User-centered comparison between classical and edge interaction on a heavy rugged tablet PC used in MCIs

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Abstract: Rugged tablet PCs used in sensitive situations and areas are different from the commonly commercialised handheld devices. Two different interaction techniques with a rugged tablet PC are evaluated. Two groups of users had to solve some tasks while interacting with the tablet user interafces (UIs) in a simulated Mass Casualty Incident scenario. This study compares two types of interaction with the tablet PC: 1) **Classical interaction**: The user while holding the tablet with one hand is interacting with the other hand 2) **Edge interaction**: The user is holding the tablet in both hands while using the thumbs for the interaction. The user study results for both interaction techniques reached comparable usability scores. Furthermore, the edge interaction technique shows better results for the fatigue and the exhaustion factors. This suggests that the edge interaction is more accepted in fatigue scenarios, but adjustments concerning usability have to be considered.

1 Introduction

Tablet PCs have become an important, supportive tool for people in many areas to solve tasks and problems. The most recent trends reveal the phenomena that the consumers want to be flexible and mobile. Laptops and smartphones have become an important factor in people's daily work-routine especially with the modern research and the product development progress that provided a lighter and smaller hardware. Tablet devices such as the "iPad" or the "Nexus Prime" may provide a new, unique and a different user experience to the masses but eventually, cannot be used in certain specific situations where the attributes "weight" and "size" only play a secondary role behind the robustness of the device itself.

This work is within the scope of the SpeedUp[1] project. The objective of the SpeedUp project is to extend the current rescue approach with an IT infrastructure to optimize the management of a **M**ass **C**asualty **I**ncident (MCI). This work focuses on the user interface (UI) for a heavy rugged tablet intended to be used by the **A**mbulant **I**ncident **O**fficer (AIO). Other than the "multimedia" functions of the tablet, the tablet PC used in this study fulfills the military standard IP65 defined in DIN EN 60529. This means that the tablet PC is able to withstand all types of weather scenarios and also endure for example a fall from a certain height. These requirements are met with some special hardware constructions to guarantee a fully functional system even in critical situations. Compromises concerning specific factors such as weight and size are inevitable to ensure that the hardware is resistant to any kind of damage and risk. While modern multimedia tablets weigh no more than 1.54 pounds (approximately 700 grams), robust solutions weigh four or five times more. Moreover, modern tablets tend to be very fragile with their displays among other things being made of simple, breakable material such as glass. Rugged tablets are safer to handle in sensitive and critical environments.

In this work, two UIs were designed and tested on a rugged tablet PC: 1.) Classical interaction while holding the tablet with one hand and interacting with the other free hand and 2.) Edge interaction by holding the tablet in both hands while interacting with the thumbs. The reason behind that is the fact that the fire department of the Technische Universität München used such a rugged tablet PC. They were holding the tablet on one arm while interacting with it with the free hand (classical interaction). According to them and from their experience, this way of interacting is exhausting and hence reduces their acceptance of that device. The results of the conducted evaluation should provide information whether the AIOs from the rescue service prefer the first or the second type of interacting with a rugged tablet in the simulated MCI scenario. In previous studies, UI concepts were provided and evaluated to move and zoom a digital map [CAN+10] and to select patients [CBA+12] during an MCI based on the special requirement to allow the user to hold the tablet PC in both hands while interacting with it on the edges with the thumbs. This study critically investigates the underlying special requirement itself. This study has been performed with 2 groups: 12 students for an initial evaluation and 6 AIOs from **A**rbeiter-**S**amariter-**B**und-München (ASB), as a target group, for the final evaluation. ASB is an organization consisting of professional and voluntary paramedics trained for first-aid and emergency cases as well as disaster situations.

2 Related work

Other related experiments in a medical environment have been done by Holzinger et al. [HHSU08] comparing finger and stylus input on a tablet PC under the following three conditions: sitting, standing and walking. Two different tablets were used, one for each input

[1]The project SpeedUp is funded by the German Federal Ministry of Education and Research (BMBF) within the program "Research for Civil Security" (May 1st, 2009 - April 30th, 2012, FKZ: 13N10175). Website: http://www.speedup-projekt.de

alternative. Both of the tablets did not weigh more than 1.5 kg and the participants were significantly faster and more accurate with the stylus than with the finger in almost every test. Among others, participants stated that solving tasks is more difficult while walking since the test persons have to pay attention to the environment. The experiment lasted for approximately 40 minutes per subject with a sequence of short tasks for each participant. The participants were exhausted and felt pain in their arm after the experiments. For mass casualty incidents, this is even more important, since all rescue units have to be very concentrated and focused on their work. A study performed by Marcora et al. in 2009 showed that the perception of physical effort of users increases when they are mentally fatigued [MSM09]. Sapateiro et al. [SAZ+08] propose a model to coordinate actions in crisis scenarios with a tablet PC. It is emphasized that in such situations, tablet PCs can greatly support the user since communication, actions and information have to be handled correctly and with fast response and interactions.

