure sector**	**Task design factors**	**Product design (tools & materials) factors**	**User individual factors**	**Social and group factors**
External factors	Are there any relevant industry standards regulating tablet use?	How easy/difficult is it to integrate tablets into current IT systems?	Does office etiquette matter/exist?	Do latest trends and popularity of tablets matter?	Are seniority levels important? Does a job title/function matter?	What are industry expectations towards adoption of the latest technology?
Work setting (the company)	Is budget an issue? Do relevant internal policies exist?	Is the relevant infrastructure in place? Technical support?	Is work / office culture relevant? Does it have an impact?	Are internal departments able to accommodate new devices?	What are the attitudes of office workers towards using a tablet?	What are the attitudes towards those who use tablets?
Workplace (the office / desk space)	Does the room size and layout matter?	What about accessibility? How important is lighting and the room temperature?	What is the context of use? What are the main tasks?	How do tablets fit into the office environment?	How important is the size of the workspace in relation to other workers?	What are the attitudes of colleagues, bosses, and clients towards those using a tablet?
Workstation (tablet use)	Is it possible to adjust the workstation? Do people use external keyboards or other aids?	How important is the workstation level lightning? Can everyone access work files and shared resources?	How often, for how long, where, and how do people use tablets for work?	Is tablet's design appropriate for the task?	What is the posture? Are there any issues e.g. with neck or wrists?	Do tablets get in the way when interacting with other people? Do people share information from the screen? Any security issues related to viewing what's on the screen?
Interaction						
User	Who uses tablets for office work and what are their characteristics? How tall are they? Do they have any existing health conditions that could have impact on the tablet use? Are there any age/gender differences in use?					

Questions from Table 4.1 were later translated into interview themes that included: main tasks, context of use, frequency and duration of use, office infrastructure, posture, relationship with other people, etc. Questions were not used literally, but only highlighted what kinds of information would be useful for the ergonomic evaluation to ensure all aspects were considered.

The Hexagon-Spindle Matrix was revisited after the research was completed and filled in with real data, resulting in an Action Table (see Chapter 8.3) outlining the key ergonomic issues and ways of dealing with the risks.

4.4 Summary

Preliminary research and the Hexagon-Spindle analysis identified areas that would be explored during the study, including:

- How and on what workstations do people use tablets for work?
- Is there a difference in how tablets are perceived in an office environment? As a work tool provided by the employer and therefore expected to be used or just an additional, personal device?
- What infrastructure and policies related to tablet use are in place?
- What are the main posture issues?

These questions were used as a basis for research design and were further explored with real users during interviews, observations and via an online questionnaire.

5 INTERVIEWS

This chapter presents how interviews were conducted and analysed. Findings are presented and discussed next, and the chapter concludes with an overview of the main issues that would be explored further during observations and with an online questionnaire.

5.1 Participants

Eight men and three women aged 25 to 50 years old were recruited from two groups: employees from the researcher's office and contacts suggested by peers. This helped to ensure that participants had different background and varying levels of experience with tablets. Only people working in an office and using tablets specifically for work were interviewed. Table 5.1 below shows more details about their occupation and tablets they were using at the time.

Table 5.1. List of interview participants

Participant ID	Occupation	Tablet model	Internet access	Tablet status	Experience with the tablet
P1	IT Director	iPad	3G/WiFi	Work device	6 months
P2	Publishing Director	iPad	3G/WiFi	Work device	14 months
P3	User Interface Designer/Manager	iPad	3G/WiFi	Work device	8 months
P4	Strategy Director	iPad	3G/WiFi	Work device	12 months
P5	Manager, Learning Technology	iPad	WiFi only	Personal device	12 months
P6	Learning Technologist	iPad	WiFi only	Work device	9 months
P7	PhD Student	iPad2	WiFi only	Work device	3 months
P8	Digital Technology Director	iPad	3G/WiFi	Work device	6 months
P9	Consultant/Business Analyst	iPad	3G/WiFi	Personal device	13 months
P10	Manager/Software Development	iPad	3G/WiFi	Personal device	12 months
P11	Freelance User Experience Designer	iPad2	WiFi only	Personal device	4 months

5.2 Research

Following the preliminary research, eleven semi-structured interviews were conducted based on a general interview outline (see Appendix B3). The interviews explored the use of tablets in an office environment, including the context of use, main tasks, external devices used, pains and discomfort, etc. They took place at the workstations of eight participants (their desks or offices) and in meeting rooms (two interviewees). P11 was interviewed in a café, as it was not possible to arrange a meeting in an office.

Interviews lasted for approximately 45 minutes each and ended with short observation sessions (described in more detail in Chapter 6). They were recorded and transcribed verbatim. Additional notes from each interview were analysed and fed into the interview themes for following sessions, with data driving what would be explored with the next participant.

5.3 Data analysis

As this study aimed to explore a new area and no initial hypothesis was formulated, Grounded Theory was applied to understand the topic. Glaser and Strauss (1998) define it as *"a general methodology for developing theory that is grounded in data systematically gathered and analyzed"* (p. 158).

To code the transcripts, the analysis process was followed as described by Charmaz (2006). First, *initial coding* was applied on the printed interview transcripts after each interview: codes describing segments of data were added and key phrases related to ergonomic issues were highlighted. It resulted in a list of top-level themes that were re-examined during following interviews to test emerging theories.

After all interviews were conducted, *line-by-line coding* was applied to examine the data in more detail. Three types of codes were used: general codes summarising each line; comments, ideas, and verbatim quotes; and tablet characteristics. The next step was *focused coding* that resulted in combining detailed codes and creating broader categories relevant to the objectives of the study.

All unique codes, comments and quotes were then transferred to colour-coded post-it notes to allow easier manipulation and further grouping. Affinity mapping (Beyer & Holtzblatt, 1998) was used to categorise the codes and build an understanding of the data. With no predefined categories in mind, individual codes were posted on the wall suggesting groups and while new ones were added, the groups grew organically, revealing common themes (see Figure 5.1). The final result were six main categories described in the next section.

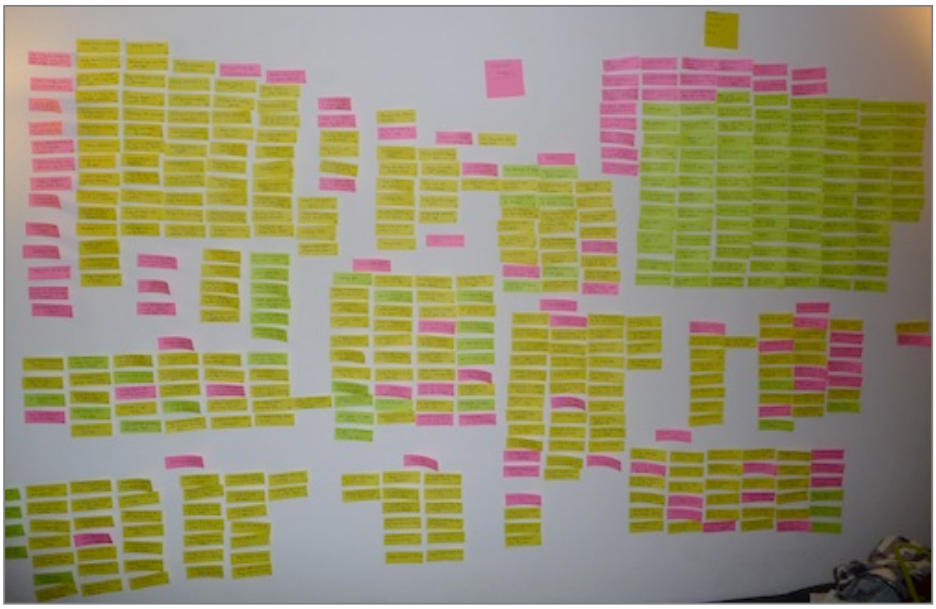


Figure 5.1. Affinity mapping output

5.4 Results

This section describes the main findings. The quotes below are direct quotes form transcripts that were cleaned for legibility.

5.4.1 Reasons to buy

Most participants admitted buying tablets without any prior plan as to how they were going to use them. To some extent, they knew what the device was capable of and expected it to be useful, but did not have any specific use in mind.

> *"I generally bought it to understand how it will fit in my life rather than because I had a need to." – P4*

If they had specific expectations, in most cases they ended up using the tablet in a different way than anticipated.

> *"I thought I'd use it for browsing, I thought I would use it for email. I didn't expect to use it for note taking." – P1*

Few participants admitted getting a tablet because they thought their role required them to have one:

> *"Given my job, I thought I should actually have an iPad." – P1*

> *"I thought that I should. I'm a cool digital technology director, so see, I should have an iPad." – P8*

Trust or sympathy towards Apple or the need to have the latest gadget were also mentioned.

> *"Because I wanted one. Because it's Apple and lovely, and you know, I've been Apple customer privately for 8 or 9 years now" – P4*

When they finally got a tablet, they tended to use it extensively for different tasks, trying to find the best use that would match their needs and justify the purchase:

> *"Initially I was trying to use it for everything. I was trying to shoehorn it into my life a little bit." – P7*

5.4.2 Shared personal and work device

All participants used their tablet for both work and leisure. The fact that it was often provided by the company did not matter: the device was seen as personal.

> *"If you're on a business trip it's nice to be able to take your music with you or video or podcast, because you'll be on a plane, or stuck on the airport (...) so it's very useful to be able to take your life with you." – P1*

Work tablets were often shared with family members:

> *"My daughter tends to use it more than I do. I use it for keeping my daughter quiet on a train. So she does lots of games on there." – P9*

Some participants suggested that tablets increased productivity by allowing them to work on simple tasks while away from the desk.

> *"I just find it's a good way of making a train journey useful if I can keep in touch with the email." – P2*

> *"In the evenings I can do more ad-hoc work, because I don't have to go and switch my laptop or a computer on. (...) So I'm sat on a sofa and just answer email or something. So it's just a way for the company to make more work out of me pretty much." – P8*

The fact that tablets are used for work even away from work suggests that they are not the main device, rather, they provide support and are used either when a "real" computer is not at hand or in-between other tasks.

> *"I use it when I'm not in my own office. Also when I'm travelling between meetings or in a train, I usually use* [it] *in dead zones of meetings, in boardrooms, at board meetings, before they start I check emails." – P4*

> *"If I haven't got time or don't want to start up my laptop* [and] *if I'm coming here for 10 minutes I will just use the iPad" – P1*

5.4.3 Tablets and other devices

Because of the size, design and functionality, tablets seem to fit in well between smartphones and laptops, and generally complement them. Each device has its place and is used in a specific context.

> *"On a way to work I use my iPad and my phone* [depending how crowded the train is]. *On way home I use my iPad and my phone. At work I use my computer or my laptop, except when I go to meetings I take my iPad." – P8*

Even though a tablet works like a smartphone, for some participants it is just a laptop with limited functionality:

"iPad, for me, is a very very very low quality laptop, so I wouldn't try to do anything serious on it." – P8

Tablets are also replacing paper. Almost all participants saw it as an interactive notebook that would replace their paper notebooks, stop them from printing, and make going paperless easier.

"I primary think that I like the most the way it helps me to shift away from using paper." – P6

5.4.4 Problems and discomfort

The most troublesome aspect of a tablet is typing. While the virtual keyboard is often seen as better and more comfortable than the one on a smartphone, it still does not seem to be adequate for office work.

"Took a little bit getting used to and it's not as efficient as a [physical] *keyboard, and it won't replace laptops for typing. I would never type up a Masters work on it, I would never do anything extensively on it. " – P8*

A size of the keys, their response to taps, and the placement of characters were often cited as sources of problems. Surprisingly, only one person mentioned the lack of haptic feedback and difficulties with touch-typing.

Another issue with the keyboard is glare and reflections, although people learn how to work around the problem.

"I was thinking, is there something they could do to stop the glare if you're using it outside? Because one of the nice things, you know, is that it's portable, but when it's remotely sunny it's a bit of a nightmare." – P3

"It doesn't work very well outside and sometimes if you have one of those overhead lights it can reflect, but it works alright on my desk so I'm lucky. Sometimes I find myself in a meeting and I have to angle it." – P5

Participants dealt with keyboard issues by using a tablet cover to prop it up for ease of typing. Every participant had a cover, regardless of whether they got their tablet from work or bought it themselves.

Few participants mentioned neck and wrist pain, but in most cases they had to be specifically asked about physical discomfort.

"So there's a bit of neck pain involved and also I find that when I'm writing for a long time (...) in that position my wrists are slightly bent backwards and after a while of typing (...) I feel a little bit wrist

> *fatigue. But if I put it firmly down onto the table then also it doesn't feel right because I* [have to] *lift the wrists a bit and I can't see the screen as clearly as I would like to. It's alright, but you know, if you're in a long meeting taking loads of notes it's not that comfortable." – P11*

However, as with other issues, participants did not see posture as a problem that would stop them from using the device and accepted it as a part of the experience.

