How-to interact with a map application on a heavy rugged tablet PC when both hands are needed to hold the device

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Abstract: This paper presents the second iteration of developing scrolling concepts for a digital map on a rugged tablet pc which can be used while holding the device in both hands. This map application is intended to be used during a Mass casualty incident (MCI) by the Ambulant Incident Office (AIOs). In the previous and first iteration the shortcomings of the developed concepts were identified and eliminated. The goal of the second iteration is to find out if the enhancements of the concepts work and to compare the elected two concepts - An enhanced Minimap and the so called Radar-Joystick. The evaluation results show that some features and functionality offered by both the enhanced Minimap and the Radar-Joystick concepts are accepted and positively rated, while other are confusing to the users. For this reason, we suggest to use a combination of both concepts and limit the functionality of the Minimap to emphasize the features which were rated as helpful and useful by the target group.

1 Introduction

Mass **C**asualty **I**ncidents (MCI) are unstable and highly dynamic and dangerous events. By definition, in an MCI, there are more injured people than the available rescue resources can handle. Because of this fact, the relief units first perform the so called triage algorithm like *START* [BKS96] or *mSTART* [KKMS06]. The outcome of the triage process is a priority indicating the need of each patient to benefit from medical care. There are many approaches and efforts to digitize this process (e.g. [NK07]).

The work presented in this paper presumes that this triage process has already been performed digitally with GPS-enabled devices. The triage priorities and the position of the patients are therefore available and can be visualized in a map application. According to the SpeedUp[1] project, it is suggested to use for mobility PDAs/smartphones for the relief units and the so called semi-mobile rugged tablet devices for the **A**mbulant **I**ncident

[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 - July 30th, 2012, FKZ: 13N10175). Website: http://www.speedup-projekt.de

Officer (AIO), while a large multitouch table should be used stationary and for collaboration with other departments (e.g. police or fire department). This strategy offers then the most fitting device to the appropriate role during an MCI. The overall concept of SpeedUp is described in more details in Artinger et al. [AMC+12].

This paper however focuses on the semi-mobile part using the rugged tablet PC and how to interact with a map application while holding the heavy device in both hands. This way, only the thumbs are able to interact with the touchscreen which introduces new requirements to the development of the **U**ser **I**nterface (UI) concepts. Furthermore, there are additional UI related requirements due to the time-critical, stressful and unstable situation that the rescue service personnel encounter. For this reason, a user-centered iterative design and development is inevitable. This requirement is emphasized by the fact that the best application with the most efficient UI will not be adopted unless the target group, e.g. the rescue service personnel, does accept it. It is therefore crucial to include the target group in the development process. The most important requirements influencing the development and the design of our UI elements are given in Section 3.

We developed and designed a map application, as well as we evaluated and improved different UI concepts to scroll (move) a digital map on a heavy rugged tablet PC. An evaluation has already been performed on the first version of those UI concepts and is described in Coskun et al. [CAN+10] in 2010. This paper presents the second iteration of this procedure and therefore the enhanced concepts and the second evaluation with the target group, in this case the **A**rbeiter-**S**amariter-**B**und Muenchen (ASB-Munich). Our concepts and the differences to the previous version are described in Section 4. Our evaluation with the target group is then given in Section 5.