Several scales has been developed to measure mental and physical demand, exhaustion and frustration. Chalder et al. developed a 14-item fatigue scale to measure the severity of fatigue. Eight items consider physical while the remaining six items consider mental symptoms [CBP+93]. Those items served as a source for our qualitative interviews. Another source for our qualitative interviews was the guideline for qualitative interviews considering the usability of a UI developed by Nestler et al. [NAC+10]. To also receive quantitative results out of our experiment we used the NASA-TLX questionnaire [G. 88].

3 Design and concept

In our simulation, each participant plays the role of a local ambulant incident officer who wants to check the patients' condition by talking with them. In this step, the triage [GHZ+06] has already been performed digitally (see Nestler et al. [Nes10] and Donner et al. [DEA+11]). Thus, the patients' locations are marked on a digital map on the tablet PC. The user's current position has been tracked by GPS and is displayed as a red dot on the map. The patients who had to be found by the participant were displayed on the map as well. As soon as the participant arrived at the patient's location, the tablet PC played a video showing an injured actor. The injured actor informed the participant about the injuries and other personal data. The task of the participants was to enter these information into the tablet PC using the two different types of interaction. For this purpose, a text input mechanism was developed for each interaction type. Both UIs were designed for the horizontal orientation mode of the tablet PC.

While there was no overall time limit for the evaluation, there was one for entering the text into the system (see section 4.4). The purpose of that was to put time pressure onto our participants like it is in a real MCI. The decision to use a keyboard has been made because people are familiar with them and they are simple to use. To be also able to compare both types of interaction in terms of the reaction speed in the case of spontaneous events in the scenario, the following feature has been added to the simulation: The display was covered by virtual rain drops at a random point in time after each injured actor was visited, see fig. 1. The participants were asked to simply press a button which also appeared on the screen to remove the rain drops. In case of the classical interaction technique, a red button appeared at a random position in the center of the display while for the edge interaction method, the button appeared randomly in a specified area at the edge. This way, the reaction speed can be compared in the case of the two types of interaction.

Through this study we aim to find out if there are any significant differences between the usability of the two types of interaction in combination with exhaustion and fatigue.

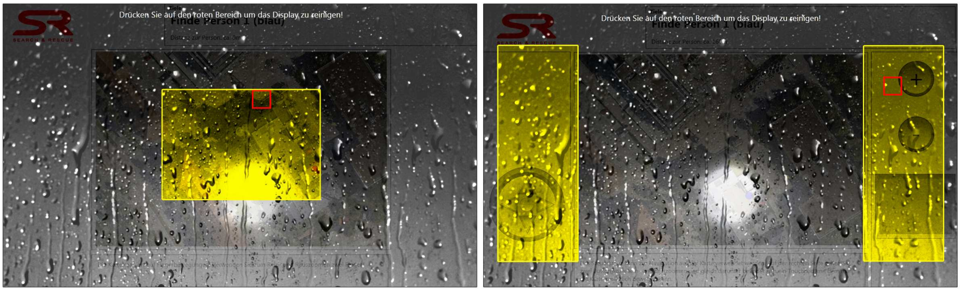


Figure 1: For the UI with the classical interaction technique (figure on the left), the red square appeared at a random position in the center of the display (yellow area). For the UI with the edge interaction technique (figure on the right), the red square appeared either at the left or at the right edge of the display.

3.1 Classical interaction

Since in the case of the classical interaction the user is able to reach everything on the screen by holding the tablet in one hand and interacting with it with the other free hand, the UI elements, like the text fields, could simply be touched by the users to select them. The classical touchscreen keyboard in this case has been used (see fig. 2). Instead of providing UI elements, the participant uses well known multi-touch gestures such as pinching to zoom in or out and swiping to navigate the map.

3.2 Edge interaction

By holding the tablet PC in both hands, the user is not able to reach each position of the screen with the thumbs. Thus, the screen is visually split into an interaction and a visualisation area. All UI elements which the user has to interact with were placed on those interaction areas like shown in figure 2. This way, the special requirement to enable the user to hold the tablet PC in both hands while interacting with it is fulfilled. For this reason, the used keyboard in this type of interaction was split to the left and to the right side.