Tablets can also cause psychological discomfort. For example, privacy can be a concern:

> *"I have mild concerns about people who could read over your shoulder, and it's a slightly larger screen than a smartphone, so they can see a bit more what you're reading. But I generally try not to read anything or look at anything too offensive." – P6*

Personal safety does not seem to be an issue, although people do take precautions to make sure they do not attract unwanted attention and protect their devices.

> *"Like I said, equally when I'm worried about showing off, I'm worried about drawing attention to myself. So I was always careful to use it in situations when there were more people on a train or I had to feel safe in that environment" – P7*

> *"*[Using it in public places] *doesn't bother me at all. I have the password protection on it (...) if anyone took it they wouldn't be able to break in." – P6*

One of the reasons participants do not worry about personal safety too much is the popularity of gadgets and the fact that many people use them in public; tablets do not stand out anymore.

> *"I think now that you see more and more people with them, I don't think safety is particularly an issue." – P9*

> *"I remember the very fist time I got* [my tablet] *out on a train when there weren't really many* [of them] *in the country, and I was very conscious of having a 400 quid kit on a southwest train and I felt pretty muggable* [sic]. *I think that's pretty much gone away." – P4*

Some participants also admitted feeling uncomfortable when using tablets at work:

> *"I think in meetings you tend to have to tell people that you're taking notes otherwise they may think you're being rude or distracted, and watching movies. (...) I guess* [it] *shows discomfort that others can feel if you are using a piece of kit, your attention is away from them (...) and when you're sitting there, typing away, they can feel a bit*

disconnected. So I think you must be careful how you use it at meetings" – P4

5.4.5 Office infrastructure

The biggest problem with infrastructure was the lack of wireless connection leading to increased costs and difficulties in accessing work files.

> *"It's pathetic not having Wi-Fi. It's useless. You can't download big documents and it costs a lot over the 3G. And it's embarrassing, we have guests in the building and we don't have a proper Wi-Fi. It's a huge discomfort." – P4*

Even with Wi-Fi present, accessing files can still be problematic and tablet users had to choose between less effective methods e.g. emailing files to themselves, or less secure e.g. uploading files to third party services like Dropbox[10].

5.4.6 Positive attitude

Despite the issues, participants were fond of their tablets, mainly because of the design.

> *"I love the touch-screen. I just like the sort of shiny lovely this and that. For fingers, it is a sense of delight and always has been. And it's so much fun playing with the iPad." – P4*

They seemed to accept limitations as given and emphasised the positive aspects:

> *"It's good, it works. It does what it says. Yes, that's key: it does what it says. I would like it (…) to be better at multitasking and searching, and all those other things, but it's not what it says it does." – P7*

5.5 Discussion

Regardless of whether people buy tablets themselves or get them from work, they like and want to use them. Even though everyone compares tablets to smartphones or laptops, they do acknowledge it as a different device. Comparisons reveal shortcomings, but since it is not clear what the purpose of the tablet is and how it can fit into one's life, limitations are downplayed and the focus is on positive aspects.

This attitude is especially visible when it comes to design limitations and ergonomic issues. Typing is problematic, and yet everyone uses tablets for taking notes. If done for longer periods and on a regular basis, typing could increase the risk of WRULDs (Pheasant & Haslegrave, 2006), especially that neck and wrist discomfort are present. The cover used for typing could be seen as a solution to this issue, but it

[10] https://www.dropbox.com/

does not always work; it can even cause additional discomfort. External keyboards could further reduce the risk, but participants neither used nor wanted them, as that would reduce portability.

In addition, the glossy screen cannot be used outside and reflections caused by overhead lighting in the office can cause irritation and distract other people. Psychosocial aspects such as security and privacy should not be ignored.

The disappearing line between work and personal life can be also seen as a potential source of ergonomic issues: office workers move away from the office to work at places where their workstation cannot be properly set up to comply with health and safety standards.

6 OBSERVATIONS

This chapter describes how observations and posture analysis were conducted to record positions in which people use tablets in an office environment, and presents an additional keyboard and typing evaluation. It ends with a summary of results and a list of identified problematic areas.

6.1 Research

Observations were conducted at the end of the interviews. Participants were asked to use their tablets and tasks were based on interview responses and reflected typical activities. Photos were taken during sessions to record the posture.

Participants were aware that the study was voluntary and they were free to withdraw at any point, and that posture photos would be used in any academic publication based on this study. P10 and P11 did not participate in observations.

6.2 Postural analysis

Postural analysis is an important part of an ergonomic investigation as it helps to identify potential occupational risks and problematic areas that could lead to developing WRULDs (Stanton *et al.*, 2005). Several analysis methods are available, including observational, instrumental or direct methods, and self-reports (Li & Buckle, 1999).

RULA (Rapid Upper Limb Assessment) (McAtamney & Corlett, 1993) was selected as the most appropriate for this study, as it had been previously used for a laptop work posture analysis (e.g. by Lima & Coelho (2011)) and was therefore deemed relevant to portable devices. Moreover, it is specifically designed to assess sedentary tasks (Stanton *et al.*, 2005), and all research participants used their tablets while sitting. However, analysis results should be taken with care: while RULA focuses on the task and its components, i.e. posture, force, and repetitive movement (McAtamney & Corlett, 1993), the analysis showed that it does not take into account the lack of back and elbow support.

Stanton *et al.* (2005) advise to take photos from the right and left side, and from the back. For this study, photos were taken from the sides only, as often the backrest was in the way or the space was too constrained to take a photo from behind of the chair. For each photo a RULA score was calculated using an online calculator[11] and scores were translated into risk levels. Figure 6.1 shows an example of a risk assessment sheet combining comments based on the risk assessment checklist and the RULA score; further examples can be found in Appendix B5.

[11] http://www.rula.co.uk/

Participant shows how he takes notes (left) and uses his tablet as an additional screen to access meeting notes and emails (right).

Possible risk factors:

- No back support
- Body leaning forward
- Neck extended and bent forward
- No elbow support
- Forearms twisted towards the inside of the body
- No wrist support

RULA score (left/right): 4/4
"Further investigation is needed and changes may be required"

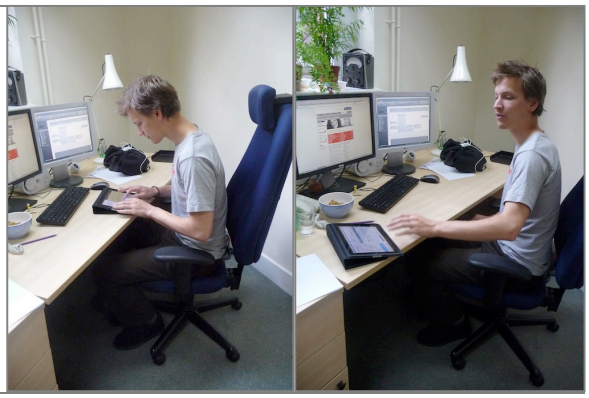


Figure 6.1. Ergonomic risk assessment sheet with a RULA score

6.3 Risk assessment checklist

RULA alone may not be enough to assess all risks due to its simplicity, and it should be used with other techniques when conducting a thorough ergonomic investigation (Stanton *et al.*, 2005). A risk assessment checklist was therefore created based on information from the UNISON risk assessment checklist (UNISON, 1998), *Working with VDUs* booklet (HSE, 2006), Pheasant & Haslegrave (2006) and Oborne (1995), and can be found in Appendix B4. Each photo (see Appendix B5 for examples) was checked against the checklist and all possible risk factors were added to risk assessment sheets (see Figure 6.1) to provide a better overview of the posture, highlight risk factors and add background to the RULA score.

6.4 Keyboard and typing analysis

Interviews revealed that most issues with tablets were caused by the virtual keyboard. Therefore, finger movements and wrist angles were analysed in more detail.

6.4.1 iPad: landscape mode keyboard

Tablets can be used in both landscape and portrait mode. During the interviews, all participants used the landscape mode for typing and the portrait mode for reading, therefore the landscape mode was used during the evaluation.

To assess wrist angles, the researcher was photographed using an iPad1 (Figure 6.2, left) and an iPad2 supported by the smart cover[12] (Figure 6.2, right). The evaluation highlighted the following issues:

[12] http://www.apple.com/uk/ipad/smart-cover/

- **Deviated wrists.** A virtual keyboard is narrower than a laptop or a regular keyboard, which causes radial hand deviation that could lead to discomfort.

- **Wrists flexed.** Regardless whether a tablet is used with or without a typing support, wrists are mostly flexed, although the angle differs slightly. This applies to typing on a desk and on the lap.

- **Fingers suspended in the air.** During typing, user's fingers are kept in the air rather than rest on the keyboard to avoid accidental activation of the touch-screen. This can lead to static loading and fatigue.

Figure 6.2. Typing on a tablet with (right) and without (left) a smart cover

6.4.2 iPad: portrait mode with a split keyboard

In 2011 Apple introduced a split keyboard to support thumb-typing in portrait mode (The Verge, 2011). On all iPad models, the keyboard in this mode is smaller than a horizontal one (146mm wide and 9mm key width vs. 195mm wide and 14mm key width for the horizontal keyboard), and the split mode makes the keys even smaller (6.5mm per key).

Figure 6.3 shows two users: user A (male) representing the 5th percentile of the population (top) and user B (female) representing the 95th percentile (bottom)[13]; the percentile groups were assigned based on the height and elbow-fingertip length compared to dimensions from anthropometric tables (Pheasant & Haslegrave, 2006).

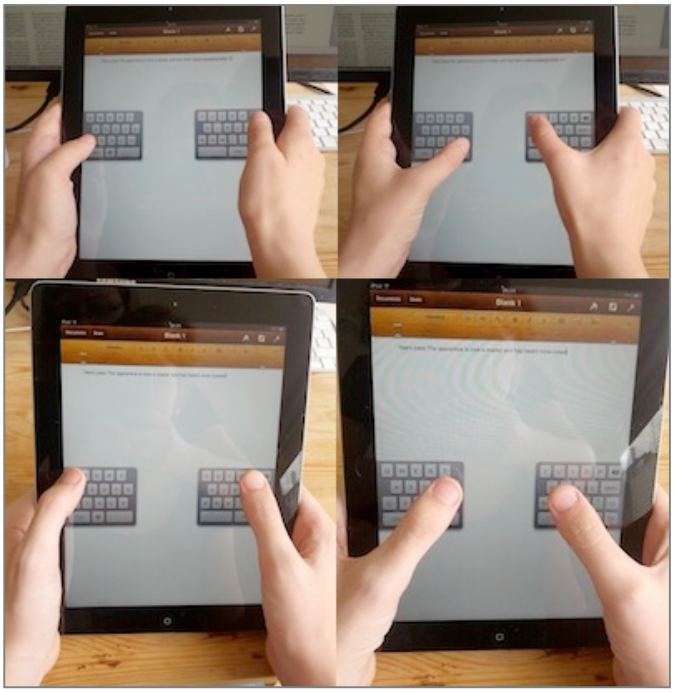


Figure 6.3. Split keyboard used by users representing the 5th (top) and the 95th (bottom) percentile of the population based on height and elbow-fingertip length

The split keyboard has additional "phantom keys" in the middle (The Verge, 2012), but as demonstrated on Figure 6.3, they are of no use to the 5th percentile of population who cannot comfortably reach the inside edge, let alone invisible keys between two parts of the keyboard.

In addition, on a regular virtual keyboard keys enlarge when pressed to confirm which one was selected, but for some reason this feature is not available on a split keyboard. With the lack of haptic feedback and key travel, removing visual cues leaves users with a much more difficult and error-prone task.

6.4.3 Other tablets

The Samsung Galaxy Tab 10.1 was measured for comparison. It allows typing in both landscape and portrait mode, and keys are a similar size to an iPad: 15mm and 9mm wide respectively. Additionally, it is possible to shrink the keyboard when in horizontal mode and move it around (see Figure 6.4), although it is not clear what the rationale is behind this feature. Keys on the movable keyboard are 6mm wide.

[13] While a woman representing the 5th percentile and a man representing the 95th would provide a wider range of sizes, it was not possible to find the right size participants at the time.

An alternative Swype keyboard[14] is also available for this tablet. It allows drawing shapes on the keyboard instead of tapping individual keys, which could reduce the finger fatigue caused by the lack of key travel. Unfortunately, this feature could not be evaluated due to very limited access to non-Apple tablets.

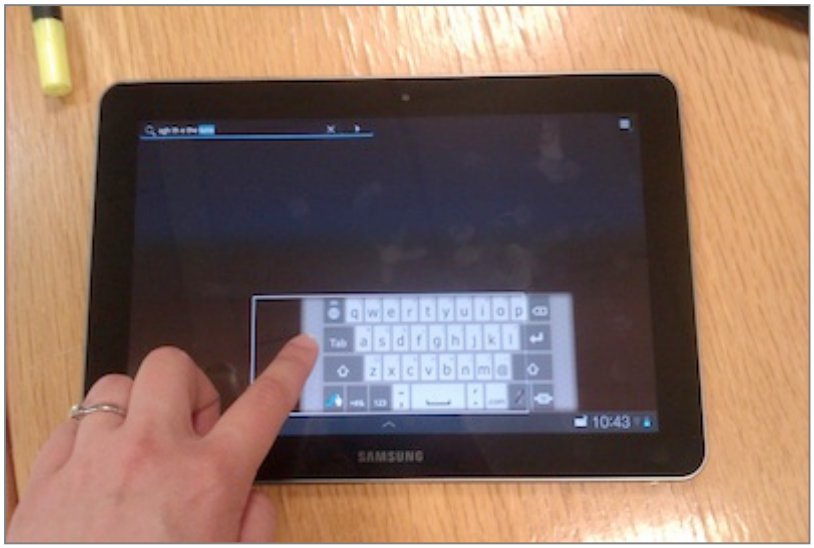


Figure 6.4. Samsung Galaxy Tab 10.1's movable mini-keyboard

6.5 Results and discussion

Results of the RULA analysis, checklist-based risk assessment and keyboard investigation were combined to better understand possible posture-related issues.

