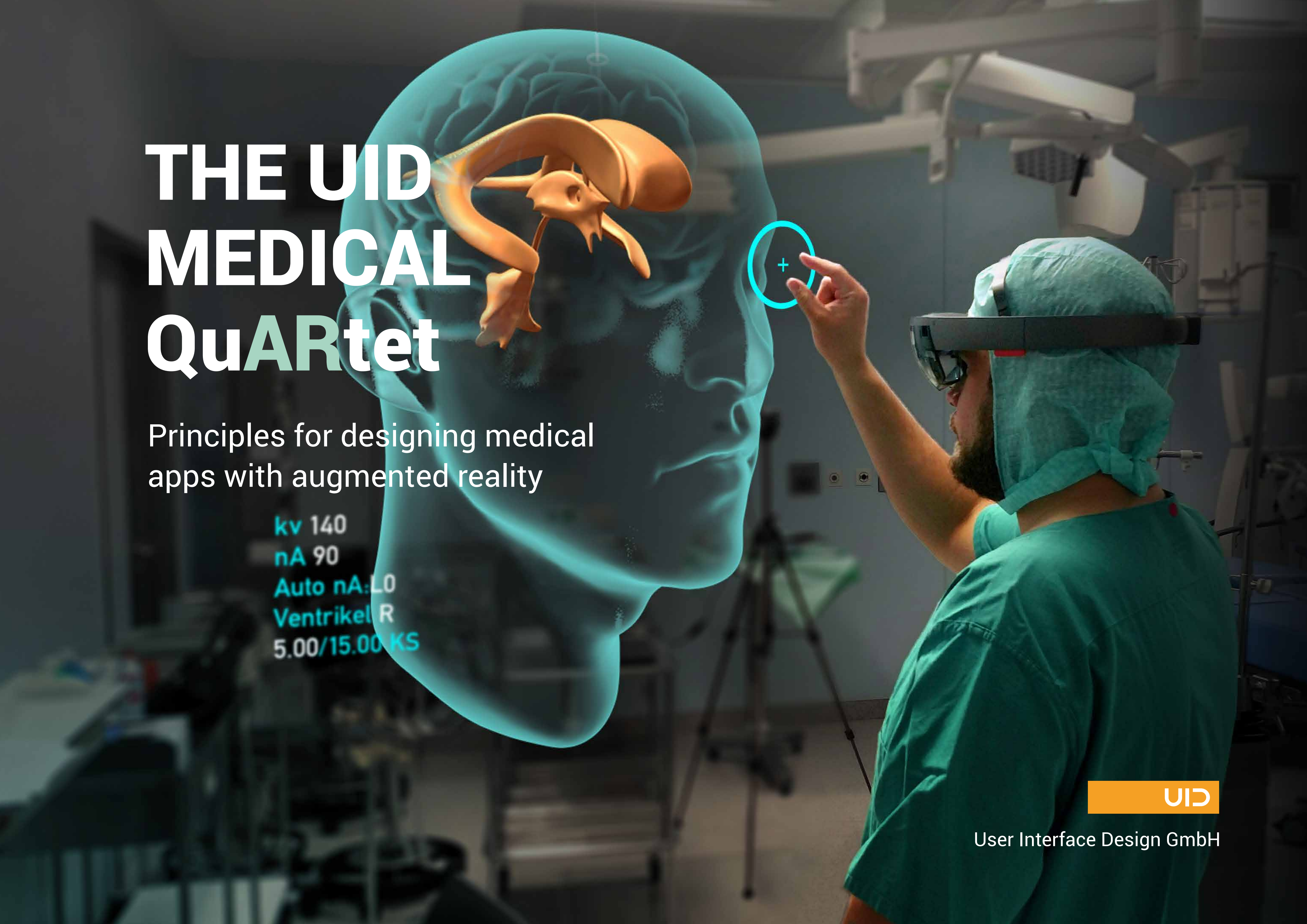

THE UID MEDICAL QuARtet

Principles for designing medical apps with augmented reality

User Interface Design GmbH

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CONTENTS

INTRODUCTION

Abstract

In the "HoloMed" research project, we are working together with our partners to develop an app for Microsoft HoloLens, whose augmented reality (AR) functionality supports neurosurgeons in the operating room. Based on the experience we have gained throughout the entire project we have been able to derive key principles for using AR in a medical environment. We have now summarized these principles in guidelines, the "UID Medical Qu**AR**tet", under four basic recommendations:

