City University London MSc in Human Centred Systems

Project Report

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Comparing reading behaviour on smartphones versus the desktop web

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Declaration

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Abstract

Smartphone ownership is on the increase, with the number of people accessing the internet through their phones growing each year. Despite the larger screen sizes of modern smartphones, they still offer 80% less screen estate than the average desktop screen. In response, digital content producers have produced apps and stripped down versions of their websites, but there is little research on what impact smartphone form factor has on people's experience of the internet compared to the desktop web. This project sets out to understand if internet reading behaviour differs on smartphones and the desktop web. A diary study was first conducted to better understand internet reading habits on both devices, followed by a within subjects exploratory study where users completed reading tasks on both the smartphone and the laptop.

Keywords:

mobile web, desktop web, digital reading, smartphone, internet

Contents

1. Introduction

1.1 Background

Accessing the internet via computers is well established – more than three quarters of UK households have internet connections (Williams 2011). Yet in the past few years there has been a significant increase in ownership of smartphones – more than 40% of the UK population owns a smartphone and this figure is set to grow (Kantar Worldpanel ComTech 2011). Smartphones' high-res screens, touchscreen interfaces and 3G connections mean increasing numbers are using them to access the internet – an estimated extra 6 million people accessed the internet via smartphones in the last year alone (Williams 2011).

Yet the internet is a vast resource that contains far more information than a single person could ever read. Between 1998 and 2008, the number of web pages grew from 26 million to one trillion (Alpert & Hajaj 2008); however any search engine query will return results that vary in terms of relevance, credibility and quality. This means people have to make quick decisions about what they will read given that the amount of time they have to read has not significantly changed (Liu 2005).

This has led to significant challenges for the desktop web in terms of both improving findability, eg through information architecture, and the user experience through both design and content.

While guidelines for producing desktop websites are well established, for example Nielsen's F-shaped reading pattern for writing content (Nielsen 2006), there are no matching principles for mobile content.

Similarly, the growing number of devices that can access websites has led to much debate among content producers about how to best accommodate these different screen sizes – for example a typical mobile phone screen of 320 x 480 pixels has 80 per cent less screen estate than a 1024 x 768 desktop screen (Wroblewski 2011). Adding to the problem is the huge variety of smartphone screen sizes that range from 5cm (eg HTC ChaCha) to more than 10cm (eg Samsung Galaxy S2).

This has resulted in a lack of agreement among content producers on whether to develop one website that fits all (eg by developing for mobile first or having a fluid layout as per responsive design) or to create separate device specific websites in the form of apps or stripped down versions (Nielsen 2012).

There is also little academic research on people's experience of the internet on their smartphones compared to the desktop web to provide evidence for these design choices. This project sets out to help address this gap and understand if internet reading behaviour differs on smartphones and the desktop web.

1.2 Choice of project

While there has been much research on the effect of font size and display size on reading (eg Dillon et al 1990, Bernard et al 2003), the majority of this research predates modern touchscreen phones, with small screens simulated by masking the desktop screen, or carried out on feature phones or

PDAs (eg Oquist & Lundin 2007, Marshall & Ruotolo 2002). Many modern smartphones also use touchscreens that enable gesture scrolling and zooming to manipulate the page on the screen.

To the researcher's knowledge, there has been no study that investigates the effect of these form factors on internet reading habits or comparing reading behaviour on the desktop web compared to the mobile web.

Equally, Liu's review of digital reading behaviour (2005) highlighted a number of other differences in people's preferences for format, both in terms of credibility – students found online text less interesting and the authors less credible than the printed version – and attitudes to content – digital content was seen as good for lightweight content and printed documents for sustained reading and complex topics.

It remains to be seen if similar differences exist between attitudes to digital content on the desktop and mobile web.

1.3 Objectives

The overall objective of this project is to investigate reading behaviour on the mobile web and the desktop web. This leads to the following research questions:

1. What do smartphone owners read on the internet on their smartphone and computer?
2. Does screen size have an impact on what is read and the amount read on the internet?
3. Does gestural interaction on touchscreens affect reading behaviour compared to point and click interaction? Are smartphone readers more or less likely to scroll?
4. Do smartphone owners notice any difference in reading on a smartphone compared to a computer? Do they have preferences in terms of device or attitudes to internet reading?

1.4 Work plan

Originally the researcher intended to conduct an experimental study to investigate reading patterns on the desktop and mobile web, using eye tracking to gather data such as reading speed and testing comprehension.

However, after discussion with their supervisor based on the researcher's wider review of academic literature than was possible for the project proposal, it became clear that collecting data on this sort of performance measure would not yield a great deal of insight into users' reading behaviour in terms of either their experience or reading habits. It would also be premature to focus on reading patterns, given a lack of recent studies on digital reading, particularly on the smartphone, with many previous reading studies on the internet looking at the difference between print and screen reading (Holmqvist et al 2003) or specialised texts for comprehension (Duggan & Payne 2006).

Instead a diary study was carried out to understand the internet reading habits of smartphone owners, which subsequently informed the development of tasks and topics for an exploratory study on internet reading, with users carrying out tasks on both the smartphone and the PC. The inclusion of the diary study pushed back the original dates for recruitment and conducting the study as detailed in the work plan in Appendix A.

1.5 Benefits

This research can contribute to the debate on how to design websites for smartphones and help content producers create more effective content for both the desktop and mobile web. Academically, this project will add to research on digital reading behaviour on both smartphones and the desktop web.

1.6 Report structure

Chapter 2 investigates the academic literature on digital reading to inform the research methods for the diary study and observations. Chapter 3 sets out the methods used. Chapter 4 contains the results of these studies, with discussions of the findings in Chapter 5. The final chapter looks at the project overall, including learnings from carrying out the research.

2. Literature review

This literature review provides an overview of previous research into reading, including:

- how we read
- reading strategies
- internet use and reading
- factors that affect reading

2.1 How we read

Research into reading predates the internet. Numerous studies have analysed how we read, with many using eye tracking technology to follow gaze patterns when reading to match them to attention.

Rayner's review of eye tracking studies (1998) identifies the following eye movements during reading:

- fixations - stable periods of about 200-250ms where the eye focuses on one point
- saccades - rapid forward movements between fixations usually around 7-9 letter spaces long
- regressions – about 10-15% of eye movements are backward movements to previously read words or lines; regressions that are longer than 10 letter spaces point to problems with understanding text
- return sweeps – movement from the end of one line to the beginning of the next

Reading is a complex activity and the combination of fixations, saccades and regressions varies greatly between individuals and within individuals depending on what is being read and for what purpose (Just & Carpenter 1980).

While we tend to think of reading as a serial linear activity where text is processed word by word, eye tracking research reveals a more complex picture.

For example, while the majority of words are fixated during reading, some are skipped – particularly frequent, short words (Rayner 1998). Context can also increase or decrease how likely words are to be skipped, eg if king comes before queen – this is known as 'priming' (Rayner 1998).

Conversely, longer, more complex words, eg eight letters long, are more likely to be fixated on and tend to have two fixations – at the start and end of the word. Difficult words are also more likely to be reread.

How likely we are to skip words also depends on our reading skill and our perceptual span – the 14 or so letter spaces to the right of a fixation where some information about the text can be interpreted (Buscher et al 2012).

Finally, research has established that while we don't have to fixate on a word to process it, we see new information during fixations and not saccades (Ishida & Ikeda quoted in Rayner 1998).

While eye movements indicate where attention is on the page, there are limitations to its insights. It may show where attention falls, but not why. The user may be focusing on the text because they are struggling with the text, find it interesting – or may be thinking about something else entirely.

2.2 Reading speed

Reading is a rapid activity with common reading speeds of between 225 and 250 words per minute (Just & Carpenter 1980, Rayner 1998). In terms of mobile reading speeds, a recent eye-tracking study (Biedert et al 2012) found a range of reading speeds of between 174wpm and 272wpm on an Android smartphone for Wikipedia-style articles; while an earlier study (Oquist & Lundin 2007) on news stories on feature phones found slower reading speeds of between 135wpm and 178wpm.

However, while these numbers indicate the speed that people can read, they say nothing about how much people do read or the strategies they adopt when faced with text.

2.3 Reading strategies: scanning, F-shape, skimming, satisficing

Eye tracking studies have shown the wide variation in what we focus on and how we process text when we read; while words are skipped in continuous reading, ie because they don't need to be fixated on to be processed, this is an unconscious result of the reader's comprehension and processing skills.

Words, paragraphs and whole pages may also be consciously skipped by the reader for any number of reasons, eg lack of interest, relevance or time.

How and why readers skip text and what they choose to read has been the subject of much research. This has led to many taxonomies of reading skills (Johnson & Johnson 1998). Two key reading strategies people adopt include:

- scanning – rapid goal driven reading to find specific information in text, eg a name in a contact list
- skimming – rapid reading to get the overall gist of the piece; text (words, paragraphs, headings) are skipped (Johnson & Johnson 1998)

It is well accepted that people scan texts and selectively focus on different areas. For example academics focus on the introduction and conclusion of journal papers and skip dense blocks of formula (Hornbaek & Frokjaer 2003). Eyetracking research by the Poynter Institute also found that print newspaper readers scanned text, with only a quarter of articles seen and around 10% read more than halfway through (Garcia & Stark 1991).

2.3.1 Screen reading patterns and the desktop web

Just as print readers scan so do online readers: work by Holmqvist et al (2003) found that online news readers typically scanned navigation pages such as the homepage and only read selected articles in depth.

Later eye-tracking research on website use by Nielsen (2006) found that people scanned web pages in an F-shaped reading pattern, typically scanning across the first few lines of the page before scanning down keywords and subheadings to quickly come to a decision about the content. This fragmented non-linear skim-reading is a pattern that other studies have also found.

A study by Buscher et al (2010) found a sideways T reading pattern when users were given reading and shopping tasks – with the stem representing scanning and the horizontal bar reading. The reading tasks involved searching through long Wikipedia style articles for information, with people tending to read across the page fully but only for a few lines' height. A similar pattern was seen when users searched for information in a table for the shopping task, but with far more keyword spotting and few lines read fully.

2.3.1.1 Satisficing

Wilkinson and Payne's 2006 study on how students read four texts on the human heart under time pressure found a different reading pattern: satisficing. Based on earlier work on search by Pirolli and Card (quoted in Wilkinson & Payne 2006), satisficing is a more linear reading strategy where users read the start of each paragraph and continue reading the text until information relevance drops below their interest threshold, when they skip to the next paragraph.

In this way, users search for information by rejecting irrelevant text rather than following an information scent (also Reader & Payne 2007).

Later work by Duggan and Payne (2011) found further evidence of satisficing behaviour by users, with most lines fixated on more than once and users reading across the screen rather than just the first few words. Like Nielsen's earlier study, the authors also found that paragraphs at the top of the page were read for longer than those lower down.

Unlike Nielsen's research on commercial websites, Duggan and Payne's study used continuous text that the participants knew they were going to be tested on.

Similarly, research into participants' digital reading strategies for scientific texts (Hornbaek & Fokjaer 2003) identified mainly linearly reading of text, apart from at the start and end of reading. Participants also performed something the authors call 'flip through' – a scroll through the entire document in less than 30 seconds at the start of tasks. However users were reading the text for the given purpose of writing an essay.

The differences between reading strategies found in the above studies indicates that users' reading behaviour changes according to text and task type – in other words, why text is read affects the way it is read (Biedert et al 2012b).

2.3.2 Skim reading and comprehension

How much information we understand when skim reading is something a number of studies have investigated.

Early research by Masson in the 1980s found that when users skim-read text, recognition of both important and unimportant information declined equally, as did the ability to make inferences from the text (Duggan & Payne 2006).

Duggan and Payne's similar study in 2006 with longer texts resulted in similar findings with no evidence that people were able to focus on more important information when reading under time pressure. They also found that skim-readers were less able to judge if statements were consistent with the original text.

However, in subsequent analysis of later research, the authors found that while skimming is less effective than reading at normal pace, skim-readers' understanding of the text they read is no less than those who have no time pressure (Duggan & Payne 2011).

2.3.3 Reading on mobile devices

While reading patterns such as the F-shape for the desktop web are established, the pace of smartphone growth has meant research has not kept up, with many published studies carried out on feature phones without touchscreen capabilities or on low-res PDAs.

That form has an effect on findings can be seen from Oquist and Lundin's 2007 study on reading behaviour on mobile phones. Their results indicated paging was faster than scrolling – but the phone's capabilities meant one click scrolled only one line of text versus the same click that loaded five lines of new text when paging. The authors also found that reading techniques that had been successful on simulations of mobile screens, eg PDAs or masked desktop displays, were not successful on the actual device.

Similarly, it is likely that modern smartphones will provide a different reading experience to feature phones.

2.3.3.1 Reading patterns

Biedert et al's eyetracking study (2012) of Wikipedia-style articles on an Android smartphone classified three types of reading patterns:

- full screen – the user reads page by page and scrolls to replace the entire screen with new text
- linewise – the user concentrates on a portion of screen which they read line by line, scrolling to fill that area with new text
- blockwise – each scroll replaces text in part of the screen

Participants also tended to scroll to move paragraphs so they could be read in total.

However, these patterns were identified with the phone mounted on a desk and fixed in place so eye tracking could be used. More research is needed to identify:

- if there is evidence of distinct scrolling styles on smartphones 'in the wild' (Rogers, Sharp and Preece 2011 p492).
- if scrolling changes depending on the task (participants knew they had to answer questions on the text), text type (eg shorter non-Wiki style texts) and the participants' experience of smartphones (10 of the 18 participants had never used a smartphone before)

2.4 Internet use and reading

Why people go online and what they read varies greatly. Weinreich et al (2008) caution against making generalisations such as the 'average web user' or about navigation behaviour, because their data logging study of website use found major individual differences among participants in:

- use of Google (from 4% to 39%)
- browsing habits such as how often they returned to a website (some participants spent nearly all their time on just four websites)

- the number of pages visited a day (from 25 to 284)
- revisiting habits, eg in the use of bookmarks or typing in the URL

In terms of length of time spent on pages, Weinreich et al (2008) found:

- 52% people visit pages for less than 10 seconds, with 2-3 seconds the most common time
- nearly 10% page visits were longer than two minutes

This indicates that pages are evaluated quickly, in the same way that newspaper readers' decision to turn a page was made in as little as 3-5 seconds (Holmqvist et al 2003).

Similarly, in terms of choosing what to read, a prevalent view is that with so much information available on the internet, attention becomes a 'scarce resource' that is focused on only the most relevant, useful and interesting documents (Buscher et al 2012, Liu 2005).

Yet Kelly and Belkin's small diary study of seven subjects (2004) did not find evidence that more relevant and useful documents are displayed for longer online – despite some differences according to task type, eg display time when reading news was significantly longer than shopping and job searching tasks.

Similarly, the most visited website visited in the data logging study was Google, accounting for 15% of page requests. This raises the possibility that these average times might be distorted by the short nature of such visits or from default display times if it was used as a homepage. More research is needed to understand how indicative these times are of the amount people read online or if the short times reflect that many web visits are to navigation and login pages.

2.4.1 How people use the web on mobile phones

Visiting the internet on smartphones accounts for 8% of time spent on the phone - 48 minutes a day on average (Cui & Roto 2008).

Sessions on the mobile web also tend to be short – Cui & Roto (2008) found web visits on feature phones were around two minutes long, while Bohmer et al's later analysis of mobile app use found sessions were on average around 71 seconds long (2011).

The portability of smartphones means their use is more opportunistic than computer use – many studies report that people use them to fill gaps of time ('micro breaks') eg waiting outside shop fitting rooms (Cui & Roto 2008, Karlson et al 2010).

Despite their portability, studies such as Church and Oliver (2011) found that the majority of smartphone use is in stationary settings such as in the home or at work, where people take advantage of smartphones being 'always on' and connected to carry out tasks such as status updates without needing to wait for their PC to boot up. They also found that searches in mobile situations are more likely to be pressing, ie the need to find the location of the restaurant where a meal is booked.