RULA showed that on a scale from 1 to 7 tablet users generally score 3 or 4, which means that *"further investigation is needed and changes may be required"* (McAtamney & Corlett, 1993, p. 96). This verdict was also supported by the risk assessment comments. Both analyses highlighted possible problems with the neck, as its angle suggests a high load that could lead to musculoskeletal discomfort, especially when a tablet is used for extended periods.

The following areas were identified as the most problematic in terms of posture:

- **Extended neck**. All participants had their necks bent during typing, and since some of them type frequently for long periods (e.g. taking notes at meetings or conferences), this can have serious health consequences. In addition, it should be noted that tables in meeting rooms where the observations were conducted were often lower than office desks, causing participants to lean further forward than they would normally do.

- **Lack of back support.** Because of its size and design, tablets encourage users to lean forward, especially during typing. As a result, users do not use backrests and the weight of their trunk is not properly supported.

[14] http://www.swype.com/

- **Lack of elbow support.** During typing, participants who were sat on chairs with armrests tended to ignore arm support – they kept elbows in the air and shoulders raised. This could cause discomfort in shoulders and wrists on which the weight of an arm is resting.

- **Wrist angle**. Wrists can be at problematic angles during typing: flexed, extended, and deviated. The typing analysis confirmed that they are at risk when using a tablet regardless whether a support device such as a cover is used.

The tablet and its portable nature make it difficult to adjust workstations for it, and as a result users often adapt their posture instead. As suggested by the RULA score, a further investigation is indeed needed to better understand how often tablet users assume positions that lead to discomfort and for how long, and how serious the consequences can be.

7 ONLINE QUESTIONNAIRE

An online questionnaire was designed to verify interview and observation findings, and to answer questions that arose during data analysis. This chapter describes the questionnaire design and presents its findings.

7.1 Research

The main objective was to gather information from a bigger sample and answer questions that had emerged earlier from the data. In addition, since all previous participants used Apple products, it was a chance to reach owners of other tablets.

The questionnaire was piloted with five users to adjust the number and legibility of questions. The final version, published with SurveyGizmo[15], consisted of 46 questions covering, among others, tablet ownership, patterns of use, and discomfort (see Appendix B6 for the list of questions). As long questionnaires may be completed less accurately by respondents rushing to finish them (Cairns & Cox, 2008), an Amazon voucher raffle and a copy of results were offered to participants – the motivation and accuracy of answers increases if there are direct benefits (*op. cit.*). The questionnaire was published in October 2011 and was available online until May 2012. During that period it was advertised on social networks, mainly Twitter[16], LinkedIn[17] and via peers.

"To what extent do you use your tablet for work purposes?" was used as a qualifying question. Since the focus of this study was specifically on work, people using their tablet mainly or only for entertainment/leisure were excluded.

7.2 Results

The questionnaire resulted in 82 complete responses; there were two partial responses and 25 users did not qualify. Table 7.1 presents the profile of respondents. Majority of them were male and the average age was 30.5 years old (SD=8.6). Nearly half of respondents admitted having some sort of a health condition.

Table 7.1. Questionnaire respondents' profile (N=82)

Gender		Age (years)		Job title group		Health conditions		Height (cm)	
Male	76%	Under 18	0%	Technical	27%	Visual impairments	18%	Under 160	8%
Female	24%	18-24	11%	Management	26%	Back problems	17%	160-169	10%
		25-34	39%	Creative	23%	RSI	9%	170-179	31%
		35-54	44%	Business support	12%	Motor impairments	1%	180-189	45%
		55+	6%			Other	3%	190+	6%
						None	57%		
		Average	*30.5*					*Average*	*177*
		SD	*8.6*					*SD*	*9.45*

[15] http://www.surveygizmo.com/
[16] http://www.twitter.com/
[17] http://www.linkedin.com/

7.2.1 General tablet information

Apple's tablets (iPad and iPad2) were the most popular devices used by 79% of respondents; other popular models included Asus Transformer (9%) and Samsung Galaxy Tab (6%). Over half of respondents (61%) used Wi-Fi only models and 81% already used a laptop/notebook or a smartphone.

Nearly half of respondents (45%) had their tablets provided by their employer and 74% were using them for both work and entertainment, regardless whether the device was their own or supplied by their employer. Figure 7.1 shows reasons for getting a tablet. A number of respondents paid for their own tablets even though they indicated it was necessary for work. Similarly, many respondents said the work tablet was a chance to try a new gadget.

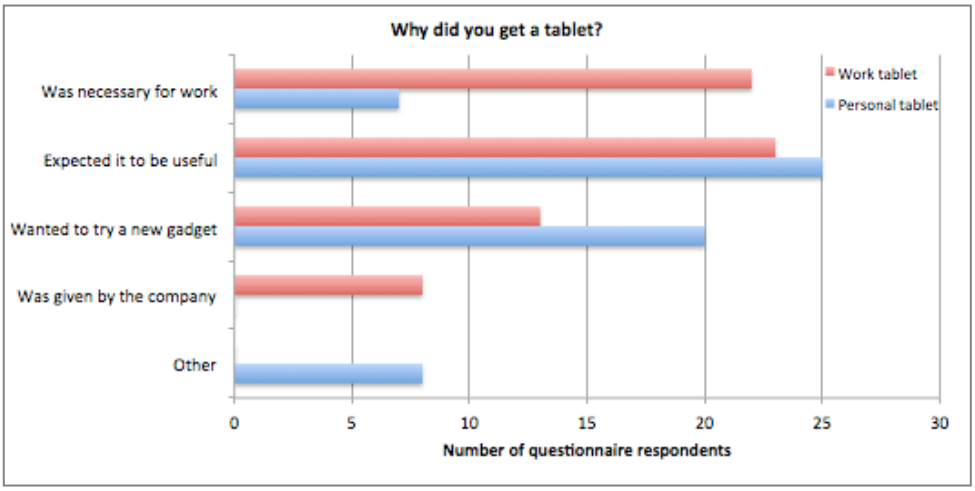


Figure 7.1. Reasons for buying a tablet or being given one by a company

7.2.2 Tablet usage

Over half of participants admitted using a tablet for work every day and on a single day they would use it usually for 1-2 hours (see Figure 7.2).

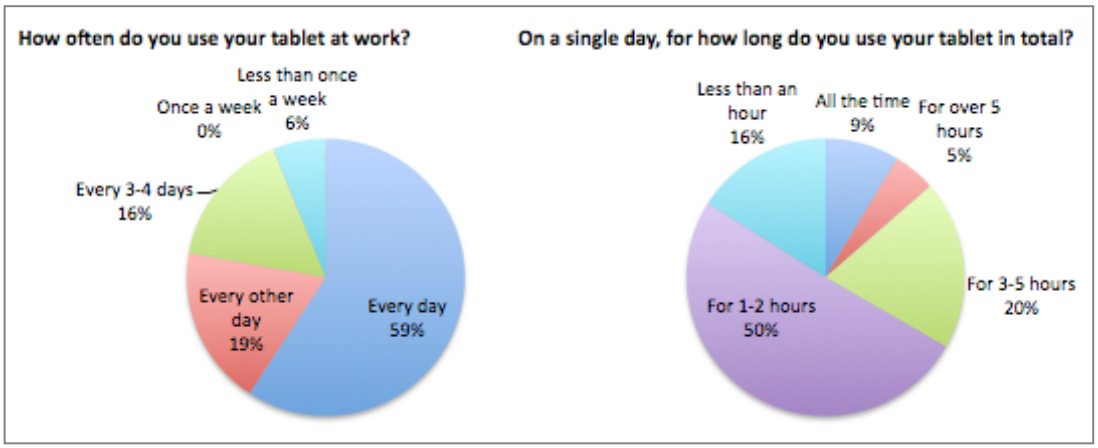


Figure 7.2. Frequency of use

Almost all participants used tablets for checking emails and web browsing. Other uses included reading work documents, taking notes at meetings, and managing appointments (see Figure 7.3).

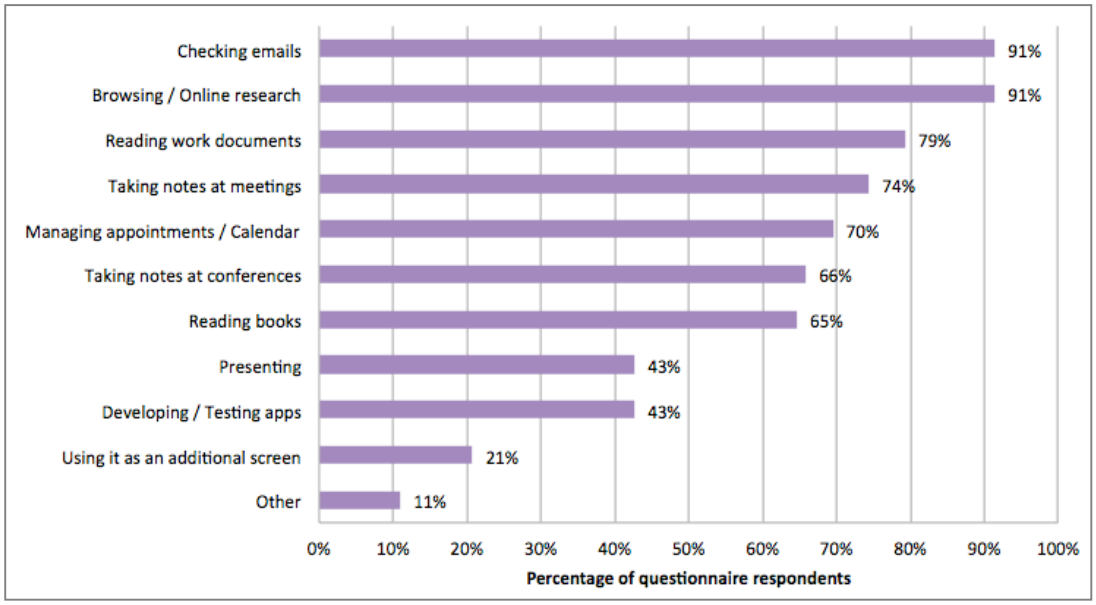


Figure 7.3. Most common office tasks done on a tablet

All respondents were accessing work documents on a tablet. The majority of them (77%) used online sharing services like Dropbox, even though 61% of them were concerned about storing potentially confidential work documents on a third party server.

Two thirds of participants (63%) shared the tablet with their partner or a spouse, children, other family members, or friends and colleagues.

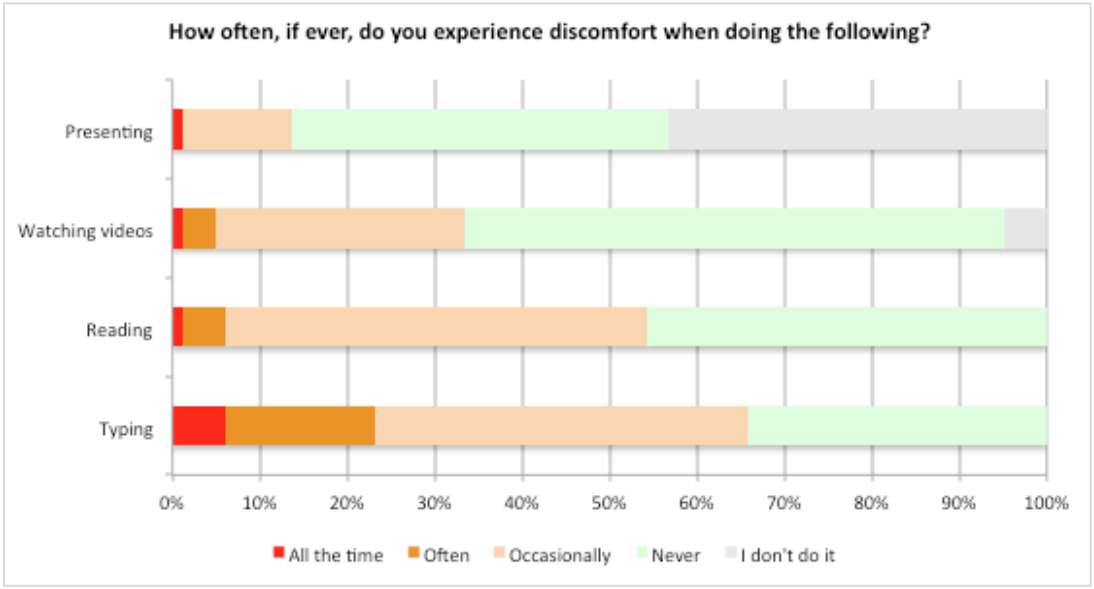


Figure 7.4. Tasks and discomfort

7.2.3 Comfort of use

When presented with statements describing the physical aspects of a tablet, the majority of respondents agreed that it was *"comfortable to carry"* (61%) and *"the size is about right"* (77%); 43% agreed that *"typing is uncomfortable"*, which was later confirmed when specific tablet activities were considered (see Figure 7.4).

