Interaction On The Move: Exploring Tilt-Based Text Input For Smartphones When Walking

Matthew Butcher
School of Physical Sciences and Computing
University of Central Lancashire, Preston, UK, PR1 2HE
matttbutcher@gmail.com

Janet C Read
School of Physical Sciences and Computing
University of Central Lancashire, Preston, UK, PR1 2HE
JCRead@UCLan.ac.uk

Daniel Fitton, Gavin Sim
School of Physical Sciences and Computing
University of Central Lancashire, Preston, UK, PR1 2HE
{DBFitton, GRSim}@UCLan.ac.uk

For the past decade it has been a common thing to notice mobile phone users using their devices in many different environments, but in recent years the rapid evolution of smartphones with improved touch screen and interactive capabilities has led to a rise in usage whilst on the move. This paper presents the results of an experiment with student users to help explore the performance of a tilt-based text input application on smartphone devices. This experiment considered 2 independent variables with 4 conditions: grip (one-handed, two-handed) and mobility (sitting, walking). The study involved 12 participants aged 18 - 26 who were each required to carry out numerous selection tasks for each condition. This paper explains the methods behind the experiment along with the test procedure have been implemented, it attempts to justify major decisions that have been made and includes an in-depth critical reflection of the findings. The qualitative results of the study unveiled interesting evidence of more errors whilst on the move, with the optimal condition being sitting using a two-handed grip. Qualitative results from a survey after the experiment revealed similar findings, that users found it much easier to use the application whilst sitting, and sitting one handed being the easiest condition. A similar experiment was previously carried out in 2013 which explores the same tilt-based application but under a different testing environment and the performance of a younger user group, the study highlighted the potential value of tilt as a technique for text input for teenage users. This study expands on previous research and identifies that there is a much greater chance for users to perform interactive tasks worse when using smartphone applications on the move instead of using them sitting down.

HCI, Mobile text input; tilt-input; performance measurement

1. INTRODUCTION

For many smartphone users, it has become second nature to use smartphones in lots of different environments that they may find themselves in. However as there is a rise in users becoming more and more accustomed to using their smartphone device anywhere they may be, background research revealed that there is also a rise in the risks that this kind of multi-tasking activity imposes. For example, the recent 'Pokemon GO' phenomenon of 2016 has been linked to many different accidents due to people focusing on their smartphones more than the real world around them (Ayers et al., 2016). This study intends to explore whether the user is more likely to perform worse using a smartphone application on the move than they would if they were sat down, this would give a further insight into other implications from using smartphones on the move.

In order to test smartphone use on the move, suitable experimental software was selected which would allow detailed results to be obtained. The software which was selected is called TiltTarget, and was used in a previous study which looked at 'Exploring Tilt-Based Text Input For Mobile Devices With Teenagers' by

Daniel Fitton, I. Scott Mackenzie, Janet C Read and Matthew Horton. (Fitton et al., 2013). The software, including all materials needed to understand and use it, can be found on I. Scott MacKenzie's personal hub on the website for York University, Toronto, Canada. Unlike the previous research study which focused on the testing of the tilt-based text input feature, this study makes use of the TiltTarget software to explore user performance using interactive applications on the move. It focuses on testing the hypothesis: "users are more likely to perform tasks worse when using applications on the move than they do whilst sitting down".

2. BACKGROUND AND LITERATURE

This section covers the background behind the study and includes lots of the literature which was explored during the project. Before starting the research study, it was very important to consider any previous research experiments which have been carried out using the same (or similar) methods / tools. It was also important to assess the importance of a repeated study in the fields of tilt-based text input and mobile device use on the move. In addition to this, research methods (such as survey design) needed to be properly analysed before they were implemented.

2.1 Background

Smartphones have undergone rapid and compelling innovation in recent years. In 2015 there were roughly 1.91 billion smartphone users in the market (Kissonergis, 2015), that number has been said to have increased by a further 22% since then, and it is estimated that there will be 6.1 billion users by 2020 (Lunden, 2015). There is no doubt that the smartphone industry is thriving. However, an area which has not seen as much rapid development is the improvement of smartphone screen use whilst **on the move**.