Mobile web use is also not a solitary activity, with people using it to settle debates with friends and to stimulate conversation in social settings (Church & Oliver 2011, Cui & Roto 2008).

That touchscreens have affected reading habits can be seen from mobile content usage: when a 2007 survey of mobile web usage was repeated in 2010 the number of respondents who access full websites on their phones had risen from 14% to 72% - with mobile-tailored websites "all but disappeared" (Kaikkonen 2011). Equally respondents visited more websites in 2010 than in 2007 – with 67% accessing five or more websites compared to less than a third of respondents in 2007.

Studies have also found that more people access the web through apps rather than their phones' browsers (Bohmer et al 2011, Church & Oliver 2011).

Similarly, there is evidence that web usage patterns on smartphones are becoming more similar to the desktop web. For example while earlier research on feature phones had found that the average search length was 2.1-2.5 words long, later research on iPhones found an increase in web sessions and query lengths of around three words – ie similar to the desktop web (Kamvar et al 2009, Church & Oliver 2011). Similarly, the average length of a web search query in Church & Oliver's 2011 study was three words long.

2.4.1.1 Barriers to mobile internet use

There are still significant barriers to internet use on mobile phones. Karlson et al (2010) asked participants to upload screenshots of barriers to completing tasks on smartphones. Just over one in 10 of the screenshots related to output problems because of the screen size, with web pages that didn't display or function properly accounting for 40% of the problems. The authors found that the single window or app view was too limiting for reading, digesting and getting an overview of information.

Similarly, earlier work on web use on feature phones by Cui and Roto (2008) found that it was difficult for users to complete information gathering tasks that involved opening new tabs and copy pasting information from multiple sources into a document.

Other barriers to internet use include network failures and not being able to access resources on the mobile, eg files stored on a corporate network (Karlson et al 2010). In terms of frustration, they found participants rated frustration with lack of access to files highest in mobile contexts (eg on bus rides).

2.4.2 What people do online

Previous studies on the desktop web have proposed categorising web activities into fact-finding, browsing (eg for news and entertainment), information gathering, communication (eg email) and transaction (Cui & Roto 2008).

In terms of what tasks people do online, responses from a survey of 245 smartphone users (Kaikkonen 2011) showed that:

- reading news, weather, sports and emails were more frequent on phones than on computers (although still common on computers)
- shopping, viewing videos, writing emails and taking part in online chats were still heavily reliant on the PC

This confirms earlier research on mobile internet use by Cui & Roto (2008) who observed few transactions in their field study and found communication (email services) the most popular use of mobile phones.

2.4.3 Motivations - why people read online

Lindley et al (2012) looked at web use and found a variety of motivations among participants. They categorised different modes of web use, including:

- opportunistic (unhurried browsing that is not goal driven)
- respite (visits to familiar sites for a quick break)
- orienting (habitual checking of set websites to mark times of the day eg end of day)
- purposeful use (goal driven)

It remains to be seen how these modes could affect reading patterns – for example the authors suggest that mobile phones are not used for opportunistic browsing but for speed and convenience – something other studies of mobile web use have also found (eg Church & Oliver).

Just as there is wide variation in individual reading patterns, so too is the web a plastic activity that supports different levels of engagement – from a quick skim read of regular website to hours-long sessions in search of new content and experiences (Lindley et al 2012). Despite this, the authors say the web can be a surprisingly small place in the context of daily life, with users relying on familiar sites and frameworks like Wikipedia and YouTube to discover new content.

2.5 Context and reading preferences

An early diary study of work-related reading (Adler et al 1998) identified many different categories of reading – for example to support discussions with colleagues, for self-reminders and skim reading to get a rough idea of text. A key finding was that reading is not a singular activity but often done with writing, and together both activities accounted for 85% of participants' time at work.

That reading is a fragmented activity carried out alongside other tasks is also a finding of two later longitudinal studies of students reading course materials on small screen PDA devices (Marshall & Ruotolo 2002 & Waycott & Kukulska-Hulme 2003).

Like the earlier study, the authors argue that digital reading devices should take account of writing, eg annotating and marking texts.

However later studies on smartphones have found that text input is one of the biggest barriers to completing tasks on the device with many users preferring to avoid these tasks on the phone and instead switching to the PC (Cui & Roto 2008, Karslon et al 2010).

Similarly research by Bao et al (2011) compared the ease of carrying out business tasks on a desktop computer versus smartphones. Their findings indicate reading emails was 15 per cent slower on smartphones than on the computer – but participants didn't feel there was much difference and were willing to read on their phones, despite overestimating the time it would take them to do this.

This raises questions about the extent to which user preferences affect reading behaviour and how far task type affects these preferences. For example the constraints of the PDAs' size had a direct impact on students' preferences and use of the devices. While text input was seen as problematic,

the portability of PDAs provided the chance to read and access texts in settings where they wouldn't be able to normally - eg to look up answers in the classroom.

Equally tasks that make use of context awareness may be quicker and easier to complete on smartphones than computer-friendly tasks of reading encyclopaedic-style information.

2.6 Factors that affect reading: screen size, font, layout

2.6.1 Screen size and line length

The effect of display size on reading was investigated in the 1980s by Dillon et al. They tested reading speed and comprehension of a multipage document on two displays – a 20-line and 60-line display – with paragraphs split across screens in half of the cases. They found neither screen size nor paragraph splitting made a difference to participants' comprehension of the text or reading times, but the smaller screen size caused participants to alter their reading direction and jump between pages more. Furthermore, in subjective ratings, three quarters of the participants who read text in the 'small screen' condition expressed a wish to increase the screen size.

Later research by Jones et al (1999) of information retrieval tasks under time pressure compared a 15-line and 30-line display. They found that participants who used the large screen display answered twice as many questions correctly as the smaller screen and spent less time scrolling. The smaller screen users clicked on a similar number of links and so made poorer choices, with the vast majority starting with search. As well as differences in the objective measures, 80% of participants who carried out the tasks on the smaller display size felt the screen size impeded the task.

Further research by Dyson & Haselgrove (2001) investigated the effect of line length and reading speed on screen reading. Like Dillon et al, they found that changing the line length of between 25, 50 and 100 characters per line (cpl) did not significantly affect reading speeds. But at a faster reading speed (at least 70% faster than an individual's usual reading speed), it led to a drop in comprehension and participants found it harder to answer incidental questions. Overall participants had better comprehension at 55cpl than 100cpl, with no difference at the shorter line length. This indicates there is a speed-accuracy tradeoff when skim-reading.

These early studies suggest a mixed picture in terms of the impact of line length on the effectiveness of reading and search tasks. Equally, while it seems clear that user preference is for a larger screen display, it is difficult to apply these findings to screen sizes and smartphones because these studies were all carried out on desktop displays that were masked to create the shorter line condition. Similarly, later studies on feature phones that investigated the use of special text presentations such as rapid serial visual presentation, where just one word displays at a time on screen, were carried out on screens that are much smaller than today's smartphones, for example fitting just six lines of text on screen (Oquist & Lundin 2007).

2.6.2 Layout

How information is presented affects reading strategies. Holmqvist et al's 2003 study of news websites found that links on the left hand side of the screen were visited more than the right hand side. Similarly Wilkinson & Payne (2006) found that participants spent more time on the left side of the screen as did Buscher et al (2009), evidence they say in support of Nielsen's F-shape pattern. In

Buscher et al's eye tracking study of 361 web pages they also found that the right hand side was largely ignored.

The size of elements on the page also affected gaze patterns, with for example a screen-width size navigation bar looked at more than a link within that bar.

Short view times for pages also mean people prioritise their attention to content immediately available on the screen – a data logging study of web use (Weinreich et al 2008) found that 75% of selected links were those visible on loading.

Work by Hornbaek & Forkjaer (2003) compared the readability of three different layouts. They found that providing overviews of content increased participants' comprehension and was more preferred than a single column presentation. Conversely the fisheye presentation (only key headings and text is initially readable), which the authors say is suitable for constrained screen spaces – and so could be potentially most relevant for mobile phone content – reduced navigation time but also comprehension.

These differences in presentation indicate that regardless of user goals and motivation, reading depends on context and presentation. Later research by Reader & Payne shows how presentation affects reading strategies. Participants had to read four texts on the heart which varied in their level of difficulty (from primary school to graduate level understanding of biology). Given no navigational information about each text, participants used a satisficing strategy to extract information – but switched to sampling (trying each text and then returning to a preferred text) when provided with an overview of the texts that contained extracts of its content. The overview allowed participants to be more selective and they viewed fewer texts for longer.

Similarly, click heat maps from a data logging study (Weinreich et al 2008) found that almost half of clicked links were in the upper left screen with hot spots on both horizontal and vertical navigation menus. Yet on further analysis of Google (the most visited website by participants) they found a different distribution: the most clicked areas of the screen was a small top left triangle and then the bottom of the screen – tallying with the next page links as users click through pages of search results.

2.6.3 Font

The impact of fonts on desktop readability appears to be limited – research by Bernard et al (2003) and Beymer et al (2008) found no difference in terms of reading speed or comprehension of common font sizes for text fonts intended for continuous reading (Chapman & Chapman 2009 p343). In other words size 10, 12 and 14 point fonts are equally readable on screen – earlier work by Tulis et al only found significant differences in spotting errors at size 6pt fonts (Bernard et al 2003).

However the picture is less clear for mobile phone displays that are not only smaller but have a lower screen resolution. Huang et al investigated the effect of font size for a searching task (identifying characters in pseudo text) and reading task on mobile phones displays (2008). They found that character size made no difference to reading speeds at the lowest resolution (because smaller characters appear bigger at a lower resolution). On higher resolution screens (200 and 250 dpi), the smallest characters (1mm and 1.4mm high) led to significantly slower reading and searching speeds.

Overall they also found that reading on the lowest screen resolution (125 dpi) was significantly slower than the other resolutions tested (167dpi – 250 dpi). As screen resolution increased, individuals' preferences for small fonts also increased – 3.8mm was the preferred font size at 125dpi compared to 2.2-2.6mm at 250dpi. This suggests users' preference for font size is affected by the quality of their display.

2.7 Scrolling and interaction

When we read we also interact with the text – for example we crease pages of print documents to remember our place and use the mouse to create digital bookmarks and click on links.

How we interact with texts when we read affects what we remember about the texts and our ease of reading. For example Liu reports in his review of digital reading habits that scrolling doesn't support people's visual memory of information nor provides an overview of the whole text in the way that flipping and scanning print documents does (Liu 2005).

Scrolling to move content through the screen is one of the main ways we interact with text when reading digitally – Weinreich et al's analysis of web user logs (2008) found that scrolling was common even on navigation pages.

A user may need to scroll vertically and horizontally to read, depending on the size of the screen or window, the length of the text and the font type and size used. But scrolling is not without a cost – previous studies on mouse and key based scrolling have found that scrolling slows down reading – the more a user scrolls, the less time they spend on reading the text. For example in Dyson and Haselgrove's study of reading speed and line length (2001), the shortest line length (25 characters per line) resulted in slower reading speeds because the increase in document length resulted in an increase in scrolling.

However it is unclear if users are aware of the extra demands on their time. In a study on reading news articles on feature phones, participants only rated the physical demands of scrolling slightly higher than paging – despite it taking them three times as many clicks to read text when scrolling than paging (Oquist & Lundin 2007).

2.7.1 Design recommendations: scrolling versus paging

Early recommendations for small screen design have been to reduce scrolling, eg by reducing the volume of content by making it task focused (Jones et al 1999). However it is unclear whether recommendations based on point and click and keyboard command scrolling still hold for gesture based scrolling (Weaver et al 2011). Equally any reduction in the amount of content per screen is likely to lead to an increase in paging, ie in search results, with slow network connections resulting in a cost to the user as they wait for another page to download (Jones et al 1999, Weaver et al 2011).

Weaver et al (2011) examined the tradeoff between paging and scrolling for inbox displays on iPhones. While displaying 'no preview' allowed more messages to fit on the screen, it made dealing with messages less efficient because participants had to open more messages to make a decision to delete or keep. Increasing the preview length from one to five lines significantly increased the amount of scrolling needed - yet overall the three-line preview was the most efficient for email handling and was liked by users.

While this seems to indicate that gesture-based scrolling has a less negative impact on interaction, other studies on smartphones still point to it causing a tradeoff between font size and readability on small screens. This is because making characters larger so they are easier to read results in an increase in scrolling (Huang et al 2008).

Schildbach & Rukzio (2010) found that text size had a big effect on scrolling behaviour on smartphones when walking: increasing the font size by 20% led to subsequent increases of scrolling of 119% (from small to medium font) and 42% (from medium to large font). This meant that increasing the font size didn't lead to the increases in accuracy and speed to compensate for the effect of walking that were found when target size was increased. Instead, improvements in readability due to increasing font size were cancelled out by the subsequent increase in scrolling.

What is clear is that small screen sizes lead to a tighter coupling of scrolling and reading behaviour – conversely with large screen sizes it may be possible to read a text with little or no scrolling. How far this impacts reading remains to be seen.

3. Methods

3.1 Approach

Given the lack of research on internet reading behaviour on smartphones or comparative studies on the desktop and mobile web, two exploratory studies were carried out:

- a diary study to gather information on internet reading habits on the smartphone and computer, which then informed the design of the second study
- observations (Rogers, Sharp & Preece p133) of users completing tasks on both the smartphone and computer

Triangulating data generation methods in this way would also lead to more robust data (Oates 2006 p37).

3.2 Diary study

Diary studies are a common research method for smartphone use alongside observations, interviews and data logging studies (Karlson et al 2010). While diary studies are typically used for more longitudinal studies of user behaviour (eg Church and Oliver 2011), in this instance the need was to quickly gather user data on internet reading habits on multiple devices: what people read on the internet, on which device, when.

3.2.1 Participants

For this exploratory study, three smartphone owners were initially recruited. However due to the low data on mobile internet use from two participants, the study was expanded to five. That data formed the basis for the decisions of which tasks to include in the observations. Following discussions with the researcher's supervisor, the study was then expanded to eight. However one participant dropped out.

Because of the tight timescales of the project, convenience sampling was used (Oates 2006 p98). Smartphone owners ware recruited from the researcher's contacts and included a housewife, student, author and office based professionals. All participants were over the age of 25 and four were male, three female.

3.2.2 Materials

One of the problems with diary studies is a low response rate (Rogers, Sharp & Preece 2011 p259) with researchers often using financial incentives to increase submissions, eg by paying participants based on the number of entries submitted (Karlson et al 2010).

To increase the response rate, the forms for the diary study were designed to give a clear steer as to the type of data required (Karlson et al 2010), with columns for time, web page visited, length of visit, location and purpose of visit. Example entries were also included at the top of each form to guide participants on the level of detailed required. The forms were produced in both Word and Excel, and could be printed out if necessary.

Brief demographic data was also collected on age, occupation and the type of phone and computer used in the study, eg tablet.

All materials used in the diary study are included in Appendix B.

3.2.3 Procedure

Participants were asked to fill in the diary form for two days, recording all internet reading activities. Instructions sent by email explained the nature of the study. Participants were also asked to sign a consent form.

On submission of the diary forms, all participants were asked the same four post study questions to gather preference data on attitudes to reading on a smartphone and computer. This would also provide some context to the diary entries submitted.

If participants read news websites during the study, they were also asked if there was any pattern to their reading behaviour. This data was collected in lieu of a detailed breakdown of the pages participants visited on the news websites (eg navigation and articles), which no participant provided.

3.2.4 Data analysis

The returned forms (Appendix D.1) were transferred into an Excel spreadsheet for analysis (Appendix F.1). The data was then visualised to help understand it, eg using histograms for frequency of use and distribution of data, and scattergrams to see if there was any relationship between length of session and time of use (Dancey & Reidy 2011 p55).