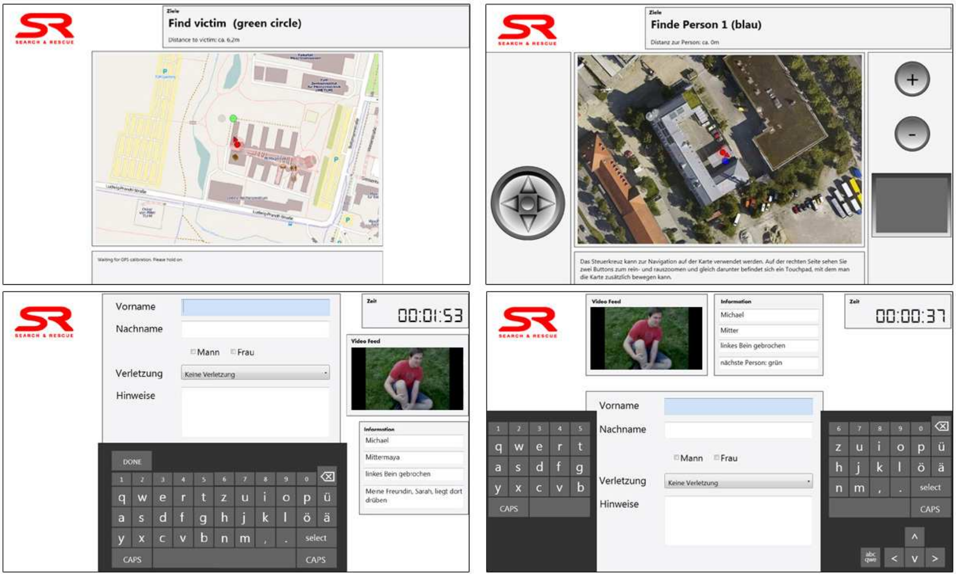


Figure 2: The UI for the classical interaction method can be seen on the left and the UI for the edge interaction can be seen on the right. The figures at the top show the map of the disaster site while the figures at the bottom show the different keyboards.

Since the participants were not allowed to click and select text fields manually, arrow keys were added to allow the user to switch between them. Moreover, a d-pad (directional pad, comes with most of the controllers for game consoles and allows to control an object into four different directions) and a touchpad were integrated in this UI to help navigate the map. Two extra buttons were added for zooming purposes.

4 Evaluation

We conducted a within-subject evaluation to compare the two conditions in two separated steps. This section describes the two groups of participants followed by a description about the apparatus used in our evaluation. Afterwards, our hypotheses are listed followed by the conducted results.

4.1 Participants

The first group consists of young people who are familiar with the usage of new interfaces. First, we wanted to try out the concepts and the evaluation task itself. This way, we had the opportunity to adjust our evaluation setup and implementation according to the feedback of the first group before the second group, our target group, could try the concepts. The second group includes AIOs from the ASB-München. Nielsen et al. [NL93] have shown through studies that a relatively small number of evaluations is sufficient to discover usability problems in the early stages.

4.1.1 Students

Twelve students were asked to participate in the evaluation, nine males and three females. The average age of this group is 24.75 with the youngest person being 20 years old and the oldest being 27. All students are right-handed and ten are studying Computer Science and half of the group was already beyond their tenth semester in their studies.

4.1.2 Target group

All six ASB members were male and the average age was 34.5 with the youngest member being 22 and the oldest being 43 years old. Every participant was right-handed and the average experience as a paramedic was 15.6 years. The mean time each member spends on the computer was 2.3 hours per day and the average experience level regarding IT was three[2] which leads to the following option: "Advanced: can safely manage and control basic functions". Five out of the six members were familiar with using devices with a touchscreen. Furthermore, three members use only one hand to type in contrast to two members using both of their hands. Only one person was already familiar with the alphabetic layout and this ASB member was also the only person who preferred that particular layout over the standard QWERTZ[3]-layout.

4.2 Apparatus

The V200 from Getac is a heavy convertible rugged notebook and has been used in this evaluation (see fig. 3). For the whole evaluation the V200 was kept in tablet mode.

The tablet's case is protected by a magnesium-aluminium alloy to ensure that the laptop can withstand any critical situations. However, this kind of rugged hardware also leads to noticeable disadvantages compared to commercial home-tablets. One major difference is that the touchscreen is not as sensitive as the displays of the commercial tablets. The reason behind is that there is a special protection layer on the touch sensitive display. Another disadvantage derived from the robustness of the tablet is the heaviness, which in fact is the source of our special requirement of edge interaction while holding the tablet in both hands (the Getac V200 weighs 2.7 kg (5.95 lbs) and the iPad 2 weighs 601 g (1.33 lbs)). The simulation, which ran on the tablet PC, was written using WPF, C# and XAML. The

[2]The following IT experience rating was used: http://www.verwaltungsmanagement.info/studium/it-ueb/ab-test/it-fragebogen.htm [last accessed 14-February-2012]

[3]In German-speaking countries, the keys "Z" and "Y" are swapped in the keyboard layout.