2 Related Work

Within the SpeedUp project Nestler et al. performed an evaluation in 2010 with people from the rescue service equipped with PDAs [NAC+10]. RFID chips were added to the paper-triage tags. The paper-triage tags are currently used in the triage process to mark the patient's triage state. The PDAs were able to exchange data, e.g. the triage state, with the RFID chips inside the paper-triage tags. In the same time when data is exchanged, the current GPS-position of the relief unit holding the PDA is transferred to a server. Because the relief unit has to be near the patient to exchange data with the RFID chip, the position of the relief unit is considered as the position of the patient. This way, an overview of all sighted patients and their degree of injury can be visualized through a digital map. A similar approach has been performed by Adler et al. [AKGM+11] in 2011. This work makes use of handheld devices for daily rescue operations and in disasters. An autonomous communication infrastructure is provided through a satellite and an distributed database concept. Another system, called RTR (comprising Radiation-specific TRiage, TReatment, Transport sites), has been developed by Hrdina et al. [HCB+09]. This system is designed for nuclear and radiological MCIs and is therefore not a system for individual patients. Instead, so called RTR-sites are built on their physical relationship to the incident. For example, RTR1 sites are near to the epicenter. Victims with major injuries are expected to be in this site. There are also research projects focusing on analyzing triage protocols of real MCIs like it has been done by Postma et al. [PWH+11] with protocols of an airline crash. The results of this study can serve as an additional source for important requirements to develop a digital support system for MCIs. MCI related aspects are also investigated by Flentge et al. [AGOP12] who digged into context aware UIs for collaborative emergency management.

A parallel work to the study presented in this paper is described in Coskun et al. [CBA+12] which focuses on developing UI elements for selecting MCI related items, like patients or resources, following the same requirements described in Section 3. In fact, it is planned to bring those concepts together in future.

3 Requirements

There are also special requirements on which our concepts are based due to the special circumstances of an MCI. First of all, there are requirements emerging from the hardware. Those hardware requirements which are influencing our UI concepts are already described in [CNA+10]. However, since they are important to understand the whole concept, they are briefly summarized in Section 3.1. Furthermore, by iteratively interviewing personnel from the fire department and from the rescue service, we could find a tendency for changes considering the hardware requirements. Second, there are touchscreen related requirements (Section 3.2) and third MCI related requirements which are given in Section 3.3.

3.1 Hardware Related UI Requirements

To be able to show location based data on our map application, the target tablet should be equipped with a GPS receiver. Additionally, the tablet has to be equipped with multiple techniques to connect to a network (WLAN, GPRS, HSDPA, ...). Furthermore, the battery should last at least 4 hours to ensure it works during the whole MCI process, even if it cannot be attached to its docking station meanwhile. This docking station is in fact the next requirement. One solution would be to install the docking station into the ambulance vehicle attached to the electronics of the car. The next requirement is originated by the nature of an MCI: Since this is an unpredictable, stressful, mobile, and time-critical situation, the tablet device will not be treated as carefully as a home tablet. It also should not suffer from sunlight, rain, dust, or extreme temperature through the wheather or through a fire for example. Standards to define the degree of protection has been introduced in DIN EN 60529. According to this standard, IP55 should be at least fulfilled. This last requirement has been derived from interviews with the fire department TUM (TUM Feuerwehr) which has an internal rescue service group. However, the tablet market developed a lot during the last 3 years. Thus, the requirements considering the touch-sensibility of the screen, the performance of the device, and even the design are in progress. The ASB staff expressed the fact that the rugged devices are too heavy. Since we still believe, that a commercial tablet device is not suitable for an MCI scenario, we conducted our evaluation on a rugged tablet device. If our concepts work efficiently with this device, and if our participants accept our concepts on it, they will also accept them on a less rugged tablet device. However, in future, we want to compare our concepts running on those strongly rugged tablet devices against more modern outdoor smartphones and tablets like the Utano Barrier T180 Dual-Sim or the ET1 tablet device from Motorola.

3.2 Touchscreen Related UI Requirements

2010 Bachl et al. [BTWG10] categorized challenges for multitouch interfaces into three groups: **a)** screen-based, **b)** user-based, and **c)** input-based challenges. One obvious fact is that the touched area is occluded (category c)). Thus, UI concepts which are designed for touchscreens should either not rely on visual feedback or provide some additional visual feedback when the user interacts with the UI element, for example a cloned view. Another requirement is originated by the fact that the fingertip of the user is not as precise as the mouse cursor [AZ03] (category c)). The user's precision is even worse if the thumbs are used to interact with the touchscreen. According to [Til02] the average size of the thumb of an adult man is 18.2mm. However, an accuracy of 99% can still be reached if the size of the interaction area is at least 22mm in width [Lew93], [LP98].

