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Usability Evaluation of a One-Handed Touch-based OR-Table Control

**Abstract:** Due to the increasing number and the complexity of devices in the operation room (OR), which are caused by the diversity and variety of proprietary interface designs, the probability for use errors increases. In order to ensure a safe intraoperative workflow in the OR, integrated OR systems with central work stations have been developed. For this, there also exist concepts for handhelds, which offer touch-based graphical user interfaces (GUI). However, those come along with various limitations, e.g. possibility for one-handed interaction, which is influenced i.a. by the size, the design and the working task. Within our investigations, requirements for an enhanced concept have been gathered by taking into account corresponding standards regarding ergonomics, risk-management and usability-engineering. According to DIN EN 60601-2-46, machinery directive 2006/42 EG and guideline VDI/VDE 3850, the stipulated user interface has been designed in order to preselect functions on the touchscreen and their subsequent activation by physical buttons. Furthermore, the accessibility of areas of interest has been considered on the touchscreen, to avoid the re-gripping of the handheld. As a first step, the OR-table control for a tablet has been realized with Microsoft Blend, using a 22' touch monitor. The usability study has been conducted in accordance with DIN EN ISO 9241-11 and IEC 62366. A group of ten surgeons and OR nurses underwent multiple tasks in the framework of a usability test, comparing the developed concept with a common keypad handheld. The study showed comparable results concerning the usability criteria effectiveness and efficiency. However, the concept clearly outperforms the handheld regarding user satisfaction, in particular due to the higher learnability and the easy transfer of daily-used GUI skills. The current approach motivates to develop a functional model of a touch-based handheld for OR-tables as well as with further integrated OR devices and to conduct additional usability studies.

**Keywords:** OR-integration, Human-Machine-Interaction, Touch-based control, handheld, OR-table, machinery directive, safe release, usability evaluation

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1 Introduction & Background

One of the main goals in Medical Engineering is to provide an effective and efficient use process, especially in a risk sensitive work system like the operation room (OR). In order to achieve that, the human-machine-interaction and their ergonomic requirements have to be considered. The increasing number of devices in the OR and their complexity raises the chance for use errors and deficiencies [1]. Furthermore, the user satisfaction is decreased by the inconsistent user interfaces of numerous companies [1][2]. Considering the economic relevance, 25-50% of the clinical patient costs are contributed by the treatment in the OR [3]. To improve this ratio, shorter intraoperative process times and the relief for the OR personnel can be achieved by a higher usability and therefore an open dynamic networking in the OR with standardised user interfaces [3].

Within this approach a central surgical work station [4] as well as a remote control with a graphical user interface have been developed. There a variety of devices and device functions can be integrated for a centralised control. Especially the interconnection of the OR-table as a central part of the OR has been focused [3].

The OR-table allows a safe patient body position with a proper access within surgical interventions and a safe monitoring for the anaesthesia [4][6]. For this, the OR-table offers various functions, which will typically be released by a hand unit with a keypad (depending on the degree of automation [5]). At present, there are also integrated proprietary OR systems like the Trumpf TruHybrid [7] and the Merivaara OpenOR [8], which include remote concepts with touch-based graphical user interface (GUI). Thus, the TruConnect [9] by Trumpf uses an eight inch touch screen that obliges the user to operate with both hands. The Merivaara Merimote [10] provides for a smaller, approximately 5 inch, touchscreen and two activation keys, mounted at the lateral top. Moreover, Maquet holds a patent [11] for a remote concept that consists of a commercially-
available smartphone, which is plugged in a case and technically-connected with a physical button. Although these concepts are taking advantage of a touchscreen as a combination of input and output device [12], they come along with various limitations.

The common one-handed posture to interact on a GUI is to use the thumb as the input [13]. Therefore, the index finger and others serve as the counterforce on the backside of the device [13]. By positioning the keys on the side of the device, users have to re-grip, leading to decreased usability [14]. The grasp also affects the accessibility of areas on the GUI [13], caused by the limited joint angles of the thumb. According to the size of the remote and unaccessible areas as well as the positioning of the release keys, the left and right one-hand interaction of these concepts seems to be uncertain. Thus, it seems inefficient and ineffective to have only one activation key (instead of two) in order to reduce the number of interactions and to adjust a movement of an OR table element instantly if needed.

According to DIN EN 60601-2-46, the machinery directive 2006/42 EG and the guideline VDI/VDE 3850, which are defining high requirements for service conditions, patient and user safety, it is necessary to first select any function on a touchscreen and afterwards release the selection by a physical button. A hand unit should also ensure an emergency stop. Quite in contrast through most of the keypad remotes, none of the existing concepts provides for a safety-critical stop button [9][10].

2 Material & Methods

To gather user requirements regarding the human-machine-interaction and usability of OR-tables, an online survey with 69 participants and interviews with experts from notified bodies and medical experts at the clinics RWTH Aachen university clinic (UKA) and the St. Joseph-Stift Bremen have been initiated. These investigations showed that users especially prefer a medium sized one-hand control, an intuitive GUI and a protection mechanism against an accidental movement release. On the other hand, disadvantages of using a touch-based control have been mentioned (e.g. using gloves, a sterile foil or dealing with fluid on the touchscreen).