- **avoiding distraction through clarity**
- **giving feedback and support with precisely positioned, contextual virtual alignments**
- **considering the real environment when designing virtual elements**
- **adapting tasks and interaction methods to the hardware used**

About this study and "HoloMed"

Many guidelines describing the use of AR have already been published. However, when using the technology in a medical context, these strategies often don't go far enough: The patient's safety has to be guaranteed at any time, which makes it necessary to precisely track and position the holograms. In addition, the working environment entails special challenges: The lighting can vary considerably and strict hygiene regulations need to be complied with. Anyone who uses AR in the medical field needs to be guaranteed 100% reliability, safety and precision. In order to achieve this, special guidelines are essential.

In the "HoloMed" research project, we are developing an application for Microsoft's HoloLens AR glasses together with our partners. The application supports brain surgeons during ventricular punctures. Even though this intervention is among the most common ones in neurosurgery, it is an error-prone task, the main reason being that the surgeons cannot see the target of the puncture — the ventricle. In order to puncture the ventricle in case of a malfunction or a trauma, they have to drill a hole into the skull and insert a catheter. Currently, the puncture site is still identified via external anatomical landmarks (e.g. eye socket, ear canal). Using this approach, however, the catheter is only optimally placed in two-thirds of the punctures. The goal of "HoloMed" is to reduce this high error rate. To achieve this, the patients' CT and MRT data are projected on their heads with millimeter precision. Graphical elements help the surgeons to locate the correct position and angle for the puncture.

Image 1: “HoloMed”’s preliminary user interface

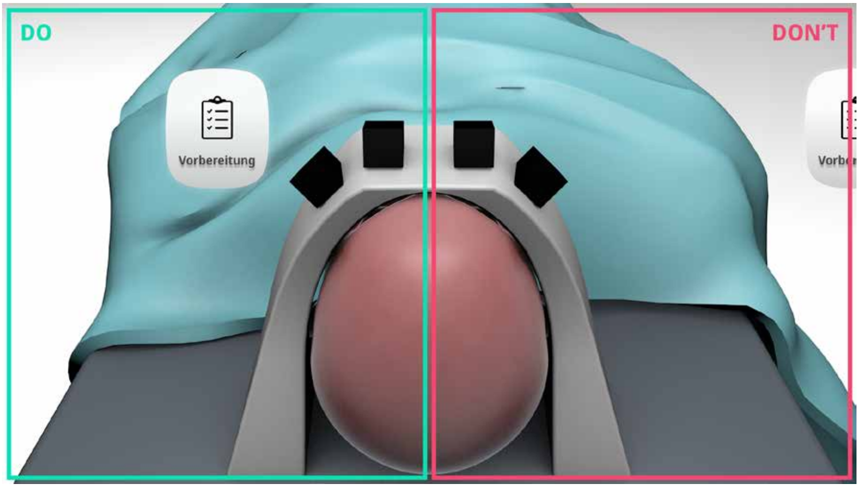
In order to perfectly adapt “HoloMed” to the users’ requirements, we have integrated neurosurgeons into the development process right from the start by analyzing their requirements onsite, testing our prototype a number of times under real-life conditions and including the resulting feedback in several iterative runs.

Now we would like to share the expertise we have gained in order to support UX designers in developing AR applications for medical environments.

