Touch & Connect and Touch & Select: Interacting with a Computer by Touching it with a Mobile Phone

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ABSTRACT

Exchanging data between a mobile phone and a computer such as a laptop is still a very cumbersome process. This paper presents two different techniques, *touch & connect* and *touch & select*, designed help to overcome this problem and facilitate and speed up spontaneous interactions between such devices. Using *touch & connect*, the user can physically touch a computer in order to pair a Bluetooth connection and initiate a file transfer between these two devices. *Touch & select* extends this concept in that users can select a specific object or location on the computer screen by simply touching it with the mobile phone. We report the implementation of these interaction techniques based on Near Field Communication (NFC) tags and present a formal, comparative study focusing on transferring images. The results provide clear evidence of the advantages of *touch & connect* and *touch & select* when compared with current Bluetooth-based implementations. Considering task completion time for uploading and downloading pictures, *touch & select* was 43% and *touch & connect* 31% faster than the conventional Bluetooth-based approach.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies; Prototyping.* H.1.2 [**Models and Principles**]: User/Machine Systems – *Human Factors.*

General Terms

Human Factors, Performance, Design, Experimentation.

Keywords

Mobile, touch, interaction, display, picture sharing.

1. INTRODUCTION

Mobile phones are increasingly used for storing images, videos, documents and Personal Information Management (PIM) data [14]. Furthermore, there is often the need to copy these files from the mobile phone to a computer or vice versa. This is typically a very cumbersome process because the user has to: first find the right file, then select the method for transferring the file (e.g. Bluetooth), then perform a device discovery process, then select the target device. And after receiving the file on the other device, the user has to decide what to do with it.

This paper presents two new interaction techniques: *touch & connect* and *touch & select*. These simplify the transfer process dramatically by reducing the number of steps for copying a file. More importantly, *touch & select* allows the mobile phone to act as a smart stylus, which can directly interact with a laptop or PC.

Although *touch & connect* and *touch & select* can be used for interaction with any kind of display through touch interaction. This paper focuses on the usage of a laptop (such a device was used for the implementation of the prototype).

Figure 1 illustrates how *touch & connect* supports copying a file (marked by an "X") from a mobile phone to a laptop and vice versa. When uploading a file from the phone to the laptop, the user simply has to select the file on the phone (Figure 1a) and to touch the laptop in order to start the transmission (Figure 1b and Figure 1c). The file is then copied to the laptop (Figure 1d).

The user can download a file to the phone by first selecting it on the laptop via the touchpad (Figure 1e), and then touching the laptop with a mobile phone (Figure 1f and Figure 1g) in order to copy the file onto the mobile phone (Figure 1h).
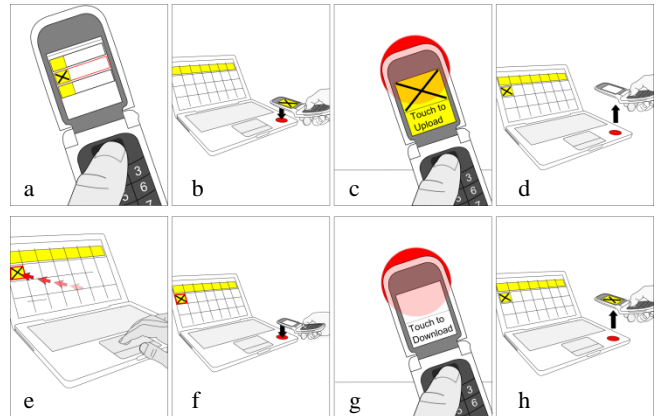

Figure 1. *Touch & connect* **interaction technique**

In *touch & connect* the user does not have to define the method for transferring the file, does not have to wait for the end of the device discovery process, and does not have to select the target device. All this information is gathered when touching the laptop with the mobile phone.

Figure 2 illustrates how *touch & select*, an extension of *touch & connect*, can be used to transfer files between a mobile phone and a laptop. When uploading a file to the laptop, the user has to first select it on the mobile phone (Figure 2a), then the mobile phone can be used to touch a location on the laptop screen in order to copy it to this place (Figure 2b-d).

The user can download a file to the phone by touching the display of the laptop with the mobile phone on the position at which the file is displayed (Figure 2e-g).

Touch & select provides all the advantages of *touch & connect* but additionally allows the direct interaction with objects, files and folders on the laptop screen; this is achieved by simply touching them with the mobile phone.
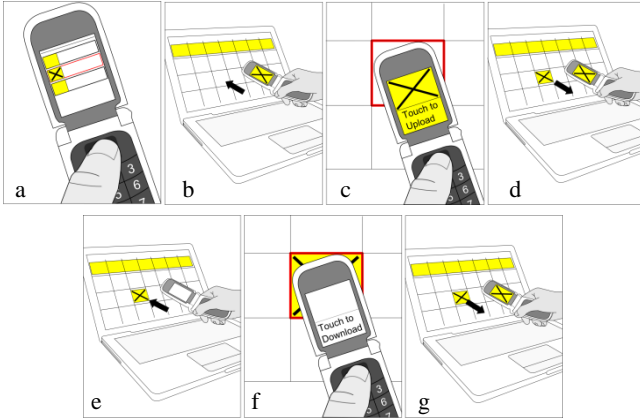
Figure 2. *Touch & select* interaction technique

The paper is organized as follows; the next section relates our work to existing approaches and focuses on ways to use a mobile phone for interactions with other devices. Following this, we report the implementation of *touch & connect* and *touch & select* using Near Field Communication (NFC) technology. We then discuss a comparative study in which the two new interaction techniques were compared with the currently used Bluetooth-based approach in order to analyze and compare: task completion time, error rate, usability satisfaction, task load and user preferences. This study focuses on exchanging pictures between a mobile phone and a laptop as this is one of the most common cases for transferring files between these two devices. Finally, the paper discusses our findings and provides an outlook on future work.