3.3 MCI Related UI Requirements

The efficiency in an MCI is important because time is very critical. The intuitiveness is important because a special training for the UI would reduce the acceptance of the device and would also cost money and time which finally would reduce its spreading. The following and the last requirement presented in this paper is the one that influenced the most the design of our concepts: The requirement is to **interact with the whole application while holding the tablet in both hands**. This way, **just the thumbs can be used to interact** with the application and just the edges of the screen can be used to place the UI elements (see Figure 1). This requirement has been gathered through our initial interviews with the fire department TUM. They have used a rugged tablet (IXpore 104) in their daily work and complained about its heaviness. They used to hold the tablet with one arm and interacted with it with the other free hand. After a short time period, this causes their arm fatigue. The tablet which the fire department used can be seen in Figure 1.

4 Concept

To ensure the acceptance of new devices it is important to iteratively develop the UI and close to the target group. In a previous study, three different concepts to scroll a digital map

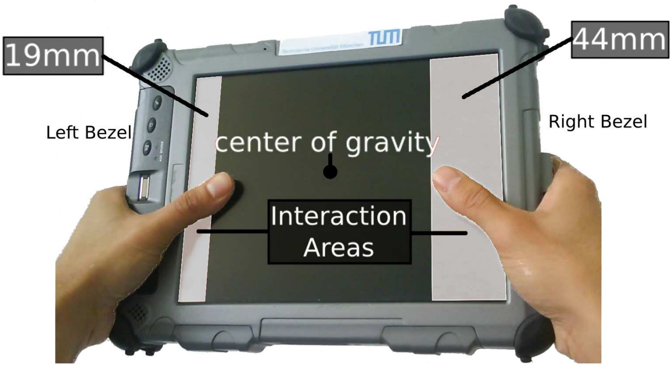

Figure 1: The rugged tablet PC which was used by the fire department in their daily work and the ergonomical way to interact with it.

while holding the tablet in both hands were developed and evaluated [CAN$^+$10]: **a)** 4 Simple buttons on each edge of the screen, **b)** an interactive minimap and **c)** a virtual joystick. To summarize, the virtual joystick performed best. However, by critically analysing the qualitative interviews, it was clear that the reason behind that good performance was the low precision of the minimap. While minimaps work great in games for example, which are controlled with the mouse and keyboard, they do not perform as good on touchscreens. This is especially the case in our setup, since only the thumbs are free to interact with the minimap. But our users also mentioned a disadvantage of the joystick compared to the minimap: The joystick does not offer an overview visualization of the patients positions. One simple solution might be to provide both, a joystick to interact with and a minimap to visualize important data and their positions on the map. But since there is just limited interaction space on the screen (because of our edge interaction requirement) we decided to eliminate the weak points of both concepts and conduct another evaluation. The new concepts are described in the following sections.

4.1 Minimap 2.0

The disadvantage of the minimap according to our previous evaluation is the lower precision. Consequently, we added the following feature to the minimap: By touching and holding the thumb on the minimap (200 ms) the behavior of the minimap changes in a way that it works similar to the joystick. The initially touched position is the center of this joystick functionality. The position of the thumb on the minimap is then not mapped 1 to 1 to the real map anymore. Instead, the map is scrolling exactly the same way, as it scrolls when using the joystick. The same happens if the user touches the rectangle inside the minimap, which is indicating the current position of the map section. This is logical, because there is no need to jump to the new position because the new position is close to the current position. If the user touches an area inside the minimap but outside this rectangle, the minimap keeps its original behavior and jumps immediately to the new position. To reduce the risk that users will not understand this dual functionality of the minimap, we enhanced the visualization of the minimap: As soon as it swaps to the joystick mode, four arrows are visualized which are scaled individually according to the thumbs distance to the initial touch position (see Figure 2 on the right side).

