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Explore and Experience: Mobile Augmented Reality for Medical Training

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Abstract

In medicine, especially in basic education, it may sometimes be inappropriate to integrate real patients into classes due to ethical issues that must be avoided. Nevertheless, the quality of medical education may suffer without the use of real cases. This is especially true of medical specialties such as legal medicine: survivors of a crime are already subjected to procedures that constitute a severe emotional burden and may cause additional distress even without the added presence of students. Using augmented reality based applications may alleviate this ethical dilemma by giving students the possibility to practice the necessary skills based on virtual but nevertheless almost realistic cases. The app "mARble®" that is presented in this paper follows this approach. The currently available learning module for legal medicine gives users an opportunity to learn about various wound patterns by virtually overlaying them on their own skin and is applicable in different learning settings. Preliminary evaluation results covering learning efficiency and emotional components of the learning process are promising. Content modules for other medical specialties are currently under construction.

Keywords:

elearning, mobile augmented reality, competency-based education, medical education.

Introduction

Motivation of mARble®

The patients and their conditions and concerns should always be at the center of attention in medicine. Beginning at an early phase of their education, medical students must learn about all aspects of interactively dealing with patients, their concerns and diseases as well as necessary diagnostic and therapeutic procedures. During the course of their studies, students must master the complex scientific background information without losing track of the "human factor." In the Model Medical Education Program "HannibaL" which is currently in use at the Hannover Medical School, students come into contact with patients at a very early stage: patients and their symptoms are a core aspect of this educational concept and are used to solidly embed both basic and clinical knowledge. Already in the first year, medical rounds to carefully selected cases serve to introduce students to the necessary knowledge and medical approaches to certain issues. In this way, practical and theoretical knowledge are closely interlinked with each other during the learning process. In the second year of their studies, students are presented with case based learning modules that integrate various medical specialties and put an emphasis on diagnostic methods. In small groups, students work intensively on acquiring the necessary skills. These skills are later tested in life-like "Objective Structured Clinical Examination" where actors pose as patients. Clinical basics are taught during clinical electives that students are required to attend. During these electives, students and their tutors critically discuss the presented cases. In the third year, the most common diseases of internal medicine are reviewed from an interdisciplinary standpoint and students are given the chance to practically apply the theoretical knowledge they gained on real patients during a block training phase. These training phases promote independent learning and working. They help to provide students with the necessary skills and to deepen their understanding. During the fourth year, additional subjects are integrated into the courses, and in their final fifth year students gain even more practical skills, train differential diagnoses and learn about various therapies using case studies; the acquired skills and knowledge are later tested in case based examinations.

As mentioned, the transfer of practical and theoretical knowledge is closely interwoven in HannibaL. The success of the HannibaL concept greatly depends on the presentation of adequate cases whenever necessary. For various areas of medicine, at least during the basic education, it may be inappropriate to use real patients for practical purposes since ethical constraints must be observed. This necessitates an approach that still allows students to make experiences similar to what would be possible in a real patient encounter but without the risk of causing any harm to patients.

Example: Education in Legal Medicine

Forensic examinations are carried out by forensic specialists who objectively document the findings they acquire from victims and alleged perpetrators, e.g. injury patterns or traces, in a legally correct way. The aim is to provide objective incriminating or exonerative evidence to be used by law enforcement officials as well as for possible legal proceedings. This may touch areas such as determining tools responsible for inflicting a specific injury, the underlying mechanisms, whether the inflicted injury was life threatening, the age of an injury, but also whether someone was legally competent at the time of the event under consideration. In most cases, examinations ordered by public prosecutors take place in different settings, e.g. directly at the crime scene, in a patient's room or also in a prison cell.

In their fifth year, students are first introduced to the basic aspects of legal medicine. Standard lectures, tutorials and practically oriented classes establish a knowledge base of the subject for their later professional careers. Students participate in a post-mortem examination; they are also presented with clinically relevant findings such as certain wound patterns that may point to the influence of physical violence by a third party. In addition, they learn about the basic techniques of acquiring forensic evidence and the normal procedures of dealing with investigating authorities.

During the course of the legal medicine module, in some cases it may be sufficient to simply present desired findings to the students using available image material and corresponding

information. On the other hand, students greatly benefit from a more realistic presentation or a hands-on approach, i.e. "learning the job by doing the job." However, the integration of victims, e.g. survivors of a sexually motivated crime into classes in order to present fresh injury patterns is ethically unadvisable since the presence of students could re-traumatize the victims and thus unnecessarily add to their emotional distress. Nevertheless, without using real cases when deemed necessary, the quality of medical education may suffer.