When asked about specific discomfort areas, the majority of respondents said they never experienced any discomfort when using a tablet. However, as shown on Figure 7.5, discomfort seems to be an issue and wrists and neck in particular are at risk.

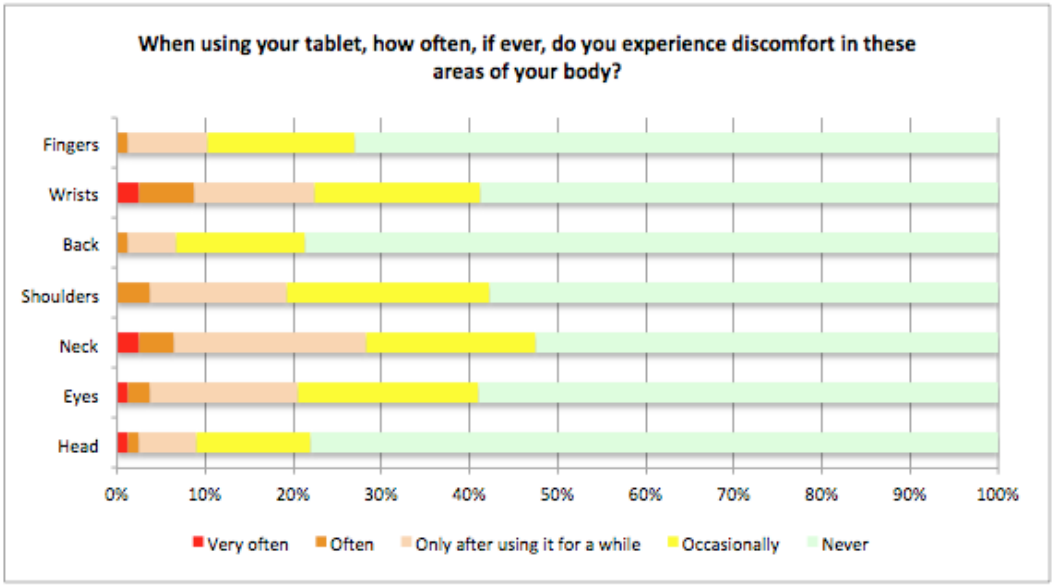


Figure 7.5. Discomfort areas

Participants had different tactics for dealing with discomfort, including changing the position or stretching (see Figure 7.6, right). To prevent discomfort and for ease of use, participants used tablet accessories (see Figure 7.6, left); those that did not (10 people only) thought they were not needed, too expensive, or too cumbersome to carry.

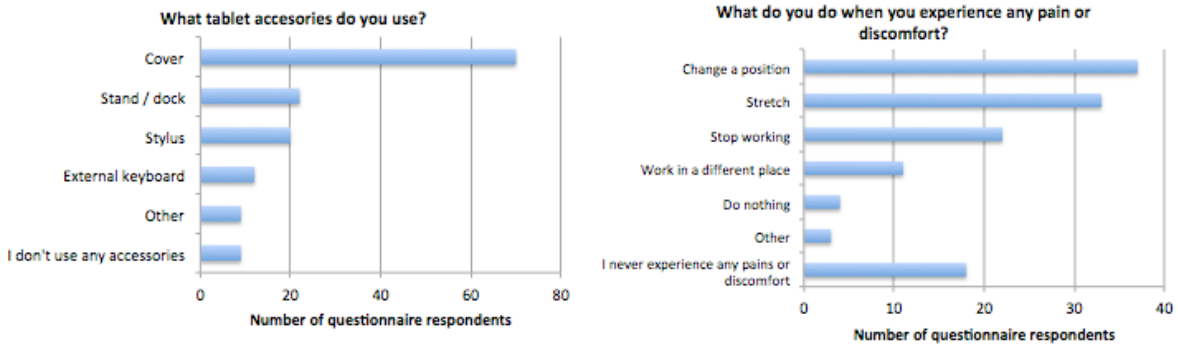


Figure 7.6. Dealing with discomfort

7.2.4 Using tablets in public

Over half of respondents (58%) felt comfortable when using tablets outside. The rest complained about glare and reflections, fear of theft and attracting unwanted attention, and the lack of support or rest area for the device.

Respondents were worried about privacy and personal safety (49% and 60% respectively). Using a tablet during commute was seen as comfortable (70% of respondents), but a fear of theft was highlighted as a possible problem.

7.2.5 Company support

The majority of respondents were not aware of any company tablet-related health and safety regulations or IT guidelines (94% and 77% respectively). Only four respondents admitted adjusting their desk to make tablet usage more comfortable.

In general, the use of a tablet was not required in the workplace, but some types of work could not be done without it, e.g. testing apps. Only a few respondents (7%) reported that there were instances where tablet use was discouraged or banned, and it was often caused by employer's security policies.

When asked how companies could make using a tablet more comfortable, the majority of respondents focused on functionality (see Figure 7.7); changes to workstations were low on the priorities list.

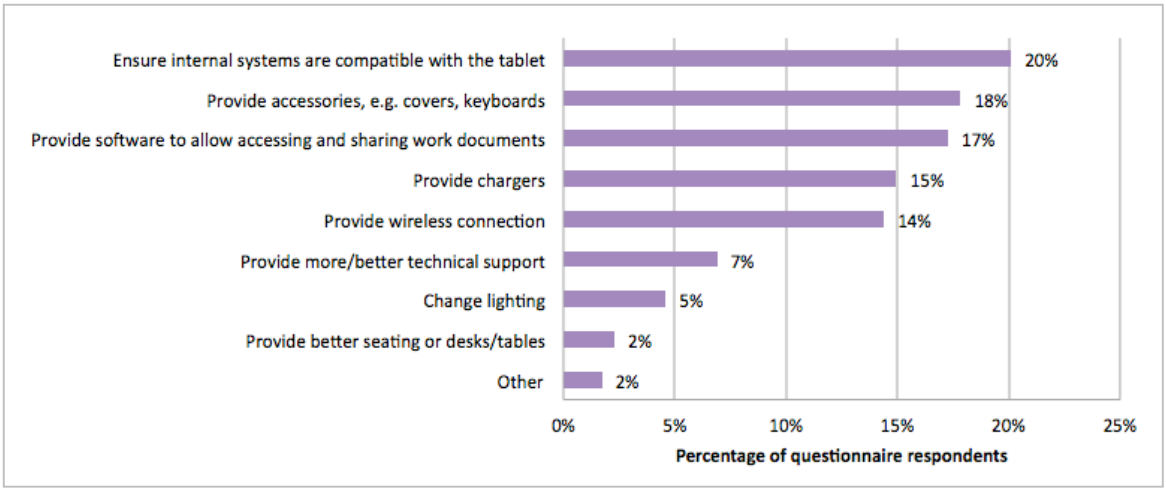


Figure 7.7. Steps companies can take to make tablet use more comfortable

7.3 Discussion

Tablets are used for work and personal purposes, and are often shared with others, which confirms the attitudes observed during the interviews. They are mainly used for tasks that require Internet access (checking emails, web browsing, etc.) and since almost half of respondents have tablets with the 3G network access, they can use

them anywhere and at any time – which they do. The design and capabilities of a tablet encourage frequent use and respondents used them mainly on the move and out of the office.

Because tablets are used in a variety of places, the fact that majority of users report some kind of discomfort is not surprising. However, almost all respondents admitted already using a laptop or a smartphone – with so many devices involved, it is not clear which is the exact cause, as all have an impact and need to be considered.

The next chapter combines findings from the interviews, observations, and the questionnaire and presents common themes.

8 RESEARCH FINDINGS

In this chapter, findings from interviews, observations and the questionnaire are combined and presented together to highlight common themes.

First, context of use is presented i.e. where, when and why office workers use tablets. The second part outlines identified potential ergonomic risks. The chapter concludes with an Ergonomics Action Table – the Application Format for the Hexagon-Spindle model (Benedyk & Woodcock, 2009) – that summarises main issues and suggests solutions that are discussed in the next chapter.

8.1 Context of use

As the research showed, tablets can be (and often are) used for office work anywhere and their use is not limited to an office environment. Regardless of whether they are provided by the company or are an employee's personal purchase, they are used for both work and entertainment, and are often shared with family members. Tablets are used for work during commuting or in the evenings, and personal tasks (e.g. visiting social networking sites) are carried out at work. The line between the work and leisure time is blurred.

When considering a tablet purchase, users generally do not know how they are going to use it – they just expect it to be useful. Those who purchase with a particular intention in mind often end up using it for something different. Using a tablet for everything and trying to fit it into one's life is quite common and usually results in finding a few core uses.

However, no "real" work is done on a tablet: tablets are mostly used for emails, browsing the web, reading work documents, taking notes, and managing one's calendar. They complement other devices – laptops and smartphones – and are used in-between more demanding tasks; tablets are seen as an extra tool to use when there is not enough time or space to use a laptop. In addition, they seem to be slowly replacing paper.

8.2 Ergonomic issues

Tablets are used frequently, but for short periods. Only occasionally does a longer use take place, usually at a long meeting or a full-day conference. The data suggest that the longer people have a tablet, the more often they use it.

These usage patterns could potentially lead to ergonomic issues and several problematic areas have been identified:

8.2.1 Typing

Typing is the most common tablet task and the most problematic from an ergonomic perspective, as the virtual keyboard can cause wrist discomfort and finger numbness. The keyboard lacks haptic feedback and key travel, and because it is not separated from the screen, it encourages poor posture. Users often use a cover to prop up the tablet to make typing more comfortable and raise the screen angle, however, it is of little help.

8.2.2 Posture issues

Several identified posture issues were caused by a tablet's size and design, including neck, wrist, and fingers discomfort. When a tablet is used on the lap and on a low table, it could cause neck pain. In addition, some users not only extend their necks, but also lean forward and do not use backrests, which can increase discomfort if that position is held for a long time. Wrists are at risk due to their angle during typing. Shoulder discomfort may be caused by the lack of elbow support: users tend to ignore armrests and keep their shoulders raised when typing or reading.

8.2.3 Psychological discomfort

Users also experience psychological discomfort: they worry about privacy and, to a lesser extent, about personal safety. They avoid attracting unwanted attention, are cautious when accessing sensitive information in public and are aware of risks related to storing files on third party servers. However, this kind of discomfort does not stop them from using a tablet.

8.2.4 Workstation design

Office workstations are not appropriate for tablet use and users do not try to adjust them. External keyboards and docking stations could be useful, but users do not want them as they reduce portability and therefore remove the main advantage of a tablet. Another issue is the fact that work is not limited to a single workstation: tablets can be used anywhere. It is therefore difficult to ensure a good posture is maintained to minimise risks.

8.2.5 Glare and reflections

Overhead lighting often causes glare and reflections, forcing users to tilt or move the tablet, which may result in an awkward position. In addition, reflections can distract other people working nearby.

Under sunlight, tablets become unusable, as the glare is too strong and users are forced to lean very close to see the screen and to try various, often uncomfortable, positions.

8.2.6 Infrastructure

The infrastructure is lacking in most offices, even though workplaces already support smartphones and mobile work. Especially a lack of Wi-Fi is a problem, due to costs of a regular 3G connection and the fact that many users own Wi-Fi-only models. Accessing and sharing work files can also be problematic.

8.2.7 Health & safety regulations

Most users are not aware of any internal health and safety regulations or IT policies related to tablet use. It is not clear whether such regulations actually exist, especially that HSE regulations covering working with DSE (2003) do not explicitly cover touch-screen tablets.

8.3 Ergonomics action table

Chapter 4 has introduced Hexagon-Spindle analysis as a tool for identifying questions that would have to be considered when designing the research. As the main use of the framework is to assess a broad range of factors that have impact on the task, identify any ergonomics risks and suggest improvements (Benedyk *et al.* 2009), the framework had to be revisited after the real world data was gathered. Research findings informed the Action Table (see Table 8.1).