Each website visit was also categorised by task type, using categories based on the task types detailed in Kaikkonen's survey of smartphone users (Kaikkonen 2011).

The tasks that were most problematic to categorise were search tasks, which ranged both in session length (1-30min) and in purpose, from quick fact checking to longer visits to a range of websites with less clear goals. Discussion with the researcher's supervisor helped resolve this issue. The search tasks were split into fact checking tasks that have a clear end answer ('Reference') and tasks with more undefined answers and goals ('Research'). This was also consistent with taxonomies proposed in earlier research (Cui & Roto 2008).

4.1 Observations

The diary study provided insights into people's reading tasks on each device and their attitudes to digital reading. However the problem with users' self-reports is that they can be unreliable and prone to exaggeration (Rogers, Sharp & Preece 2011 p259). This was a particular concern for the news and email information because most participants provided little detailed breakdown of their sessions.

To extend the initial findings from the users' self-reports with evidence of what users 'actually do' (Oates 2006 p202), an observational study was carried out. Sixteen smartphone users (seven female, nine male) performed tasks on both their smartphone and a laptop. Participants were recruited who were smartphone owners over the age of 18 and who spoke English as their first language. The requirement for native English speakers was based on earlier research on reading speed that found non-native English speakers read more slowly than native English speakers, leading to variation in the results (Beymer et al 2008).

While this convenience sample differs from the tendency to use a more homogenous group of students in much academic research (Buscher et al 2012), the aim for the observations was that data came from people with a wider range of backgrounds (Lindley et al 2012). The researcher also felt that only using students would affect the ecological validity of the observation because it is not clear

how appropriate observations based solely on this group would be (Rogers, Sharp & Preece 2011, p471).

4.1.1 Design of study

A within subjects design was used for the observations, with the smartphone device and a laptop computer being the two independent variables. This enabled the researcher to collect comparative data from the same participants for both devices, with the effect of outliers affecting both conditions equally (Rogers, Sharp & Preece 2011, p489). It was also the most practical solution in terms of recruiting participants given the timescales for the research.

The dependent variables included:

- reading times
- number of scrolls
- number of articles and navigation pages read
- subjective data on reading preferences, ease of use and suitability of device for the task

4.1.2 Design of tasks

The full results of the diary study can be found in the Results Chapter, but key findings for the design of the observation study were that the most common reading tasks carried out on smartphones and computers were visits to news websites and to check email. Participants were also more likely to carry out research and fact checking tasks on the computer and social media tasks on their phones.

Tasks were designed to have high ecological validity, and were based on the reported use from the earlier diary study. Much academic literature investigating digital reading has focused on performance measures such as reading speed in information retrieval, using stylised texts and essay writing to test comprehension (eg Duggan & Payne 2006, Buscher et al 2012, Biedert et al 2012). However the narrow focus of these studies was not appropriate for the purposes of this research – to try to understand how people's natural reading behaviour differs when they read the internet on different devices. Instead naturalistic open tasks (Holmqvist et al 2003) were used.

Ideally the researcher would have tested a range of reading tasks on both devices, but the need to carry out tasks on two devices in one session limited the task choice to two.

4.1.2.1 News

News reading was chosen because it was one of the most common reading tasks for smartphone owners on the internet. Previous research on internet news reading habits (Holmqvist et al 2003) also used an open browsing task.

Email was discounted because of the feasibility of setting up a test. Previous studies investigating email use on phones either used dummy data (eg Bao et al 2011) – which would have poor validity for understanding reading habits – or created an app for users to use with their email client (Weaver et al 2011).

In terms of data collection, the use of a within study design meant that time limits needed to be set for the open browsing tasks that would allow sufficient data to analyse but not exhaust participants' interest in the website.

Five minutes was set as the length of time for participants to read the news, based on the times used in previous research (Holmqvist et al 2003). It was also the average length of a news reading session in the diary study, and in terms of data collecting would give enough time for participants to read more than one article.

To ensure the observation data was based on actual use, participants visited the website they usually used for news.

4.1.2.2 Research

As a counterpoint to the news task where reading is common on smartphones, a research task was chosen for the second task where usage was greater on the PC. The task had to be similar enough to be carried out twice in one session. Candidates for this task included researching information on Wikipedia, products on Amazon or restaurants on Tripadvisor (Appendix C.4).

Ultimately the Tripadvisor task was chosen. This allowed for an open task where users could make decisions according to interest, in a similar way to interview-based tasks advocated by Spool (2006), but also provided some control in the pages that participants viewed for each task.

4.1.2.3 Social media

Finally an extra task was included on social media for those participants who used Twitter to see if their reading habits differed from news reading and research tasks. Based on the diary study data, not all participants would be able to complete this task. To address any privacy concerns users might have about reading their own feeds, a reading study account was set up for participants to use in lieu of their own feed. Because these tweets may not then be of interest to the participant, a secondary task was created to follow up a news story they had read.

4.1.3 Questionnaires

Preference data was collected at the end of each task on each device using the SUS Questionnaire, which was adapted for the purposes of the study to collect data on five measures:

- trust/credibility
- findability (ease of navigation)
- connection (speed of navigation)
- information on the page
- reading experience

These measures were based on analysis of the diary study qualitative data, with trust included based on findings from Liu's review of digital reading habits (2005).

Using the SUS Questionnaire enabled the researcher to use a validated scoring method (Sauro 2011). Rating each device after each task gave a better reflection of the reading experience and avoided the chance of recency bias if participants were asked at the end of the study which version of the website they preferred.

To triangulate this data further, data was collected on device usage for nine key reading tasks before the tasks and then device preferences for the same nine tasks in the post task questionnaire. This enabled the researcher to understand how consistent the ratings for the observations were with use and preferences.

The post-task questionnaire (Appendix C.5) also contained the same three questions asked in the diary study, and asked a range of questions about the reading experience on a smartphone and computer.

4.1.4 Pilot

A pilot study was carried out using one of the participants from the diary study, with the different versions of the research task. This resulted in the selection of the Tripadvisor task for the observations. Care was taken to ensure the list of restaurants for each location had an equal number of entries (18), was not too overwhelming for candidates and were similarly presented (eg in terms of photos for entries). Minor changes were also made to a couple of the statements on the individual task ratings questionnaire.

4.1.5 Counterbalancing

To minimise the effect of task order and learning (Rogers, Sharp & Preece 2011 p489), the news and research tasks were counterbalanced to try to ensure any differences observed were due to the device (Appendix C.3).

There were two sets of tasks for each device, with the Tripadvisor location of either Chipping Norton (Set 1) or Haworth (Set 2) also rotated for each participant (2 x 2).

Finally, the order the tasks were performed was rotated, with the first eight participants completing the news task then research task, and the next eight participants performing the research task first.

The Twitter task could not be counterbalanced because the researcher did not know in advance how many participants would complete this task. Also, if participants did not want to read their own tweets, the task was to follow up on a news story they had read using the reading study account.

4.1.6 Location and materials

The researcher had planned to conduct the study in one location (City University). However, the difficulty in recruiting participants meant a more flexible approach was necessary, eg going to people's place of work.

Participants carried out tasks on their own smartphones. Sessions were recorded using a Panasonic HD camcorder on a tripod for stability.

The researcher's laptop was used for the computer reading tasks, using Camtasia Studio 8 screen recording software to record the sessions. While it was not feasible for the researcher to be able to observe participants on their own computers, participants were given the choice to use whichever browser they were most comfortable using out of Internet Explorer, Google Chrome and Mozilla Firefox.

4.1.7 Procedure

Participants were sent an email before the study asking them to avoid reading news on the day of the observation and to bring their phone with enough charge to carry out 15 minutes of browsing.

Participants were welcomed and informed about the purpose of the study and their rights. To ensure consistency, a test script was used (Appendix C.2), which was adapted from one used by Steve Krug (2010). Participants were then asked to sign the consent form (Appendix C.1).

Participants were first asked questions about their news reading and Twitter habits so the researcher knew whether to include the Twitter task.

Participants performed the tasks either on the smartphone or the laptop. To avoid interference with reading times, thinkaloud was not used. After each task participants rated their experience of the website.

Participants then carried out the second set of tasks on the second device. After completing the tasks, participants were asked to complete the post task questionnaire. Finally, the researcher read the questionnaire and followed up on any of the answers that were not clear.

4.2 Data preparation and analysis

4.2.1 Data preparation

Raw data from the questionnaires and transcriptions of the videos can be found in the Project file (questionnaires) and on the Project CD (transcriptions).

Video recordings from the observations were transcribed using InqScribe. This enabled time codes to be added to the transcriptions and allowed the video to be slowed to take accurate timings of user actions.

This data was then transferred into Excel for coding (see Excel files on the Project CD). The qualitative data from the post-task follow up interviews was also transcribed and transferred to Excel. Data from the questionnaires was entered directly into Excel.

4.2.2 Data analysis

Pre-task responses to frequency of use for nine tasks were converted into ordinal data (Oates 2006 p247) to allow statistical comparison (Appendix F.1 – see project CD).

The scores for the SUS-based questionnaire were calculated, although adjustments had to be made to the calculations because two negative statements were included for the amount of information on the page.

Following discussion with their supervisor, t-tests were then carried out on the raw scores for the SUS-based questionnaire.

The SUS scores were then compared with the data provided on usage and preference.

The data from the observations was coded according to activity on the page. As part of this process the data was cleaned – for example articles that one participant reread on the mobile after misinterpreting the task instructions were removed from subsequent timings analysis.

Following advice from their supervisor, talking times and times watching videos or viewing images were also removed from the reading times data. Pivot tables were created from the data summarising the time on task, page download time etc.

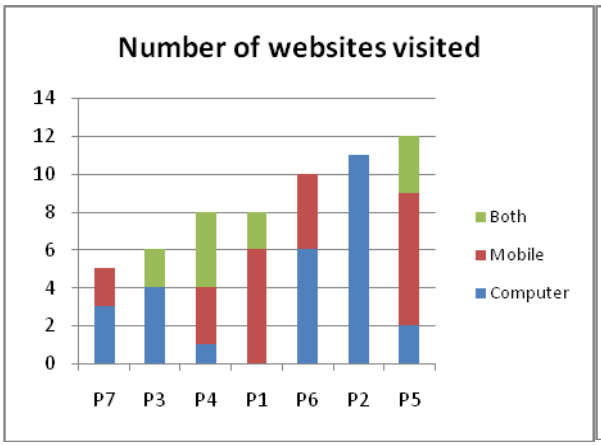
Finally the qualitative data from the post task follow up interviews was then categorised using an inductive approach (Oates 2006 p269) (Appendix F.2 – see Project CD). The same categories were

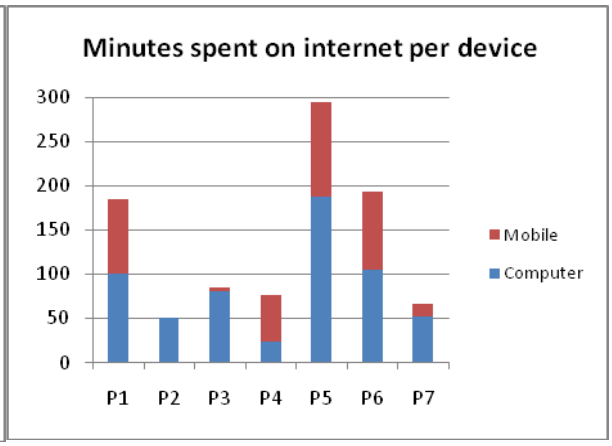
then applied to the data from the post task questionnaires. Finally the qualitative data from the diary study was incorporated with the observation study to give a fuller picture of the issues raised.

4. Results

4.1 Diary study

4.1.1 Usage during study





The number of websites visited over the two days of the study ranged from 5-12, with the number of sessions recorded ranging from 11 (DP7) to 45 (DP5).

Those with the highest mobile use had a higher average number of visits per website overall, with DP1 and DP5 averaging almost 4 visits per website, with frequent checking of email, news and social media sites. News apps were most popular in the study (DP3, DP4, DP5).

While all participants used the PC, not everyone uses the internet on their smartphone:

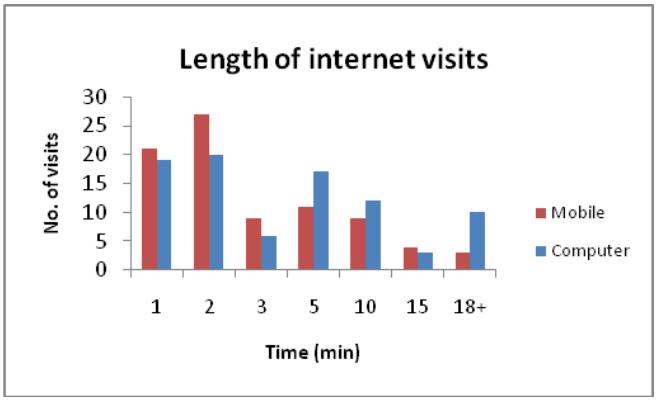
- DP2 posted no entries for mobile and said reading on the phone was 'too strenuous' for their eyes – this participant also preferred print outs for reading
- DP3 and DP7 posted two entries – DP3 reads on their phone if no other choice, and for both days of the study was mainly at home; DP7 is new to the phone and also only reads news when out or if they have missed the news on TV

That context has an impact on volume of use can also be seen from the fact that high smartphone use was not just from participants who preferred reading on their smartphone (DP1, DP5), but also DP6 who used their phone when commuting and in bed, ie where a computer would be impractical.

Most participants (n=6) spent more time reading the internet on the PC, with DP4 the exception.

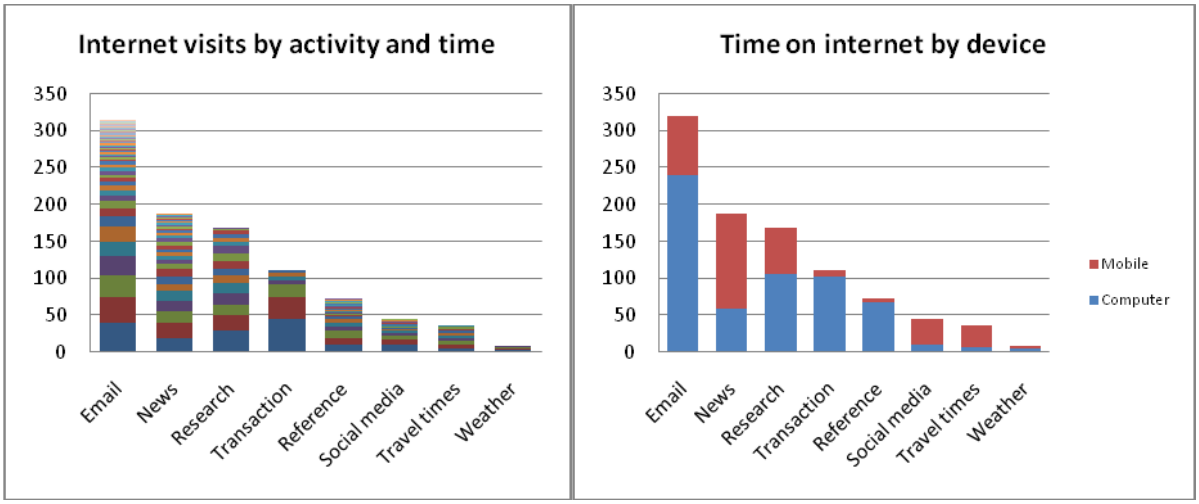
4.1.2 Time spent reading

Most visits to individual websites were short, with 76% lasting 5min or less and half (51%) 2min or less. Overall mobile sessions were shorter than on the PC, with 2min the median length of time per visit for the mobile and 3min the median time for the computer. However 2min was the most common length of an internet session on both devices.



Differences in times are noticeable in the upper ranges, with more visits recorded on the PC from 5min and above, and the longest session on a mobile lasting 20min compared to 45min on the PC.