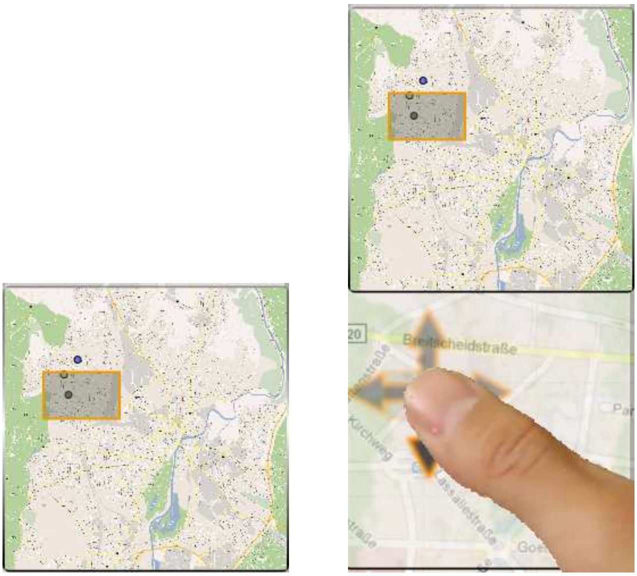

Figure 2: The minimap not touched on the left side and touched on the right side

4.2 Radar-Joystick 2.0

The weak point of the joystick was that there was no visualization showing the patient's positions. For this reason, we added a visualization feature to the joystick which works similar to a radar. The relative positions of the patients are shown inside the background of the joystick. This way, patients which are not inside the current map section and therefore not visible on the map are visible inside the Radar-Joystick. The missing visualisation was mentioned as the main disadvantage of the previous version of the joystick while the usability was rated quite high. Figure 3 show both the graphical representations of the Radar-Joystick when it is not touched and when the user is interacting with it on the left and the right figure respectively. The interaction itself was rated as intuitive and good in the first iteration. For this reason, no changes have been made to the way of interacting with the joystick. There are 2 areas inside the joystick: The inner precise area and the outer fast area. Those 2 areas are visible in figure 3. The scrolling speed increases with the distance of the thumb to the center of the joystick. While it increases 1:1 inside the inner area it increases 1:4 inside the outer area.

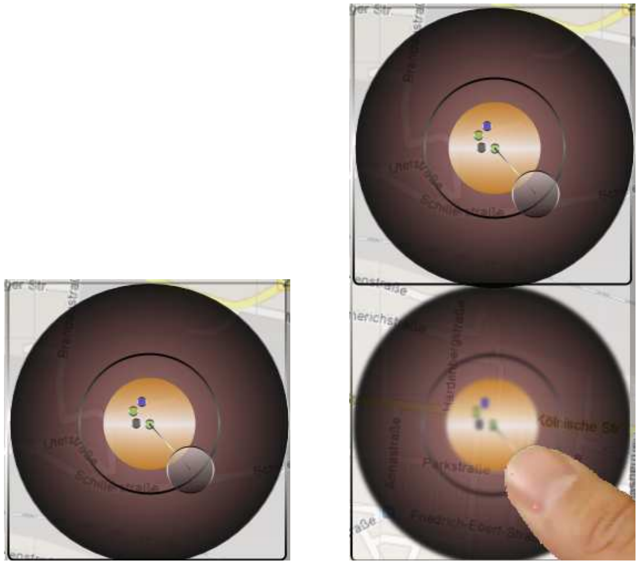

Figure 3: The radar joystick not touched on the left side and touched on the right side

4.3 New features for both concepts

We also faced some problems originated from the ruggedness of the used device. Their touchscreens are not as sensitive as nowadays home tablets are. Sometimes, the touchscreen loses the contact to the finger although the finger is still touching it. For this reason, we added a short time delay of 50ms in which touch up events are just ignored. Thus, if the system loses the contact to the finger for a short period of time, the user does not even recognize this. On the other side, another consequence is, the map for example keeps scrolling for 50 ms, when the user intends to release the finger. But since this is almost not noticeable, we kept this feature in the current version of our concepts.