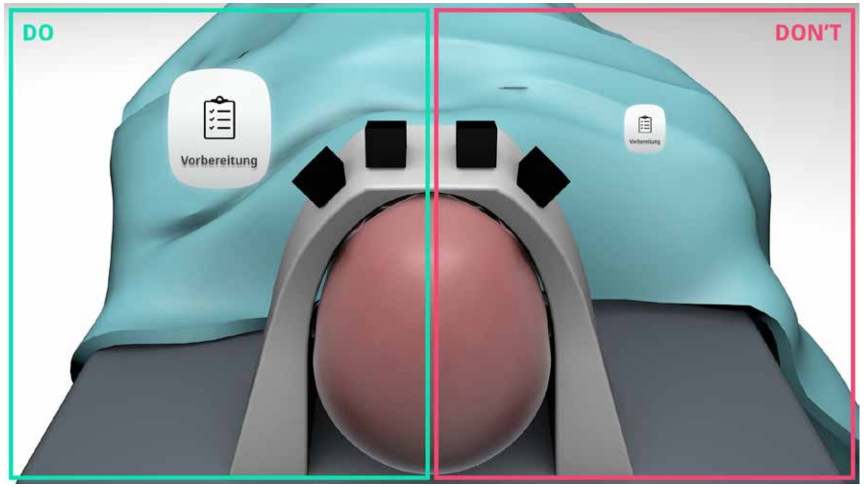
1 FOCUS & CLARITY

Avoiding distraction through clarity

In general, AR offers the possibility of positioning holograms 360 degrees around the neurosurgeons. In operating rooms, however, the **focus** has to be on the patient (image 2). Virtual elements should therefore be positioned in a way that ensures that the surgeon doesn't have to turn away too far from the patient (illustr. 1). Any distraction can lead to errors. Since **clarity** reduces the danger of distraction, the dialog between the user and the system needs to be clear and easy to understand. Depthwise, Holograms shouldn't be displayed too close or too far away (illustr. 2).



Illustr. 1: Positioning the holograms close to the patient preparation



Illustr. 2: Distances

The closer or further away holograms seem to be, the more confusing the information displayed in the surgeon's field of vision may become, potentially causing discomfort for the user of the glasses. It is therefore essential to properly arrange the individual elements in depth.

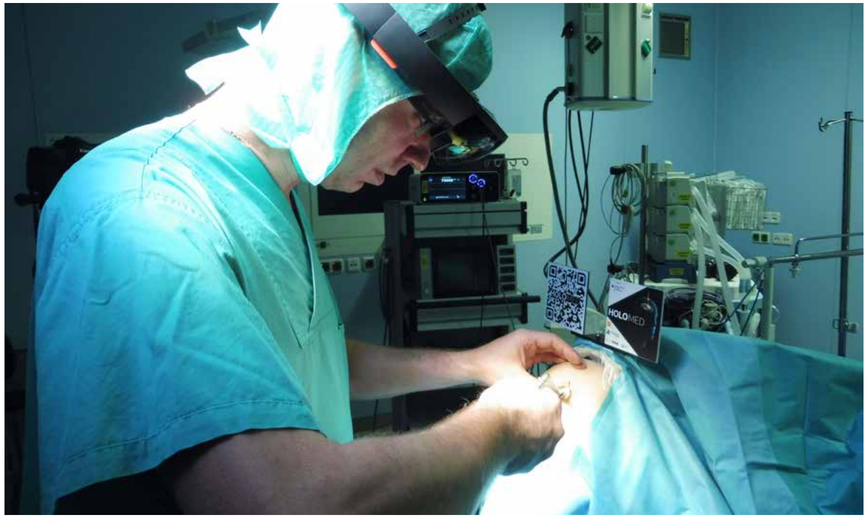
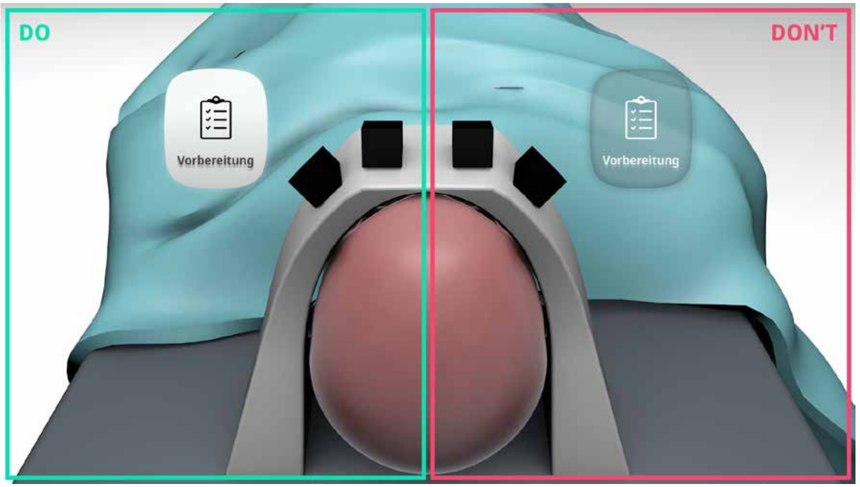