2. RELATED WORK

Mobile devices are often used for taking pictures, recording videos, storing files, or receiving MMS. In order to backup, email and view these files, these need to be transferred to laptops or PCs. Bluetooth has now replaced cabled connections. However, this requires either the standard Bluetooth support of the operating system (running on the PC or laptop) or special applications like the Nokia PC Suite. Unfortunately, pairing devices and transferring data using Bluetooth requires a relatively large number of steps, and the two devices interact with each other in a very technical way that is transparent to the user.

The IrDA interface follows more closely the paradigm of bringing two objects close to each other in order to establish a connection. However, the connection can be unstable and the data rates are low.

A much more promising technology is Near Field Communication (NFC) which is based on RFID and is already supported by some commercially available mobile phones (e.g. Nokia 3220, 6131 and 6212). It is expected that many mobile phones will support NFC in the future [1] and it is predicted that several hundred million NFC equipped mobile phones will be used in 2013 [12]. Such phones could be used with our implementation of *touch & select*. The *touch & connect* interaction technique has already been described by ECMA International in 2004 [6], the basic principle is since 2007 also part of the Bluetooth 2.1 standard and implementations have been shown recently [13], [20], but so far no evaluation has been conducted which proves the envisioned advantages.

There have been many research projects and products focusing on the usage of mobile devices for interactions with objects, devices, displays and locations in the last years (see [3] for a corresponding overview).

Fitzmaurice was one of the first who discussed a system for direct mobile interaction with a display [7] where one could get more information about a specific area on a map by pointing at it with a mobile device. Using the Hermes Photo Display, a person can use a mobile phone to interact with a public display to upload, manage and view pictures [5].

The concept of touching an object with a mobile device has been widely investigated in the last years. Most implementations are based on RFID/NFC technology. Want et al. were among the first who connected an RFID reader to a mobile device and equipped objects in the environment with RFID tags [25]. They augmented objects such as books, documents or business cards with tags and through touching these objects with the mobile phone, the user could, for example, order the corresponding book or dial the number mentioned on the business card.

Reilly et al. developed a system in which they augmented a paper map with a mesh of RFID tags [21]. Through this, it was possible to touch any position on the map in order to select a point of interest. The *touch & interact* system, presented by Hardy and Rukzio, used the same approach using a projection instead of a paper map [8]. With this approach, it was now possible to change the information shown on the projection according to the interaction of the user. When a user touched the display at a certain position, both the projection and mobile phone display changed accordingly. The *touch & select* interaction technique presented in this paper is very similar except that a laptop display is used to overcome several disadvantages of using a projection-based system. The most important disadvantage of *touch & interact* is the occlusion of the projection when the user touches the screen with the mobile phone.

Beside touch-based approaches, there exist direct pointing-based interaction techniques that could be used to control a cursor, widget or object on a remote screen. The Point & Shoot [2] and SpotCode [16] systems are examples for this. These were implemented using markers shown on a remote display which were interpreted by the mobile phone in order to calculate the change of distance or orientation to the display. The C-Blink system used the opposite approach. Here, the mobile phone acted as the marker through the emission of visual patterns tracked by a camera mounted on the display [18]. An approach which works without the need for any markers is Shoot & Copy using pattern matching in order to compare the content of the screen with a picture taken by the mobile phone camera [4].

A large set of research prototypes use a mobile device as an indirect remote control. An example for this is the usage of a PalmPilot touchpad in the Pebbles project [19]. On the other hand, Silverberg et al. analyzed the usage of a joystick (integrated in many mobile phones) as a pointing device for interaction with a remote display [24].

Rukzio et al. [23] give an in-depth comparison of several interaction methods. Although they concentrate on general object selection tasks, they also point out the advantages of touch-based interactions, e.g. using NFC technology.

Both Pick-and-Drop from Rekimoto [22] and the two interaction techniques presented in this paper share the concept of interaction

between a mobile device and a display. However, Pick-and-Drop requires an additional pen which is used as the interaction device whereas our approach eliminates the use of a pen as both devices touch each other directly. The conceptual model of Pick-and-Drop is that the user picks an object with the pen by clicking on it, the object is stored on the pen, and touching another display with the pen then drops the object.

Further related to the *touch & select* research area is the usage of interactive surfaces like Microsoft Surface [17] which supports interaction with mobile devices. It is possible to put a mobile device such a mobile phone, digital camera or PDA, on a Microsoft Surface and drag & drop photos in order to copy them to or from the mobile device. The difference between Microsoft Surfaces and *touch & select* is that, with Microsoft Surfaces, the user primarily interacts with the interactive surface, and the mobile phone acts primarily as a data container. In *touch & select*, the mobile phone is the primary interaction device and both displays (mobile phone and dynamic screen) are used in parallel.