4.1.3 Website visits by activity



Most participants (n=6) read emails and news over the two days of the study.

Email was visited more often on a computer, with three times as long spent on email on the PC than on the mobile. Computer sessions included writing emails, with DP5 the only participant who sent emails from their phone.

Participants made a similar number of visits to news websites on the PC and mobile, but twice as long was spent on mobile news overall, ie longer sessions for the same visits.

News was checked more than once a day, with times from DP5 and DP1 indicating the average time they spent on each article was 2min.

Social media was predominantly a mobile activity (with almost 10 times as many visits on mobile than PC), with a mix of short visits to Facebook (DP3, DP1) and longer sessions on Twitter (DP3, DP5). Four participants (DP2, DP4, DP6,DP7) did not use social media at all.

Research was carried out equally on both devices (8 sessions on each) but 1.5 times as long was spent researching on the PC than on the mobile.

Reference or fact-checking visits were mainly carried out on the computer, which had six times as many sessions as on the mobile. Most participants (n=6) carried out these tasks with lots of short sessions.

The remaining categories had low data, with reading travel information predominantly a mobile activity and transactions a PC activity.

4.1.4 Location

Overall stationary contexts accounted for 74% visits, with most participants (n=6) using the internet in up to three locations. Home is the most frequent location for using the internet on both the PC and phone, with work and the bus the next most common contexts (DP4, DP5, DP6). Half the locations were unique to one participant, eg walking, shopping.

4.2 Observation results

4.2.1 Reported use of device per task

Pre-task responses to frequency of use for nine tasks were converted into ordinal data, with 0 = never and 5 = several times a day.

Reading emails, checking travel information and reading or posting social media tended to be carried out equally frequently on the computer and the PC.

Unlike the diary study, news reading is something the participants in this study do more frequently on a PC. The average score for reading on a PC was 4.4, equivalent to once a day (SD = 1.3). It was 3.6 on a mobile, equivalent to once a week (SD = 1.6), p=0.04.

Participants more frequently reported using the PC to send emails, buy online, research information and check facts. These differences were significant, while sending email was approaching significance.

	Sends email		Buy online		Research info		Check facts	
	PC	Mobile	PC	Mobile	PC	Mobile	PC	Mobile
Mean	4.7	3.8	2.4	1.1	3.4	2.6	4.1	2.6
SD	0.7	1.5	1.0	1.0	1.4	1.5	1.0	1.7
T-test	0.055		0.005		0.022		0.012	

Comparing individual scores for use, P1, P2, P10 and P12 all reported using the computer significantly more than their phones. P5's scores were higher for the PC but not quite significant.

Conversely, P6 and P11 reported using their phones significantly more than the PC for these tasks.

	Device use				
	PC		Mobile		T-test
	Mean	SD	Mean	SD	
P1	4.3	0.9	3.4	0.9	0.01
P2	3.1	2.1	1.3	1.7	0.03
P5	2.7	2.1	2	2.1	0.08
P6	2.7	1.4	3.4	1.7	0.02
P10	4.2	1.2	0.7	1.1	<0.001
P11	2	1.7	2.9	2.4	0.04
P12	3	1.8	1.3	1.3	0.04

4.2.2 News

4.2.2.1 Websites visited in observations

Participants were asked to visit the website they most often used for news.

Twelve participants visited the BBC News websites on the mobile and the PC. Four participants visited other news websites:

- P7 read articles on Ars Technica for science/technology on the mobile and PC as well as briefly visiting BBC News on their mobile
- P8 visited The Vancouver Sun website as well as the BBC News website. This participant initially looked at Google News and News1130 on the PC
- P10 visited Yahoo News
- P15 used Twitter for news, visiting BBC News, The Guardian and The Telegraph website by following links on tweets

P9 used RSS feeds from the BBC on their mobile as their starting point for news. This meant they rapidly read a series of very short snippets before linking through to a full article on the desktop version of the BBC News website.

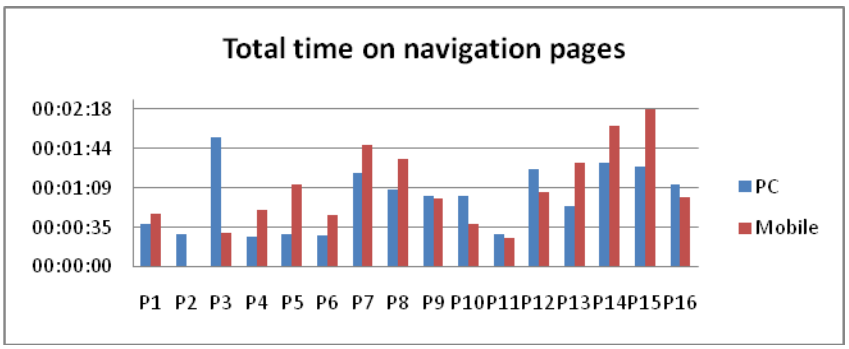
Phone news	Apps	Mobile	Full
BBC	4 (P2, P3, P13, P14)	4 (P4, P5, P6, P16)	4* (P1, P9, P11, P12)
Ars Technica		1 (P7)	
Vancouver Sun	1 (P8)		
Twitter	1 (P15)		
Yahoo News		1 (P10)	

*Based on the majority of time spent by P11 on the full BBC News website.

4.2.2.2 Time spent on navigation pages

There was no significant difference in the amount of time participants spent on navigation pages on the mobile and on the PC.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Average time on navigation	00:00:36	00:00:42	00:00:26	00:00:23	0.24
Total time on navigation	00:01:06	00:00:37	00:01:00	00:00:28	0.50



Individual times show a mixed picture for the impact of apps on navigation: of the five participants who used news apps, two spent far less time navigating on the PC than the mobile (P2,P3) and three spent more time on navigation pages (P8, P13, P14). In all cases the difference was more than 25s. However none of the participants who spent longer navigating on the app was aware that you could swipe from article to article rather than returning to the navigation page each time [Appendix].

With seven participants only looking at one navigation page it wasn't possible to perform t-tests on their raw reading times. For the other participants, no significant difference was found between reading times on navigation pages between devices.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
No. of navigation pages viewed	4.2	6	3.3	1.9	0.52
No. visits to navigation pages	7.1	6.4	5.5	2.8	0.28

Overall there was also no difference in the number of navigation pages participants looked at on their mobile phones compared to a computer or the number of times they visited navigation pages. However the number of navigation pages participants visited on the PC (M=3.3, SD=1.9) compared to the number of articles on the PC (M=4.7, SD =2.7) was significantly lower (p=0.03). There was no significant difference on the mobile, even disregarding the 22 pages of RSS snippets viewed by P9.

	Mobile				PC			
	Articles #	Nav page #	Total visits	Time on nav	Articles #	Nav page #	Total visits	Time on nav
P1	3	3	4	28%	5	2	3	17%
P2	8	1	1	0%	2	2	2	14%
P3	4	1	2	11%	5	5	10	46%
P4	2	3	7	38%	4	3	3	22%
P5	6	4	10	27%	4	2	4	11%
P6	6	4	7	16%	4	3	6	11%
P7	4	4	5	36%	2	2	3	23%
P8	5	6	13	33%	4	3	5	29%
P9	2	26	26	41%	6	5	10	31%
P10	3	1	1	35%	2	1	1	43%
P11	2	2	2	35%	3	4	6	53%
P12	3	4	4	26%	5	5	7	28%
P13	3	1	4	33%	2	1	4	29%
P14	11	1	12	50%	13	6	8	31%
P15	3	1	4	63%	7	1	7	31%
P16	2	5	11	62%	6	7	9	42%

Overall, at least half of the participants visited navigation pages more than articles on either the PC (n=9) or the mobile (n=11). However usually this was just one more visit.

On the PC P3 and P9 made the most visits (n=10) to navigation pages. Both visits were the second time seeing the BBC News website.

On the mobile, five participants made more than 10 visits to navigation pages (P5, P8, P9, P14, P16). For three of these participants, it was their second time reading the news.

P16 spent most of their time searching for stories (62%) while P14 spent half their time looking. P9's high number of navigation pages is because they read 22 short RSS snippets on their mobile for up to 1s on each before selecting one to take them through to the full BBC website.

4.2.2.3 Time spent on article pages

Overall participants spent a similar, short amount of time reading article pages on the mobile and on the PC.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Articles read	00:00:34	00:00:25	00:00:33	00:00:30	0.75

However when using a two sample unequal variance t-test to compare the times each participant spent on articles on each device, two participants' time differed significantly (P5 and P7). Both participants spent significantly longer on fewer articles on the PC compared to the mobile.

	Time on articles				
	PC		Mobile		Ttest
	Mean Time	SD	Mean Time	SD	
P1	00:00:38	00:00:16	00:00:39	00:00:12	0.91
P2	00:00:44	00:00:41	00:00:39	00:00:24	0.84
P3	00:00:34	00:00:20	00:01:00	00:00:38	0.28
P4	00:00:23	00:00:07	00:00:40	00:00:33	0.58
P5	00:00:59	00:00:13	00:00:32	00:00:19	0.03
P6	00:00:44	00:00:30	00:00:33	00:00:24	0.54
P7	00:02:14	00:00:18	00:00:48	00:00:16	0.04
P8	00:00:42	00:00:49	00:00:32	00:00:23	0.72
P9	00:00:20	00:00:15	00:00:44	00:01:02	0.68
P10	00:00:41	00:00:07	00:00:36	00:00:21	0.77
P11	00:00:08	00:00:03	00:00:24	00:00:21	0.48
P12	00:00:43	00:00:40	00:01:03	00:00:29	0.46
P13	00:01:05	00:00:33	00:01:02	00:00:23	0.93
P14	00:00:15	00:00:10	00:00:11	00:00:06	0.30
P15	00:00:28	00:00:11	00:00:16	00:00:21	0.27
P16	00:00:17	00:00:10	00:00:19	00:00:06	0.78

However, time spent on articles also includes time when participants were navigating away from the page, eg by scrolling up at the end of articles or when reading related links and the right hand navigation components, for example the 'Most Popular' stories component on the BBC News website. Discounting this time, plus time at the end of articles when users scrolled rapidly down if they did not rest at the end of the page for more than 1 second, left a tighter measure of what constitutes article reading.

Even within this there are still examples of quick scrolls and it is possible participants were reading other elements on the page on the PC, but this is as good a measure as was feasible given the data collection method.

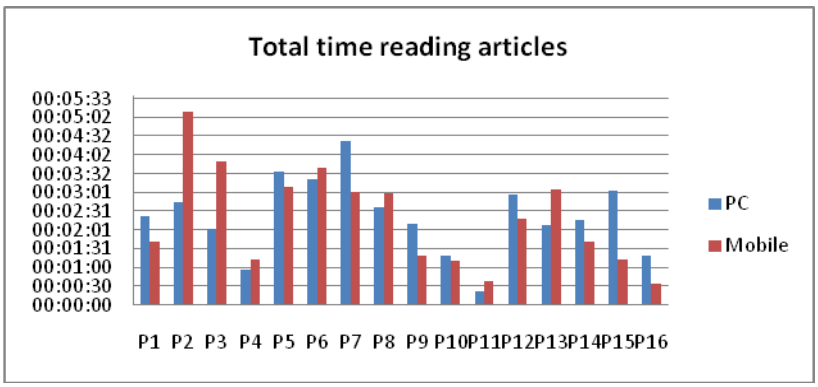
4.2.2.4 Time spent reading articles

Overall most participants (n=9) spent longer reading articles on the PC than on the mobile. However there was no significant difference in the average time participants read articles, the total time spent reading or the number of articles read on the PC or mobile.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Average time on news	00:00:37	00:02:22	00:00:37	00:00:30	0.97
Total time on news	00:02:19	00:01:19	00:02:22	00:01:02	0.49
No. news articles read	4.5	2.6	4.6	3.0	0.84

The average time spent reading articles on both the mobile and the PC was the same, with 10 articles being read for 1 minute or more on both devices. However, only one article on the mobile was read for more than 90 seconds compared to three articles on the PC.

Three participants (P4, P10, P11) stopped reading before the task end on both devices, while P16 stopped reading early on the mobile.



In terms of individual times, seven participants had at least a 45s difference between their reading times on the devices. Four (P7, P9, P15, P16) spent longer reading articles on the PC and three (P2, P3, P13) spent longer reading on the mobile (all BBC News App users). The greatest time difference was for P2 who spent 2m 27s longer reading on the mobile.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
P5	00:00:32	00:00:19	00:00:54	00:00:18	0.098
P7	00:00:46	00:00:18	00:00:41	00:00:32	0.043

Both P7 and P15 spent more than 1min longer reading articles on the PC than phone, but it was only a significant difference for P7, who read science news articles on Ars Technica.

The difference in reading times for P5 across devices is no longer significant when navigation time is excluded the average time on PC was, indicating that part of the reason for P5's increased reading time on the PC was navigation within an article.

Finally, looking at the length of time that participants read articles on the mobile, all participants who read articles for more than 3min (n=7), used either an app or mobile version.

The difference in reading time for apps compared to non-app versions of news websites on the mobile was nearly significant while the difference between reading times on the app versus mobile was not as great. The difference in reading time between app versions and the desktop versions of news was significant.

App vs mobile				App vs non app				App vs desktop			
App		Mobile		App		Non app		App		Desktop	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
00:03:23	00:01:17	00:02:01	00:01:14	00:03:23	00:01:17	00:01:50	00:01:04	00:03:23	00:01:17	00:01:30	00:00:43
T test		0.099		T test		0.0511		T test		0.029	

4.2.2.5 Amount of articles read

It isn't possible to determine how much participants read on a page without eye tracking data. Even then, this only shows where the eye rests, not whether the information is processed or 'read'.

Instead, the figures below are calculated based on whether participants saw the end of article pages that they opened and how long the end of the article remained in view. Articles with an early natural stop point, eg the Medal Table and Games In Numbers infographic, and tweets were excluded from the analysis. As a conservative baseline, 1 second was used as the cut-off point as a reasonable assumption that no content was read in that time.

	Mobile							PC						
	Total articles viewed	End article seen 1s or less	End article not seen	Total articles not completed		Viewed whole article		Total articles viewed	End article seen 1s or less	End article not seen	Total articles not completed		Viewed whole article	
				No.	%	No.	%				No.	%	No.	%
P1	3	1	1	2	67%	1	33%	5	1	2	3	60%	2	40%
P2	8	0	4	4	50%	4	50%	2	0	2	2	100%	0	0%
P3	4	3	0	3	75%	1	25%	5	1	2	3	60%	2	40%
P4	2	2	0	2	100%	0	0%	4	0	2	2	50%	2	50%
P5	6	2	3	5	83%	1	17%	4	1	0	1	25%	3	75%
P6	6	1	0	1	17%	5	83%	4	0	0	0	0%	4	100%
P7	4	3	0	3	75%	1	25%	2	1	0	1	50%	1	50%
P8	5	2	3	5	100%	0	0%	4	2	0	2	50%	2	50%
P9	2	1	1	2	100%	0	0%	6	1	4	5	83%	1	17%
P10	3	0	3	3	100%	0	0%	2	0	0	0	0%	2	100%
P11	2	1	1	2	100%	0	0%	3	2	1	3	100%	0	0%
P12	3	1	1	2	67%	1	33%	5	1	2	3	60%	2	40%
P13	3	0	0	0	0%	3	100%	2	0	0	0	0%	2	100%
P14	11	7	3	10	91%	1	9%	13	3	5	8	62%	5	38%
P15	3	0	3	3	100%	0	0%	7	0	3	3	43%	4	57%
P16	2	1	1	2	100%	0	0%	6	2	4	6	100%	0	0%
Total	**67**	**25**	**24**	**49**	**73%**	**18**	**27%**	**74**	**15**	**27**	**42**	**57%**	**32**	**43%**

Participants view a similar amount of articles on their smartphones as on the PC. However participants were more likely to abandon articles on their phones with 73% of articles not completed on a mobile phone compared to 57% of articles on the computer. A t-test on the percentage of articles abandoned was statistically significant. However, the t-test on the raw number of articles was not significant, with the low number of articles read by many individual participants indicating that more work is needed to verify this result.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
% articles not completed	76.50%	31.00%	52.70%	33.80%	0.01
Total articles not completed	3.1	2.3	2.6	2.2	0.44

Seven participants did not read to the end of any of the articles they opened on a mobile compared to three participants on the PC. The biggest differences per participant were for P5, P10, P15.