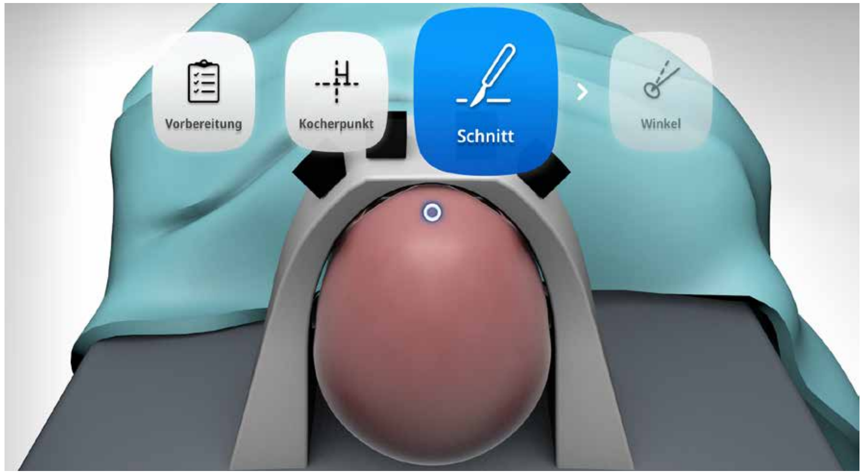
Image 2: The surgeon's focus is on the user.



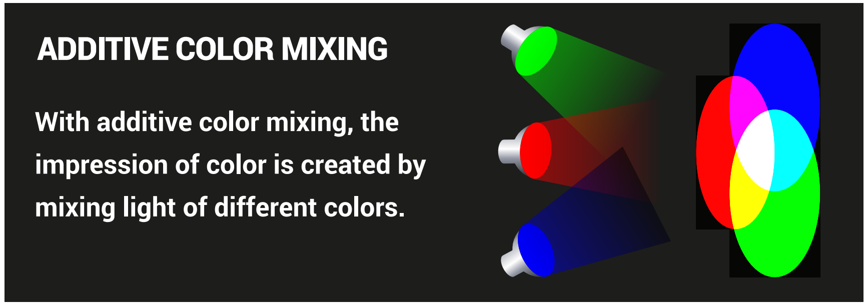
Illustr. 3: Clearly legible fonts in front of high-contrast surfaces

On the other hand, the optimal readability of the holograms requires clearly legible fonts, font sizes and colors with sufficient contrast against the background (see also "Environment and Context").

In the "HoloMed" project, we achieved this by displaying texts in front of high-contrast surfaces (illustr. 3). However, black should be avoided for surfaces, since the additive color mixing specified by HoloLens causes transparency. Augmented reality holograms are created by mixing light of different colors. Therefore, a minimum of light is needed to display black holograms, as a result of which objects become invisible.