This paper is the first to report on an interaction technique in which a mobile phone can be used to touch a LCD/TFT/Plasma screen at any position in order to perform a selection (*touch & select*). A second contribution of this paper is the formal evaluation of the *touch & connect* and the *touch & select* systems. The prototypes and user study discussed in the following show the advantages of the two interaction techniques when compared to the typical usage of Bluetooth today.

3. PROTOTYPES

This section discusses the implementation of *touch & connect* and *touch & select*. For these interactions, we focused on the implementation of a photo exchanging and browsing application as we see this scenario as the most common for connecting a mobile phone with a computer.

These prototypes and an additional prototype called *standard Bluetooth* (which is almost identical to current Bluetooth-based solutions) were developed in order to compare task completion time and usability of these three interaction techniques in a corresponding user study.

All three prototypes provided functions for uploading (from the mobile phone to the laptop) and downloading (from the laptop to the mobile phone) pictures.

We developed two photo browsing applications (Figure 3), one for the mobile phone and one for the laptop. We developed these two rather than adapt existing applications (e.g. Google Picasa or iPhoto) to support the new interaction techniques *touch & connect* and *touch & select*. This allowed us to keep a consistent interface on the mobile phone and on the laptop for all three interaction techniques. This was required in order to conduct a controlled user study. Moreover, it was then simple to add logging features to our own applications through which it was easily possible to control the user study and to automatically gather information like task completion time.

The mobile phone photo browser application was designed to look very much like the standard photo browser of the Nokia 6131 NFC phone (which was used in the study). In both applications, the user was able to browse through the available pictures using the directional keys (phone and laptop) or the mouse (laptop) in order to enlarge pictures and to select pictures in order to see available options.
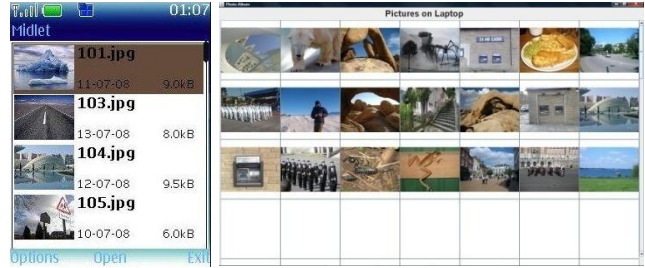

Figure 3. Photo browsing application on mobile phone (left) and laptop (right)

In the subsequent sections, the usage of the three different implemented interaction techniques *standard Bluetooth*, *touch & connect* and *touch & select* will be discussed.

3.1 Standard Bluetooth

To upload a picture, the user selects a picture on the phone and selects *send* in *options* and *Via Bluetooth* (Figure 4 left). The phone will search for available Bluetooth devices and present a corresponding list (Figure 4 middle). After selecting the laptop, the image is copied and displayed in the picture browsing application (Figure 4 right).

Figure 4. Uploading a picture from the phone to the laptop with standard Bluetooth

In order to download an image, it is selected using the mouse in the picture browsing application on the laptop, then *Send To* and *Bluetooth device* are selected (Figure 5 left) and the laptop searches for available Bluetooth devices. A corresponding list is presented and once a device is selected, the image is copied to the mobile phone (Figure 5 right).
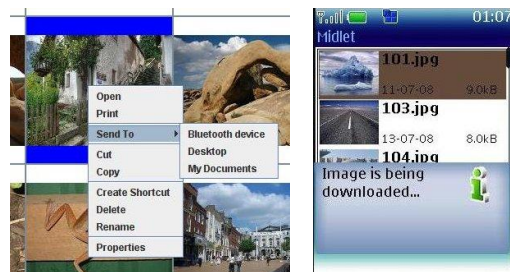

Figure 5. Downloading a picture from the laptop to the phone with standard Bluetooth

3.2 Touch & Connect

A yellow sticky note was used to indicate the location of the NFC tag so that the participants knew where to touch.

To upload a picture, the user first selects a picture on the phone, then chooses *upload*. The mobile phone informs the user (Figure 6

left) to touch the yellow tag on the laptop in order to upload the image (Figure 6 middle). The picture is then copied and displayed on the laptop (Figure 6 right).

Figure 6. Uploading a picture from the phone to the laptop with *touch & connect*

In order to download an image, it is selected using the mouse in the picture browsing application on the laptop, then *Send To* and *Mobile phone via yellow tag* are selected (Figure 7 left). The user can then touch the yellow tag on the laptop (Figure 7 middle) to copy the image to the phone (Figure 7 right).
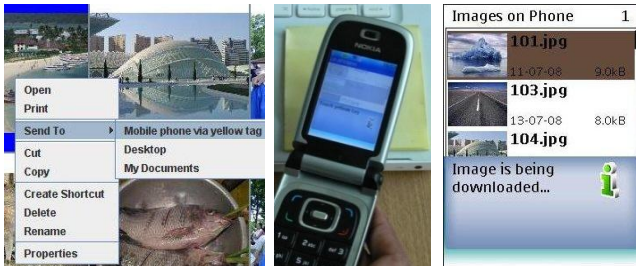

Figure 7. Downloading a picture from the phone to the laptop with *touch & connect*

3.3 Touch & Select

To upload a picture, the user first selects a picture on the phone and chooses *upload*. The mobile phone then informs the user that an empty square on the display can be touched in order to upload the image (Figure 8 left). When a user touches the display (Figure 8 middle), the corresponding picture is uploaded and shown on the screen of the laptop (Figure 8 right).