Smartphones have developed so rapidly that recently there has been more and more concern about using messaging and other applications whilst on the move. In 2014, Dr. Dietrich Jehle, a professor of emergency medicine at the University of Buffalo in New York stated that "while talking on the phone is a distraction, texting is much more dangerous because you can't see the path in front of you." (Robinson, 2014). In addition to this, more than 1,500 pedestrians were estimated to be treated in emergency rooms in 2010 for injuries related to using a cell phone while walking (Grabmeier, 2013). More recently, (taking on board both driving and walking in the on-the-move category), a report was published which includes an assessment of drivers and pedestrians distracted by the Pokémon GO game. 'Pokémon GO - A New Distraction for Drivers and Pedestrians' (Ayers et al., 2016), highlights evidence of crashes potentially caused by the game following a mining of social and news media reports. A big concern is that motor vehicle crashes are the leading cause of death among 16- to 24-year-olds, whom the game targets (Ayers et al., 2016).

This experiment aims to explore the significance of moving whilst using smartphone applications and texting. There is a lot of recent evidence to suggest that using smartphones on the move is becoming more and more of an issue. However it would be interesting to gather data which could explain the extent of the problem through practical test performance results and user experience survey findings.

2.2 The Software

Fortunately, like most of Scott MacKenzie's software, 'TiltTarget' has been developed in a way which makes it extremely easy to test with and record data. This is due to how well the application takes into consideration the needs of both the test user and the investigator. Jakob Nielsen stresses the importance of maintaining an aesthetic and minimalist design throughout the development of interactive products (Nielsen, 1994), this application makes sure to do so. An example of this is the feedback that a user receives in the form of more prominent highlighting over target squares when the ball hits their boundary. The user also receives auditory feedback whenever a selection is made (regardless of if this is a hit or a miss selection). Good user feedback ensures that the application is easy to use, as suggested in Shneiderman's "Eight Golden Rules of Interface Design", which states that for every operator action, there should be some system feedback (Shneiderman, 1998). On top of this, from the investigators perspective, repeating past tests in similar ways was made straight forward with the inclusion of a very neat and detailed setup menu (*Figure 1*).

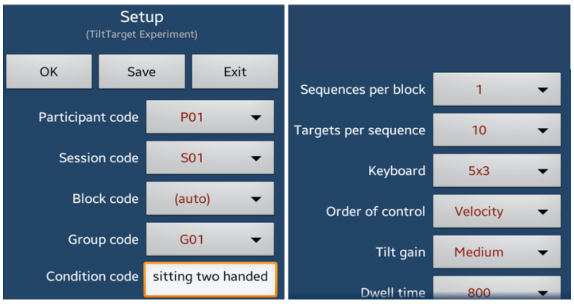

***Figure 1**. TiltTarget Setup Menu.*

In 'Preliminary Guidelines for Empirical Research in Software Engineering' the authors stress the importance for making sure that "the description of the research provides enough detail for other researchers" (Kitchenham et al., 2002). MacKenzie made sure to include a full API on the workings of the TiltTarget application (MacKenzie, 2013), therefore the level of detail that has been put forward to allow future experiments is very high.

2.3 Likert Scales

Many of the questions involved in the post-experiment survey adopted Likert Scales. The work of Brown, 2010 enabled the investigator to properly assess good uses of Likert Scales for this specific study, the published examples acted as a good base of understanding to begin with. It was important however to keep in mind that to use Likert Scales correctly, they should measure attitude providing "a range of responses to a given question or statement" (Cohen et al., 2013). Likert Scales are particularly useful as they force the user to pass judgement and properly "indicate which of several response choices best reflects their response to the item" (Gliem and Gliem, 2003). Typically there are 5 categories of response but it is important for any researcher to keep in mind that "intervals between values cannot be presumed equal" (Jamieson, 2004). Therefore it is a particularly important issue for a researcher to understand that if they are using Likert Scales they must take care not to *assume* an interval scale if a mean result indicates a value in between the scales that have been defined.