Another outcome of the first evaluation was the well known occlusion problem on touchscreens. For this reason, we added the clone-feature to both concepts: As soon as the user interacts with either the joystick or the minimap, a cloned view pops up on the top of the UI element. This cloned view is still visible while the UI element itself is occluded by the finger (see Fig. 2 and 3).

5 Evaluation

The selection of the participants of the current study are described in Section 5.1. The evaluation procedure is then given in Section 5.2 and the used hardware is presented in Section 5.3.

5.1 Participants

In our previous iteration, we evaluated the different alternatives with students. This has been done because the intention was to find usability problems, errors, and also ideas to improve the initial design of our concepts. In the current iteration, the shortcomings of the concepts were already identified and eliminated. The purpose of the second iteration is, on the one hand, to see if those enhancements work, and to test them with the real target group. Since the map application is intended to be used by the AIO, the participants were also AIOs. This way, the qualitative results of the evaluation gain more importance, because people from the target group will always try to associate their evaluation task with a real tasks during an MCI. Therefore, their feedback is crucial to further adapt the concepts to the specific needs of the system's participants. According to literature it is suggested to use three to five test participants to evaluate a UI [Nie94]. The reason for that is the fact that most usability problems are found with the first few test participants. More participants will most likely only encounter the same issues. Another parameter for choosing the number of participants is the number of alternatives which are evaluated, two in our case. Consequently, the number of participants has to be even, to be able to randomize their sequence during the evaluation. For this reason, four AIOs participated in our evaluation. All of them are male and right handed with a work experience of 26.25 years in average. They were between 35 and 52 years old. Three of them used a touchscreen and a map application before and one had no experience with touch screens at all.

5.2 Procedure

To be able to experience and rate the two concepts, the participants need to use them first. Thus, the evaluation setup consists of different tasks. The ideal goal of designing those tasks is to fulfill both: representing the tasks in a real MCI and identifying the advantages and disadvantages of each UI alternative. However, if the tasks are designed in a more realistic way, there is a risk that the questions considering the UI concepts will not answered. This can only be assured if the tasks are restricted in a way they constrain the participants to use the concepts to fulfill the tasks exactly the expected way. For this reason, we designed simple tasks which only include the scrolling feature of our map application. To still provide an impression of a real MCI, we included MCI related elements in our map application and the evaluation task.

The evaluation setup consists of two rounds. Each round is partitioned into three sessions. The sessions were designed to emphasize the advantages and the disadvantages of both concepts. Each session consists of multiple patients and a different distribution on the map. The goal is to scroll the map to the currently visible patient using one of the two concepts. Once the map is centered to the currently shown patient, the next patient appears until the system informs about the end of the round. The participants were explicitly asked to scroll to the patient **as fast** as possible and **not as accurate** as possible. To freeze the accuracy, the whole evaluation is divided into the two rounds dealing with different accuracy settings. Both rounds have to be solved in each session with both concepts by our participants. Thus we had 12 executions of rounds per participant (Round 1-ABC and Round 2-ABC with both concepts). A semi-transparent circle positioned at the center of the screen was shown to the user. The goal was to position the map in a way the patient is inside this circle. Thus, in the first round the participants have to perform the three sessions with a large circle (very low accuracy) and in the second session the size of the circle was reduced which increased the needed accuracy to position the patient inside this circle. Since all participants used both concepts we randomized the sequence of the concepts for each user to consider the learning effects (within-subject design). The following paragraphs describe and explain the differences between the three sessions. The distributions of all three sessions are shown in Figure 4. However, this is just to illustrate the distribution of the patients in this paper, the participants never saw the overall distribution in one task. Just the next patient which should be found by the user was shown. After the completion of a session with one UI concept, the participants were asked to fill out the standardized SUS questionnaire, which is a standard usability scale [Bro96]. Additionally, a short guided interview was conducted to get qualitative data and professional feedback from the AIOs. Afterwards, they repeated the same procedure with the other concept. The results of both our qualitative and quantitative results are presented in Section 6.