Table 8.1. Ergonomics Action Table

Levels	External factors	Work setting	Workplace	Workstation	User
All influencing factors	No tablet specific regulations related to health & safety. People often buy tablets because they expect them to be useful, not because they need them.	Company infrastructure often does not support tablets. Internal health & safety policies are either not known or not in place.	Tablets are used for work in different environments, often outside the office. The line between work and personal life is blurred. Tablets as a support device, fitting between a laptop and a smartphone.	Office furniture is not adjusted for tablets. Typing requires the use of a virtual keyboard. Tablets often used during commute, including standing up in a moving vehicle.	People of varying height. Mostly senior or management staff.
Ergonomic issues	No official regulations to guide internal policies.	Concerns over storing work files on third party servers. The lack of awareness of potential health and safety issues.	Not possible to determine where a tablet is going to be used and in what context. Privacy and security concerns. Sunlight.	Posture issues. Glare and reflections. Vibration.	Problems with posture: neck, wrists, fingers, and back discomfort. Privacy issues (access to confidential work documents).
Ergonomic approaches to situations	Update or create new, relevant regulations and standards.	Ensure internal systems are compatible with tablets. Provide access to wireless internet. Educate users about possible health and safety issues.	Educate users about privacy and security issues, and how to be safe. Provide spaces with sofas where tablets can be used in a more relaxed position.	Provide covers to make typing more comfortable. Provide software that allows handwriting or a stylus. Provide external keyboards in meeting rooms. Provide anti-glare screens.	

The table presents the context and factors influencing the use of a tablet as an office device, and assigns identified ergonomic issues to each of them. For each issue it lists examples of ergonomic approaches to minimising risks.

As Table 8.1 demonstrates, there are no easy solutions. The portability of tablets makes it almost impossible to ensure that a workspace is adjusted for them. Providing stands and external keyboards could work – after all, there are docking stations for laptops – but tablets are almost never used at a desk.

Another way to reduce risks could be educating users, raising awareness of possible posture issues, and suggesting breaks and exercises. Information about privacy and security could also be beneficial. Therefore, relevant internal policies are needed and should be developed.

The next chapter discusses research findings in more detail and in relation to the literature and current developments, and presents a set of recommendations for minimising uncovered risks.

9 DISCUSSION

The goal of this study was to understand how and why people use tablets for office work and what potential ergonomic issues could arise as a result. Not much academic research has been conducted to date to investigate the use of tablets in an office environment or to evaluate them from an ergonomic perspective. Therefore, this study – via interviews, observations and an online questionnaire – explored the tablet use and highlighted possible ergonomic risks.

This chapter discusses findings from Chapter 8 in relation to literature and presents recommendations for minimising identified risks. Limitations of the study are also considered.

9.1 Tablets as an office work tool

Study findings show that in the case of tablets, office work takes place primarily *out of an office* (e.g. during commute, at home) with an exception of meeting rooms. Tablets, regardless whether they are work or personal devices, are used for both work and leisure. This behaviour is supported by existing research on portable devices e.g. by Heasman *et al.* (2000) and a more recent study by the European Commission (2010).

The majority of research participants admitted purchasing a tablet without much consideration as to whether they actually needed one or how they would use it. Purchase was often followed by a period of increased usage caused by testing and appropriating the device to one's needs; these attitudes confirm findings by Geyer & Felske (2011) and Hess & Jung (2012) who observed similar patterns. The lack of pre-purchase planning could be explained by the familiarity with tablets and their capabilities, fashion, or expectations set by smartphones and laptops. In the case of this study, however, it might also have been a result of a population sample of technology enthusiasts, who eagerly buy new gadgets.

Although usage decreases after the exploration phase and tablets are used for shorter periods than laptops (Heasman *et al*, 2000), such use still poses risks. According to Business Insider's report (2012), users spend 2-5 hours per day using their tablets and questionnaire findings show a similar trend: 51% of respondents (N=81) reported using tablets for 1-2 hours a day and 20% for 3-5 hours. Prolonged use, especially outside an office, can lead to ergonomic issues that are discussed in the next two sections.

9.1.1 Musculoskeletal disorders

As the postural analysis showed, research participants used tablets in a way typical to other portable devices i.e. in fixed positions that limit the range of possible postures (Heasman *et al*, 2000). Tablets were used primarily in sedentary positions with the device often held on a meeting table or a lap, confirming Young *et al.*

(2012) findings. REBA identified the neck as one of the risk areas, which is not surprising, as neck discomfort is linked to the keyboard use (Szeto *et al.*, 2002). Since such discomfort can appear while using a physical keyboard on a workstation set up accordingly to health and safety guidelines, it is even more likely to occur when using a portable device with a screen that cannot be separated from the keyboard (European Commission, 2010) and is not positioned at an optimal height (Young *et al.*, 2012).

The analysis also highlighted issues with wrist angles during typing regardless of whether a cover was used to prop up the tablet. Young *et al*. (2012) suggest using covers to improve the viewing angle and reduce neck discomfort, but they disregard the fact that a cover increases the wrist angle. The more extended the wrist, the more flexed (or 'curled') fingers are (Nelson *et al.*, 2000), which can increase discomfort, especially when users hold their fingers suspended in the air as was observed during this study.

Musculoskeletal risks could be reduced by using docking stations, external keyboards, or screen-top keyboards, although no studies have been conducted to evaluate tablet accessories. Gesture-based keyboards (e.g. Swype) should also be considered: drawing shapes on a screen is less tiring to wrists and fingertips than typing as it does not require tapping force or holding hands in a fixed position, and users type one stroke per word instead of a tap per letter (Zhai & Kristensson, 2003). However, it can be difficult to type without looking at the screen and neck discomfort would not be reduced. Unfortunately, an ergonomic evaluation of a gesture-based keyboard is also not available.

9.1.2 Work environment

Portability of a tablet makes it difficult to ensure that the workstation is comfortable and follows health and safety guidelines, especially that existing regulations apply to the only workstation that tablets are hardly used at – a desk. With tablets, work can be done *anywhere* as long as a user has a seat or a wall to lean on. This suggests that education and raising awareness of possible health and safety issues, and providing a proper support for the device could potentially reduce risks.

The majority of workplaces seem to be ready for tablets and few infrastructure issues identified during research have already been resolved. Data gathered during summer 2011 suggested that the lack of Wi-Fi was a problem. This may not be the case anymore: with smartphone support in place (43% of smartphone users use Wi-Fi at work (Ofcom, 2012)), existing infrastructure could be adapted to accommodate tablets (Geyer & Felske, 2011). Research participants also mentioned difficulties with accessing and exchanging work files, and since then Apple released iCloud[18] – a service that allows easy synchronisation of all documents, music, and apps across all devices (The Verge, 2011).

[18] http://www.apple.com/icloud/

Glare can be a serious problem for tablet users due to the glossy screen (Hess & Jung, 2012). Research participants reported a need to change their position to avoid reflections, and being unable to use their tablets outside on sunny days, which in both cases led to assuming a poor posture. However, ways of minimising glare and reflections inside the office are described by existing regulations e.g. HSE (2003) and can apply to tablets. For outside use, anti-glare protectors exist on the market, e.g. ClearTouch Anti-Glare[19], although it is not clear how well they work as no research is available to evaluate their effectiveness.

Users also worry about personal safety and privacy, although it does not stop them from using tablets in public. Research participants were aware of the risks, e.g. did not want to attract unwanted attention, but still used tablets in public transport. Additional privacy concerns could be caused by the lack of clear division between the work and leisure use and tablet sharing, e.g. family members could easily access work information. Companies already have privacy and confidentiality policies for smartphones and could adapt them to tablets, but they must keep in mind that with this device the separation of work and personal life is not feasible.

In general, as work devices, tablets are problematic: their use could lead to musculoskeletal discomfort and problems cannot be mitigated due to uncontrolled work environments. Employers are responsible for health and safety of their staff, but in this case their options are limited. Moreover, as discussed next, existing standards and regulations are not relevant.

9.1.3 Policies and regulations

At present, there are no health and safety regulations or standards that directly apply to tablets. Although the DSE Regulations (2003) cover portable devices, especially laptops, the focus is on removing portability and ensuring the device is used at a desk. ISO 9241-410 (ISO, 2007b) describes input devices and covers both tablets and touch-sensitive screens, but touch-screen tablets are not described.

While a standard regulating the design of a tablet would be beneficial, specific health and safety regulations may not be needed, as it would not be possible to enforce them. Despite tablets having similar capabilities to laptops and posing similar risks, the context of use and portability make them closer to smartphones, but there are no smartphone regulations. Regulating tablet use would require defining the good posture and, as observed during the study, it is not possible for office work. Enforcing the use of external keyboards or other accessories would prove fruitless as users explicitly said they were not interested in such devices as they reduce portability.

Therefore, while the lack of regulations is worrying, there is not much that can be regulated, especially that tablets are used mainly outside the office. However, simple steps can be taken to minimise risks in the office environment.

[19] http://www.boxwave.com/screen-protectors/cleartouch-ultra-anti-glare/bwpds/mmm/

9.2 Recommendations

Table 9.1 presents recommendations for reducing risks and making tablet use more comfortable, although further research is needed to evaluate their effectiveness.

Table 9.1. Recommendations for minimising risks related to tablet use

Workplace	• Adapt existing infrastructure and ensure internal systems are compatible with tablets. As many companies already support smartphones, significant changes may not be required. • Provide access to company-wide Wi-Fi to allow access to work documents and enable sharing. This not only reduces mobile network costs, but also increases efficiency. • Consider providing breakout spaces where tablets can be used in a more relaxed position. • Accept that it is not possible to separate work and leisure use of a tablet and ensure that privacy and confidentiality policies reflect that.
Workstation	• Ensure that chairs are adjustable, so users can use tablets with their backs and arms supported. • Ensure adjustable window blinds and overhead lights with glare preventing baffles are installed in meeting rooms and breakout areas where people are likely to use tablets. • Equip meeting rooms with accessories (e.g. external keyboards) that can be used by anyone.
Device	• Provide covers to all users to support typing. • Provide any other external aids (stands, docking stations, external keyboards, etc.) when required or requested for users who use tablets at their desks. • Consider alternative input methods e.g. encourage the use of a stylus where possible or provide tablets with gesture-based keyboards (e.g. with Swype keyboards). • Provide anti-glare protectors to reduce eye strain.
User	• Educate staff about possible health and safety risks, particularly related to poor posture, e.g. discourage use on the lap and suggest using tables for typing. • Educate staff about possible privacy and security risks, and describe ways of dealing with them.

9.3 Limitations of the study

The biggest limitation is the fact that the study was conducted over two summers and, in the meantime, several new tablets of various sizes and functionality have been released.

All interview participants were iPad users and fond of Apple products, therefore their comments might have been biased. At the time it was not possible to recruit non-Apple tablet owners who used tablets for work, which also made it impossible to test alternative input methods, e.g. Swype-like keyboards.

Observation sessions were conducted at the end of interviews and participants were aware of the topic of the study, therefore, questions about the comfort of use might have made them unconsciously avoid poor posture. In addition, photos for the posture analysis were taken during artificial tasks (participants were asked to briefly type and/or read an email) rather than actual use. This could have been avoided by either scheduling observations for a different day or planning longer sessions, ideally before the interviews. Video recordings would have been more appropriate.

The posture for analysis was photographed from the side, even though Stanton *et al*. (2005) advises to take photos from the back as well to assess the twisting of the spine. This was not possible due to restricted area around workstations and the size of some backrests.

The questionnaire was distributed online on Twitter and LinkedIn, and some respondents were approached directly by the researcher at various technical events, which might have skewed the sample towards a more tech-savvy audience.

Interestingly, one quarter of questionnaire respondents fell into the 95th percentile of the population in terms of stature (Pheasant & Haslegrave, 2006). It suggests that either the sample was skewed or errors were made during the data collection or analysis: all participants were asked to enter their height in a text box using their preferred metric, and results were later converted into metres by the researcher. In addition, it is known that people tend to overestimate their self-reported height (Spencer *et al.*, 2001), and even though the differences are not significant (1.11-1.34cm for men, 0.51-0.71cm for women), it could have pushed people into the 95% percentile category.

Regardless of these limitations, however, identified ergonomic risks are still relevant.

10 CONCLUSIONS

Since the launch of the iPad in 2010, several media reports have been published warning against the potential risks related to tablets including bad posture (Jafri, 2010), RSI (McCauley, 2011), or neck discomfort (Tessler, 2012). Usage trends identified during this research confirm that these risks are real: tablets do encourage poor posture and a prolonged use could lead to neck, back, wrist and finger discomfort. In addition, due to tablets' portability, office work is often done away from the office. Tablets are used at home and the boundary between leisure and work use is disappearing.

10.1 Implications

As discussed in the previous chapter, the use of tablets puts users at risk of developing musculoskeletal disorders. Any adjustments to the device itself (e.g. the use of accessories) may not be possible, as its design and portability are the features users value the most. It is also not possible to control where the devices are used and to ensure workstations are set up correctly, therefore health and safety training is needed to raise awareness of possible issues. While companies can ensure certain office areas are tablet-friendly and the infrastructure supports their use, they must also acknowledge that most of the time the devices are used outside the office in non-ideal locations.

Moreover, the popularity of tablets can have far wider implications for employers and office workers than just posture issues. Blurring of the boundary between personal and work life observed in the study is worrying as it encourages working longer hours and makes managing the work/life balance challenging (Hill *et al.*, 1996, 2003). Mobile work is becoming more popular and employers may need to adjust their policies to address this shift and support their employees who work in multiple locations and manage multiple devices (Vartiainen & Hyrkkänen, 2010).