3. METHOD

The various methods that have been used for the study are described in this section. Specifically, the participants that were used have been defined, as have the procedures that were carried out during the practical experiment and research survey. In addition to this, two independent variables are explained in detail including their four resulting conditions.

3.1 Participants

12 university students aged between 18 - 26 (mean age 21.5) were selected. In terms of gender, 83% of the participants were male. There was no specific formal selection criteria that was used in choosing participants, they were selected haphazardly from a pool of personal friends, associates or links. The participants were not required to have used tilt-based text input before, or where they even required to own a smartphone. However post study survey results revealed that all of the participants owned a smartphone. All participants were required to sign a consent form before taking part *(see the supporting documents which accompany this report)*. The consent form clearly explains the purpose of the experiment, why the participant has been selected, covers the experiment procedure, confirms that confidentiality measures will be put in place and highlights how there is no likelihood of discomfort or risk associated with

participation. They are also made aware that they do not need to answer certain questions if they do not want to and that they can withdraw from the study at any time without penalty.

3.2 Setup

Before any testing was carried out, it was important to check the purpose and the questions that the study wished to raise and answer. All of the necessary documentation, *(see the supporting documents which accompany this report)*, such as participant instructions, the post study survey, consent forms and the 'TiltTarget' API, were printed off and double checked. This cautiousness ensured clarity for the participants and it was a vital supplement in allowing the researchers to "state clearly... what questions the investigation intended to address and how it would address them" (Kitchenham et al., 2002).

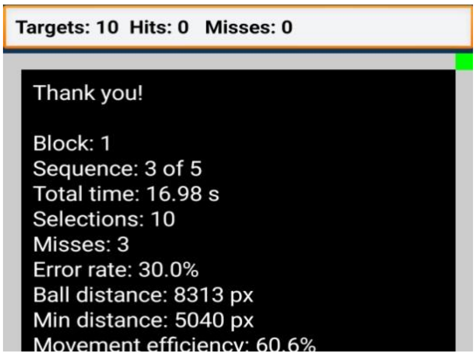

Figure 2*. TiltTarget Results Screen.*

Unlike previous tests of the TiltTarget application, tablet devices were not used. Instead a single Android smartphone (Samsung Galaxy A3) was used to make sure to accurately address the specific questions that the study wished to raise; how well users can operate smartphone applications on the move. The experiment was carried out indoors with any light being blocked my drawn blinds, this is to take into consideration any risk of glare from sunlight. Reducing this risk was an important step because glare may have had unintended input effects due to participants tilting away from glare to better see the screen.

The experiment settings were adjusted prior to the arrival of the participants. With the help of the TiltTarget API documentation (MacKenzie, 2013) it was easy to identify which settings would be best for this study. The participant code was changed each time a new participant carried out the test. The session code remained the same because all of the testing was carried out on the same day and in the same environment, this ensures that the test would remain fair. Unlike previous experiments (Fitton et al., 2013), the participants were not tested in groups, therefore the group code setting was not changed. The condition code field would be changed depending on the condition that the participant would be testing the application under. One sequence of letters was specified for each condition, this would randomly generate a different sequence each time, the length of the sequence was set to 10. The tilt gain and keyboard settings were kept at the default settings to ensure that the tests were not too difficult (or too easy) from the outset. The dwell time was reduced from 1000 to 800 because in pre-experiment tests it appeared to take a long time for the ball to select a target. These settings were chosen because they allowed the testing to be carried out quickly and properly. Due to the environment that had been selected, all of the testing needed to be done in one session, it was therefore important to select settings which would ensure that all of the participants could be tested within the designated timeslots. *Figure 1* shows the final base settings which were used. *Figure 2* shows an example of the results screen which appears once a condition had been tested on the participant.