Session A Task A consists of seven patients which are positioned closely to each other (clustered patients). The reason behind that is to emphasize the advantage of the Radar-Joystick. Based on our experience in the first evaluation we expect the joystick to perform best in this session during both precision settings (The rounds). We also expect that the result of the minimap gets worse in the second round since the needed accuracy increases (smaller target circle). Because of that, we expect that the performance of the minimap suffers more in Round 2 than the performance of the joystick. The distribution of the patients in Session A is shown for both concepts in Figure 4 on the left side.

A1: Joystick performs better than Minimap in Session A in both rounds.
A2: The minimap performs worse in the second round.
A3: The performance of the minimap suffers more when more precision is needed than the joystick

Session B For Session B the distribution of the seven patients was increased. Thus, the included visualisation of the patients' positions inside the Radar-joystick and the Minimap have to be used in this case to be able to find the patients. We expect that there will be no relevant difference between both concepts in this task. This distribution is shown for both concepts in Figure 4 at the center.

A4: There is no relevant difference in speed for both concepts in Session B.

Session C In Session C the whole map was used to distribute the seven patients. Thus, to fulfill the task, the participants have to scroll the map from one edge to the other for each patient. Because of this fact, we expect that the minimap will perform faster in Task 3, even for Session 3 in which more accuracy is needed to complete the task. This distribution is shown for both concepts in Figure 4 on the right side.

A5: The minimap will perform better in Session C for both rounds.

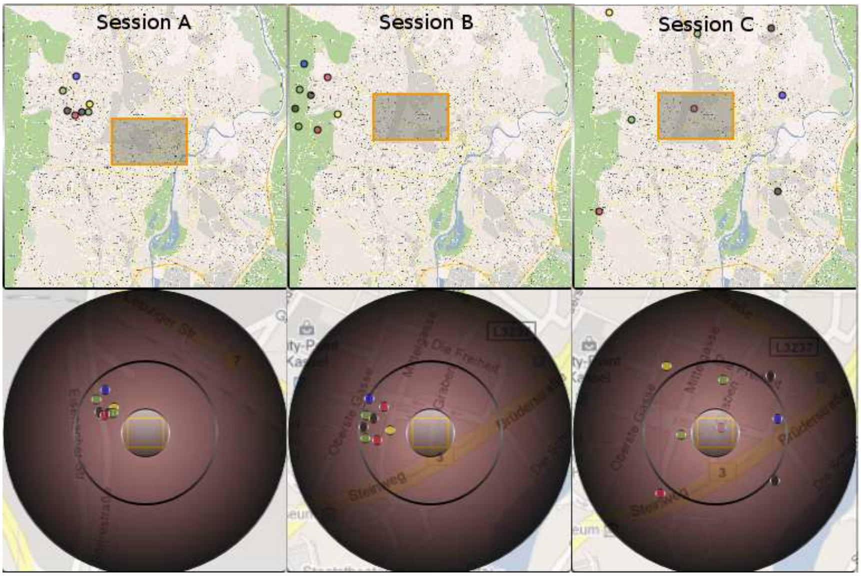

Figure 4: Both concepts and their patient visualisation in all three sessions.

5.3 Apparatus

As a hardware, we used the convertible rugged tablet PC Getac V200. As being a convertible rugged notebook its weight is even higher than the normal rugged notebooks. Another disadvantage of the device is its width of 5cm. But in the same time, compared to other notebooks, it has a high performance equipped with an Intel I7 processor and 8 GB of RAM. Another advantage is that the touch display is much more reliable and sensible than other rugged tablets like the XPlore 104, which we used in the previous evaluation. Still, the display is still not as reliable and sensible as the tablets which are used at home. During our evaluation, Windows 7 was running on the Getac V200 and the whole application has been written in WPF and C#. Figure 5 shows the device.

6 Results

The results can be classified into three different main categories:

1. Automatically logged data (process-oriented objective data),
2. Results from the SUS-questionnaire and preferred interaction metaphor (subjective

Figure 5: The used rugged convertible notebook during the evaluations: Getac V200

quantitative data) and

3. Subjective feedback from the interviews (subjective qualitative data).

In the following these three categories will be described separately.