Looking at the data, P10 viewed articles on the smallest screen (2.4 inches) with only 10 lines of text on the screen, often with no line breaks. They also clicked through to a full website article, but had to abandon it because the text was too small and they did not know how to zoom in.

P15 used Twitter to access news stories, which meant that each article opened on their phone took 9s or longer to download. This led them to abandon one article completely after 28s of waiting.

Neither connection time or content type can explain the difference for P5 who viewed only one article completely on the mobile and abandoned only one article on the PC.

4.2.2.6 Scrolling - news

Overall, participants scrolled more on the mobile than on the PC.

For news pages, the difference in scrolling down was not significant for navigation pages on the PC compared to the mobile, but was significant for article pages.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Scroll up - navigation	6.5	6.7	4.8	3.7	0.33
Scroll up - article pages	9.8	9.9	3.9	3.6	0.01

However, the variation among participants was considerable, with P2 who used the BBC News App and tapped from page to page recording no scrolls or swipes on the navigation page and only scroll downs on article pages.

4.2.2.7 Task preference data

Overall news reading on both devices was given similar positive scores by participants on credibility, reading experience, speed, comprehensiveness and ease of navigation. There was no significant difference for any statement (Appendix F.1) and the average total score was the same for both devices, indicating that participants like both devices equally for this task.

At an individual level, nearly half of participants scored the PC higher (n=7) for the news task, with 5 scoring mobile news higher and a quarter scoring the devices equally.

The most marked differences were for P16 and P14, which were nearly significantly different for PC and mobile:

- P16's scores differed for seven statements, rating the PC as better than the phone on trust, reading experience, speed of pages to display and amount of information on the page
- P14's scores differed on three statements, rating information on the PC as more likely to have too much information on the page and to be missing information

	Task preference scores				
	PC (Mean)	PC (SD)	Mobile (Mean)	Mobile (SD)	T test
P14	3.1	3.1	2.8	1.1	0.081
P16	2.5	2.5	3	1.6	0.052

Pre-task device preferences for reading news were also mixed, with equal numbers of participants preferring to read news on a PC (n=6), a mobile (n=6) and the remainder preferring both (n=4).

Comparing these preferences with the ratings people gave for the news tasks, most people's task rating score (n=9) did not tally with their expressed device preference:

- two people preferred reading news on a PC, but scored the mobile higher (P5, P9)
- one person preferred reading news on their mobile but scored the PC higher (P15)
- three people liked reading news on both devices, but two scored the PC higher (P11, P16) and one scored the mobile higher (P14)
- three people preferred reading news on their mobile but gave both devices the same score in the tasks (P3, P12,P13)

4.2.3 Tripadvisor

4.2.3.1 Website versions used on the mobile

The majority of participants (n=11) searched for Tripadvisor via their phone's browser and were directed to the mobile version of the website.

Four participants used the Tripadvisor app (P1, P6, P14, P15), which looks the same as the mobile version of the website, but when visiting external websites, the Tripadvisor header bar remains, allowing participants to return to their results. P14 installed the app during the study.

P1's version of the app on Android and the mobile version on P10's Blackberry looked substantially different in terms of design, ie the pages were little more than blue links on a white background, but had similar functionality to the other mobile versions.

P12's Google search resulted in them visiting the desktop version of Tripadvisor.

4.2.3.2 Familiarity with website

Most participants used Tripadvisor monthly (n=7), with one using it weekly and three yearly. One participant used it weekly on the PC but was new to it on their phone (P10). Four participants were new to the website (P2, P5, P7, P11).

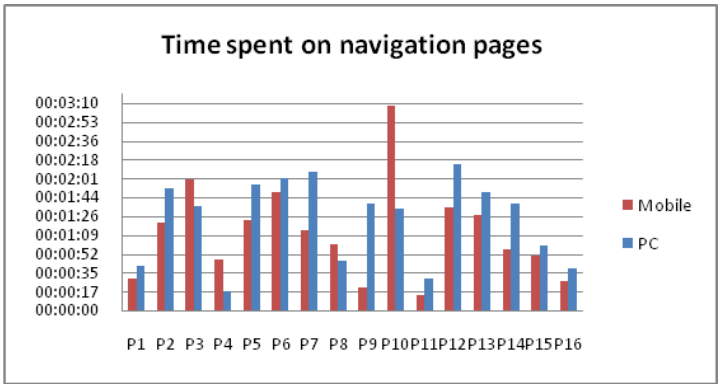
One participant (P2) had never used their phone's browser to access the internet before.

4.2.3.3 Time spent on navigation pages on Tripadvisor

Overall participants spent longer on navigation pages on Tripadvisor on the PC than they did on the mobile phone, but this difference was not statistically significant for average time spent or for total time spent. Only P10 spent longer than two minutes navigating on the mobile. Half of this time was spent inputting text on the Blackberry.

Overall participants visited an average of 2.6 navigation pages on the mobile compared to 3.1 pages on the PC, but this difference was not significant.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Total time on navigation	00:01:11	00:00:44	00:01:23	00:00:38	0.15
Average time on navigation	00:00:32	00:01:23	00:00:29	00:00:15	0.58
Navigation pages visited	2.6	0.9	3.1	0.9	0.10



Participants who used the mobile or app version of Tripadvisor on their Android phones or iPhones (n=14) spent significantly less time overall on navigation pages than on the desktop version on the PC. Only two participants who used the app or mobile version spent longer than 1.5min on navigation pages (P3, P6), but 8 out of the 14 participants spent more than 1.5min on navigation pages on the PC.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Time spent navigating -Android	00:01:01	00:00:33	00:01:19	00:00:38	0.04

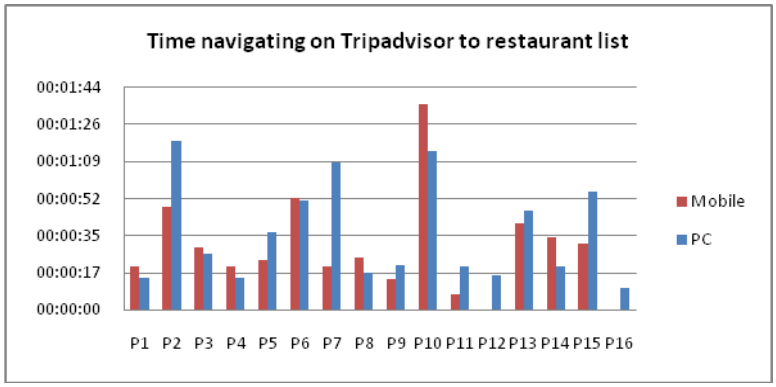
In terms of navigation pages there were two main activities that account for this time:

- time spent on navigation pages to get to the list of restaurants
- time spent reading the list of restaurants or applying filters before choosing restaurants to view

4.2.3.4 Time spent searching on Tripadvisor for the restaurant list

Overall, it took participants longer to find the list of restaurants on Tripadvisor on the PC. Excluding time waiting for pages to download, it was quicker to navigate to the restaurant list on the mobile phone, but this was not significant. While navigating to the restaurant list on Android phones and iPhones was also quicker than on the PC, the difference was more marked, but not significant.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Time to navigate - all phones	00:00:29	00:00:23	00:00:36	00:00:23	0.14
Time to navigate - iPhone and Android	00:00:26	00:00:15	00:00:34	00:00:22	0.09



The amount of time it took participants to find the list of restaurants for Haworth and Chipping Norton on the Tripadvisor website varied considerably – for example P12 and P16 spent no time searching on the Tripadvisor website on the mobile because their Google search took them straight to the list..

Only one participant spent more than a minute searching on the mobile (P10). Most of this time was spent re-inputting text after they clicked the Restaurants link instead of search, which took them to the Restaurant search form. P15 also did this, but spent far less time entering text than P10, who also experienced problems with the form on their Blackberry, when the prompt text in the input box did not automatically disappear on typing.

On the PC three participants took more than a minute to get to the restaurant list. P2 could not recover from a validation error on the place name without help, P7 struggled to find restaurants after landing on the hotels pages and P10 had a similar problem finding restaurants from Tripadvisor's search results page.

Three other participants (P4, P13, P15) who ended up on Tripadvisor's search results page also failed to find the correct link on the page, with two (P15 and P4) clicking on the link in the left hand box. This took them to a subset of results - and while P15 then found the restaurant list after clicking on a restaurant, P4 never reached the full list of restaurants on the PC.

Only P12 clicked on the correct link from the search results page, but this was because they used a more specific search term and so it was the top link.

4.2.3.5 Navigation paths to the restaurant list

On the PC four participants reached the restaurants list via the homepage (P1, P2, P3, P8), with two using the Restaurants dropdown input box on the navigation bar and two using the 'Plan The Perfect Trip' box on the homepage.

12 participants reached the restaurants list via other pages on Tripadvisor:

- four participants arrived via the general Tripadvisor search results page
- five participants first saw hotel results pages
- P6 went via the Restaurants search page
- P9, P15 went via the location's homepage, eg Haworth Holidays

In all this meant that on the PC most participants (n=11) reached the restaurant search list via a secondary navigation page, with seven participants (P4, P5, P7, P10, P11, P12, P14) viewing hotel pages first on the desktop PC website.

Of those participants who used the 'Plan The Perfect Trip' search box on the homepage (n=10), only two searches (P1, P2) led directly to the restaurant list, and for P2, they needed help to recover from a validation error before they reached this page. Of the remaining eight searches:

- P10 and P13 did not use validated names (P13 ignored the suggestions and P10 hit enter before they displayed) and so ended up on the general results page
- four participants landed on hotel pages because they did not change the radio button from hotels to restaurants (P5, P7, P11, P14)
- two searches were affected by problems with participants starting their searches before the page had downloaded (P6, P15), this meant the page did not respond when they pressed enter, resulting in both initial searches being abandoned.

On the mobile phone participants either entered text into the search box on the homepage or went via the search form after clicking Restaurants on the homepage. None of the participants visited hotels results pages on the mobile phone and all reached the full list of restaurants.

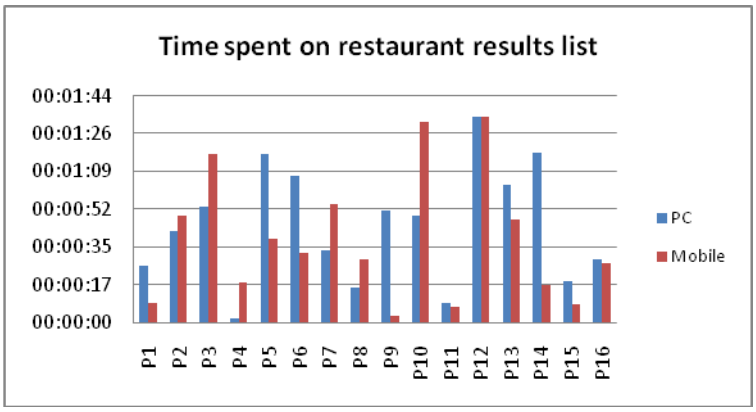
4.2.3.6 Mobile navigation problems

Six participants clicked on Menu in the Tripadvisor header bar (P3, P4, P5, P8, P9, P13), which opened up a new page with Home, Near me Now, My saves, Tools options.

Five participants tapped back without selecting anything: 'Hmm, that's not right' (P9). In the post task interview, P13 thought it would take them to the restaurant's menu (see Appendix F.2 – project CD).

P4 spent 15s on 'Near me Now', despite tapping decline, before tapping back four times to try to exit. This caused them to return to the Google homepage, losing the results list and forcing them to start their search again.

4.2.3.7 Time spent reading the restaurants results list



Overall participants spent a similar short amount of time on the restaurant results list on both the PC and on the mobile. The difference was greater between those who viewed the app or website version on an Android phone or iPhone and the PC, but not significant.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Time on restaurant results list - all phones	00:00:38	00:00:29	00:00:44	00:00:27	0.36
Time on restaurant results list - iPhone and Android	00:00:30	00:00:21	00:00:40	00:00:25	0.16

4.2.3.8 Time spent reading restaurant pages

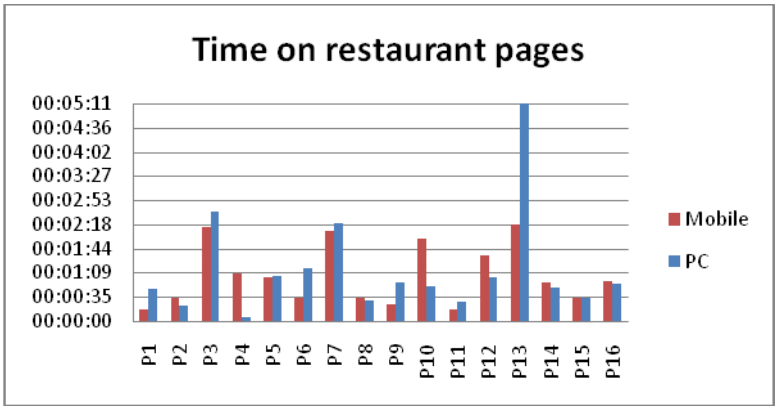
Overall participants spent more time reading the information on individual restaurants on the PC than on the mobile, however the difference in total time reading was small (2min 11s), as was the average time spent on each option.

Average time on options			
Mobile		PC	
Mean	SD	Mean	SD
00:00:28	00:00:12	00:00:30	00:00:23
T test		0.75	

In terms of individual differences, P13 spent nearly twice as long reading restaurant information pages on the PC than on the mobile, however this difference was not significant.

P7 spent longer reading fewer information pages (n=3) on the PC than on the mobile (n=6) and this difference was significant. Conversely the opposite was true for P14 who read two information pages on the mobile for longer than the four they read on the PC and this difference was also significant.

	Average time on options				
	PC (Mean)	PC (SD)	Mobile (Mean)	Mobile (SD)	T test
P7	00:00:47	00:00:05	00:00:22	00:00:13	0.05
P13	00:01:44	00:01:08	00:00:28	00:00:01	0.21
P14	00:00:12	00:00:06	00:00:28	00:00:01	0.01



4.2.3.9 Time spent reading reviews

There was little difference in the number of restaurant pages participants viewed on the PC (n=37) and the mobile (n=39). However there was a marked difference in whether the participant saw reviews on the page, with participants reading reviews for 81% of the restaurants (n=30) they viewed on the PC compared with 49% on the mobile (n=19). This difference was not significant in terms of numbers of reviews seen but was approaching significance for the percentage of restaurants for which reviews were read.

Overall participants spent almost twice as long reading reviews on the PC compared with the mobile. However, the difference in time spent reading was not significant when a t-test was used on the raw times.