Figure 3: The Getac V200 is a convertible tablet PC with a full keyboard. The tablet mode can be seen on the right.

application consists of three parts. The first part introduces the user to the application and the evaluation task. As soon as the users confirm that they got acquainted with the application the second part started. The second part was the map application displaying the participants current position and the position of the next patient.

4.3 Procedure

A pilot study with three users was executed to test parameters for the simulation. Through several test runs, the results showed that 2 minutes and 30 seconds was a sufficient time window for the tasks. Changing the keyboard-layouts resulted in longer writing-periods and therefore, the time-limit for the forms was increased to 4 minutes.

The schedule for a single evaluation can be seen in table 1.

Estimated time	To do
5-10 min.	Introduction
5-15 min.	Test run with UI 1/2
15-20 min.	Simulation with UI 1/2
10-15 min.	Questionnaires and interview
1-5 min.	Break
5-15 min.	Test run with UI 2/1
15-20 min.	Simulation with UI 2/1
5-10 min.	Questionnaires and interview

Table 1: This table shows an evaluation schedule for one UI.

To determine and research the usability of the two UIs, the System Usability Scale (SUS) was used. Some small changes to the original text and template were made to adapt it to the user interface evaluation. After each test person completed the evaluation, the SUS scores were calculated. Since everyone had to answer two questionnaires and therefore two SUS forms, two scores were determined (two scores for each of the UIs respectively). The SUS score indicates the overall usability of the UI and the number ranges from 0 to 100 [Bro96].

While multimedia tablets are small, thin and lightweight, the robust tablets are thick and heavy. These differences explain the exhaustion and the fatigue-factor of the participants. People might think and feel differently after each evaluation and to assess the subjective workload, the NASA Task Load Index, short TLX, was used. The NASA TLX is based on six scales: mental demand, physical demand, temporal demand, performance, effort and frustration level. The weighted workload is a number representing the subjective workload assessment and it is calculated through a series of comparisons and ratings [G. 88].

Another aspect of the evaluation, is to observe the participants to learn how they were holding the tablet while walking or running from one injured patient to another. During the introduction, all participants were told in advance that for the UI with the edge interaction, the tablet should be held with both hands the whole time, even while walking or running and for the UI with the classical interaction, the participants were specifically advised to hold the tablet with only one hand during the whole procedure. In rare cases, the participants had to support the tablet with the other hand because of exhaustion for the UI with the classical interaction method. After the evaluation is performed with one of the interaction types, the participants filled out the SUS and NASA TLX questionnaires. An interview followed to find answers and receive comments as well as feedback to some of the following themes: IT-expertise, touch-device expertise and interaction preferences in such scenarios. After this interview, the participants could either take a break to relax or continue with the second type of interaction. Since a within-subject design has been used the sequence of the two interaction types has been randomized for each participant.

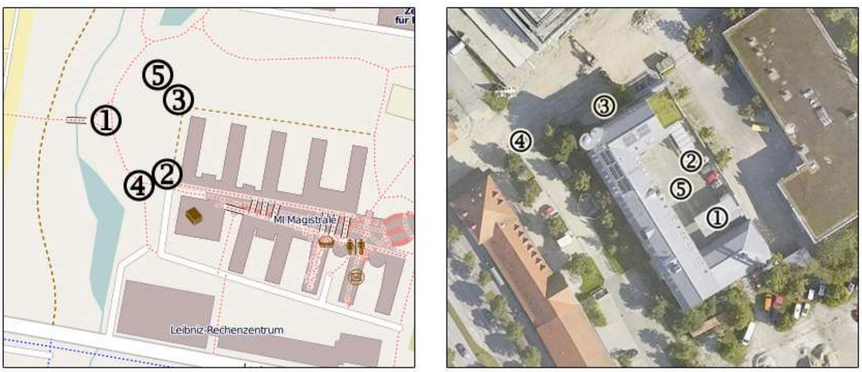
The following parameters were automatically logged by the system: The total time for the evaluation run, the number of backspaces pressed and four different scores for the "rain"-events. For each rain-event, a separate score was calculated. Each participant touches a quadratic area in the size of 50x50 pixels (13.22x13.22 mm) to get rid of the rain drops (see fig. 1). The closer the user touches the center of this area the higher the score is. Hitting exactly the center results in a score of 100 while the border results in 0.