Mobile Augmented Reality

A potential workaround for this dilemma may be the integration of augmented reality (AR) based learning modules that make it possible for students to practice examination or interview techniques in simulated situations. In this way, an interactive alternative to bedside teaching is provided that makes it possible to respect ethical boundaries. The mobile app "mARble®" that is presented in this paper follows this principle and can be used in a variety of settings, including a "skills lab" for forensic medicine or other medical specialties, whenever the integration of real patients may be problematic. For example, for legal medicine, with the help of augmented reality, relevant wound patterns may virtually be projected onto the bodies of the students to simulate certain findings. AR technologies make it possible to bridge the gap between the real, physical word and virtual reality by overlaying a real scene with additional, digitally available information that can be presented in various ways [1]. The aim is to let users interact with the scene including the presented additional information. Often, objects of the real world, e.g. certain equipment or tools are also integrated in this process.

Due to its variability, augmented reality may be applied in many different settings. In the early days, applications making use of augmented reality were often restricted to stationary use, i.e. computers and laptops with appropriate camera techniques, due to limitations in computing power. Nowadays, the hardware of mobile devices has become powerful enough to allow the integration of augmented reality in mobile application scenarios. When looking into the application stores of common mobile platforms, many of the available AR based apps simply add information to the scene acquired using the device's camera by evaluating geolocation data. Other available apps making use of AR technologies are games or simulations of certain processes.

In medicine, augmented reality based applications – independent of whether they are used in a stationary or mobile setting – can be divided into different categories. On the one hand, there are applications that offer AR supported simulations for specific diagnostic or therapeutic procedures such as laparoscopic surgery [2] and may also be used for educational purposes. Other applications simply add information during diagnostics or therapy, e.g. intraoperatively [3]; however, when used for such purposes, one may question whether "too much" information may for example have a negative influence on the surgeon's attention [4].

Augmented Reality Based Educational Concepts

Outside of medicine, application scenarios for augmented reality include the simulation of more or less complex processes by simply enhancing the depicted scene by overlaying information. One of the first concepts that integrated augmented reality in a common educational setting was the "classroom of the future" [5] which had the goal of improving the interaction between students and teachers. Other interesting early educational concepts covered many different areas including diverse subjects such as geography [6] or mathematics [7]. All these approaches have in common that they allow the presentation of complex processes or relationships in a comprehensible manner that would simply not be possible using conventional learning materials. Nowadays, many AR based approaches are embedded into complex learning scenarios, with AR being only one – but still important – part of the learning experience offered to the students [8]. With careful planning, mARble® can be integrated into complex learning scenarios for medical education in a similar manner.

Methods

Use Case: mARble® "Forensic Medicine"

The technical realization of mARble®, including the principles, components and libraries on which the multi marker detection integrated into the app has been based, will be part of a separate, more technically oriented publication. In this paper, the primary emphasis will be placed on the functionality of the app and its practical application. A use case can be described as follows: when starting, one or more paper based markers containing characteristic black and white patterns (Fig. 1) are placed within the scene. These markers represent specific digital content, e.g. depictions of certain wound patterns that will be integrated into the scene acquired through the mobile device's integrated camera. Figure 2 (top left) shows such content being overlaid onto the upper chest of a student: the app detects the marker in the scene in real time and adds the required virtual information; thus, a mixed image is generated. As soon as the angle or distance of the camera changes in any way, the projection of the wound pattern is adapted accordingly, i.e. it becomes smaller or larger or the angle of the projection is adjusted so that the projected image or pattern always stays in sync with the plane – in our case, the student's chest – on which the paper based marker has been placed.

In the example shown in Fig. 2, the marker is replaced by a representation of a gunshot wound. In addition to the depiction of the wound, it is also possible to provide practice questions and corresponding answers, e.g. the user may be asked about the "characteristics of a gunshot wound."

Following a flashcard like concept, both questions and answers are presented in textual form as well as voice output. To enhance the learning experience, complementary content, i.e. multimedia content such as additional images, audio or video material, is accessible.

By calling up an answer, users can check their learning progress. In the form of images and videos, it is also possible to document the steps taken during the learning process for later reference, presentation purposes or discussions with other learners or tutors. Via a personal gallery, users have full access to the data they generated in this way.