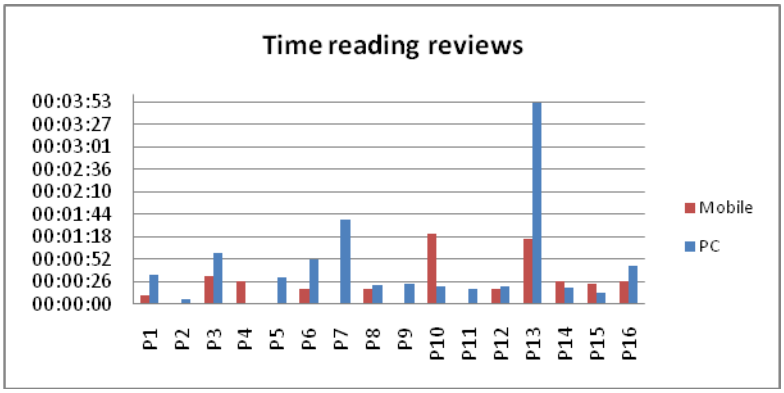
	Mobile		PC		T test
	Mean	SD	Mean	SD	
Reviews read	1.2	1.2	1.9	1.1	0.09
Reviews read as a % of options	54.7%	43.0%	81.8%	29.5%	0.06
Time spent reading reviews	00:00:19	00:00:13	00:00:23	00:00:25	0.43

On the mobile, users usually had to tap on the link 'Show reviews' on restaurant pages to open up the reviews. This meant some users did not spot the reviews at all (n=5), particularly if the mobile version was used first (P5, P7, P9, P11).

On the PC only P4 spent no time reading reviews for individual restaurants.

Most participants spent less than 30s on reviews on either the PC (n=13) or the mobile (n=9). P7 was one of only two participants to read reviews for longer than 1min on the PC.

In terms of individual differences, the majority of participants read reviews for longer on the PC than on the mobile (n=12), with a quarter reading reviews longer on the mobile (n=4) . The greatest difference in reading times between devices was for P7 (1min 37s), who read no reviews on the mobile and commented at the end of the task that their decision was in part due to the fact the other restaurant pages 'had very little information on them' (Appendix F.1 – see project CD).



4.2.3.10 Visiting restaurant websites

Nine participants tried to visit external websites on the mobile phone to help them make their decision:

- 7 participants viewed one website
- 2 participants abandoned the action when faced with a dialog box giving information about trying to open the website in a new window (P2, P3)
- P5 also saw the dialog message and clicked OK – however, when they tried to use back to get back to the results list it could not work, so they restarted the search process again in the new window

P9 also tried to visit the restaurant's website on their phone, but only to get directions rather than as part of the decision making process. The search for the restaurant failed because the restaurant did not have a website.

Nine participants tried to visit restaurant websites on the PC to help them make their decision, with two searches ending in failure (P1, P5) because the restaurant did not have an external website.

Overall the average time spent on external websites was similar on both devices: 39s on the phone and 33s on the PC.

In terms of differences between devices, six participants wanted to view restaurants on both devices (P2, P3, P5, P12, P14, P16).

Two participants viewed restaurants on their smartphones only – one participant because of a lack of information about cuisine type on the mobile site (P6) and one after a discussion sparked by them trying to use the 'Menu' button on their phone (P8).

P13 viewed a restaurant website only on the PC, because they were 'a little bit fed up' by reading through the reviews on the mobile (Appendix F.2 – see project CD).

4.2.3.11 Scrolling - Tripadvisor

Overall, participants scrolled more on the mobile than on the PC.

For Tripadvisor, the difference in scrolling down was not significant for navigation pages on the PC compared to the mobile, but was approaching significance for restaurant option pages.

The difference in scrolling up was not significant for navigation pages on the PC compared to the mobile, but was significant for article pages.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Scrolling down - navigation	14.3	12.8	12.2	7.6	0.47
Scrolling down - restaurant options	24.8	22.2	14.4	11.1	0.07
Scrolling up – navigation	6.5	6.7	4.8	3.7	0.33
Scrolling up - restaurant options	9.8	9.9	3.9	3.6	0.01

Removing data for those new to Tripadvisor or who used it yearly (n=7), there was no statistical difference in the amount of scrolling down or up on article pages.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Scrolling down – restaurant options (regular users)	27.3	26.5	17.6	12.8	0.30
Scrolling up – restaurant options (regular users)	8.6	10.1	4.0	4.1	0.15

Of the six novice users who used the mobile version of Tripadvisor, five did not open or read any reviews. Tapping back from a photo provided a cue for P4 who had not tapped on reviews until that point. This suggests that these users were scrolling more on the restaurant pages in search of information.

4.2.3.12 Task preference scores

Overall post task ratings for reading information on both devices was given similar positive scores by participants on reading experience, speed and ease of navigation. There was a significant difference in ratings for the statement 'There was too much information on the page' (Appendix F.1 –see project CD).

Preference score – Too much information on the page			
Mobile		PC	
Mean	SD	Mean	SD
2.1	0.7	2.7	1.2
T test		0.034	

Overall participants disagreed with the statement for both devices, however seven participants scored the phone as better on this measure, indicating they thought the PC had too much information on the page compared to the phone.

Both statements on credibility were approaching significance :

- overall participants trusted the information they read more on their phones than on the PC, with no-one disagreeing with this statement for the mobile.
- participants were more likely to want to check the information they read elsewhere on the PC, although more than half the participants agreed with this statement for both devices (n=9).

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Preference score - I trusted the information	3.9	0.7	3.6	0.9	0.096
Preference score - I'd want to check the info	3.8	1.1	4.1	1.2	0.096

At an individual level, the most marked difference was for P1's scores. Their scores differed on six statements in favour of the PC: trust, page speed, findability and amount of information on the page.

The average total rating for the Tripadvisor task was higher for the phone than for the PC, indicating participants preferred this task on the phone. The majority of participants scored the phone higher (n=10), with 5 scoring the PC higher and 1 scoring the devices equally.

This is in contrast to the pre-task device preferences reported for research tasks, which shows a clear preference for the PC (n=13).This meant most people's task rating score (n=11) for Tripadvisor did not tally with their expressed device preference:

- eight people preferred researching information on a PC, but scored the mobile higher (P5, P6, P10, P12, P13, P14, P15, P16) - one of these participants (P5) did not see the reviews on the mobile version
- one person liked researching information on both devices, but scored the PC higher (P4)
- one person liked researching information on both devices, but scored the mobile higher (P3)
- 1 person scored the mobile higher, but stated a preference of 'don't know' on the questionnaire because they don't usually do this sort of task (research) (P11).

Of the 8 participants who scored the mobile higher but usually prefer the PC, all experienced difficulties finding the restaurants section on the desktop version of Tripadvisor, eg first landing on hotels.

For two participants (P6, P15), the slowness of the page to download on mobile broadband on the PC caused a usability issue. Both participants used the homepage search box and correctly changed the radio button to restaurants. But when the Tripadvisor homepage has not completed downloading the following issues occur:

- the search button does not change from 'Find hotels' to 'Find restaurants' on clicking of the radio button (page needs to reload to change)
- the pop-under content advert that's triggered by clicking in the search box is visible for longer (as a blank window)
- the place checker suggestion list when typing does not work
- the input placement text (Enter city or hotel name) does not automatically disappear when the user starts typing

4.2.3 Twitter

4.2.3.1 Reported usage

Only half of the participants used Twitter (n=8), with a further participant using it as an aggregator for news and therefore used it as part of the news task.

Six participants use Twitter daily on the phone, while P1 uses it infrequently and P12 is new to Twitter on their phone.

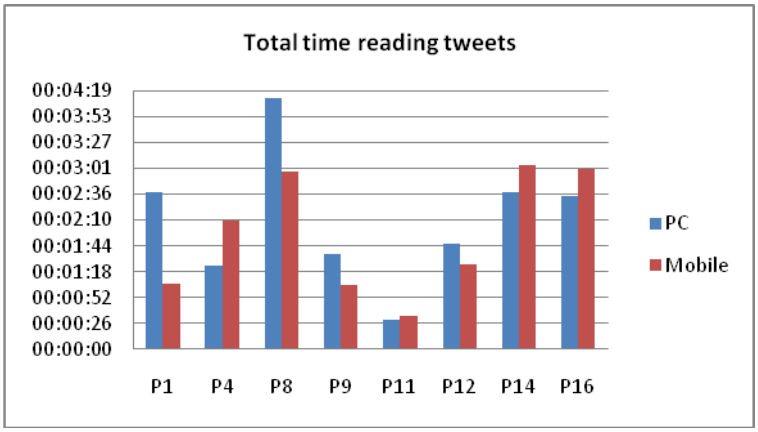
Five participants use Twitter daily on the PC, with P9 using it weekly, P1 monthly and P12 infrequently.

Four participants could not remember their login details on the PC and so used the reading study account (P4, P8, P12, P16) while it took P11 three attempts to log in. One participant preferred to use the reading study account (P1).

4.2.3.2 Time spent reading

Participants spent a similar amount of time reading tweets on the PC and mobile, spending slightly longer reading tweets on the PC although this was not significant.

Reading tweets			
Mobile		PC	
Mean	SD	Mean	SD
00:01:55	00:01:01	00:02:09	00:01:06
T test		0.45	



In terms of individual differences, P1 and P8 spent longer reading tweets on the PC, despite P8 using the reading study account on the PC compared to their own tweets on the phone. Three participants spent longer reading on the phone – in part because P4 and P16 were reading their own feeds on the phone compared to the reading study account on the PC.

While seven participants read tweets in the conventional way, updating then reading, P11 spent less than 35s reading tweets despite rating the content as 'quite interesting' compared to the lower ratings of 'quite boring' for the news and Tripadvisor tasks. But this participant had notifications set up, so only visited Twitter when they received a text update rather than actively going to read their

Twitter feed as a task. This participant also indicated they tended to tweet more than read, 'spamming' people with promotional tweets about their band.

This was in contrast to four participants who said they read tweets more than they posted (P1, P9, P14, P16).

None of the individual differences in reading times across devices was significant.

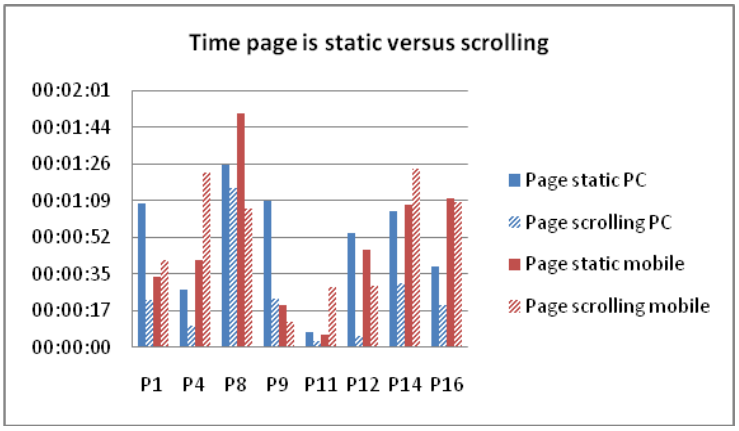
Both P4 and P11 stopped reading before the task end on both devices, while P12 stopped reading early on their mobile (their own Twitter page).

4.2.3.3 Finding tweets

A difference between Twitter and the other tasks is the size of the list participants scrolled through on the homepage. This was substantially longer than the size of the list in the Tripadvisor task and the lengths of news articles and other navigation pages. The page is also absent of structural elements such as headings, subheadings and sections, that help users make decisions on relevance and interest. Instead all tweets are listed chronologically, so navigating, searching and reading are closely coupled on the same page. Three participants commented on the irrelevance of tweets that appeared in the list (P1, P9, P12).

During observations all participants on the phone, bar P16, would rapidly scroll through a screen's worth of tweets quicker than they could read any text, then stop the page when something caught their eye. At this speed at most only the profile image next to the tweet could be seen, perhaps indicating some participants were searching for tweets from certain people they follow to find things of interest. On the PC this behaviour was less marked with only two participants (P8, P14) demonstrating this habit.

To investigate this, the percentage of time the page was static was compared to time spent scrolling. While some of these scrolls were slow enough to read, it gives an indication if there was any difference between this reading pattern across both devices.



Overall the average time the page was static on both devices was similar – 52s on the PC (SD = 26s) and 49s on the mobile (SD = 33s). However the average time spent scrolling on the mobile is twice as long as the average spent scrolling on the PC. This is a significant difference.

In terms of the percentage of time on page, participants on the phone spent more than half their time scrolling, compared to 28% of their time on page on the PC. Again this difference was significant.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Page scrolling	00:00:51	00:00:27	00:00:24	00:00:23	0.03
Proportion of time scrolling	52.80%	15.90%	28.50%	10.70%	0.008

4.2.3.4 Scrolling

The difference in scrolling down on personal Twitter homepages was not significant on the PC compared to the mobile. The difference in scrolling up was significant on Twitter homepages.

	Mobile		PC		T test
	Mean	SD	Mean	SD	
Scrolling down - Twitter home page	44.9	28.2	31.9	24.5	0.22
Scrolling up - Twitter home page	17.1	8.4	5.9	3.7	0.02

One of the noticeable differences between the PC and mobile versions of Twitter is that when a user updates their tweets on the smartphone, all new tweets load above the previous ones but the user's position on the page remains static. This means the user has to scroll up to get to the most recent tweets, before scrolling down. Users would also flick rapidly through tweets, then stop the list and scroll up to a tweet that caught their interest (P1, P4, P8, P9, P12, P14).

4.2.3.5 Task preference data

Overall the task rating scores for Twitter were less positive than for news but broadly similar to Tripadvisor (Appendix F.1 –see project CD).

Participants were more reticent about how quick it was to get information, how much they trusted the information they read and were more likely to rate reading as a strain.

Comparing overall scores for each device, participants rated reading on Twitter as more enjoyable on the phone, with information easier to find, but rated pages as slower to download.

However, these differences were small and there was no significant difference in scores for the individual statements for Twitter across the phone or the PC, in the total scores per device or in the individual's scores for each device.

The average total score for Twitter was higher on the phone than the PC, indicating a preference for using Twitter on the phone. This also tallies with the eight participants' reported preferences after the study, with most participants preferring to read social media on the phone (n=6). At an individual level, five participants scored the phone higher, with three scoring the PC higher.

The one participant who scored the PC higher for the task, but said they preferred reading social media on their phone, had run out of data and so pages were slow to download, causing them to abandon pages mid task.

4.3 Preference data

In all, 23 participants were asked the same three questions in the diary study and the observations about:

- any differences they notice between reading on the smartphone and the web
- what they prefer to read on
- what website version they prefer to use on their phone.

Participants in the observations also filled out a questionnaire on digital reading, with further answers provided in a post task interview (Appendix E.1 – see Project File).

4.3.1 Differences between reading on the smartphone and the web

In terms of differences between reading on a smartphone and a computer, 22 participants noticed a difference, with more than half (n=13) directly mentioning either screen size, font size, scrolling or zooming.

4.3.1.2 Screen size

Most participants (n=22) across the two studies mentioned the impact of screen size as either a difference between reading on a smartphone and computer or the thing they liked or disliked about reading on a smartphone or PC.

In terms of benefits of the computer, screen size was the most common reason (n=11) given as the best thing about reading on a PC, with participants finding things easier to see and select on a big screen (P3, P9, P10, P13, P14). Only P15 saw the smaller screen size on the smartphone as solely a positive, resulting in a 'simple layout' and uncluttered presentation that increased reading speed.

4.3.1.3 Font size

The small font size on the smartphone was raised by 12 participants across the two studies (P1, P2, P3, P4, P5, P6, P7, P12, DP2, DP4, DP5, DP6) as having an impact on reading on the smartphone. When asked about font size, five participants (P5, P6 P12, P13, P14) mentioned having to increase it, with participants finding it 'a faff' (P1, P14) that can increase page download time (P13).

However it is not an issue for all participants. When asked, five participants said they did not notice any difference in the font size on their smartphone compared to a computer (P7, P8, P11, P15, P16). All of these participants expressed a preference for apps or mobile versions of websites.

4.3.1.4 Scrolling and zooming

Scrolling and zooming is an issue for 11 participants, with four saying it is the thing they like least about reading on their smartphone (P1, P9, P10, P12).

P16 finds having to keep zooming in on a page 'annoying', with P3 agreeing, while P4 doesn't find it 'ideal' and says you need to 'know what you're doing with it'. For P5, the annoyance is trying to read text that is half off the screen after increasing the size of the page.