3.3 Procedure

During the testing session each participant was invited to carry out the test in set time slots, one after the other. On arrival they would sign the consent forms and read the participant instructions sheet. They were then given a brief demonstration on how the application works and the objective. The experiment boundaries were explained, one marked corridor boundary (*Figure*

3) for the walking tasks and one chair in the room to the left of *Figure 3* for the seated tasks, as were the conditions - sitting and one handed, sitting and two handed, walking and one handed, walking and two handed. These conditions would help to not only test the addition of mobility to the tasks, but also different grips; this would ensure that different ways of operating the smartphone have been taken into account. There were no practise tasks as this experiment intended to focus very much on how the participants currently used their smartphones. Therefore it was even more important to make sure that a Latin Square technique was implemented. This technique ensures that the conditions were not assigned to participants in the same order each time. Specifically, the design of the Latin Square used is based on the "Sampling + 1" methods which are demonstrated in Munholland and Borkowski, 1996.

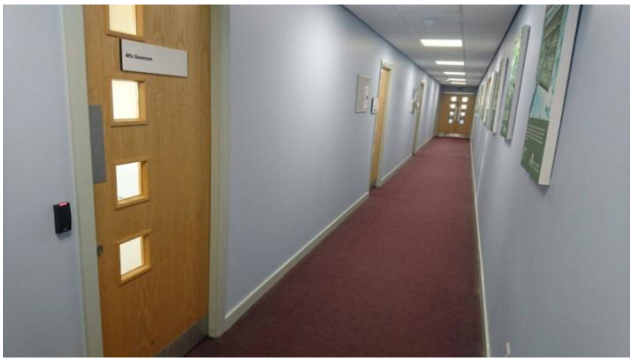

Figure 3*. Right: corridor boundary and Left: MSc Baseroom testing room*

Although the conditions were assigned to the participants in different orders each time, the conditions always made sure to maintain the same boundaries. The participants were seated on the same chair in the same room for the sitting condition, and walked up and down the same corridor for the walking condition (*Figure 3*); stopping and turning around at each end of the corridor until the sequence had been completed. When each sequence had been completed, the application automatically saved the results in an SAS (extension '.sd2') file on the smartphone that was used.

Once the participant had completed all of the conditions, they were then required to answer a small series of survey questions. These questions aimed to provide a further (post-experiment) look into the experience of the participants. The application does not allow the user to submit how they felt about using the application, and the survey would help gain a better understanding of what the students thought about their participation. The survey asked whether the participant owned a smartphone, how often they used it on the move, a statement based question and a series of TiltTarget specific questions. Many of the questions adopted Likert Scales. The main focus of the survey rested on the question assessing the condition that the participants felt was easiest to use the application with. *This survey can be seen with the other supplementary project documentation which accompany this report*.

4. FINDINGS

4.1 Quantitative results

Each participant was observed during their time slot, there appeared to be no problems during the practical sessions which would negatively affect the validity of the results. Many different results were recorded (some of these data types are shown in the example in *Figure 2*), but the quantitative results which were most important for this study for each condition were: task completion times (*Figure 4)*, error rates (*Figure 5*) and movement efficiency (*Figure 6*). For a full results list see *the supplementary project documentation which accompany this report*. Task completion times, error rates and movement efficiency was recorded by the application for each condition per participant. In order to easily spot trends in the data, the mean rates for each of these values per condition has been calculated and presented in the form of column charts.