4.4 Feedback and changes

The weather played a big role in the two different evaluations. While the first test group had their runs in mid-September, the second group was evaluated between the end of November and the beginning of December. The weather in September was warm during the evaluation while temperatures dropped significantly in mid-November and the participants felt cold after spending certain amount of time outdoors with the tablet in their hands. This also leads to a decrease in motivation to finish the evaluation with all the forms filled out as good as possible and frustration increased when something was not working as expected by the users.

Based on our experience and the feedback from the first group, some minor changes were made to the evaluation setup. The first group of participants complained about the keyboard being placed too low and therefore they had a hard time pressing keys while holding the tablet PC. The structure of the keyboard, which was used in the evaluation with the students, had only two keys which allowed switching between upper- and lowercase but it stayed either upper- or lowercase until the person manually pressed the key again. In almost every interview, people stated that they would prefer a “Shift”-key instead of a “Caps only”-key. This was changed in the evaluation with the target group and after typing one character in uppercase, all other keys would change back to lowercase automatically.

The second evaluation with the target group was done at the ASB-München. Figure 4 shows the buildings and the surrounding area where the evaluation was held. The course which was created for the evaluation is also shown in figure 4.



Map (1) Map (2)

Figure 4: The map on the left shows the location where the evaluation was held with the ASB while the map on the right shows the area where the students were evaluated. The numbers represent the positions of the injured people on the maps.

Beside the location, the following feature was also changed for the second group. According to the students, one factor which seemed to influence the results was the keyboard layout for the two UIs. Many participants in the first evaluation mentioned that they had to look left/right and constantly search for letters on the split keyboard. The hand-eye coordination was more difficult than the displayed keyboard with the QWERTZ-layout. The users stated that the full keyboard was easier to use because they were already used to the layout. To avoid such a disadvantage for the split keyboard, changes were made before the second evaluation to equalize both input methods. Figure 6 shows the split German QWERTZ-layout which was then changed to a keyboard with alphabetic layout. This way, our participants have to search the correct keys in both types of interaction. Additionally, the keyboard was also split in two parts but still in a way that they could not be reached with the thumbs (see fig. 5).

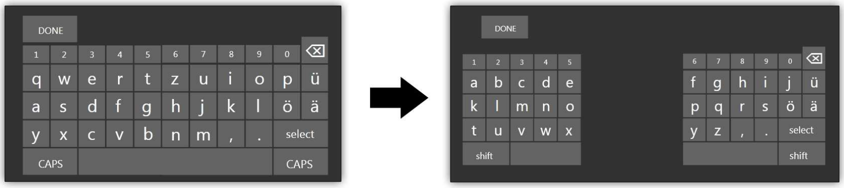


Figure 5: The keyboards are integrated in the forms which the participants see once an injured person is found (see figure 2). The keyboard layout was changed for the UI with the classical interaction technique. The keys were arranged differently (alphabetic layout).

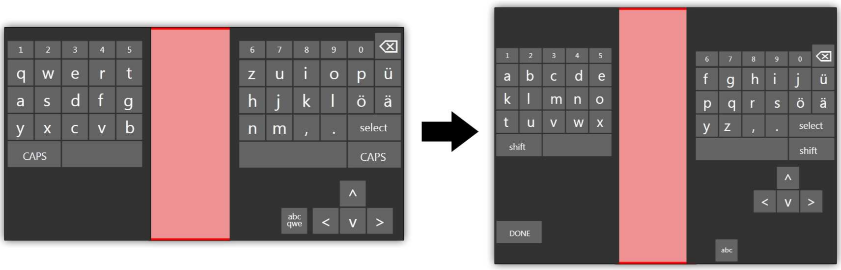


Figure 6: The layout for the split keyboard was changed (keys in alphabetic order) and the whole keyboard was pushed up by a small margin.

4.5 Hypotheses

The participants were more under pressure than under normal circumstances and most of the controls require concentration and focus (pressing the correct keys on the keyboard) to solve the tasks. One of the assumptions was that the participants would take longer to solve the tasks using the UI with edge interaction. It is also assumed that the participants will be more exhausted operating the UI with the classical interaction technique. In terms of usability, it is expected that the participants will prefer the more familiar UI, which would be the UI with classical interaction. This leads to the following three hypotheses:

- **H1**: The participants take longer to solve tasks using the UI with the edge interaction technique compared to the UI with the classical interaction technique.
- **H2**: The participants are more exhausted operating the UI with the classical interaction technique than the UI with the edge interaction technique.
- **H3**: The participants prefer the UI with the classical interaction technique over the UI with the edge interaction technique.