Illustr. 4: Display according to work step (preparation, Kocher's point, incision, drilling)

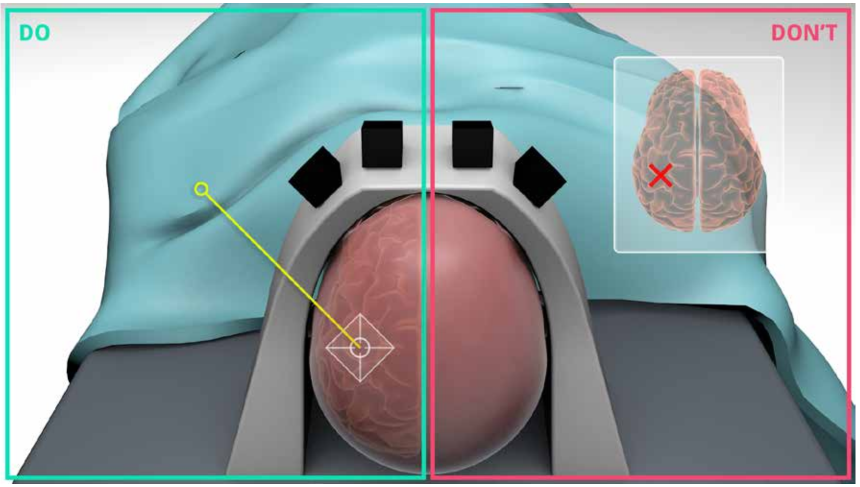


Moreover, only the most important elements should be displayed so as to ensure that the surgeon's field of vision is not obstructed. In "HoloMed", we used a dynamic approach to overcome this challenge. By only displaying the elements necessary for the current work step (workflow orientation) (illustr. 4), the surgeon doesn't lose focus. Holograms that move too fast (in depth) can attract the surgeons' unintentional attention or irritate them.

2 FEEDBACK & ALIGNMENT

Giving feedback and support with precisely positioned, contextual virtual alignments

Another specific advantage of AR is that **holograms or feedback** on the interaction can be directly displayed on real objects and thus on the respective points of reference (illustr. 5). The drilling angle indicator, for example, is displayed right where the surgeons need it, i.e. at the puncture position — the point of reference — on the head.

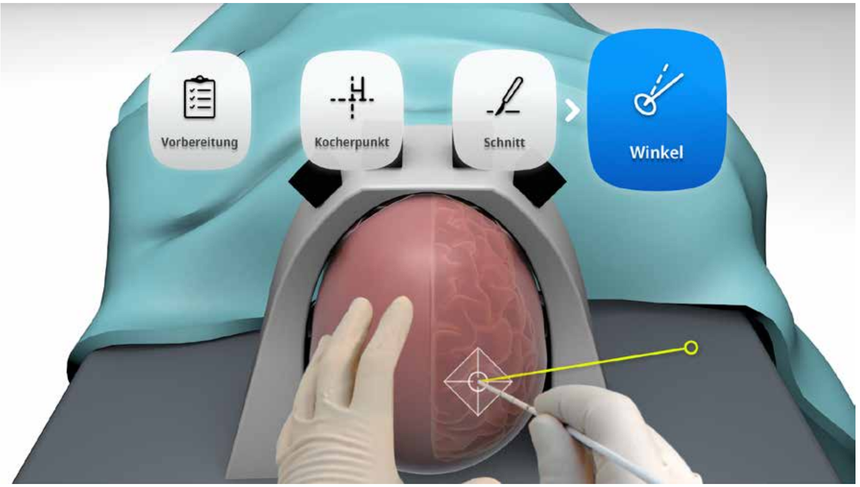


Illustr. 5: Displaying object statuses at the point of reference (e.g. Kocher's point on the head)

AR deals with the **alignment** of real and virtual objects. Especially in surgery, the highest-possible precision in placing, aligning and sizing the holograms is indispensable to achieve safe results. In order to ensure such precision, appropriate tracking technologies need to be employed. The tracking feature has always been a special challenge for "HoloMed" (image 3). By connecting to the hospital's network and retrieving the patients' individual data (e.g. CT and MRT scans), we managed to improve the precision.