6.1 Automatically logged data

To be able to compare the efficiency of both concepts the application logged the time needed to fulfill each task for each participant.

The first diagram in Figure 6 compares the speed of the Joystick and the Minimap for all sessions in Round 1. In this round, the participant did not need to be very precise when scrolling to the target. In Session A the participants needed approximately the same time with both concepts (Joystick 3% faster than Minimap). In Session B the distances between the targets were increased and the participants did need 15% more time to solve the whole session with the Minimap (85,43s) than with the Joystick (74,06s). This tendency changed in Session C, in which the scrolling targets were distributed over the whole map. In this session, the Minimap (93,60s) was 17% faster than the Joystick (113,11s).

The second diagram in Figure 6 shows the same data for Round 2. The participants had to be more precise. For this reason, the participants needed in general more time with both concepts to fulfill the same tasks like in Round 1. However, the Minimap suffered more than the Joystick. This can be seen for example in Session B: In Round 1 the Minimap needed 15% more time than the joystick. The difference increased in Round 2 - Session B to 37%(Minimap: 113.91s, Joystick: 83.41s).

The third diagram compares the sums of all means for all sessions per round. This means, the diagram shows the results when the amount of short and long scrolling distances are mixed. The differences in speed for both concepts reduce in this case to 2 and 4%.

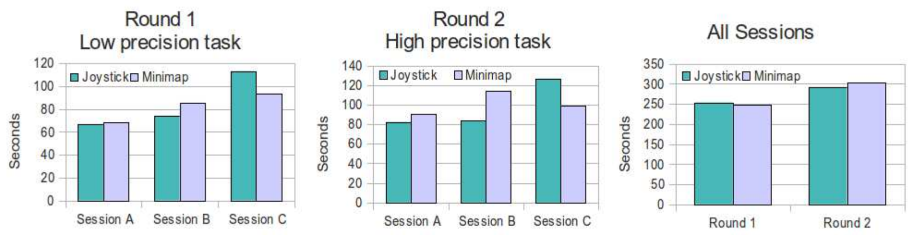

Figure 6: The needed time in seconds to solve each sessions in Round 1, Round 2, and for all sessions per round

ID	Assumption	Result
A1	Joystick performs better than Minimap in Session A in both rounds	yes
A2	The minimap performs worse in the second round	yes
A3	The performance of the minimap suffers more when more precision is needed than the joystick	yes
A4	There is no relevant difference in speed for both concepts in Session B	no
A5	The minimap will perform better in Session C for both rounds	yes

Table 1: Our initial assumption and whether they are fulfilled or not.

Table 1 summarizes our assumptions and whether they are confirmed by our quantitative data.

6.2 SUS-Questionnaire and Preferred Interaction Metaphor

The SUS scores of the two different selection alternatives (Joystick vs. Minimap) of our formal evaluation are illustrated in Figure 7 on the left side. The mean SUS score of the Joystick is 75.0 and therefore higher than the SUS score of the minimap with a mean of 55.6. According to Tullis et al. [TA08] the score of the Radar-Joystick is positioned at the upper bound of the average SUS scores which appear in literature. Thus the usability of the Radar-Joystick can be considered as high. The SUS score for the Minimap is below the lower bound of the average SUS scores studied by Tullis et al.. Thus the usability of the minimap is not good enough to be able to be suggested as a concept for interaction purposes on touchscreens which are used with the thumb and in which the participant can not deal with precision while interacting. Additionally, our participants were asked to rate the two concepts with a six item Likert-Scale. A value of 0 means: “I would never use the concept in future” while a value of 6 means “I would definitely use this concept in future”. The minimap mean value considering this question is also below the value of the

Radar-Joystick which supports the results obtained by the SUS questionnaire. However, it is still interesting that although the SUS-score of the Minimap is quite bad, the Likert value of the Minimap is still above three. If people rate the usability of a concept bad but also say that they might use this concept in future, this could mean that they liked at least some aspects of the concepts but had difficulties to use it. The results of our qualitative interviews, given in Section 6.3 also try to clarify the reasons behind the subjective results.