The sensitivity of the touchscreen when trying to scroll and zoom was raised by two participants (P13, P14), with P14 finding it 'dangerous' because you can accidentally interact with the screen when scrolling and 'like' things on other people's Facebook pages that you didn't mean to.

The only participant who had a non-touchscreen phone (P10) found scrolling a chore on the phone, with using the trackpad 'so much harder than a mouse'.

4.3.2 Reading preferences

Preference for the device participants preferred to read on was split:

- 10 participants (43%) preferred a computer for reading (P1, P2, P4, P5, P8, P9, P10, P14, DP4, DP7)
- 5 participants preferred their phone (22%) for reading tasks (P6, P11, P15, DP1, DP5)
- 4 participants had preferences for more than one device (17%), depending on factors such as task type (P12, P13, DP6)
- 3 participants preferred an iPad for reading (P7, DP3 and P3 - interview)
- 1 participant preferred print (DP2)

4.3.3 Mobile website version preferences

Similarly participants were divided on which website version was better to use on their smartphone:

- 8 participants (35%) preferred to use apps (P2, P4, P13, P14, P15, DP2, DP4, DP5)
- 8 participants (35%) felt it depended on either task (P1, P3, P6, P11, P12, P16, DP3) or availability (P11) – with 6 choosing apps as one of their preferences, ie in all 60% having some preference for an app
- 5 participants (22%) preferred mobile versions of websites (P8, P10, DP1, DP6, DP7)
- 2 participants preferred full websites on their mobile phone (P5, P9), although a further five participants mentioned it as one of their preferences - usually alongside apps (P1, P3, P6, P11, DP3)

4.3.4 Mobile web

The mobile web provides:

- quick (P2, P3, P4, P8, P9, P11, P12, P13, P15, DP1) and easy access to information on the go (P1, P2, P3, P5, P6, P7, P8, P11, P12, P13, P16, DP1, DP4) to fill in downtime (P9) or as a back-up (P10, DP3)
- access to the internet with no need to login, eg to email (P5, P12) or wait for a computer to boot up (P3, P4, P11, P13)
- easy to follow, uncluttered information (P2, P14, P15, DP4, DP5)

But the mobile web also results in:

- a small screen size (P4, P12, P14, DP3) that becomes tiring for long articles (P8, DP2)
- small fonts (P3, P6, P12, DP5, DP6) and the need to scroll and zoom more (P1, P9, P12, DP2) for pages not set up for the phone (P16, DP6, DP7)
- slow pages and connectivity (P5, P9, P14, P16, DP4)

In terms of reading experience, discomfort was mentioned by P8 when reading long articles, P13 in holding the phone and P14 being 'hunched' over the phone.

Two participants said there was nothing they disliked about reading on the smartphone (P11, P15).

4.3.5 Website versions on mobile phones

Mobile versions of websites and apps are seen as:

- easier to follow (P2, P15) and navigate (P7, DP7) whose layout allows phones to be used portrait (P7, DP4)
- often better than full versions, eg because the font size has been designed for mobile (P1, P3, P4, P7, P8, P13, P14, P15, P16, DP1, DP2, DP3, DP4, DP5, DP6, DP7)
- having more focused information because there is less information (P6, P8, P14, P15, DP4), adverts or clutter (P6, P7, P14, P15, DP5) than on the desktop web

But this ease of use and focus can also result in:

- missing information (P1, P5, P9, P12, P13, P16, DP6) or functionality (P3, P6, P7, P9, P11, P8, DP3, P14), eg comments on a news app (P7), filters on shopping websites (P6) or live updates on train information (P3)
- reduction of choice (P7, P8, P9, P12, P14, DP4)
- restrictive navigation (P5)
- information deemed as less important to users being harder to find (P7, P9, P12, P13, P14, P15)

4.3.6 Desktop web

The desktop web provides:

- a larger screen (P6, P7, P8, P9, P10, P11, P12, P14, P15, P16, DP3, DP6) with a coherent layout (P4) that enables fast scanning of information (P1, P14) and easier selections (P3, P13)
- more information (P1, P5, P10, P13, DP4) that is more in depth (P2)
- the ability to access multimedia quickly (P3)
- greater navigation options, with browsers offering easy switching between tabs, windows and applications (P5, P6, P9, P12, P13, P14, P16) making it easier to compare products and information and navigate between pages

But desktop websites can also:

- offer too much choice that can lead to slower reading, more clicks (P2, P14) and confusion (P15 – Facebook, P12 – Twitter)
- have too many distractions such as adverts or links to other sections (P2, P5, P6, P7, P8, P14, P15, DP5)

In terms of reading experience, discomfort was mentioned by three participants (P1, P9, P12) and so was having to be in one place (P6, P8).

Four participants said there was nothing they disliked about reading on the computer (P3, P4, P10, P15).

4.3.7 Connectivity

When asked, nine participants said connection problems impact on their internet use (P4, P5, P7, P10, P12, P13, P14, P16, DP4).

Four participants said signal problems were one of the things they least like about reading on the smartphone, with P5 mentioning it six times in six answers on the post study questionnaire.

But network problems caused the biggest problem for P10 who described the lack of signal problems as a 'nightmare', leading to an 'awful' experience on the internet, where they 'give up' because a 'it takes five minutes to load a little page'. These problems stopped P10 from using the internet on their smartphone and ultimately caused them to change network provider.

Five participants don't find connectivity a big issue (P3, P8, P9, P11, P15), using workarounds such as updating feeds before they travel (P8, P9).

4.3.8 Location and context

Which device people use to read is both location and task dependent.

Using the phone as a backup or last resort on the go is common (P2, P5, P9, P10, P13, P14), eg if lost when driving (P5), on holiday (P14) or in the car during a lunch hour (P2).

Seven participants read the internet on their phone when they commute or when travelling (P7, P8, P9, P12, P14, P15, P16). One participant only uses social media like Twitter on their phone because they can't access it on the PC at work and they don't tend to use the internet at home.

Location also has an impact in task purpose. For example, P13 uses their phone 'on the go' to check news quickly or 'because I'm out and about and I think, Oh, I need to find out about that or I need to look where I'm going or I want to see if that shop's got item available'. Reading on a computer on the other hand is 'nice', a way of relaxing with a coffee when they get home and 'enjoy the time to read things'.

Three participants gave shopping as an example of a task that they would only complete on the computer (P12, P13, P16), with four avoiding replying to emails on their phones (P8, P10, P12, DP4).

4.3.8.1 Multi-tasking

The PC is a multi-tasking environment, with six participants mentioning using tabs and new windows (P5, P9, P11, P12, P13, P14). Reading on the internet in this context competes with other activities such as instant chat (P5, P8) and multimedia as 'background noise' (P11). P14 says they have loads of tabs open and are 'looking at different things all the time, flicking between them, checking stuff'.

Participants talk about using their phones in different contexts, eg during ad breaks when watching TV (P11) or walking and reading at the same time (P8) where attention may be split, but not in terms of carrying out multiple tasks on the phone at once. For example P12 says they are 'quite ruthless' about 'sticking to one thing', shutting it down once they've found it on the phone: 'I don't tend to browse'. This is something future work could explore.

4.3.9 Skim reading and scanning

Seven participants said they skim read or scan information on their smartphone (P2, P4, P7, P9, P12, P13, P14, DP3). P2 skim reads to get information quickly ('highlights') and sees it as a 'choice', depending on how much the content interests them.

Two participants don't tend to read news articles all the way through on their phone (P1, P5), with P5 saying they read much more comprehensively on a PC, reading articles from 'top to bottom'. This

tallies with P5's reading behaviour during the news task. Conversely, P8 says they are more likely to read the 'whole thing' on a smartphone rather than on a PC, but abandoned more articles on the phone.

Two participants say they find it easier to scan information on the computer (P14, P1), but for DP2, scanning results in a drop of comprehension.

For P12 the difference in reading pattern is both speed and attention – they are slower on the PC and take in more information. Reading on the phone is a quick activity which is a positive for searches but a negative for comprehension because they don't pay much 'attention' to news stories they read on the phone, often re-reading them on the PC later.

4.3.10 Reading speed

Participants are divided over which device they think is faster for reading:

- 8 participants think they read faster on a PC, with reasons given including faster comprehension (P1, P14) and less skim reading (P4), while scrolling on the phone (P1, P7, P10) and non-mobile friendly web pages (P16) slow reading
- 6 participants think they read faster on a mobile phone, with reasons given including fewer distractions (P2, P8), simpler layout (P15), easier clicking and scrolling (P6, P11)
- 2 participants (P3, P12) don't notice much difference in the speed of their reading

4.3.11 In-depth reading

In terms of in-depth reading, preference for the PC was more noticeable, with most participants (n=11) preferring the PC and three their smartphone (P3, P11, P15).

Similarly, of the 13 participants who gave a frequency for in-depth reading:

- 11 read in depth daily on a computer compared with 5 on their smartphone
- 7 rarely or never read in depth on their smartphone

Twelve participants were asked to estimate the maximum time they would spend reading in a single session on their different devices:

- half said they spent less than 30 minutes on their phone but 'hours' reading on a computer with P9 saying 'it's the real web'
- 3 participants read for similar times on the PC and their phones, but generally spent no more than 30 minutes on either
- 3 participants said they read for longer on their phones than on the PC, with one reading books on their phone for hours (P15)

5. Discussion

The exploratory nature of both studies and the small numbers of participants, means these results are speculative and need to be confirmed by further research.

5.1 Diary study

Overall participants spent a short amount of time reading on the internet, with the most common session length of just two minutes on both the PC and mobile. This is longer than the average session from data logging study on the desktop web (Weinreich et al 2008), but more similar to the average session length reported for feature phones (Cui & Roto 2008) and for app use (Bohmer et al 2011).

Longer reading sessions were more frequently carried out on the PC, with no entries longer than 20min posted for the mobile phone. However 14 sessions on the mobile were at least 10 minutes long, compared to 20 sessions on the PC. This seems surprising given the data from the earlier studies and suggests that for some participants reading times on the internet are similar on their phones to those on the PC. However it is difficult to truly compare these figures because data for longer sessions from the other studies is not available.

The most common reasons for internet visits were to read email, news, social media and for fact checking (reference) and research. This broadly tallies with other studies on internet habits (Cui & Roto 2008, Kaikkonen 2011). Reading news, social media and travel information was more common on the phone, with email, transactions, research and reference activities more common on the PC.

The surprising finding for the researcher was that not everyone reads the internet on their smartphone. Two of the three participants who recorded less than three entries for mobile internet did not enjoy reading on their phones. The third participant was new to the phone and used it as a backup, eg when they were out.

Location is also likely to have impacted the amount of diary entries posted for the mobile because almost half of all sessions were recorded at home, where participants had access to other devices.

Total data for the diary study was low with an average of 20 sessions posted over the two days. This means these findings are indicative only and would need further study. For example while the split preferences for reading device were consistent with data from the later observations, the small number of participants meant preferences for the mobile website version appeared more clear cut, with all the diary study participants preferring either the app or mobile version of websites.

5.2 Reported use

In contrast to the data from the diary study, participants in the observations did not use their phones as frequently to read travel information, social media or to post social media updates.

Participants also reported using their phones significantly less than the PC to read news, buy online, research information and to check facts. While the prevalence of using computers for buying online tallies with Kaikkonen's survey (2011), the significant difference for news does not. However the reported usage difference between devices in the survey was only 6% and could also be explained by the small sample size. Limitations in the descriptions used for the survey categories mean it is only possible to directly compare frequency data for these two tasks.

5.3 Time spent reading information

Participants spent a similar amount of time reading news articles, restaurant information and tweets on both the PC and the mobile. For restaurant information and news articles, the average time spent reading was just 30 seconds. For Twitter, the average time spent reading tweets on both devices is around two minutes.

The similarity in times spent reading on both devices confirms research by Bao et al (2011) who found reading speeds were broadly comparable on the PC and the smartphones.

In terms of the diary study, while the Twitter time tallies with the times reported for reading social media, the news reading times are shorter than 2min, with only 10 news articles (15%) in the observations being read for 1min or more on both devices. However the times spent on single articles were based on estimates from two participants, so a discrepancy is to be expected.

5.4 News

While overall there was no difference in reading times per device, two participants spent significantly longer reading fewer news articles on the PC compared to the mobile. However when reading times were reduced to account for end of article navigation, only one participant read articles for significantly longer on the PC than the mobile and they read science news. In the diary study, one participant also read specialist news for longer, indicating that subject matter influences reading time, which would be worth exploring in future work.

It is also interesting that all participants who read articles for more than 3min on their smartphone used either an app or mobile version of a news website. While the difference in reading time between mobile-friendly versions of news websites and the desktop site on the smartphone was significant and also noticeable for app users alone, the very low data for comparison means more research with more participants is needed to confirm this speculative finding.

5.4.1 Navigation

Overall participants spent a similar, short amount of time on news navigation pages on the mobile and on the PC, with participants spending an average of around 20 seconds reading before selecting an article to open, with half the sessions on the mobile lasting less than 8s – similar to the half of sessions that lasted 10s in an earlier data logging study (Weinreich et al 2008).

This indicates participants make quick decisions about which articles to read. However on the mobile phone this comes at a cost, with nearly three quarters of articles abandoned – significantly more than on the PC. In total, almost three quarters of articles on the smartphone were not fully read.

In two instances articles were abandoned because of problems with download speed and font size, but this doesn't explain the differences for the remaining participants. While the difference in percentages of articles abandoned is significant, the low number of articles read by many individual participants indicates that more research is needed to verify this result.

There was no difference between devices in terms of the number of navigation pages participants viewed or the amount of time spent reading them.

However, on the PC participants viewed significantly fewer navigation pages than article pages. While this could indicate that participants used fewer navigation pages to find articles on the PC and

greater use of within article links, when data for participants who used Twitter and RSS snippets to navigate to news websites was removed, the results were no longer significant.

It is surprising that smartphone users did not view significantly fewer news navigation pages, given the use of apps and mobile versions with fewer navigation options than the desktop versions. Similarly, with direct swiping from article to article possible, it suggests that overall visits to navigation pages should be lower than on the PC, as seen in the case of one app user who only visited a navigation page once.

However a reason for apps not significantly reducing the number of visits to navigation pages became apparent when three of the five app users were not aware they could swipe from article to article. There are also differences between apps, with the BBC News App having one navigation page compared to the multiple navigation pages on the Vancouver Sun App. More research is needed to explore these findings.

5.5 Tripadvisor

Overall participants' preference scores indicated they preferred carrying out this task on the phone, in contrast to their usual use of a PC for research tasks and their usual preferences for carrying out research tasks on the PC.

This is perhaps not surprising given the navigation problems participants experienced on the desktop website, with 11 participants reaching the restaurant results list via secondary navigation pages, seven participants viewing hotels pages first and one participant who did not reach the full restaurant list.

One of the biggest sources of navigation problems was the 'Plan the Perfect Trip' search box on the desktop version's homepage. Of the 10 people who used this feature only two arrived directly at the restaurant list. While two of these failed searches were affected by connection issues, one of the successful searchers needed help to overcome a validation error. Without help, it is likely this search would have failed too.

None of the participants viewed hotel pages on the phone. In contrast to the news reading task, not only did participants view fewer navigation pages on their phones than on the PC, the time spent on navigation pages by participants who used the mobile or app version of Tripadvisor on Android phones or iPhones was significantly lower than the time the same users spent on the PC.

In terms of understanding the reasons for this difference, Android and iPhone users spent less time on navigation pages to get to the restaurant results list, but more research is needed to understand whether this difference would become more noticeable with more participants. These participants also spent less time reading the restaurant list than on the PC but not significantly so.

As well as reading restaurant information for a similar amount of time on both devices, participants viewed a similar number of restaurant pages to reach a decision, despite there being more initial information on the desktop restaurant list such as cuisine type and price to help users narrow their decision.