Image 3: Marker tracking used in "HoloMed"

The positioning of the holograms directly at the point of reference also had negative effects. Some real objects were covered by virtual elements, an effect the surgeons described as “irritating”. We solved this problem for “HoloMed” by displaying pulsating elements instead of constantly visible feedback (illustr. 6). This ensures that objects are aligned as exactly as possible while avoiding to cover the real objects.



Illustr. 6: The drill is covered by the drill angle visualization

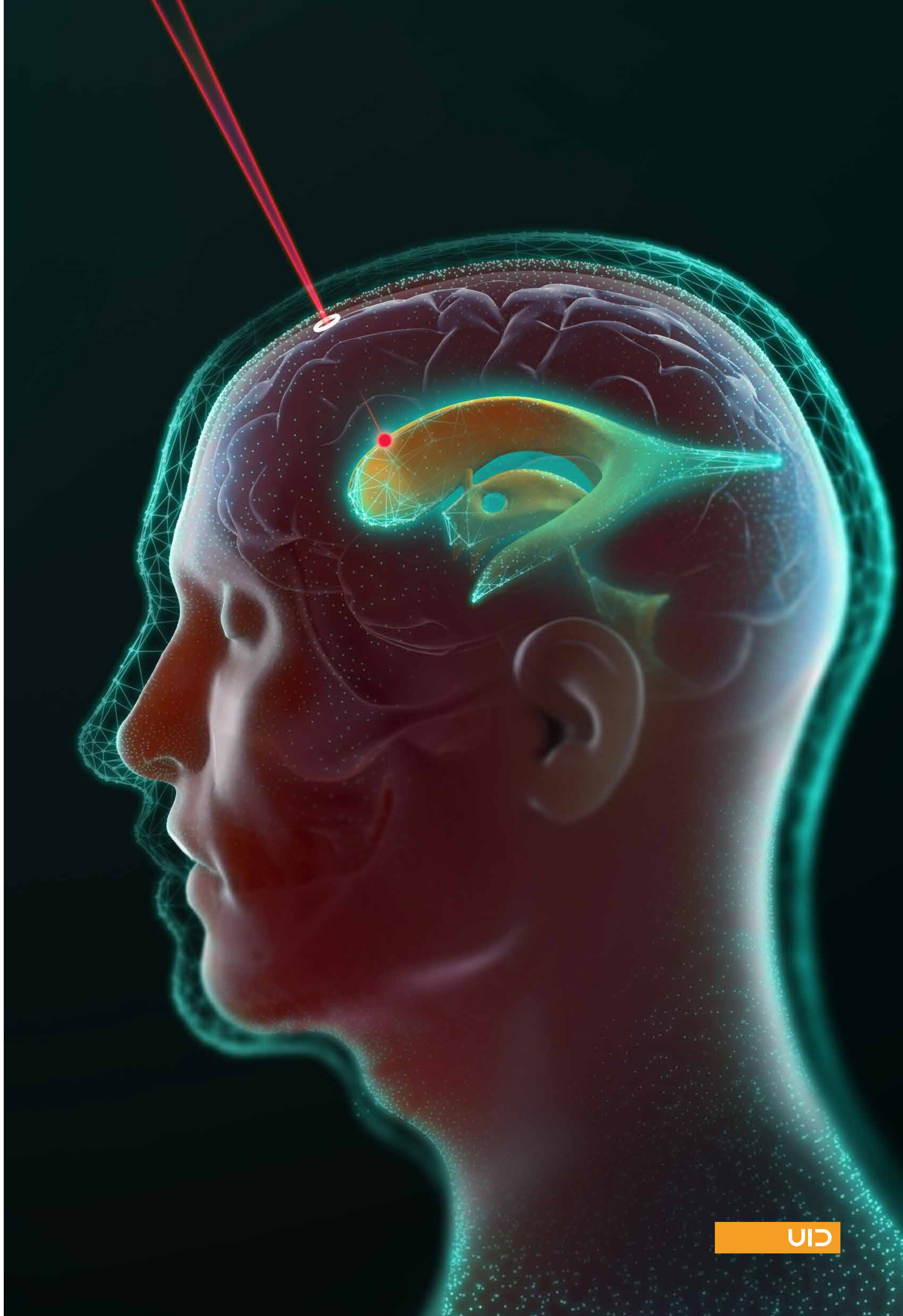
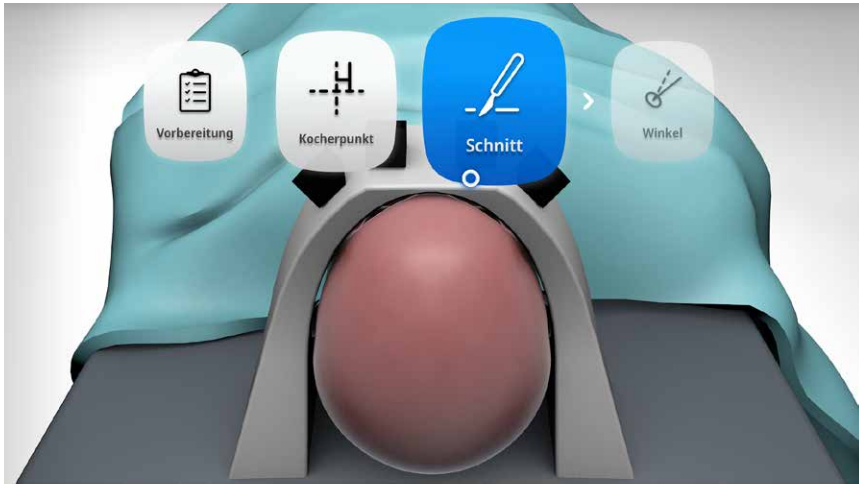