4.6 Results

In the following section, the SUS-, NASA TLX- and simulation results for both groups will be presented.

4.6.1 Students - Results

System Usability Scale The arithmetical mean for the SUS score regarding the UI with the edge interaction technique is 73.750 (standard deviation: 13.8785) while the mean for the UI with the classical interaction technique is 78.542 (standard deviation: 12.9447). A boxplot-representation can be seen in figure 7.

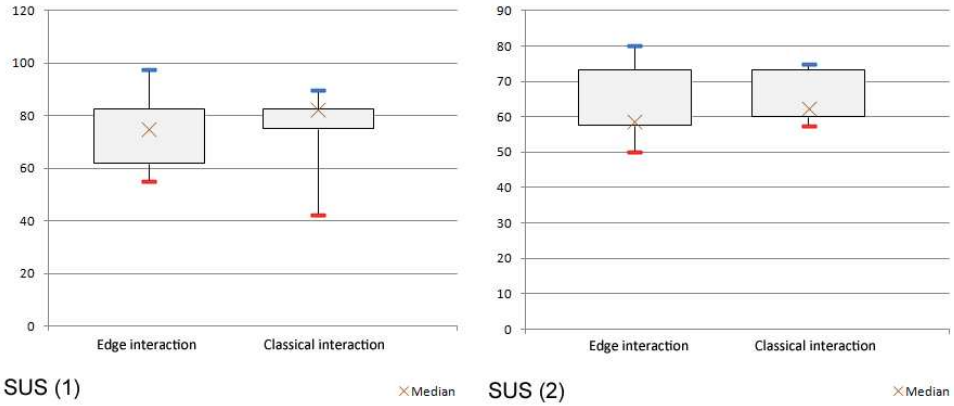


Figure 7: SUS (1): Boxplot diagram for the mean student SUS scores. SUS (2): Boxplot diagram for the mean ASB SUS scores.

NASA Task Load Index The computed mean for the TLX questionnaire with the edge interaction method is 10.8917 (standard deviation: 3.61785) with the mean for the other questionnaire for the classical interaction method being 11.7508 (standard deviation: 3.66587). For both groups, the average workload was calculated according to [G. 88]. A bar diagram for the six factors of the NASA TLX can be seen in figure 8.

"Rain"-event scores The mean for the "rain"-event scores for the UI with the edge interaction technique is 35.0667 (standard deviation: 13.12947) and the mean for the scores for the UI with the classical interaction technique is 34.4267 (standard deviation: 16.92056).

Time The average time to solve all tasks using the UI with edge interaction was 00:12:58 (hh:mm:ss) and 00:11:01 for the UI with the classical interaction.

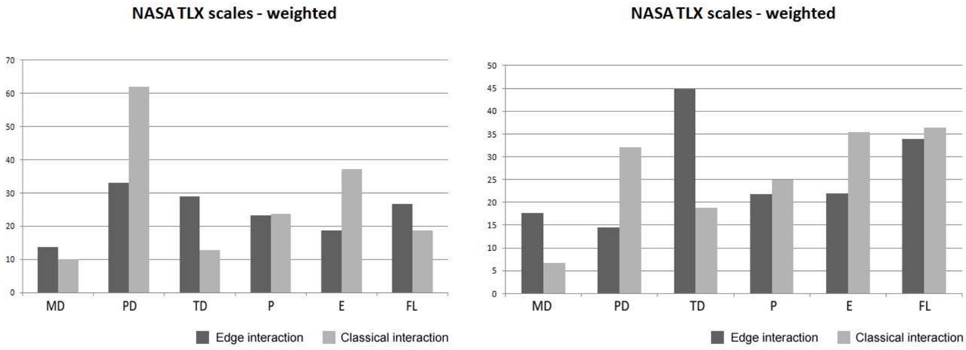


Figure 8: Left: Bar diagram with the six factors of the NASA TLX for the students. Right: Bar diagram with the six factors for the ASB group. The six factors are: mental demand (MD), physical demand (PD), temporal demand (TD), performance (P), effort (E) and frustration level (FL).

4.6.2 Target group - Results

System Usability Scale The mean SUS score for the UI with the edge interaction technique is 63.75 (standard deviation: 12.11) with the minimum score being 50 and the maximum being 80. The mean SUS score for the UI with the classical interaction technique is 63.75 (standard deviation: 6.27) with the minimum being 57.50 and the maximum being 75.