Figure 8. Uploading a picture from the phone to the laptop with *touch & select*

In order to download an image, the user switches to download mode on the mobile phone (Figure 9 left) and selects the picture on the laptop by touching it with the mobile phone (Figure 9 middle). The picture is then copied to the mobile phone (Figure 9 right) and displayed there.

Figure 9. Downloading a picture from the phone to the laptop with *touch & select*

4. IMPLEMENTATION

A MacBook laptop and a Nokia 6131 NFC phone were used for the implementation of the prototypes. The picture browsing applications and the logging functionalities for the study were developed in Java SE for the laptop and Java ME for the mobile phone. The implementations specific to each interaction technique will now be discussed.

4.1 Standard Bluetooth

This prototype simulates the typical method that is currently used with most operating systems and mobile phones to transmit images via Bluetooth. Java SE and the Bluecove library (http://code.google.com/p/bluecove/) were used to implement the communication on the laptop. On the phone, Java ME and the Java APIs for Bluetooth (JSR 82) were used. Bluecove and JSR 82 were also used for the following two interaction techniques.

4.2 Touch & Connect

For *touch & connect,* a Near Field Communication tag from toptunniste.fi (Trikker BT43) was attached to the laptop as shown in Figure 6 or 7 (middle) and Figure 10 (left).
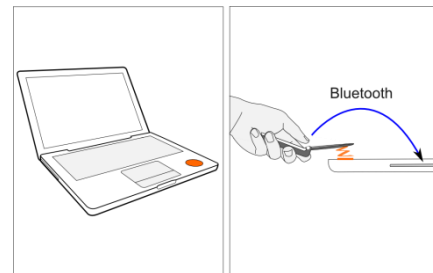

Figure 10. Implementation of *touch & connect*

This tag stored the Bluetooth MAC address of the corresponding laptop through which it was possible to establish a spontaneous connection without the need for a device discovery process. The two devices communicated with each other over this Bluetooth link to exchange the pictures (Figure 10 right).

4.3 Touch & Select

For *touch & select,* the back of the laptop display was augmented with a mesh of 7 x 4 NFC tags (Trikker BT43) as shown in Figure 11 (left). Each tag stored its location (Figure 11 middle) and the Bluetooth MAC address of the laptop. When touching the front of the laptop display (Figure 11 right), the NFC phone is able to read the stored information almost instantly. It then connects with the laptop using the Bluetooth MAC address (stored in every NFC tag) and submits the coordinates of the tag, e.g. (2,2), to the laptop. Once a connection is set up, the picture browsing

application on the laptop can receive messages indicating which picture or empty square was selected and responds accordingly.

The MacBook was used because its plastic casing ensures a good connection between the NFC phone touching the front of the display and the NFC tags attached to the back of the display. One could imagine such NFC functionalities to be embedded in many commercial displays in the future.
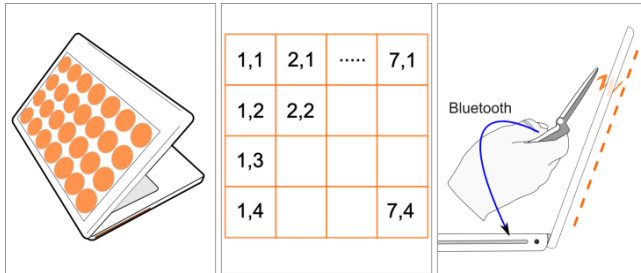

Figure 11. Implementation of *touch & select*

5. EXPERIMENT

The aim of the experiment was to compare task completion time, error rate, usability satisfaction, task load and user preferences of the three interaction techniques in order to see how *touch & connect* and *touch & select* perform compared to the currently used Bluetooth-based approach.

5.1 Participants

19 paid participants, 8 females and 11 males, took part in the experiment. All of them owned a mobile phone, were students or employees of Lancaster University who are not involved in the presented research, and were aged between 23 and 53 (mean 30.4). We used the following scale to rank experiences: 1=none, 2=poor, 3=medium, 4=high, 5=expert. On average, participants rated themselves as having a high experience with computers (mean 4.3) and with mobile phones (mean 3.9). They showed only medium experience (mean 3.0) in using mobile phones to send or receive pictures.

5.2 Experimental Design

The experiment used a repeated measures within-participant factorial design 3 x 2 x 3 (interaction technique x transfer type x task type). The independent variable interaction techniques consisted of three levels: *standard Bluetooth*, *touch & connect* and *touch & select*. The independent variable transfer type consisted of two levels: *upload* and *download*. The independent variable task type consisted of three levels: *event*, *property* and *single* as defined in [11]. An event task is defined as one where the user needs to search for a set of three pictures which are related to a particular event (e.g. *find pictures of a graduation party*). The property task is defined as one where the user needs to look for a set of three pictures which share similar characteristics or features (e.g. *find pictures of Formula 1 racing cars*). Lastly, the single task is defined as one where the user has to search for one particular picture which has a unique attribute (e.g. *find a picture of a football*).

The sequence of interaction techniques and transfer types was counterbalanced to minimize learning effects. For each interaction technique and its related transfer type (upload or download), a unique picture set was used.