Although the OR-table is a first class medical product [15] there are safety-critical functions of the OR-table which provide potential serious harm for the patients: Movements by the column or table top, Mobility (Floorlock and motorized 5th wheel) and Emergency-Stop. Contrary to these, the adjustment of further functions like the table settings does not implicate patient harm. So, the aim of the concept should allow a guaranteed one-handed grip to hold and to operate on the touch-based GUI in order to release in particular the risk-sensitive functions in a safe way.

Involving the actual analysis of the requirements so far, the concept has been designed as a combination of a touchscreen and three physical buttons. The required emergency stop can be initiated with one button. The others are meant to function as soft keys, for the selected functions from the GUI (Figure 1).

![Figure 1: Process flow chart for the GUI](image)

The physical buttons are positioned on the front-bottom of the tablet. Therefore the thumb can be used for the touchscreen as well as the physical keys. Caused by the hand posture at the low end, the upper part of the GUI provides information and the adjustment of function assignment to the soft keys. This is to avoid shifting the control in the hand, due to unaccessible areas. By using the usability and human risk analysis method mAIXuse, the concept has been pre-evaluated and afterwards enhanced regarding aspects e.g. the layout of the tabs. Then the concept has been implemented with Microsoft Expression Blend for the use on a touch-monitor in the laboratory of the Helmholtz-Institute.

To test and evaluate the developed concept in comparison with the Trumpf TruSystem 7500 OR-table, which offers a keypad remote combined with a small touchscreen for settings and positions e.g. memory of a table position or Beach Chair as a specific position, a usability study with a group of ten surgeons and OR nurses form the UKAachen has been conducted. The studies framework contained multiple tasks, where the subjects had to release
table functions or to adjust settings. Subsequently, a questionnaire to detect comprehensibility, advantages, disadvantages, opportunities, threats and the user satisfaction have been handed out.

2.1 Usability criteria

To verify the usability criteria effectiveness, efficiency and user satisfaction, the design and evaluation of the study was set up in accordance with DIN EN ISO 9241-11, IEC 62366 and ISO/IEC 25062.

The effectiveness of each task is determined by calculating the success rate, which is defined as the number of subjects, which passed the specific task in relation to the number of subjects (see equation 1).

$$\text{success rate} = \frac{\text{number of subjects, which passed the task}}{\text{number of subjects}}$$ (1)

The efficiency of any task is identified by two parameters. At first a key figure has been determined, which compares the inefficient steps of a task with the efficient ones (see equation 2). We set an upper limit of 1/3 as the minimum steps of the concept are three and allowing the user one error also. An error has been defined as a false activation of a function.

$$\text{key figure} = \frac{\text{errors}}{\text{minimum step}}$$ (2)

Moreover, in order to rate the efficiency the time for task fulfilment by the subjects has been assessed.

To investigate the user satisfaction and learnability during the study, the subjects conducted the Thinking Aloud technique while performing the tasks. Afterwards, a questionnaire with free texts options as well as the 5-point Likert-scale has been conducted.

3 Results

The study showed an improved usability of the developed concept. Thus, the effectiveness of both systems has been similar with a success rate of 84% and 85% (Figure 2). However, while operating with the concept, the users were confused through the ambiguous wording of two adjustable speeds in task 4 (drive speed referring to mobility and table speed referring to movement of table segments). When excluding this task, the success rate of the new concept reaches an average of 96%. As seen in Figure 3, until the second half of the tasks the users didn’t make any mistakes at all. The major issue of operation on the remote control from Trumpf has been the confounding of different directions (task 7) or table segments to be adjusted (task 6), e.g. caused by small and incomprehensible icons.

The efficiency, measured by equation 1, of the concept has a minimal advantage in comparison to the Trumpf remote, due to the fully given efficiency in the second half of the tasks (Figure 3). In accordance to the opinion of the subjects and also the observations, this was caused by a short acclimatisation period of using the touch-based GUI.
The Trumpf lacks in the same above mentioned factors. When taking into account the less required minimum numbers of steps to pass a task, the compared efficiency of the Trumpf seems even lower. But regarding the efficiency (Figure 4) this circumstance affects the measured time of Trumpf in a positive way. However, the subjects took an unusual long time for task 1 with the concept, which is caused by the acclimatisation process with the GUI and its operational logic.

The evaluation of the user satisfaction showed a clear advantage of the concept, due to the higher intuitivity of the GUI. The unanimous opinion by the subjects shows a higher learnability of the concept, which can also be detected by the improved operations at task 5 to 8. All in all, the subjects would prefer to use the concept in their daily working routine in comparison to the Trumpf handheld.

4 Discussion and Results

The interaction-centered usability evaluation showed a deficit according to the number of subjects and their experience. Furthermore, the Wizard-of-Oz usability test has been realized on a touch monitor instead of a tablet, due to the fast implementation possibility of the GUI in Microsoft Blend. Nevertheless, the study proved the users’ acceptance of the touch-based concept and the easy transfer of their daily skills using tablets and smartphones. Due to that, it seems reasonable to realize a functional model of a touch-based handheld for OR-tables and additionally to integrate further devices and functions. Therefore, the standard IEEE 11073, e.g. developed in the project OR.NET [16], can be used for the implementation of any device. To build up the handheld, a commercially-available smartphone or tablet can be used in specific housing, which offers the required physical safety buttons. By doing that, e.g. the US patent by Maquet [11] has to be taken into account. Thus, additional usability studies have to be conducted to evaluate the final model. These should allow the comparison to common keypad remotes as well as other conceptional touch-based handhelds. We also recommend to implement this concept for a mobile and motorized operating table.

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