In its current implementation, mARble® was developed for the iOS platform (for all phones and tablets with an integrated camera) using XCode/Objective-C 2.0. The marker detection is based on the C++ version of the open source NyARToolKit 0.9.0. Since the NyARToolkit only contained the core functionality for detection of the markers and calculation of the

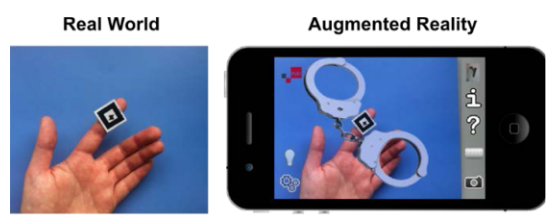

Figure 1 – mARble® running on a mobile device

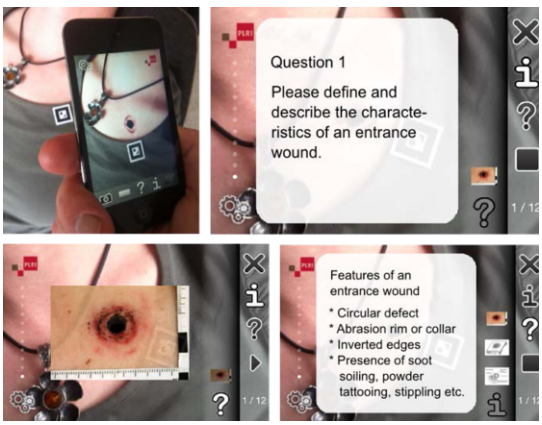

Figure 2 – Use case "Legal Medicine", top left to bottom right: "Mixed image" of a shotgun wound overlaid onto a student's body, flash cards with questions, additional multimedia content and corresponding answer.

necessary spatial transformations, the toolkit had to be extended to allow multi marker detection.

Content is always kept separate from the application's source code: for content management purposes, mARble® uses an XML based file format that makes it easy to change and adapt the available content and even implement content for new subjects. In a later stage, this would also make it possible to easily reuse the generated content should it be decided to port mARble to other mobile platforms.

Key Functionality of mARble®

The application content can both be called up using the markers as well as accessed via navigation elements that are displayed on the screen. These elements also make additional features available. They remain accessible even when virtual content has been triggered via a detected marker. Screenshots of the currently displayed content can be generated using the camera symbol at the bottom. The images can later be viewed via the image gallery symbol. If the surroundings are not sufficiently illuminated, the LED flash of the device (if available) can be activated using the light bulb symbol. An electronic ruler is provided for either measuring the distance between the marker and the mobile device or to determine an object's size. The corresponding values are displayed near the top border of the display.

Sample questions for the currently active medical condition or wound pattern can be accessed via the question mark symbol, corresponding answers are provided when the information symbol is selected. A progress indicator shows the progression of the user through the available content. By choosing the × symbol, users can exit the interactive presentation of additional information, questions and answers.

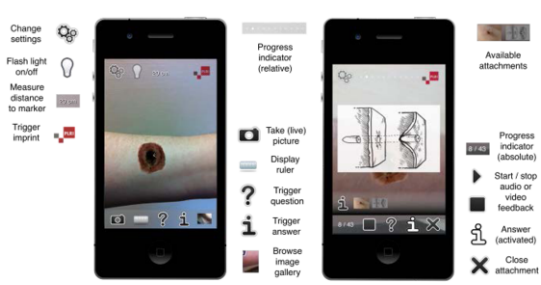

Figure 3-Navigation elements of mARble®

Preliminary Evaluation

In a preliminary study, six third year students were provided with iPhones with a preinstalled copy of mARble®. After they had the chance to learn using mARble® for 30 minutes, they were surveyed using an AttrakDiff2 questionnaire based on Hassenzahl's paradigm of experience design [9]. According to Hassenzahl, this approach allows to determine the emotional involvement of the users in a product as well as its pragmatic qualities and usability.

Results

The standardized content available from within the application may easily be used in a number of settings, for example in group sessions, but also in a stand-alone fashion. Students get the chance to replay cases that have been presented in a class without having to observe the usual restrictions regarding time and location. In addition, compared to conventional classes, with mARble®, users have to take a more active role in the learning process by integrating them as learning objects in their own learning process. Learners can make experiences either on their own or in a group setting in order to gain a deeper understanding of the presented material. By making use of mARble's XML based content management, the teaching staff can easily add new material and cases without having to do any programming or losing additional time due to complicated editing tools [10, 11]. Just as for other teaching methods, the main task for the staff is to collect the necessary information as well as the corresponding image and multimedia material.