NASA Task Load Index The mean TLX score for the UI with the edge interaction technique is 11.41 (standard deviation: 2.97) with the highest score being 16 and the lowest being 7.86. For the UI with the classical interaction technique, the average TLX score is 11.55 (standard deviation: 2.35) with the minimum being 8.6 and the maximum being 15.06.

“Rain”-event scores The mean score for the “rain”-events using the UI with edge interaction was 32.93 (standard deviation: 16.43) and 27.81 (standard deviation: 14.62) for the UI with the classical interaction technique.

Time The average time of the evaluation using the UI with the edge interaction technique was 00:19:04 (hh:mm:ss) and 00:18:19 for the UI with the classical interaction.

4.6.3 Analysis

The results of the SUS-, NASA TLX- and the simulation-evaluation were analyzed with the “Paired Samples T-Test”. The Paired Samples Test is supposed to be used for a group of test subjects who are related to each other and go through a process twice but under different circumstances. These conditions were fulfilled since there was always one group of test subjects who got to test two different UIs and therefore, do the evaluation twice.

System Usability Scale The Paired Samples T-Test failed to reveal a statistically reliable difference between the mean SUS scores of the UI with the edge interaction technique and the classical interaction technique, $t(11)$ = -1.017, p = .331, α = .05.

NASA Task Load Index The Paired Samples T-Test didn't show any relevant statistical difference between the mean NASA TLX scores of the UI with the edge interaction technique and the classical interaction technique, $t(11)$ = -1.750, p = .108, α = .05. For the factors "Physical Demand", "Exhaustion" and "Temporal Demand", the Paired Samples T-Test revealed a significant difference between the weighted scores for the UI with the edge interaction technique and the classical interaction technique, $t1(11)$ = -4.545, $p1$ = .001, $t2(11)$ = -3.330, $p2$ = .007, $t3(11)$ = 3.183, $p3$ = .009, α = .05.

"Rain"-event scores The Paired Samples T-Test didn't reveal a statistical difference between the mean "rain"-event scores of the UI with the edge interaction method and the classical interaction method, $t(11)$ = .091, p = .929, α = .05.

5 Discussion

According to the SUS scores, the students tend to prefer the UI with the classical interaction technique to the UI with the edge interaction technique but the results show no significant difference - the scores do not support the hypothesis **H3**. More than 70% of the students work in the computer science field and spend more than five hours a day in front of a computer which leads to the assumption that many were accustomed to the full, standard QWERTZ-keyboard layout. More than 66% said that they have never had any experience with the alphabetic layout before and have seen a split keyboard for the first time. Therefore, they had to get used to the new layout, whether it was QWERTZ or alphabetic. Many said that they were not used to constantly looking left and right for the correct keys to press and that the hand-eye coordination was more difficult than with the other UI. The fact that the participants were unfamiliar with a split keyboard concept can be also taken into consideration when comparing overall times for the test runs. Almost 75% of the test subjects were slower with the UI with the edge interaction technique than with the UI with the classical interaction method. The average times for both groups support the hypothesis **H1** (the participants take longer to solve tasks using the UI with the edge interaction).

While the students slightly favor the UI with the classical interaction technique, the results from the NASA TLX evaluation show the opposite. The ASB group said that the average workload for the UI with the classical interaction method was higher. The difference is not significant but the trend is more apparent than the trend for the SUS scores. It is interesting to note that the physical demand and exhaustion factors were both significantly higher for the UI with the classical interaction technique (thus supporting hypothesis **H2**) while the other factors (mental demand, temporal demand, performance and frustration level) were higher for the UI with the edge interaction technique or even on the same level for both UIs. The mean score for the "rain"-events with both interactions is comparable even though the students preferred the UI with the classical interaction technique. The average SUS scores for both UIs from the evaluation with the ASB members were identical. This leads to the assumption that with the new changes, the ASB people did neither see the advantages nor the disadvantages using the respective UIs. Additionally, the NASA TLX scores revealed that the overall workload for the UI with the classical interaction technique was greater compared to the UI with the edge interaction technique. The factors for temporal and mental demands were both significantly higher for the UI with the edge interaction technique while the remaining four factors were higher for the other UI. Therefore, UIs with the edge interaction method developed for rugged tablets have to take the temporal and mental factors into consideration and optimize the UI especially for the needs of the application and its users. Furthermore, it is recommended that the applications for robust tablets including objects which need the user's constant attention (for instance, a map with various events and interaction possibilities) are developed so that users can hold the tablet with both hands while using the program.