5.3 Procedure and Dependent Measures

Participants took part in the experiment individually and used the previously discussed prototypes. Before using a new combination of interaction technique and transfer type, e.g. uploading with *touch & select*, this combination was explained using a corresponding handout with screenshots and pictures. Afterwards, participants performed a training phase for this combination consisting of either uploading or downloading three single pictures depending on the transfer type. The lists of pictures that had to be transferred were written on a piece of paper. For each training phase, a unique picture set consisting of eleven pictures were used.

After transferring the three pictures in the training phase, the actual experimental tasks were carried out. Before each task, they had to read corresponding instructions on a piece of paper (e.g. *Download three pictures of cars from the laptop to the mobile phone.*) and, when ready, press start on the mobile phone in order to start logging. Users were reminded that their task completion time would be recorded and they had to do each task as quickly as possible.

For each combination of interaction technique and transfer type there were five tasks consisting of one event, one property and three single tasks that have to be completed. This leads to a total of 30 trials per participant (3 interaction techniques x 2 transfer types x 5 tasks). For each task, the prototypes would automatically record the task completion time and the number of pictures that are incorrectly uploaded or downloaded. The application did not notify the user when a wrong a picture is transferred. Pictures had to be copied one by one.

6 unique picture sets were used for the 6 different combinations of the 3 interaction techniques and 2 transfer types. Each set had a total of 21 pictures consisting of 2 events each with 3 pictures, 1 property with 3 pictures, 5 singles and 7 random pictures.

In order to control the time required for scanning for other Bluetooth devices, we measured at 10 different locations at our university (e.g. in a lab, student dormitory, lecture theatre, library or restaurant) how much time was required to scan for the nearby Bluetooth devices. Therefore, we used (as in our prototype) the Nokia 6131 and a MacBook. The Nokia 6131 needed on average 16.4 seconds and the MacBook in average 13.7 seconds to finish the scanning process. In the user study, we controlled the scanning process when using *standard Bluetooth* in such a way that during the first scan, it took either 16.4 seconds (mobile phone) or 13.7 seconds (laptop) to find the nearby devices. Afterwards, the instantly presented list of already found devices was used by the participants to use the target device. Thus, the time for pairing was modeled realistically but represented only a minor slowdown compared to the whole interaction time for all pictures.

After completing the tasks for a particular transfer type by using one interaction technique, the mobile phone was returned to the experimenter who configured the mobile phone for the second transfer type (upload or download) using the same interaction technique. It was necessary to return the phone to the researcher because the picture set on both the laptop display and mobile phone had to be changed for each transfer type and interaction technique so as to minimize any learning effects. Again, participants were given an introduction using a handout and performed three file transfers in the training phase before conducting the measured tasks. The same procedures were repeated for each transfer type and interaction technique.

Therefore, a total of six training phases were done with each user (3 interaction techniques x 2 transfer types).

Moreover, the application automatically stops a timer when a particular task type has been completed and notifies the user to read the next task. Therefore, the user does not need to press any keys after completing a particular task.

For each interaction technique, a post-task questionnaire was used to gather the opinions of the participant. This questionnaire consisted of a series of questions taken from the IBM Computer Usability Satisfaction Questionnaire [15] and the NASA Task Load Index [9]. Finally, the participants were asked to comment on any positive or negative aspects concerning the interaction techniques. After completing all the tasks with each of the three interaction techniques, the users had to rank the different combinations of interaction techniques and transfer type.

6. RESULTS

6.1 Preferences
At the end of the experiment, the participants were asked to state their first, second and third preference for downloading (transferring a file from laptop to mobile phone) and uploading (transferring a file from mobile phone to laptop) pictures. The results are presented in Figure 12.

As the figures indicate, *touch & select* was the most popular, ranked by 15 participants (79%) as their first preference for downloading and ranked by 12 participants (63%) as the first preference for uploading. One can see that *touch & connect* was mostly their second choice and that *standard Bluetooth* was least preferred.

An important difference between these two figures is the shift of three persons between downloading and uploading when considering *touch & connect* and *touch & select*. 15 participants saw *touch & select* as their first preference for downloads but 12 saw it as their first preference for uploads. On the other hand 2 participants saw *touch & select* as their first choice for downloading but 5 when uploading.

6.2 Task Completion Time

6.2.1 Upload
Figure 13 shows the mean task completion time for uploading pictures of the three task types using the different interaction techniques. A Two-Way Repeated Measures ANOVA was used to analyze the mean task completion time of the interaction

techniques. The results showed significant differences between the three interaction techniques ($F_{4,162}$ = 15.9, p < .05). Bonferroni pairwise comparisons show that there is no significant difference between the *touch & connect* and *touch & select* (p > .05). Also, it showed that there was significant difference between *touch & connect* and *standard Bluetooth* (p < .05) as well as *touch & select* and *standard Bluetooth* (p < .05).