Image 4: Special bright light sources and blue walls in the operating room



Illustr. 7: High-contrast UI elements

3 ENVIRONMENT & CONTEXT

Considering the real environment when designing virtual elements

In AR, the virtual and the real environments are closely connected. When displaying holograms, the **environmental context** needs to be considered. This includes the **lighting conditions**: In operating rooms, extremely bright light sources are used to illuminate the working area as best as possible (image 4).

Additive color mixing may have negative effects on the visibility of the holograms. These are created through light, which may interfere with the ambient light. It is therefore not advisable to use very dark colors (see also Focus & Clarity). On the other hand, the **color temperature** of the light and the environment (walls, ceiling, etc.) has to be considered, too, in order to ensure that the necessary contrast level is achieved. Depending on the color scheme used, the holograms have to blend in with or stand out against the environment (illustr. 7).

The **auditory component** of the environment can also influence the form of interaction. During loud work steps (e.g. drilling), voice control is not the method of choice, since voice commands cannot be reliably identified and analyzed.

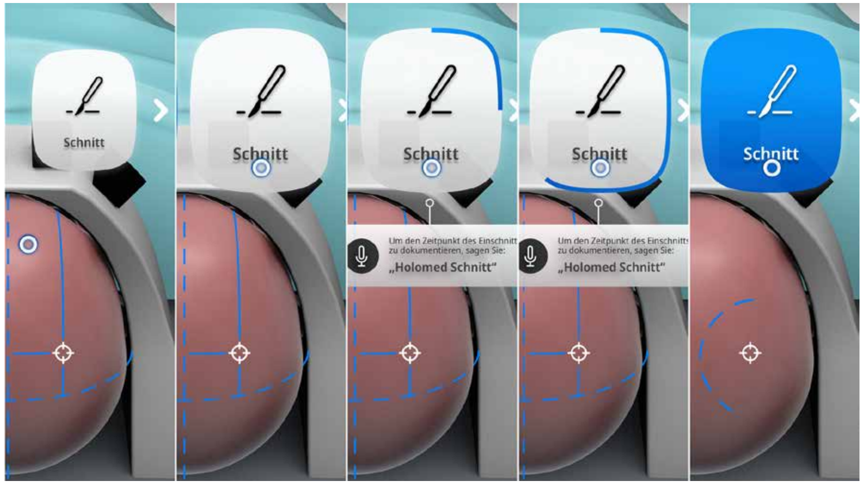
And last but not least, the **boundary surfaces** of the room need to be analyzed and considered: Holograms should not protrude into the walls but should be positioned on plane surfaces — our surveys revealed that this is what the users expect. The proper positioning can be facilitated by relevant contextual feedback, such as markers.