As tablets' popularity is still growing, they may soon become a must-have work device, just as smartphones have penetrated the business world (Ofcom, 2012). Therefore, changes to the work practice are unavoidable and a thorough understanding of all underlying issues is needed.

10.2 Further research

This study is the first one to focus on tablets as office work devices and explore related ergonomic risks and also the first to take a holistic approach and evaluate all ergonomic factors (user individual factors, social and group factors, product design, environment and infrastructure) in relation to the tablet use. Even though these factors were not explored in detail, the study highlighted a number of problematic areas that require further research.

First, a more rigorous postural analysis is needed, similar to the study by Young *et al.* (2012), but focusing specifically on office work and typing. Typing force and wrist discomfort need to be researched in more detail to assess the level of risk. Evaluation of tablet accessories would help to understand their benefits and limitations, and suggest design improvements. Research should also include non-Apple tablets, as different dimensions (size, weight) may have an impact on users and cause different levels of discomfort.

In addition, longitudinal studies could help to evaluate long-term effects of tablet use and mobile work on posture, the impact on the work/life balance, and the extent to which the boundary between the work and leisure use is blurred.

As relevant standards and guidelines do not exist, a detailed evaluation of existing DSE regulations would be beneficial to assess whether they can be adapted for tablet use and whether they are needed in the first place. Recommendations presented in this thesis need to be evaluated and their effectiveness measured. Since employers are not able to control where tablets are used and therefore cannot be held fully responsible for users' health and safety, there may be no need for official tablet regulations as it would not be possible to enforce them. However, guidelines for minimising risks and best practice should still be developed.

With powerless employers, irrelevant regulations, and users who cannot be held responsible for the use of a consumer device, it is only through design that risks can be minimised. However, the design is fundamentally flawed from an ergonomic perspective and minimising risks will not be possible without reimagining the device. Therefore, a better understanding of all issues is needed to drive the evolution of a tablet and future technologies.

A. REFERENCES

Adams, S. (2012) *iPads 'carry RSI risk'*. Retrieved July 10, 2012 from http://www.telegraph.co.uk/health/healthnews/9079334/iPads-carry-RSI-risk.html

Ankrum, D. R., & Nemeth, K. J. (2000) "Head and Neck Posture at Computer Workstations - What's Neutral?" In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 44.

Arthur, C. (2012) *Revealed: iPad prototype from 2002 that Steve Jobs denied existed*. Retrieved July 25, 2012 from The Guardian: http://www.guardian.co.uk/technology/2012/jul/19/ipad-prototype-ive-2002

Atkinson, P. (2008) "A Bitter Pill to Swallow: The Rise and Fall of the Tablet Computer". *Design Issues*, 24 (4), 3-25.

Beaumont, C. (2010) *Apple iPad review*. Retrieved July 19, 2012 from The Telegraph: http://www.telegraph.co.uk/technology/apple/7087088/Apple-iPad-review.html

Benedyk, R., & Hadjisimou, M. (2008) "Laptops in the lecture theatre: an ergonomic focus on the critical issues". In P. D. Bust (Ed.), *Contemporary Ergonomics 2008* (pp. 389-394). The Ergonomics Society.

Benedyk, R., & Woodcock, A. (2009) "The Hexagon-Spindle Model for Ergonomics". In P. Bust (Ed.), *Contemporary Ergonomics 2009* (pp. 393-400). The Ergonomics Society.

Benedyk, R., Woodcock, A., & Harder, A. (2009) "The Hexagon-Spindle Model for educational ergonomics", *Work*, 32, 237-248.

Bergqvist, U. (1989) "Possible health effects on working with VDUs", British *Journal of Industrial Medicine*, 46 (4), 217-221.

Bergqvist, U., Wolgast, E., Nilsson, B., & Voss, M. (1995) "Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors", *Ergonomics*, 38 (4), 763-776.

Berolo, S., Wells, R. P., & III, B. C. (2011) "Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: A preliminary study in a Canadian university population", *Applied Ergonomics*, 42 (2), 371-378.

Beyer, H., & Holtzblatt, K. (1998) *Contextual Design. Defining Customer-Centred Systems*. Morgan Kaufmann Publishers.

Brand, J. L. (2008) "Office ergonomics: A review of pertinent research and recent developments". In C. Carswell (Ed.), *Reviews of human factors and ergonomics* (pp. 245-282). Santa Monica, CA: Human Factors and Ergonomics Society.

BSI (1990) *Guide to Ergonomics Principles in the Design and Selection of Office Furniture*. London: British Standards Institution.

Business Insider (2012) *iPad Usage Survey Results*. Retrieved July 21, 2012 from http://www.businessinsider.com/ipad-usage-survey-results-2012-7?op=1

Buzan, T. (1974) *Use Your Head*. BBC Books.

Buzan, T. (2006) *The Mind Map Book*. BBC Active.

Cairns, P., & Cox, A. L. (2008) *Research Methods for Human-Computer Interaction*. Cambridge: Cambridge University Press.

Charmaz, K. (2006) *Constructing Grounded Theory. A Practical Guide Through Qualitative Analysis*. SAGE Publications Ltd.

Ciccarelli, M., Straker, L., Mathiassen, S. E., & Pollock, C. (2011) "Diversity of tasks and information technologies used by office workers at and away from work", *Ergonomics*, 54 (11), 1017-1028.

Director (2010) *What the experts said: Apple iPad*. Retrieved July 19, 2012 from http://www.director.co.uk/magazine/2010/3_March/iPad_63_07.html

European Agency for Safety and Health at Work. (n.d.) *Office Ergonomics. E-facts 13*. Retrieved July 17, 2012 from http://osha.europa.eu/en/publications/e-facts/efact13

European Commission. (2010) *The increasing use of portable computing and communication devices and its impact on the health of EU workers*. Institute for Employment Studies.

Falaki, H., Mahajan, R., Kandula, S., Lymberopoulos, D., Govindan, R., & Estrin, D. (2010) "Diversity in smartphone usage", In: *Proceedings of the 8th international conference on Mobile systems, applications, and services (MobiSys '10)*, pp. 179-194. New York, NY, USA: ACM.

Foster, C. (2012) *iPads in the Office: What Are They Really Good For?* Retrieved July 13, 2012 from ReadWriteWeb: http://www.readwriteweb.com/enterprise/2012/04/ipads-in-the-office-what-are-they-really-good-for.php

Gartner. (2011) *iPad and Beyond: The Media Tablet in Business*. From http://www.gartner.com/resources/211700/211735/ipad_and_beyond_the_media_ta_211735.pdf

Gerr, F., Marcus, M., & Monteilh, C. (2004) "Epidemiology of musculoskeletal disorders among computer users: Lesson learned from the role of posture and keyboard use", *Journal of Electromyography and Kinesiology*, 14 (1), 25-31.

Geyer, M., & Felske, F. (2011) "Consumer Toy or Corporate Tool: The iPad Enters the Workplace", *interactions*, 18 (4), 45-49.

Glaser, B. G., & Strauss, A. L. (1998) *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine.

Gold, J., Driban, J., Yingling, V., & Komaroff, E. (2012) "Characterization of posture and comfort in laptop users in non-desk settings", *Applied Ergonomics*, 43 (2), 392-399.

Hagberg, M., & Sundelin, G. (1986) "Discomfort and load on the upper trapezius muscle when operating a word processor", *Ergonomics*, 29 (12), 1637-1645.

Heasman, T., Brooks, A., & Stewart, T. (2000) *Health and safety of portable display screen equipment*. HSE Books.

Hess, S., & Jung, J. (2012) "Does the iPad add value to business environments?" In: *Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts (CHI EA '12)* (pp. 335-350). New York, NY, USA: ACM.

Hill, E. J., Hawkins, A. J., & Miller, B. C. (1996) "Work and Family in the Virtual Office: Perceived Influences of Mobile Telework", *Family Relations*, 45 (3), 293-301.

Hill, E. J., Ferris, M., & Märtinson, V. (2003) "Does it matter where you work? A comparison of how three work venues (traditional office, virtual office, and home office) influence aspects of work and personal/family life", *Journal of Vocational Behavior*, 63 (2), 220-241.

HSE. (1992) *Workplace health, safety and welfare. Workplace (Health, Safety and Welfare) Regulations 1992. Approved Code of Practice*. HSE Books.

HSE (2002) *Upper limb disorders in the work place*. HSE Books.

HSE (2003) *Work with Display Screen Equipment: Health and Safety (Display Screen Equipment) Regulations 1992 as Amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002: Guidance on Regulations*. HSE Publication L26. Sudbury, UK: HSE Books.

HSE (2006) *Working with VDUs*. Health and Safety Executive.

Hughes, M., Aulck, L., & Johnson, P. W. (2011) "Are there differences in Typing Performance and Typing Forces between Short and Long travel Keyboards?" In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (pp. 954-957). Human Factors and Ergonomics Society.

iPass (2011) *The iPass Global Mobile Workforce Report. Understanding Enterprise Mobility Trends and Mobile Usage*. iPass Inc. http://www3.ipass.com/wp-content/uploads/2011/05/iPass_MWR_Q2_2011.pdf

Irwin, C. B., & Sesto, M. E. (2012). "Performance and touch characteristics of disabled and non-disabled participants during a reciprocal tapping task using touch screen technology", *Applied Ergonomics*, 43 (6), 1038-1043.

ISO (2001) *ISO 9241. Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)*. Geneva: International Standards Organisation.

ISO (2007a) *ISO 9241-400:2007. Ergonomics of human-system interaction — Part 400: Principles and requirements for physical input devices*. Geneva: International Standards Organisation

ISO (2007b) *ISO 9241-410:2007. Ergonomics of human-system interaction — Part 410: Physical input devices — Design criteria for products*. Geneva: International Standards Organisation

Jafri, S. (2010) *5 Reasons the iPad may be Bad for Ergonomics*. Retrieved July 11, 2012 from Suite101.com: http://www.suite101.com/content/5-reasons-the-ipad-may-be-bad-for-ergonomics-a222510

Karlson, A. K., Meyers, B. R., Jacobs, A., Johns, P., & Kane, S. K. (2009) "Working Overtime: Patterns of Smartphone and PC Usage in the Day of an Information Worker", *Pervasive Computing. Lecture Notes in Computer Science*, 5538, 398-405.

Kuniavsky, M. (2003) *Observing the User Experience. A Practitioner's Guide to User Research*. Morgan Kaufmann Publishers.

Lee, D. L., Kuo, P.-L., Jindrich, D. L., & Dennerlein, J. T. (2009) "Computer keyswitch force-displacement characteristics affect muscle activity patterns during index finger tapping", *Journal of Electromyography and Kinesiology*, 19 (5), 810-820.

Li, G., & Buckle, P. (1999) "Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods", *Ergonomics*, 42 (5), 674-695.

Lima, T. M., & Coelho, D. A. (2011) "Prevention of musculoskeletal disorders (MSDs) in office work: A case study", *Work*, 39 (4), 397-408.

Lozano, C., Jindrich, D., & Kahol, K. (2011) "The impact on musculoskeletal system during multitouch tablet interactions", In: *Proceedings of the 2011 annual conference on Human factors in computing systems (CHI '11)* (pp. 825-828). New York, NY, USA: ACM.

Lundervold, A. (1958) "Electromyographic investigations during typewriting", *Ergonomics*, 1 (3), 226-233.

MacLeod, I. S., Wells, L., & Lane, K. (2000) "The Practice of Triangulation". In P. McCabe, M. Hanson, & S. Robertson (Eds.), *Contemporary Ergonomics 2000*. London: Taylor & Francis.

Marcus, M., Gerr, F., Monteilh, C., Ortiz, D. J., Gentry, E., Cohen, S., Edwards, A., Ensor, C., Kleinbaum, D. (2002) "A Prospective Study of Computer Users: II. Postural Risk Factors for Musculoskeletal Symptoms and Disorders", *American Journal of Industrial Medicine*, 41 (4), 236-249.

McAtamney, L., & Corlett, N. (1993) "RULA: a survey method for the investigation of work-related upper limb disorders". *Applied Ergonomics*, 24 (2), 91-99.

McCauley, D. (2011) *iPad Neck - ergonomics experts warn of tablet injury*. Retrieved July 11, 2012 from Herald Sun: http://www.heraldsun.com.au/technology/tablets/switching-from-a-computer-to-ipad-could-be-a-pain-in-the-neck-ergonomics-experts-warn/story-fn5qlb5w-1226113141390

Mobile Review (2010) *Apple's Phone: From 1980s' Sketches to iPhone. Part 3*. (2010). Retrieved July 10, 2012: http://mobile-review.com/articles/2010/iphone-history3-en.shtml

Myers, B. A. (1998) "A brief history of human-computer interaction technology", *interactions*, 5 (2), 44-54.

Nelson, J. E., Treaster, D. E., & Marras, W. S. (2000) "Finger motion, wrist motion and tendon travel as a function of keyboard angles", *Clinical Biomechanics*, 15 (7), 489-498.

Nguyen, B., & Chaparro, B. (2011) "iPad Usage Patterns On-the-Go and at Work", *Usability News*, 13 (2).