The graph shows that *standard Bluetooth* results in the highest task completion time for all task types. Figure 13 clearly shows that the difference in the task completion time between *touch & connect* and *touch & select* is marginal. Aggregating the mean task completion time for uploading for each of the three task types for standard Bluetooth resulted in 136 seconds (SE = 6.3), for *touch & connect* 80 seconds (SE = 2.3) and for *touch & select* 83 seconds (SE = 6.0).
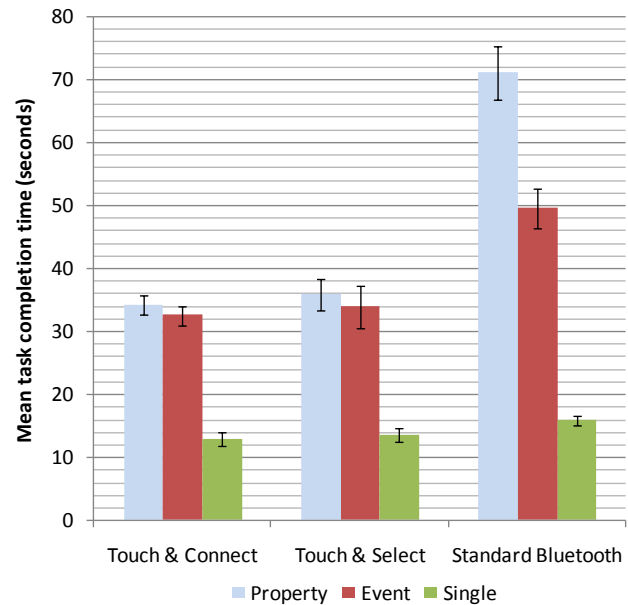

Figure 13. Average task completion times uploading including visualization of standard error

6.2.2 Download
Figure 14 shows an illustration of the average task completion time for the three interaction techniques that were used for downloading pictures from the laptop to the mobile phone. The
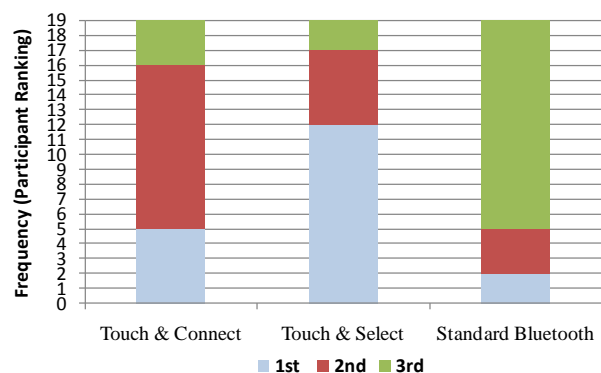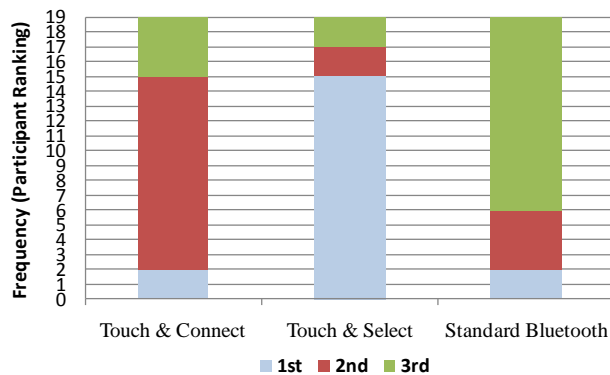

Figure 12. Preferences for downloading (left) and uploading (right)

results of a Two-Way Repeated Measure ANOVA showed that the differences between the mean scores for the three interaction techniques were statistically significant ($F_{4,162} = 3.9$, $p < .05$). Bonferroni pairwise comparisons showed that *touch & select* is significantly quicker than *touch & connect* ($p < .05$) and *standard Bluetooth* ($p < .05$). However, it also showed that there was no significant difference between the *touch & connect* and *standard Bluetooth*. The *Standard Bluetooth* prototype resulted in the worst performance for all three task types. Aggregating the mean task completion time when downloading for each of the three task types for standard Bluetooth resulted in 74 seconds (SE = 3.8), for *touch & connect* 66 seconds (SE = 8.1) and for *touch & select* 37 seconds (SE = 1.7).
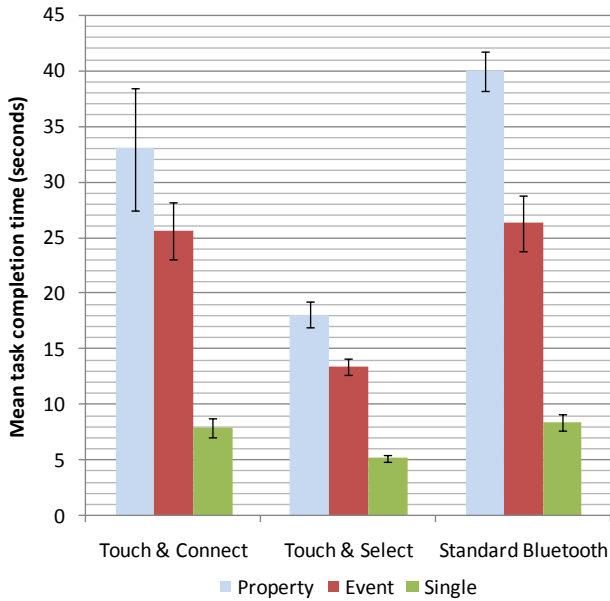

Figure 14. Average task completion times for downloading including visualization of standard error