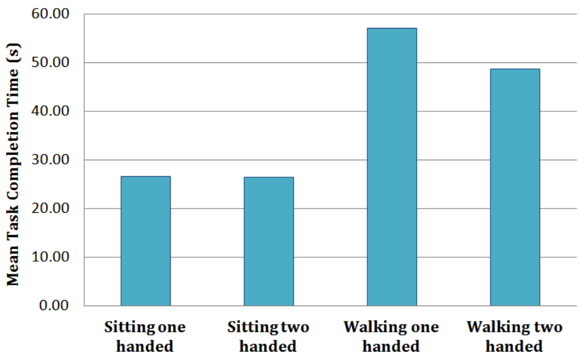

Figure 4. *Mean task completion times for all conditions.*

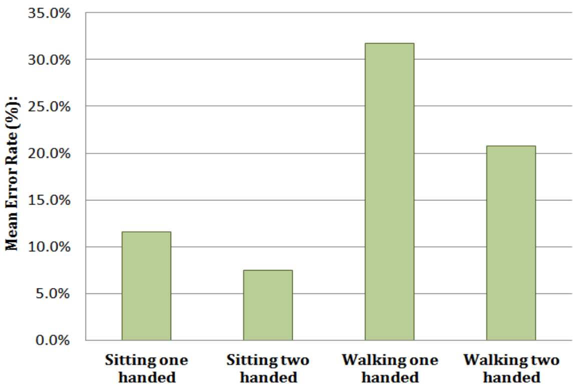

Figure 5. *Mean error rates for all conditions.*

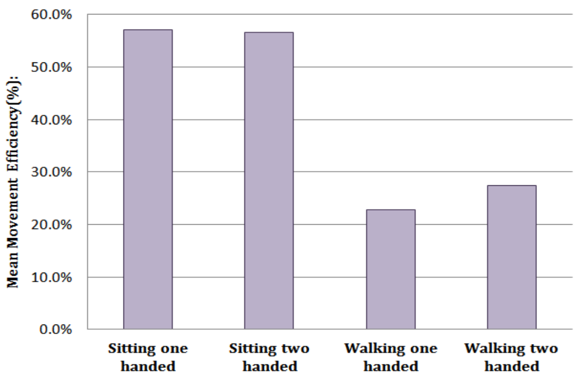

Figure 6. *Mean Movement Efficiency Rates for all conditions.*

Mean task completion times are significantly longer during the walking conditions when compared to the sitting conditions. The fastest task completion times were found when the participants were sat down and using two hands to control the smartphone with a mean time of 26.43 seconds. The slowest average (by more than 30 seconds) was walking and holding the smartphone with one hand with a mean time of 57.02 seconds.

The mean error rate for walking with one hand controlling the device was 24.2% higher than sitting and using the device with two hands. Error rates for walking were also 10.9% lower on average when the participant used two handed grip to control the smartphone while walking instead of one handed grip. Whilst sitting, error rates were 4.1% lower on average when the participant used two hands to control the smartphone instead of one.

Matching with the trends set by the task completion times and error rates, the movement efficiency data found that the sitting tasks were over 29% more efficient on average than the walking tasks. However, there were only small differences in efficiency between the grip conditions for each area of mobility - the largest difference being 4.7% between walking one handed and walking two handed. Overall, according to the results, walking one handed was the least efficient method of using the application, with an efficiency rating of 22.8%.

4.2 Qualitative results

The post experiment survey aimed to identify the participants thoughts on smartphone use on the move and their experience of using the TiltTarget application. The survey found that all participants owned a smart phone and of those, 58.3% of users said that they used their smartphone "Very Often" whilst on the move. When asked to what extent they agree with the statement *"I make more unwanted errors when using my smartphone on the move than I do whilst sitting down"*, 50% of users said that they agree, 25% strongly agreed, 16.7% were undecided and 8.3% (1 person) said that they disagree. Responses to what the participants thought was the hardest condition to use the application under indicated that walking one handed was the hardest with a score of 10 out of 12. When asked what was the easiest *(Figure 7),* 7 out of 12 participants chose sitting and using one hand, whilst 5 out of 12 said sitting with two hands was the easiest.