Oborne, D. J. (1995) *Ergonomics at Work. Human Factors in Design and Development*. John Wiley & Sons.

Ofcom. (2012) *Communications Market Report 2012*. Retrieved July 21, 2012 from http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr12/CMR_UK_2012.pdf

OPA (2012) *A Portrait of Today's Tablet User, Wave II*. Online Publishers Association & Frank N. Magid Associates.

Oppenheim, A. N. (1992) *Questionnaire Design, Interviewing and Attitude Measurement*. Continuum.

Pheasant, S., & Haslegrave, C. M. (2006) *Bodyspace. Anthropometry, Ergonomics and the Design of Work* (3rd ed.). Taylor & Francis.

Price, J. M., & Dowell, W. R. (1998) "Laptop configurations in offices: Effects on posture and discomfort", In: *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting* (pp. 629-633). Human Factors and Ergonomics Society.

Punnett, L., & Wegman, D. H. (2004) "Work-related musculoskeletal disorders: the epidemiologic evidence and the debate", *Journal of Electromyography and Kinesiology*, 14 (1), pp. 13-23.

Radwin, R. G., & Jeng, O.-J. (1997) "Activation Force and Travel effects on Overexertion in Repetitive Key Tapping", *Human Factors*, 39 (1), 130-140.

Richardson, J. T. (1996) *Handbook of Qualitative Research Methods for Psychology and the Social Sciences*. Leicester, England: British Psychological Society.

Rieman, J. (1993). "The diary study: a workplace-oriented research tool to guide laboratory efforts", In: *CHI '93: Proceedings of the INTERACT '93 and CHI '93 conference on Human Factors in Computing Systems* (pp. 321-326). New York: ACM.

Rieman, J. (1996) "A Field Study of Exploratory Learning Strategies", *ACM Transactions on Computer-Human Interaction*, 3 (3), 189-218.

Seghers, J., Jochem, A., & Spaepen, A. (2003) "Posture, muscle activity and muscle fatigue in prolonged VDT work at different screen height settings", *Ergonomics*, 46 (7), 714-730.

Sharp, H., Rogers, Y., & Preece, J. (2009). *Interaction Design. Beyond Human-Computer Interaction* (2nd ed.). John Wiley & Sons.

Shin, G., & Zhu, X. (2011). "User discomfort, work posture and muscle activity while using a touchscreen in a desktop PC setting", *Ergonomics*, 54 (8), 733-744.

Sillanpää, J., Huikko, S., Nyberg, M., Kivi, P., Laippala, P., & Uitti, J. (2003) "Effect of work with visual display units on musculo-skeletal disorders in the office environment", *Occupational Medicine*, 53 (7), 443-451.

Sommerich, C. M., Jones, S. M., & Psihogios, J. P. (2001) "Effects on Computer Monitor Viewing Angle and Related Factors on Strain, Performance, and Preference Outcomes", *Human Factors*, 43 (1), 39-55.

Spencer, E. A., Appleby, P. N., Davey, G. K., & Key, T. J. (2001) "Validity of self-reporeted height and weight in 4080 EPIC-Oxford participants", *Public Health Nutrition*, 5 (4), 561-565.

Stanton, N., Hedge, A., Brookhuis, K., Salas, E., & Hendrick, H. (2005) *Handbook of Human Factors and Ergonomics Methods*. CRC Press LLC.

Stock, S. R. (1991) "Workplace Ergonomic Factors and the Development of Musculoskeletal Disorders of the Neck and Upper Limbs: A Meta-Analysis", *American Journal of Industrial Medicine*, 19 (1), 87-107.

Straker, L., Burgess-Limerick, R., C.Pollock, & Maslen, B. (2009) "The influence of desk and display design on posture and muscle activity variability whilst performing information technology tasks", *Applied Ergonomics*, 40 (5), 852-859.

Straker, L., Jones, K. J., & Miller, J. (1997) "A comparison of the postures assumed when using laptop computers and desktop computers", *Applied Ergonomics*, 28 (4), 263-268.

Szeto, G. P., Straker, L., & Raine, S. (2002) "A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers", *Applied Ergonomics*, 33 (1), 75-84.

Tessler, F. (2012) *The hidden danger of touchscreens*. Retrieved July 11, 2012 from InfoWorld: http://www.infoworld.com/t/laptops/the-hidden-danger-touchscreens-181774

The Stationery Office (1974) *Health & Safety at Work etc Act 1974*.

The Verge (2011) *iOS: A visual history*. (2011). Retrieved June 18, 2012 from http://www.theverge.com/2011/12/13/2612736/ios-history-iphone-ipad

The Verge (2012) *iPad tip: 'phantom' keys in the middle of the split keyboard*. Retrieved June 18, 2012 from http://www.theverge.com/2012/2/4/2770085/ipad-trick-phantom-keys-split-keyboard

Thomas, J. P., & LaRosa, K. A. (2011) *Does Your Company Have a Smartphone Policy?* Retrieved August 05, 2012 from http://www.pepperlaw.com/publications_update.aspx?ArticleKey=2224

UNISON (1998) *Health and safety and the use of laptop computers. Guidelines for UNISON branches, safety representatives and stewards.*

Vartiainen, M., & Hyrkkänen, U. (2010) "Changing requirements and mental workload factors in mobile multi-locational work", *New Technology, Work and Employment*, 25 (2).

Viken, A. (2009) *The history of Personal Digital Assistants 1980 – 2000*. Retrieved July 24, 2012 from Agile Mobility: http://agilemobility.net/2009/04/the-history-of-personal-digital-assistants1/

Villanueva, M. B., Jonai, H., & Saito, S. (1998) "Ergonomic Aspects of Portable Personal Computers with Flat Panel Displays (PC-FPDs): Evaluation of Posture, Muscle Activities, Discomfort and Performance", *Industrial Health*, 36, 282-289.

Vu, H. (2012) *Since Launch, Apple Has Sold 250 Million Units Of The iPhone, Generated $150 Billion In Revenue*. Retrieved July 24, 24 from http://iphone4s-guide.com/since-launch-apple-has-sold-250-million-units-of-the-iphone-generated-150-billion-in-revenue.html

Wahlström, J. (2005) "Ergonomics, musculoskeletal disorders and computer work", *Occupational Medicine*, 55 (3), 168-176.

Young, J. G., Trudeau, M., Odell, D., Marinelli, K., & Dennerlein, J. T. (2012) "Touch-screen tablet user configurations and case-supported tilt affect head and neck flexion angles", *Work*, 41 (1), 81-91.

Zhai, S., & Kristensson, P.-O. (2003) "Shorthand writing on stylus keyboard", In: *Proceedings of the SIGCHI conference on Human factors in computing systems (CHI '03)* (pp. 97-104). New York, NY, USA: ACM.

B. APPENDIX

B1. Information sheet

Touch-screen tablets in the office

Research information sheet

This study has been approved by the UCL Research Ethics Committee.

Project ID Number: MSc/1011/022

It is conducted by Katarzyna Stawarz (Katarzyna.stawarz.10@ucl.ac.uk) and supervised by Rachel Benedyk (r.benedyk@ucl.ac.uk).

This research focuses on how people use touch-screen tablets for work in the office. We aim to investigate for what purposes workers use tablets, in what circumstances they use them and how tablets fit into their current workflow and their work in general.

The session should take about an hour and will include an interview (lasting about 45 minutes) and a short observation of tablet usage (lasting about 15 minutes). During the observation part you will be asked to complete some typical tasks you normally do on your tablet and some pictures of you may be captured.

The participation in this study is voluntary. If you choose not to participate it will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

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

B2. Consent form

Touch-screen tablets in the office

Research information sheet

Thank you for participating in my thesis research.

The participation in this study is voluntary and you are free to withdraw your consent at any time without any explanation.

The interview will be recorded (audio only) to allow me to review the notes and analyse the information. I will also take some photos of you using your tablet and the surroundings to help me with the analysis of the office space.

Interview transcripts will be anonymous and your name or personal details won't be used. If you agree, I may use some of your photos to illustrate the findings.

If you have any questions after today's session, feel free to contact Katarzyna Stawarz at katarzyna.stawarz.10@ucl.ac.uk.

Participant's Statement

I agree to participate in the research and I understand that I am free to withdraw from the study at any point.

Print your name _____

Signature _____

Date _____

I agree to have my photos used for academic purposes related to this study.

Print your name _____

Signature _____

Date _____

B3. Interview outline

- Can you briefly describe your role and what you do at work?
- What tablet do you use? What model is it?
- Is it a work tablet? / Do you have your own?
- How long have you been using your tablet?
- What do you use your tablet for?
- What types of information (work-related) do you access on the tablet?
- What other electronic devices do you use at work?
- And how do the tablet and other devices fit into your work? / Are there any specific things you do only on your laptop or only or your tablet, etc.?
- Where do you use your tablet for work?
- How often do you use the tablet? And for how long?
- How comfortable do you find using the tablet in [the places you mentioned]?
- Is there anything that could be improved in terms of office equipment, infrastructure, etc.?
- Before you got your tablet, how did you do [task from the previous question]?
- Why did you get a tablet in the first place?
- Before you bought/got your [tablet], how did you plan to use it?
- Why did you start using your tablet to do [task from the previous question]?
- How different is using the tablet to do [task] than using [the thing you used before] for that?
- What would you do if you weren't able to use the tablet anymore?
- Was there a difference between your initial plans, the way you used the tablet at first and the way you use it now? How did it change? Why?
- How do you transport your tablet?

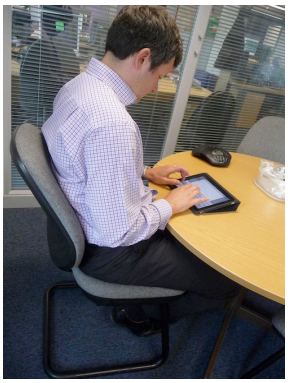
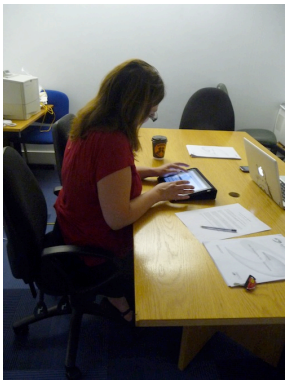
- Do you use it in public places? / Do you ever think about your security or privacy when using it in public?
- Do you use any additional devices or aids, for example keyboards, stands for typing? Which ones?
- Why do you (not) use them?
- Is there any type of an external device you would like to have?
- Is there anything in particular that you like about the tablet, especially as a work device?
- Overall, what do you think about the design in terms of weight, shape, screen?
- And what do you think about the functionality?
- Is there anything that you dislike about the tablet or something that could be improved? What is it?
- Is there anything else you would like to add?

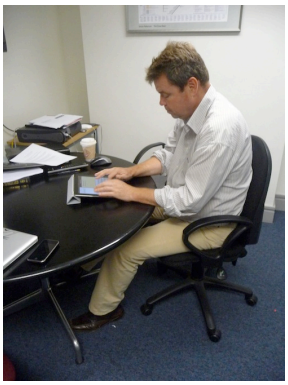
B4. Ergonomic risk assessment checklist

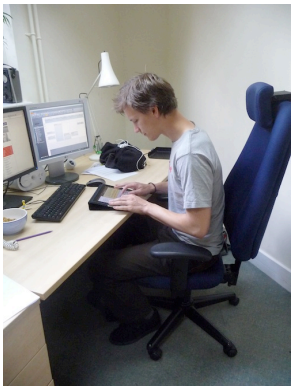
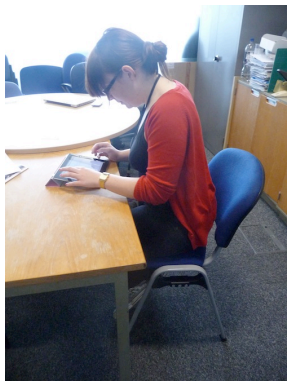
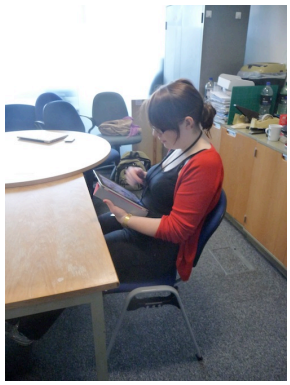
Check all that apply:

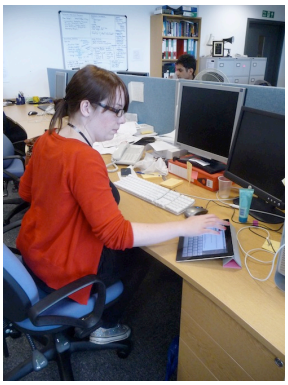
- Repeating the same movement
- Cycle of sequences
- Intensive use of wrists/hands/fingers
- Regular shoulder/arm movement
- Bent wrists
- Hands held with no support (e.g. palms facing down)
- Repetitive bending of the neck or holding the neck bent
- Visual demands (i.e. a task requires to view fine details and adapt an awkward posture)
- Large range of joint movements (side-side, up-down)
- Using a lot of force
- Stretching and twisting the body
- Carrying out a task for a long period of time
- Poor working environment (glare, reflections, noise, vibration, temperature)
- Improvised changes to work equipment, furniture, or tools