6.2.3 Upload and Download

Figure 15 shows the time taken to upload and download pictures with each interaction technique.
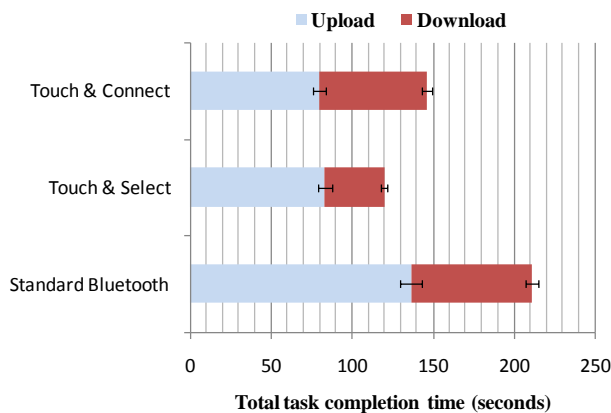

Figure 15. Combined average task completion times including visualization of standard error

Considering both upload and download transfers, adjusted pairwise comparisons show there is no statistically significant difference between *touch & select* and *touch & connect* ($p = .73$). However, *standard Bluetooth* is significantly slower than both alternatives ($p < .01$).

6.3 Error count

While considering the results for the number of pictures incorrectly transferred by the participants, the average number of errors is negligible. Using the three interaction techniques, each participant made on average only 0.17 errors while uploading and downloading pictures. The errors were mainly due to incorrectly recognizing the picture that was described in the task instruction.

6.4 User Feedback

Figure 16 shows the mean results of the feedback received from the participants after completing the tasks for each interaction technique. The questions were taken from the IBM usability satisfaction questionnaire [15].

The One-Way Friedmann's ANOVA shows that the type of interaction technique significantly affected the IBM questionnaire results ($\chi^2(2) = 21.14$, $p \ll .01$).
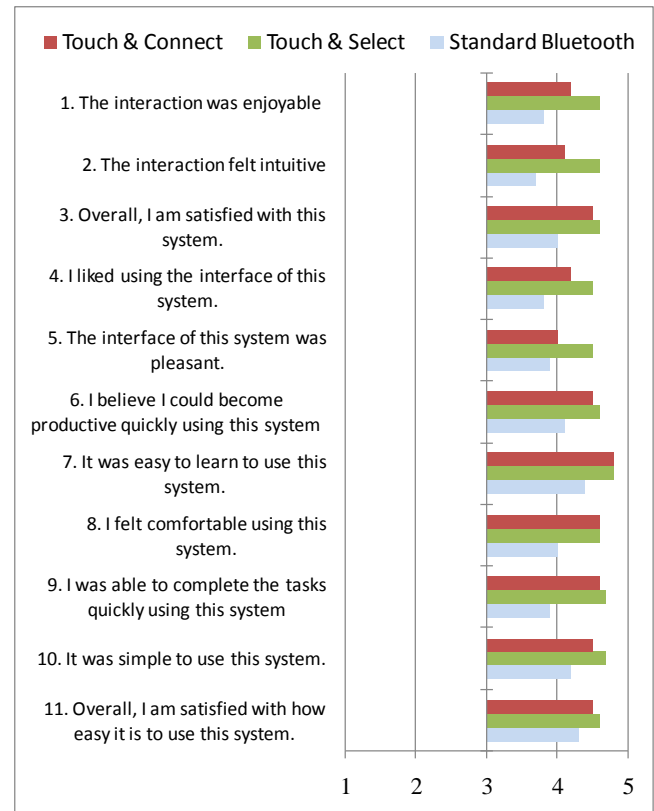

Figure 16. Average user feedback for IBM usability satisfaction (1 – strongly disagree to 5 - strongly agree)

Figure 17 depicts the results of the average NASA task load ratings which were given by the participants after completing each interaction technique [9].

A One-Way Friedmann's ANOVA shows no significant differences in the NASA Task Load Index results ($\chi^2(2) = 2.00$, $p > .05$).

With regards to practical significance, the average results of all participants show that *touch & select* performs better than *touch & connect* and *standard Bluetooth*.
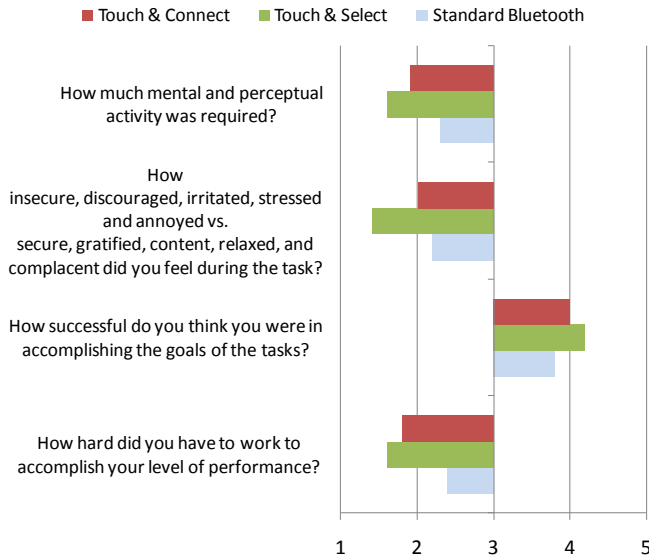
Figure 17. Average user feedback regarding the NASA task load index questions (1 – very low to 5 – very high)

6.5 Qualitative Results

After completing each interaction technique, participants were asked about their opinion on any positive or negative aspects. Further comments and suggestions were recorded in the post-study questionnaire.