Results for the preliminary evaluation using Hassenzahls AttrakDiff2 questionnaire showed an average value of 0,381 (CI: ±0,492) for pragmatic quality. The calculated mean value for hedonic quality, which includes stimulation, identification as well as attractiveness ratings, was 1,179 (CI: ±0,440). According to Hassenzahl's method, mARble's pragmatic quality (which represents its usability aspects) is in the average range, while the hedonic aspects were rated above average, which is attributable to its high attractiveness. In a non-standardized follow up interview, the participants were interviewed regarding their emotions while using the app. Users consistently confirmed that using mARble® was stimulating, fascinated them and they were also in favor of its interactivity. Negative emotions such as dissuasive effects or disturbing properties were consistently denied. For the flashcards, the immediate feedback provided by the available answers was rated positively.

Discussion

Due to the small number of participants and the study design, the current results may only be used for generating hypotheses. A comparative follow up study is currently in preparation. It will include a much larger number of participants and will also take a closer look at the various emotional and practical aspects of using mARble®. An additional emphasis will be placed on the learning efficiency compared to standard textbook based learning material.

Conclusion

The widespread use and high availability of mobile devices among students are an "alluring option for teaching and learning [12]." This is also stated in the Horizon Report published in 2010 [13]. The authors specify that "the portability of mo-

bile devices such as smart phones and their ability to connect to the Internet almost anywhere makes them ideal as a store of reference materials and learning experiences."

The integration of augmented reality based solutions into existing curricula opens up new ways for medical education and has the potential to significantly improve the learning process while additionally giving learners the opportunity for learning independent of the usual constraints regarding time and location. Compared to conventional learning materials and approaches, mARble® is probably more able to catch the attention of today's students who have already grown up using the Internet and mobile devices. In addition, when using the app, it is possible to learn in an almost realistic manner independent of whether a real case is available or not. Users are not negatively influenced by feelings of anxiety or reservation that might come up in situations that are potentially demanding in reality, which might deter their attention or receptiveness especially at an early stage of the learning process.

Although group oriented learning is a key concept of HannibaL's model curriculum, due to the aforementioned ethical constraints it cannot be used in all situations. On the other hand, traditional teaching concepts are often at a disadvantage regarding the transfer of knowledge to practical situations, while mARble® can easily be integrated in HannibaL's concept. This can be illustrated using an example with three students: one student takes the role of a tutor and chooses the markers for construction a virtual case. He then places the markers on the second student's skin, who is assigned the role of a patient. The third student performs an "examination" of the presented case and interacts with the "patient." All three participants can benefit from this role play. Since the tutor has to take care of constructing plausible virtual cases, she or he must at first take a closer look at the condition or wound pattern that is to be presented in order to be able to aid the other two members of the group. This tutor also serves as an "objective observer." The second student can take a closer look at the patient's perspective, which may provide valuable insights. In his role as examining physician, the third student can practice his bedside manner as well as the necessary examination techniques. By using different cases and rotating the three roles, all members of the group get the chance to deepen their understanding of the different roles and situations.

mARble's mobile learning concept allows all participating persons to interact in a very flexible manner. During role plays, students get the chance to experience both sides of modern medicine: they can find themselves in the patient's shoes but may also take a professional role or take an "outsider's look." Actions are either taken or endured, requiring an intensive and personal interchange between all participants, which lets them experience the learning content from different perspectives. In this way, in-depth discussions covering much more than the presented content may be triggered. Finally, the complete experience can be discussed with experienced professionals, thus adding another layer to the learning process which can be an enriching experience for everyone involved.

During self-study, learners may also improve their knowledge. In this case, they simply place the markers on their own skin or choose the desired case using the application's menu. They can review corresponding findings and check their learning progress by making use of the interactive flashcard system by working through the provided questions and answers.

Aside from the currently available module for legal medicine, other specialties with a large share of visually oriented learning content may also profit from mARble's concept. Currently, a module for dermatology that may be used in student education as well as for beginners in dermatology is under construction. Based on this new dermatology module, a larger scale evaluation of mARble's concept will be performed.

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