5.5.1 Time spent reading reviews

While the average time participants spent reading the restaurant pages was not significantly longer, what participants read to make their decision differed markedly between devices. Participants read reviews for most of the restaurants they viewed on the PC, compared with just under half of the mobile. This difference was approaching significance for the percentage of restaurants for which reviews were read and warrants further investigation.

Part of the reason that participants did not read reviews on their smartphones was because they usually had to tap on the link 'Show reviews' on restaurant pages to open up the reviews. Five users did not tap on this link and one only saw the reviews by chance.

However even when reviews were seen, most participants spent less than 30s on reviews on both devices. With seven participants using Tripadvisor yearly or less, this could point to participants being unaware of the website's purpose. This was clear from comments made by two participants during the task (P7,P9).

Evidence of learning could also be seen, with one participant reading no reviews on their first visit on the mobile, then being one of only two participants to read reviews for longer than 1min on the PC – a significant difference in their reading times per device.

However the impact of the mobile page layout on reading times is not clear cut, with P14 reading fewer information pages on the mobile for longer and this difference was also significant. This participant used Tripadvisor monthly, indicating that stripped-down page layouts may be most effective for regular users of the site.

Similarly, participants rated the phone less negatively than the PC for the measure 'There was too much content on the page'. While this is a positive in terms of navigation, it is questionable how far the same can be said for the restaurant information pages, given that participants did not open reviews – the primary purpose of this website.

5.5.2 Visits to external websites

In terms of the expressed preferences for researching information and the limitations of phone browsers for comparison tasks, it was surprising that just over half of participants attempted to visit external websites on the mobile phone to help them make their decision. However, these attempts were not entirely successful, with three participants confused by the Tripadvisor website trying to open the restaurant page in a new window. Two cancelled the request and a third lost their initial search results because it wasn't evident they were on a second page. This points to a significant learning curve for smartphone users to exploit the browser's limited multi-tasking capabilities.

However the decision to continue and research an external website is not just a question of functionality of the phone's browser – one participant was so fed up of reading the reviews they didn't want to spend any longer on the task, while another only searched for the restaurant website because of a lack of information about the cuisine type on the stripped-down website.

5.5.3 Connection difficulties

It is worth noting that connection speed may also have had a negative impact on participants' ratings for the desktop version of Tripadvisor. While it only directly impacted the search success of two participants, five of the eight participants who preferred researching information on a PC but

scored the mobile higher used the desktop website with mobile broadband. Despite these participants' average ratings for Tripadvisor on the PC being slightly more positive than the participants who used wifi (Appendix F.2 – see Project CD), mobile broadband could be a confounding variable. More research is needed to clarify if this is the case.

5.6 Twitter

The average task rating for the Twitter tasks indicates that participants preferred using Twitter on their phones. This tallies with participants' reported preferences after the study, although half the participants used the reading study account and so were not reading tweets on the PC that were relevant to them.

Reading behaviour on Twitter differs from the reading observed in the other tasks, and involves rapid flicking through long lists of tweets. The only ordering of content is chronological, with no other structural elements on the page to help users find tweets of interest. This means navigating to find tweets and reading occur simultaneously, resulting in longer times spent on the page of tweets overall compared to article or news pages.

The lack of any categorisation or structural elements to aid relevance decisions resulted in the two novice users of Twitter becoming frustrated at why certain tweets were displaying in their searches. Despite both novice users giving this as a reason for not using Twitter, both were trying to follow up on news stories in an account other than their own and so this could be a result of the task set.

5.7 Summary

The smaller screen size of smartphones causes three main issues for participants:

- font size that needs increasing for desktop websites
- layout, eg content and functionality not being visible on screen
- increased scrolling and zooming to read information

5.7.1 Scrolling

Participants scrolled more on their smartphones for all tasks.

For news, the greatest difference was in the amount of scrolling down article pages, as a result of longer page lengths. For Tripadvisor the difference was greatest in terms of scrolling up on restaurant pages.

For Tripadvisor a large number of scrolls up came from novice users of Tripadvisor. Of the six novice users who used the mobile version of Tripadvisor, five did not open or read any reviews. This suggests that these users were scrolling more on the restaurant pages in search of information.

Participants scrolled up significantly more on their smartphones when using Twitter. While the need to scroll up on the phone after updating their tweets' list is part of the reason for the higher number of scrolls, most participants also flicked more rapidly through tweets on their phones than on the PC. This meant by the time they stopped the page, they had to scroll back up to the tweet of interest. Overall participants spent half their time scrolling through tweets on their smartphones compared to less than a third of their time on the PC.

Negative aspects of scrolling were most raised in relation to having to zoom in, and this was observed by the researcher when users had to keep swiping back and forth to read text that was half off the screen (P5).

An interesting issue raised by two participants was the sensitivity of the touchscreen leading to unwanted interaction. The researcher did not come across this issue in their literature review, suggesting it may warrant further exploration.

In terms of the impact of scrolling on the reading experience, scrolling on the phone was cited by participants as a reason for their reading being both quicker and slower than on the computer.

What does seem clear is that stripped-down versions of websites and apps benefit users with regards to reducing the need to manipulate the page size through pinch zoom and scrolls, with the five participants who said they were not affected by font size all using apps and mobile versions of websites.

Despite the increase in scrolling experienced by participants, overall task rating preferences per device resulted in the phone being preferred over the PC for two of three tasks, with equal preference for the news tasks. This suggests that scrolling does not have a significantly negative impact on the reading experience, but more research would be needed to confirm this.

5.7.2 Device and website version preferences

Both the similarity in reading times per device and better task ratings for the phone suggest that the experience of reading the internet on smartphones can be similar to the desktop web, particularly in terms of findability for top tasks (McGovern 2010).

Despite this, participants were more likely to prefer using a computer for reading the internet, particularly for in-depth reading.

The majority of participants (87%) also expressed some preference for the use of apps or stripped-down mobile versions of websites on their phone. Only two participants always preferred full desktop websites.

However, what was also clear from the preference data is although mobile versions of websites and apps have benefits in terms of font size and more focused content, this also leads to frustrations for participants used to the full desktop web experience. In particular, participants had noticed that functionality was missing on the mobile versions of websites they used, with content more difficult to find if it was not part of the main navigation options.

In common with other studies, quick, convenient access to information on the go is one of the main reasons for choosing to use the internet on the phone (Bao et al 2011, Church & Oliver 2011). The lack of time needed for the phone to boot up and use of apps to avoid login were also benefits, to the extent that half the participants in the Twitter study could not remember their password for their accounts.

While the multiple navigation options on the desktop web make for easier comparisons in research tasks, the amount of ‘clutter’ on pages in terms of adverts, navigational elements and content had a negative impact on participants’ perception of the desktop reading experience. As content

producers look to monetise the mobile (eg Facebook introducing adverts to mobile BBC News 2012), it will be interesting to see if the gap between the two narrows – and more participants cite clutter for the smartphone too.

5.7.3 Connection problems

Overall connection problems for participants were limited to commuting, with a minority of participants spontaneously raising it as a problem. This may in part be due to workarounds such as updating social media feeds before travel, but may also reflect the use of smartphones in stationary contexts (Church and Oliver 2011, Bao et al 2011), which was also seen in the diary study.

6. Evaluation, reflections and conclusions

6.1 Evaluation of objectives

Overall the aims of this project were met. The diary study provided data on users' internet reading habits on the smartphone and computer, with some tentative findings from qualitative data on the differences between reading on each device.

The observations extended these findings by providing evidence of participants' reading behaviour in terms of what was read and where time was spent on the page. It was also possible to track scrolling habits, with noticeable differences between devices.

Finally the qualitative data collected in the post task questionnaire and interviews provided valuable insight into the differences that users perceived in the reading experience on both devices. Collecting additional data on reported use and device preferences enabled a broader picture to emerge of how consistent participants' ratings were with their observed behaviour.

6.2 Reflections

6.2.1 Method

Comparing reading habits across two devices led to a number of challenges in designing tasks.

While tasks were counterbalanced across device, the length of the news reading task (five minutes) was too long for three participants who stopped before the allocated time on both devices and one participant who stopped only on the mobile. Similarly five of the seven participants who recorded more than 10 visits to news navigation pages were reading the news for the second time.

For the Twitter task, two participants stopped reading early on both devices with another participant stopping early on their phone. While a between subjects design would ensure this behaviour reflects reading habits rather than the reptitiveness of the task, it would bring other challenges in terms of understanding if this reading behaviour was typical or not.

6.2.2 Diary study

The inclusion of the diary study was instrumental in choosing tasks for the observations that were naturalistic and based on what people actually do.

However, the diary study pushed back the timings of the observations because it was difficult to get people to return their entries in a timely manner. The original intention was to get some data quickly from two or three participants to inform task selection for the observation, however two participants took more than a week to send their entries back, with a low number of sessions recorded overall and just two sessions recorded for mobile use. This meant further time was spent recruiting more participants, and the subsequent data analysis greatly increased time pressures for the rest of the project.

The diary form used was largely successful, but hardly any participants recorded individual times for articles and emails. It may be that the form was too generic for news reading and email tasks and a different version, eg an online version that captures the URL of the page and time spent would be better. However using an online version would likely further decrease the response rate for mobile entries.

One area of future study could be to extend the study over a longer period to capture a broader picture of use, particularly to see if the findings replicate the long sessions recorded for the smartphones and to gain a better understanding of mobile contexts. Offering a financial incentive may increase viability of a longer diary study (Karlson et al 2010).

6.2.3 Recruitment

The need to recruit smartphone owners with English as their first language for the observations posed significant challenges for the researcher. Recruitment took longer than expected so observations were carried out over a three week period instead of the intended two. It also meant the researcher had to test in different locations, going to people's place of work and in one case hiring a meeting room. With no access to wifi, mobile broadband was used for six participants, and was used at the start of one session before being able to switch to wifi.

This had an impact on the speed of pages downloading, which caused usability problems for two participants in the Tripadvisor task who did not wait for the page to finish downloading before starting their search.

Times were adjusted as much as possible during data cleaning, but other interactions came into play, eg one participant then typed in the wrong location. To carry out the study again, the researcher would only use locations with a wifi connection – however P1 also experienced connection issues using 3G and City University wifi on their phone, having to abandon pages in the Twitter task, suggesting this would not completely solve this issue.

Two participants in the study were novice users of the internet, but this is something that is likely given the growing numbers of smartphone users. Interestingly one of the novice users could use the news app, but not the phone's browser. Investigating whether apps help novice users would be an area for future study.

6.2.4 Observation procedure

The counterbalancing of tasks, devices and Tripadvisor location made preparing preference data task sheets challenging, particularly on days when more than one observation was carried out. The test script ensured consistency, but in one case (P12) the participant carried out the news task before the Tripadvisor task on the PC. This was in part because the researcher did not update their master task list to reflect the revised order mid-way through the study (participants did not see this sheet).

Recording the mobile screen was sometimes challenging, with glare from overhead lights interfering with the screen. This caused particular issues with the news task for P5, whose screen was dim during the task (in part because they had low charge left on their battery). Participants' hands and thumbs occluding the screen also caused occasional problems.

Participants also presented a number of challenges. One participant had run out of data on their iPhone the day before the study so had to borrow a colleague's iPhone to complete the news and Tripadvisor tasks. This participant also thought they needed to re-read the same news stories on the phone and the time lapse between the tasks meant this was not picked up until mid-way through the task.

One of the novice users needed substantial help to get to the Tripadvisor homepage on their smartphone.

Four participants did not initially read silently during the tasks, despite being asked to read as they normally would. Three of the participants were aware of the think aloud technique. While three participants responded to prompts and read silently, one participant continued to talk (albeit it for less time). It was challenging to handle these situations because by its very nature intervention by the researcher changes the nature of the task. On reflection the researcher should have more clearly stated the request to P12 while the prompt for P3 to read 'silently' rather than 'normally' was too strong.

Participants used a broader range of news websites in the observations than in the diary study and in addition, three participants preferred using the desktop version of the BBC news website on their phones with one being directed there through search.

This resulted in a multitude of websites and versions on the mobile phone, making it difficult to judge the overall consistency of the reading experience and tease out whether the differences noted were due to the format, content, device or the participant. For further research it would be advisable to control both the website explored and the version used for the mobile – however this would be at the loss of participants' familiarity with the news and so the ecological validity of the research.

6.2.5 Twitter

Half the participants who used Twitter could not remember their login details and so used the reading study account. Also it became evident that most participants (n=7) were more familiar with Twitter on their phone and so comparing use across devices may not have high ecological validity. Measures that could address these problems include screening participants on their Twitter use during recruitment and pre-study instructions for participants to know their login details.

6.2.6 Data preparation and analysis

Although in terms of sample size the number of participants was small, the data generated from this and the earlier diary study was overwhelming.

Preparing data for analysis was a huge task that the researcher underestimated. Transcribing the scrolling actions in particular was time consuming but ultimately worthwhile. The researcher added considerable new Excel skills in using pivot tables, filters and formulas to make data analysis easier.

Coding the quantitative data for analysis raised many challenges with regards to how to categorise user actions, for example the RSS snippets viewed by one participant in the news task. Input from the researcher's supervisor was helpful but ultimately making decisions on these grey areas in the data was difficult. For future work, the researcher would want to work with another researcher to triangulate the coding and make the analysis more robust.

Similarly coding the qualitative data from the post study interviews was difficult because originally the researcher had more than 60 categories. In reducing the categories, the researcher lost some of the useful granularity that some of them provided, eg focus. Ultimately time pressures meant there was a limit to how far the qualitative data could be analysed.

6.3 Conclusion

Data from the diary study shows that users perform similar reading tasks on their phones and PC, with frequent visits to read email and news. In terms of differences between devices, reading social

media was predominantly an activity carried out on the phone, with research, shopping and reference tasks carried out more often on the PC. Usage information from the observations broadly tallies with these findings.

Key findings from the diary study include both the length of time people read on their phones, with sessions recorded of up to 20 minutes, and the non-use of internet on smartphones because users didn't enjoy the reading experience or were new to the phone. Similarly two participants in the observations had not used their phones' browsers before.

In terms of reading behaviour on individual pages, data from the observations showed there was little difference in terms of reading times for information on the smartphone and PC. On both devices, the average time spent reading information was less than 30 seconds for news and restaurant information, suggesting that few articles can be read in full. Whether there is a pattern to what content users skip, eg in skim-reading or satisficing, is a potential area for future research.

While news articles on mobile versions of news websites were read for longer, participants were more likely to give up on reading articles on their phones. This high abandonment rate could be because users can't scan information quickly to get an overview of length in the same way as they can on the PC. Again, this is an area for future research.

Overall, most users expressed some preference for an app or stripped down version of websites on their smartphone. However the impact of apps and mobile versions on the internet reading experience is mixed.

On the one hand they provide benefits in terms of the font size and layout being appropriate for the screen size. On the other, the simplified navigation options and content helped users to find the restaurant list on Tripadvisor more quickly, but left them unsure what to do once they got there. Similarly, functionality in apps is not always apparent, eg the ability to navigate from article to article by swiping, resulting in a limit to how effective these apps are in improving the reading experience for users.

Overall the task ratings by participants for both devices were similar, with higher average scores for Tripadvisor and Twitter on the phone. The Tripadvisor result is interesting because data from both the diary study and reported usage in the observations indicated a clear preference for carrying out research tasks on the PC.

This suggests the differences between the internet experience on the smartphone and PC can be small and that the question for content producers is not just one of device specific website or not, but of clear and consistent design that makes the site's purpose and functionality evident to users.

Similarly despite spending more time scrolling on their phones than on the PC, and in the case of Twitter scrolling twice as long, both task ratings and reading times were similar for both devices. This suggests that the impact of screen size and scrolling on reading and interaction may be limited for certain tasks on smartphones – something future research could investigate.

Finally the data in this study suggests that differences between devices become more apparent for in-depth reading, with greater preference for the PC.

Future studies could expand on this research, for example by focusing on comparing the app or mobile version of a specific website to the desktop version, with all users experiencing the same versions.

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