6.5.1 Standard Bluetooth

A few participants mentioned that they felt comfortable using this interaction technique as they have already often used it beforehand. Furthermore, it was mentioned that this interaction technique involves the least physical effort as there is no need for touching the laptop itself or its screen with the mobile phone.

The majority of the participants regarded the scanning and device selection process as very time consuming and noted also the relatively high number of key presses and mouse movements that must be executed by the user.

6.5.2 Touch & Connect

Several participants commented that *touch & connect* is very easy and (in particular) practical when uploading pictures. It was also stated that touching the yellow tag on the laptop is actually simpler than looking for an empty square on the screen and to touch it as in *touch & select*. Some noted that it is convenient to touch the laptop always at the same location on the laptops armrest.

Some participants noted that they did not like the fact that they had first to select a picture on the laptop with the mouse and then use the phone to touch the yellow tag for downloading. A left-handed user said he felt slightly uncomfortable because the yellow tag was attached on the rightmost corner of the laptop's armrest.

6.5.3 Touch & Select

The majority of participants said that *touch & select* was very easy and convenient to use. It was also commented that they liked the direct way of exchanging images between a laptop and a mobile phone. It was also noted that *touch & select* would be particularly useful for novice and elderly users. Another participant mentioned that it was "as simple as grapping a physical object" as an analogy to downloading pictures from the laptop to the mobile phone. Moreover, a participant stated that he liked the fact that there is no need to remember many steps and key presses before transferring the images. In addition, several users found it fun and practical to use and that the touch interaction was very responsive when the mobile phone approaches the laptop's grid display. Another user stated that this system would easily allow him to group pictures in different positions on the grid.

A few participants were afraid that they would damage the laptop display when touching it frequently with the mobile phone. A user explained that, having the NFC tag reader in the mobile phone always switched on, he could pick or drop a picture on the display by mistake. Another user stated that arm fatigue could be an issue while working with a large quantity of pictures. Moreover, some participants suggested that they would like to select multiple pictures at a time and then transfer the selected pictures by a single touch action.

6.6 Summary

The study clearly shows that most participants prefer *touch & connect* and *touch & select* over the current method used for transferring files between a laptop and a mobile phone. They clearly saw the advantage of the direct interaction techniques over the indirect technique. Especially when looking at the results for downloading pictures with *touch & select,* one can see that the majority (15 out of 19, 79%) preferred the interaction in which one can directly touch a picture in order to download it.

When considering task completion times, one can see that the high number of steps for transferring a picture with standard Bluetooth leads also to the expected highest task completion time. This result is not self-evident, as, e.g., Holleis et al. [10] showed that the interaction with a mobile phone web browser can be faster than a direct, NFC-based interface to the same data. When focusing on downloading, one could also clearly see that just touching a picture with the phone when using *touch & select* leads to a very low task completion time when compared with *touch & connect*. On the other hand, the task completion times when uploading pictures with *touch & connect* and *touch & select* are very similar. This was expected as the only difference here is that, when using *touch & select,* the user has to select to which position the picture has to be uploaded. In contrast, when using *touch & connect*, the picture gets automatically uploaded to the last empty position.

The answers to the IBM usability satisfaction questions and the NASA task load index again showed that *touch & select* outperforms *touch & connect* and standard Bluetooth.

7. DISCUSSION AND OUTLOOK

This paper introduced a new interaction technique, *touch & select,* in which a user can interact with objects or locations on the laptop display by touching them with their mobile phone. The advantage of this is the ability to directly interact with displayed objects without requiring a complicated device coupling and selection process.

Furthermore, we present an implementation of *touch & select* and *touch & connect* interaction technique using current NFC technology. With *touch & connect*, the user is not able to select objects displayed on the laptop screen using the mobile phone. But the device coupling process and the initiation of a file transfer is easily done through touching a tag on the laptop's armrest.

In a comparative study, it was shown that *touch & select* is significantly better than *touch & connect,* which is again significantly better than the currently used Bluetooth-based approach when considering user preferences, task completion time, usability satisfaction, task load and qualitative feedback from the study participants. When focusing on task completion time for uploading and downloading pictures, the conventional Bluetooth-based implementation was 44% slower than *touch & connect* and 76% slower than *touch & select*. When asked for their preferences for uploading and downloading, 71% saw *touch & select* as their first choice but only 18% saw *touch & connect* and 11% standard Bluetooth as their first choice.

Currently, the NFC-based implementations presented in the paper have the disadvantage that such mobile phones are not widely available everywhere. However, it has the potential to be integrated in most future phones [12]. *Touch & select* also requires an NFC enabled screen and it is unlikely that we will see such displays in the market soon even though it would be extremely cheap. A further disadvantage of *touch & select* is the limited input resolution defined by the currently relatively large NFC tags and the size of the mobile phone. Several solutions for this such as showing an enlarged version of the selected area on the laptop display have been discussed by Hardy and Rukzio [8] and could be also applied for *touch & select*.

In our future work we will extend *touch & select* and *touch & connect* such that these systems support the upload and download of groups of pictures and the management of pictures using folders. We will also focus on new interaction techniques that combine the mentioned advantages with those of touch screens provided by mobile phones as well as the laptop. In addition, we will focus on application areas other than photo browsing such as synchronization of a mobile phone with a laptop, general file transfer, and using *touch & select* and *touch & connect* for interactions with electronic picture frames and larger public displays.

8. ACKNOWLEDGEMENT

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