6 Conclusion and future work

A user study has been executed to compare the usability of the two user interfaces and the comfort of using different interaction techniques for rugged tablet PCs.

There is an apparent need to develop user interfaces for rugged tablets so that they can support the user effectively and overcome the problems emerging from high weight of the device. Overall, people got along well with both user interfaces as no usability test showed significant trends for one UI. Factors such as exhaustion and fatigue played a big part in the analysis of the evaluations. Holding the tablet even a relative short time (no matter with one hand or both hands) was exhausting and resulted into complaints. This observation is also confirmed by the results from the questionnaires. In general, we have observed that the UI elements that cannot fit as a whole in one edge, in our case the touchscreen keyboard, and has to be split for the edge interaction suffer from a decrease in the reaction time when used in the edge interaction. As earlier mentioned that could be due to the mental load of the hand-eye coordination.

Further tests and evaluations regarding the two interaction techniques using rugged tablet PCs have to be made with more realistic tasks. Additionally, already developed concepts following the edge interaction technique (see [CAN$^+$10], [CBA$^+$12]) have to be compared to the classical interaction technique.

References

[Bro96] John Brooke. SUS - A quick and dirty usability scale. *Usability evaluation in industry*, pages 189–194, 1996.

[CAN+10] T. Coskun, E. Artinger, S. Nestler, A. Benzina, and G. Klinker. Tablet device interaction with geographical information in time-critical, life-threatening and unstable situations. In *GMDS 2010*, Mannheim, Germany, September 2010.

[CBA+12] Tayfur Coskun, Amal Benzina, Eva Artinger, Clemens Binder, and Gudrun Klinker. User-Centered Development Of UI Elements for Selecting Items on a Digital Map Designed for Heavy Rugged Tablet PCs in Mass Casualty Incidents. In *Proceedings of ACM SIGHIT International Health Informatics Symposium (IHI 2012)*. ACM Press, 2012.

[CBP+93] Trudie Chalder, G. Berelowitz, Teresa Pawlikowska, Louise Watts, S. Wessely, D. Wright, and E. P. Wallace. Development of a fatigue scale. *Journal of psychosomatic research*, 37(2):147–53, January 1993.

[DEA+11] A. Donner, S. Erl, C. Adler, A. Metz, M. Krüsmann, T. Greiner-Mai, and M. Ben-Amar. Projekt e-Triage: Datenmanagement für die elektronische Verletztenerfassung und Akzeptanz bei Rettungskräften. *INFORMATIK 2011 - Workshop zur IT-Unterstützung von Rettungskräften*, October 2011.

[G. 88] Sarah G. Hart. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. 1988.

[GHZ+06] W Gutsch, T Huppertz, C Zollner, P Hornburger, M V Kay, U Kreimeier, W Schäuble, and K G Kanz. Initiale Sichtung durch Rettungsassistenten. *Notfall Rettungsmedizin*, 9(4):384–388, 2006.

[HHSU08] Andreas Holzinger, Martin Holler, Martin Schedlbauer, and Berndt Urlesberger. An investigation of finger versus stylus input in medical scenarios. *ITI 2008 - 30th International Conference on Information Technology Interfaces*, pages 433–438, June 2008.

[MSM09] Samuele M Marcora, Walter Staiano, and Victoria Manning. Mental fatigue impairs physical performance in humans. *Journal of applied physiology (Bethesda, Md. : 1985)*, 106(3):857–64, March 2009.

[NAC+10] S. Nestler, E. Artinger, T. Coskun, Y. Yildirim, S. Schumann, M. Maehler, F. Wucholt, S. Strohschneider, and G. Klinker. Assessing Qualitative Usability in life-threatening, time-critical and unstable Situations. In *10. Workshop Mobile Informationstechnologien / Mobiles Computing in der Medizin (MoCoMed 2010)*, Mannheim, Germany, September 2010.

[Nes10] S. Nestler. *Design, Implementation and Evaluation of User-Interfaces for Life-Threatening, Time-Critical and Unstable Situations*. PhD thesis, Technische Universität München, July 2010.

[NL93] Jakob Nielsen and Thomas K. Landauer. A mathematical model of the finding of usability problems. In *Proceedings of the INTERACT '93 and CHI '93 conference on Human factors in computing systems*, CHI '93, pages 206–213, New York, NY, USA, 1993. ACM.

[SAZ+08] Cláudio Sapateiro, Pedro Antunes, Gustavo Zurita, Nelson Baloian, and Rodrigo Vogt. Supporting Crisis Management Processes by Wirelessly Interconnected Tablet-PCs. *2008 IEEE International Conference on e-Business Engineering*, pages 87–93, 2008.