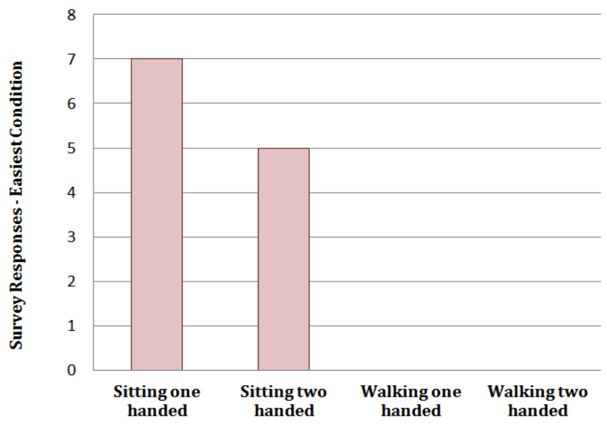

Figure 7. *Responses - "Which condition presented the easiest way of using the application?".*

5. DISCUSSION

Although different numbers of participants were used to the previous TiltTarget study (Fitton et al., 2013), similar trends were obtained. Observations from the study revealed that there were no issues for the participants when it came to completing the tests, but this was expected with an older participant age range. However the investigator did need to occasionally tell the participants to speed up or slow down their walking pace depending on their movements.

One of the most fascinating findings that have come from the study was that the mean completion time was significantly longer for the walking conditions rather than the sitting, with a difference of more than 30 seconds between the fastest and slowest times (*Figure 4*). Error rates followed a similar trend, with the walking tasks showing a greater degree of average error than sitting tasks. Walking and using the application with one hand resulted in a large mean error rate of 31.7%. In addition to this, walking and using one hand also resulted in the worst efficiency rating (22.8%) than all other conditions.

It is interesting to see how in the qualitative findings, none of the participants selected a sitting condition to be one of the hardest conditions to use the application, on the contrary, no participants selected a walking condition as one of the easiest conditions (*Figure 7*).

When both the quantitative and qualitative findings are taken into account, there is clear evidence that the condition which is likely to produce the least errors (*Figure 5*), the quickest results (*Figure 4*), the best efficiency (*Figure 6*) and the easiest use (*Figure 7*) is when sitting and using one hand. Perhaps this is due to the participants being used to using their smartphone devices with one hand. In previous studies (Fitton et al., 2013), tablet devices were used for the testing, this may have been why two handed grip results were better than one handed; it is much easier to control a smartphone with one handed grip than it is to control a tablet with one handed grip.

Interestingly, sitting and using the application with a two handed grip resulted in a lower mean error rate, in fact it was the lowest overall mean error rate (7.5%). This might be down to a greater degree of control over the smartphone.

On the other hand, just from observing the tests, it was clear that for the most part, the users felt that there was definitely a greater degree of difficulty when walking and using one handed grip. This is reflected in the results, where the worst performance statistics overall came from the walking and one handed condition. Survey results also greatly supported the experimental results, with most participants (10 out of 12) claiming that walking and using one handed grip to control the smartphone was the most difficult condition to complete the tasks.

The final results give an overall measure of the different degrees of challenge that the four conditions imposed. In order of performance, results suggest that sitting and one handed grip gives the highest performance, followed by sitting and two handed grip, followed by walking and two handed, followed by walking and one handed. Survey findings support this trend to a large extent, with 75% of participants either agreeing or strongly agreeing that they are more likely to make unwanted errors when using their smartphones on the move than when they use them sitting down.

6. CONCLUSION

Findings from this study back up previous similar results from tests on the TiltTarget application in the past, with mean completion times, error rates, and movement efficiency all showing worse performance data with the walking conditions than the sitting conditions. Quantitative results also indicate that the participants found it easier to use the application using the sitting and one handed grip condition, supporting the quantitative findings. Performance metrics derived from the data collected during the study support the hypothesis which was stated at the start of the study; that users are more likely to perform tasks worse when using applications on the move than they do whilst sitting down. Though it should be noted that the tilt-based aspect of the software may have had some effect on how difficult it was to use the application whilst walking. Further testing in this field (one which looks at messaging and other interactions) should therefore be carried out to add strength and support to the findings and conclusions of this study. Nevertheless, the results were obtained using very well structured and professional methods, therefore the findings definitely contribute towards research into interaction on the move. It could therefore be suggested that not only does using smartphones on the move cause more accidents (as inferred in background research) but these findings also show that the user is more likely to perform interactive tasks worse when on the move.

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