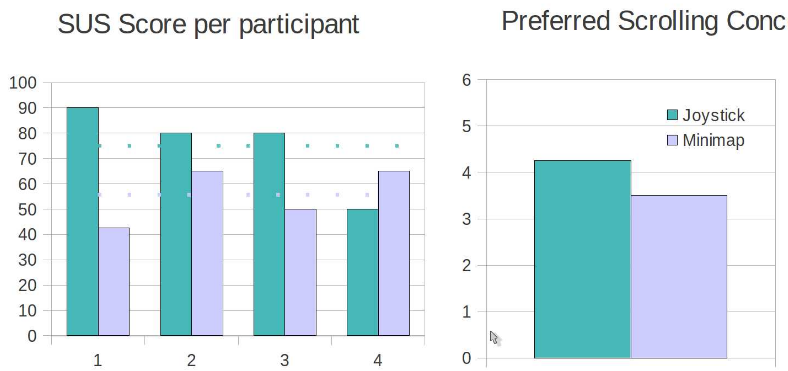

Figure 7: System Usability Scale (SUS) for each participant on the left side and the subjectively preferred concept on the right side

6.3 Qualitative Interviews

To be able to understand the reasons for the scores of the concepts and to learn which features worked well and which are problematic, qualitative interviews with the participants are indispensable. Overall, the qualitative interviews confirmed the results of the SUS questionnaire. The participants argued that the Radar-Joystick was much easier to use and more intuitive. In contrast to the Minimap, the participants did not need further explanation to understand the functionality. The major reason why they needed help to understand the Minimap functionality was the added dual functionality: If the user holds the finger on the screen instead of just tapping it or if the thumb initially touches the Minimap inside the rectangle showing the current cutout of the map, the Minimap switches to a Joystick similar mode to be able to vernier adjust the scrolling. This feature was added to overcome its precision problem. However, this feature was not obviously understood by our participants without further explanation. Thus, the intuitivity clearly suffers due to this added feature. The usability also suffers through the duality, because the participants sometimes activated the vernier adjustment feature although they wanted to just perform a tap and vice versa. This was the main source of frustration in our evaluation which consequently leads to the low SUS score of the Minimap. The reason behind the fact that the participants expressed the will to still use the Minimap in future can be thanks to its visualization part and its ability to quickly jump to the desired position on the map by tapping somewhere outside the rectangle. The visualization clearly gives them an overview about the whole incident area, the distribution, and triage state of the found patients and the quick-jump feature enables them to quickly jump to any position.

7 Discussion & Future Work

The outcome of our second iteration is clearly that a Minimap helps to get an overview about the whole situation and increase significantly the speed of scrolling. However, our try to enhance the Minimap to be also able to vernier adjust the scrolling confused our participants. Thus, the duality presented in our Minimap 2.0 concept should not be used. Instead, we suggest to just enable the feature to immediately jump to the desired position on the map by tapping the Minimap at the wanted position. But we also suggest to include the Radar-Joystick. Since in the suggested setup both UI elements are provided, the Radar-Joystick visualisation scaling can be reduced. It does not need to visualize the distances to all patients, since this can also be seen on the Minimap. Instead, the Radar-Joystick should only visualize the distances to patients, which are close to the current position of the tablet PC user. But this setup would use more space on the edge of the screen, which is actually another disadvantage. For this reason, another plan is to equip the Minimap with the Joystick. The Joystick is then faded when not touched by the user. Just a small circle will be visible to the user indicating that there is another functionality. Once this small circle is touched by the user, the Joystick will be opened and immediately enabled to be used by the user. And as soon as the user releases the finger from the Joystick/screen, it automatically collapses or fade again. In our next development, we will provide this setup and compare it with setups, in which both concepts are just provided separately. If the performance with the integrated and the separated concepts are approximately the same, the merged version can be used without apprehension.

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