Image 5: Numerous instruments for which surgeons need to use their hands

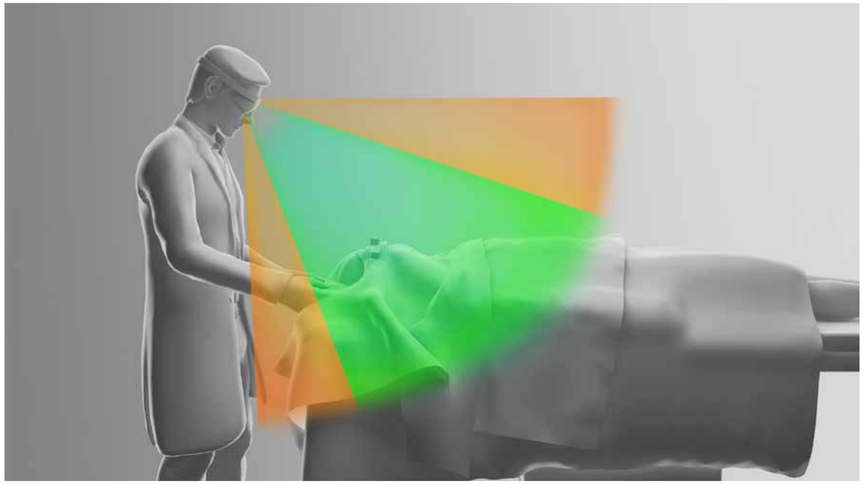
4 TASK ORIENTATION & INTERACTION

Adapting tasks and interaction methods to the hardware used

Task orientation is a widely acknowledged design principle, not only for AR. In this context, several special requirements with regard to hygiene and safety have to be considered in the medical field. In addition, the method of interaction has to be adapted to the hardware used. The new AR data glasses offer **interaction methods** that are suitable for the tasks carried out by surgeons. In the "HoloMed" project it became evident that hands-free interaction has major advantages: The neuro-surgeon does not have to put down the real instruments or turn away from the surgical site in order to use the application (image 5).



Illustr. 8: Long-gaze interaction and voice control



Illustr. 9: Favorable/unfavorable rotation angle of the head

In order to control the application without gestures, "HoloMed" uses voice control and long-gaze interaction (illustr. 8): The user activates elements by focusing them with a cursor, which is controlled by rotating the head, for a specified period of time. In this interaction concept, however, the doctor's physical health and ergonomics need to be considered: holograms, for example, should not be positioned too far apart so that the surgeons are not forced to use head movements that harm their physical health (illustr. 9).

Moreover, operating errors or slow reactions caused by too short or too long focus times need to be avoided. When individual elements are only focused for a short period, they should not be activated in order to avoid operating errors. At the same time, too long activation periods — especially in time-critical interventions such as ventricular punctures — can cause dissatisfaction with the users. In our case, activation periods of between 1.5 and 2 seconds have proven to be appropriate.

OUTLOOK

Our "HoloMed" project demonstrates that AR is perfectly suitable for use in medical engineering. The technology supports surgeons in their work and makes procedures more efficient while increasing the patients' safety. But the project also shows that, especially in a medical context, special dangers and risks need to be considered.

Our guidelines were drawn up to help identify these risks fast and react adequately in order to make full use of the potentials of AR.

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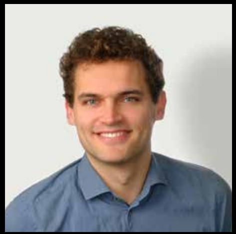

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