B5. Posture analysis: RULA (examples)

	**Task: typing an email.** Note: He said he usually typed like that, but before the interview he was typing something with his tablet on his desk, sloping forward much more. Possible risk factors: • Neck bent and fixed in this position • No support for the elbows • Wrists twisted inside • Repeated typing movements • Legs not flat on the floor **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: browsing the internet and reading articles online.** Possible risk factors: • No back support • Bent forward • No support for the tablet, has to hold it with one hand • Left hand locked in this position for longer periods of time • Wrists twisted • Leaning forward on the chair • No proper leg support • Screen away from the head and much lower, he may bend his neck as well • Repeated movement of the right hand when scrolling down (e.g. reading longer articles) **RULA score (left/right): 3/3** "Further investigation is needed and changes may be required"
	**Task: taking notes.** Note: she also keeps her tablet in the same way on her desk and uses it for emails or as an additional screen. Possible risk factors: • No back support • Neck bent forward • Shoulders raised • No elbow or wrist support • Palms held with no support, facing down • Forearms twisted inside R**ULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: taking notes.** Note: occasionally she prefers to type with her tablet on her lap. Possible risk factors: • Neck bent forward • No arm support • No elbow support • Knees raised to support the tablet • Wrists twisted • Palms lifted • Repeated typing movement **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"

	**Task: taking notes.** Note: he mentioned occasional neck pains after using the tablet for long. Possible risk factors: • Shoulders slumped forward • Neck slightly bent • The screen much below the sight line • No elbow support • Wrists twisted inside and slightly lifted • Repeated typing movement **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: taking notes.** Possible risk factors: • No back support • Body bent forward • Neck bent forward • Arms away from the body in order to support elbows on arm rests • No support for wrists • Wrists extended • Uneven body weight distribution – sitting with one leg over another **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: reading work documents.** Note: she reads in a room next door. She doesn't read longer documents at her desk. Possible risk factors: • Bent neck • Screen away from the eyes • Arms away from the body to reach arm rests • Uneven body weight distribution – sitting with one leg over another to lift the tablet RULA score (left/right): 4/4 "Further investigation is needed and changes may be required"
	**Task: taking notes.** Note: he usually types like that – that's one of his most comfortable positions. He generally prefers leaning backwards than forwards. Possible risk factors: • Leaning back, body not in the upright position • Slightly leaning towards the left side of the body • Neck slightly bent forward • Screen below the sight line • Right wrist flexed • No right elbow support • No wrists support • Right leg lifted, leaning on the left knee **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"

	**Task: taking notes.** Note: that's how he usually takes notes on formal meetings when he can't sit too comfortably and keep the tablet on his lap (see picture above). Possible risk factors: • No back support • Body leaning forward • Neck extended and bent forward • No elbow support • Forearms twisted towards the inside of the body • No wrists support **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: using a tablet as an additional screen.** Possible risk factors: • No back support • Neck twisted to the left • Screen way below the sight line • Left arm lifted and extended to the left • The distance between the keyboard and the extra screen (the tablet) too big – requires large joint movements • Need to lean to the side when typing / touching the screen **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: taking notes and responding to emails.** Possible risk factors: • No back support • Body leaning forward • Neck bent • No wrist support • Body slightly twisted to the right as the tablet is not in the front • No wrist support, occasionally wrists flexed **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: reading work documents.** Possible risk factors: • Neck bent forward • No elbow support • Left hand locked in this position, supporting the tablet • Right hand turning pages – regular swiping movements **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"

	**Task: using a tablet as an additional screen.** Possible risk factors: • No back support • Body leaning forward • Neck twisted to the right • No elbow support • Right hand away from the body, extended to reach the tablet • No proper leg support **RULA score (left/right): 3/4** "Further investigation is needed and changes may be required"
	**Task: taking notes.** Possible risk factors: • Body slightly bent forward • Neck bent forward • Forearms twisted inside • Repetitive finger movements (typing) **RULA score (left/right): 3/3** "Further investigation is needed and changes may be required"
	**Task: reading and editing work documents.** Note: he mainly uses his tablet in a train, so this is just a demonstration. He always uses a bag on his lap to support the tablet. Possible risk factors: • Leaning forward • No proper back support • Neck bent • Supporting the tablet with one hand (left hand locked in this position) **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"
	**Task: reading while standing in a train (a demonstration).** Note: he still uses the tablet when he has to stand on a train. He doesn't use it when it's too busy, but he does use it when he's able to lean against something. • Neck slightly bent • No arms or elbows support • Holding a device in a locked position • Needs to maintain balance (standing on a moving train) **RULA score (left/right): 4/4** "Further investigation is needed and changes may be required"

B6. Online questionnaire

Question	Answers
1. Preliminary questions	
First, I would like to ask some general questions about your tablet.	
1.1 Which tablet do you use? *If you use more than one tablet, please focus on the one you use most often for work.*	a) Apple iPad b) Apple iPad2 c) Samsung Galaxy Tab d) Motorola Xoom e) Blackberry Playbook f) Other
1.2 Do you use a 3G mobile network to connect to the Internet on your tablet?	a) Yes b) No (Wi-Fi only) c) Don't know
1.3 Was your tablet paid for by your company?	Y/N
1.4 To what extent do you use your tablet for work purposes?	a) Only for work b) Mainly for work c) About the same for work and entertainment/leisure d) Mainly for entertainment/leisure e) Only for entertainment/leisure
1.5 How long have you been using your tablet?	a) Less than a month b) 1 – 3 months c) 3 – 6 months d) 6 – 12 months e) Over a year
1.6 What other electronic devices do you use for work?	a) Desktop computer b) Laptop / Netbook c) Smartphone d) Other e) None
1.7 Why did you get a tablet?	a) Was necessary for work (e.g. for apps development and testing) b) Expected it to be useful for work c) Wanted to try the new gadget d) It was given by the company e) Other
2. Usage patterns	
In this section, I would like to learn more about how and where you use your tablet for work.	
2.1 What do you use your tablet for?	a) Checking emails b) Taking notes at meetings c) Taking notes at conferences d) Reading work documents e) Reading books f) Browsing / Online research g) Developing / Testing apps h) Presenting i) Managing appointments / Calendar j) Using it as an additional screen k) Other
2.2 How often do you use your tablet in the following locations? *(Answers on a scale from Never to Very often)*	a) At desk b) In a meeting room c) On a train or the tube d) On a bus e) On a plane f) At home g) Outside (e.g. in a park) h) In public places (e.g. cafés, pubs, airports)
2.3 How do you access work documents?	a) Email them to myself b) Online file sharing apps (e.g. Dropbox)

	c) Company's intranet / bespoke app d) Other e) I don't access them at all
(If 2.3b) *2.4 To what extent are concerned about the security issues related to keeping work files on a 3rd party server like Dropbox?*	a) Not at all b) A little c) Very concerned
2.5 When using your tablet at work, are there any situations where tablet use is recommended or even compulsory?	Y/N
(If 2.5 Yes) *Please shortly explain when and how tablet use was recommended or compulsory.*	Open-ended answer
2.6 When using your tablet at work, are there any situations where tablet use is discouraged or banned?	Y/N
(if 2.6 Yes) *Could you shortly explain when and why was it discouraged or banned?*	Open-ended answer
(if 1.5 d or e) *2.7 Is there a difference between how you used it 6 months ago and how you use it now?* *Answers on a scale from Using it less to Using it more + I've never used it for this.*	a) Checking emails b) Taking notes at meetings c) Taking notes at conferences d) Reading work documents e) Reading books f) Browsing / Online research g) Developing / Testing apps h) Presenting i) Managing appointments j) Using it as an additional screen
2.8 Is there a difference between how you used it 6 months ago and how you use it now? *Answers on a scale from Using it less to Using it more + I've never used it there.*	a) At desk b) In a meeting room c) On a train or the tube d) On a bus e) On a plane f) At home g) Outside h) In public places (e.g. cafes, pubs)
3. Comfort of use	
Now I would like to ask you about the frequency and the comfort of use.	
3.1 How often do you use your tablet at work?	a) Every day b) Every other day c) Every 3-4 days d) Once a week e) Less than once a week
3.2 And on a single day when you have your tablet with you at work, for how long do you use it in total?	a) All the time b) For over 5 hours c) For 3-5 hours d) For 1-2 hours e) Less than an hour
3.3 How often do you carry your tablet with you? (e.g. during commute)	a) All the time b) Few times per week c) Only for meetings / conferences d) It's in the office all the time e) Other
3.4 Below is a list of things people say about their tablets. Please select statements you agree with:	a) It's too heavy b) It's comfortable to carry c) It's too cumbersome to carry d) The size is about right e) It's too big f) It's too small g) Screen is too big h) Screen is too small i) Screen is too shiny j) Typing is comfortable

	k) Typing is uncomfortable l) Keyboard is too small
3.5 How often do you experience any discomfort when doing following things on the tablet: *Answers on a scale from Never to All the time + I don't do it*	a) Typing b) Reading c) Watching videos d) Presenting
3.6 What tablet accessories do you use?	a) Cover b) Stand / dock c) External keyboard d) Stylus e) Other f) I don't use any accessories
(If 3.6) *3.6 Why do you not use any accessories?*	a) Not needed b) Too expensive c) Too cumbersome to carry d) Other
3.7 How often do you use your tablet in those situations: *Answers on a scale from Never to Very often*	a) Sitting at a desk / table b) Sitting on a sofa / chair c) Sitting in a car / train / plane d) Standing e) Laying in bed
3.8 When using your tablet, how often, if ever, do you experience discomfort in these areas of your body? *Answers on a scale from Never to Very often*	a) Head b) Eyes c) Neck d) Shoulders e) Back f) Wrists g) Fingers
3.9 When you experience any pains or discomfort when working on a tablet, what do you do?	a) Continue working in a different posture b) Work in a different place c) Stop working d) Stretch e) Other f) I never experience any pains or discomfort g) Do nothing
4. Using tablet in public places	
In this section I would like to ask you how comfortable – or not – do you find using your tablet outside your home and office environment, mainly in public spaces and public transport.	
4.1 How comfortable do you find using your tablet outside? (e.g. in a park)	a) Very comfortable b) Comfortable c) Uncomfortable d) Very uncomfortable e) I don't use it outside
4.2 Could you briefly explain what makes using a tablet outside uncomfortable?	Open-ended question
4.3 When using your tablet in public, how worried are you about privacy?	a) Not worried at all b) Worried a little / Occasionally c) Worried d) Very worried e) I don't use it in public
4.4 When using your tablet in public, how worried are you about your personal safety?	a) Not worried at all b) Worried a little / Occasionally c) Worried d) Very worried e) I don't use it in public
4.5 How comfortable do you find using your tablet in public transport, e.g. during commute?	a) Very comfortable b) Comfortable c) Uncomfortable d) Very uncomfortable e) I don't use it in public transport
4.6 Could you briefly explain what makes using it in public	Open-ended question

transport uncomfortable?	
4.7 What, if any, special precautions do you take to prevent your tablet from being stolen?	a) Keep it close at all times b) Keep it entirely at home c) Keep it entirely in the office d) Lock it away when not using it e) Never use it in public f) Have insurance g) Use password protection/remote wipe h) Other i) Not concerned/Don't take any precautions
4.8 Do you share your tablet with your friends and family or colleagues?	a) Share with partner or spouse b) Share with kids c) Share with other family members d) Share with friends e) Share with colleagues f) I don't share my tablet
5. Company facilities	
In this section I would like to learn more about the facilities at your work and whether you adjust your workspace to make it more comfortable to use the tablet.	
5.1 Have you made any adjustments to your workspace to make it more comfortable to use your tablet on it?	Y/N
(if 5.1 Y) *5.2 Could you explain how / what adjustments?*	Open-ended
5.3 What could your company do to provide facilities to improve your ability to use your tablet in comfort?	a) Provide wireless connection b) Ensure internal systems are compatible with the tablet c) Provide software to allow accessing and sharing work documents d) Provide better seating or tables/desks e) Change lighting f) Provide more/better technical support g) Provide accessories, e.g. covers, keyboards h) Provide chargers i) Other
5.4 Are you aware of any health & safety guidelines provided by your company related to using a tablet?	Y/N
5.5 Are you aware of any IT regulations related to the tablet use in your workplace?	Y/N
6. About you	
Now I'd like to learn a little bit about you.	
6.1 Where do you work?	Built-in drop down with industry sectors
6.2 What is your job title?	Open-ended
6.3 What is your age?	a) Under 18 b) 18-24 c) 25-34 d) 35-54 e) 55+
6.4 What is your gender?	a) Female b) Male c) Other / Rather not say
6.5 What is your height? *(Complete either in feet and inches or in cm)*	Open-ended
6.6 Do you suffer from any long-term health conditions or disabilities that could affect the way you use your tablet?	a) Visual impairments b) RSI c) Back problems d) Motor impairments e) Other f) None

C. LIST OF FIGURES

D. LIST OF TABLES