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Virtual Patients in a Real Clinical Context using Augmented Reality: Impact on Antibiotics Prescription Behaviors

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Abstract. The research community has called for the development of effective educational interventions for addressing prescription behaviour since antimicrobial resistance remains a global health issue. Examining the potential to displace the educational process from Personal Computers to Mobile devices, in this paper we investigated a new method of integration of Virtual Patients into Mobile devices with augmented reality technology, enriching the practitioner's education in prescription behavior. Moreover, we also explored which information are critical during the prescription behavior education and we visualized these information on real context with augmented reality technology, simultaneously with a running Virtual Patient's scenario. Following this process, we set the educational frame of experiential knowledge to a mixed (virtual and real) environment.

Keywords. Antibiotics, Antimicrobial Resistance, Guidelines, Virtual Patient, Augmented Reality, Mobile Education

Introduction

Antibiotics have been considered as a determining factor for saving lives and minimizing the suffering of patients for more than sixty years. The widespread inappropriate use of antibiotics provoked the manifestation of antibiotic resistance organisms. Antimicrobial resistance is one of the biggest public health challenges [1]. Previous studies [2]-[5] have shown that combining educational methods and intervention strategies to general practitioners can reduce the antibiotics prescription in the range between 3% and 12% [4],[5]. Developing effective educational methods in the healthcare workers' context could therefore further lower unnecessary prescriptions. Two types of technologies could be appropriate: virtual patients (VPs) defined as "interactive computer simulations of real-life clinical scenarios" [4] and Augmented Reality (AR), a technology that provides the opportunity to computer-generated virtual imagery information to be overlaid onto a live directly or in-directly real world environment in real time [7]. AR bridges the gap between the real and the virtual in a seamless way [8]. AR technology embeds digital artifacts in physical setting. Both of these technologies seem to provide a complementary approach, but interestingly, we

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have found a limited number of studies that have investigated this combined educational method in health care education.

The aim of this study was to design and evaluate an innovative educational method (vpAR) that includes VPs embedded in mobile mediated contextual environment (AR). The hypothesis is that such an educational method would bring the best of both worlds into an effective educational intervention that could optimize the prescription behavior of healthcare professionals. The following research questions were investigated:

- What educational aims are addressed using vpAR?
- What are the technological affordances of vpAR?
- What are the pedagogical affordances of vpAR?

1. Methods

Two research methods were examined for the development of the prototype: the ''Model'' methodology, which focuses on defining an abstract model for a real system [9] and the Design Based Research Methodology (DBR), which informed our study design [10] . We carried out the empirical process in continuous cycles of design and evaluation. The design decisions were justified through theory, formative and summative evaluation and in a close interaction with healthcare practitioners. We conducted the study in the authentic learning environment [12].

1.1. Selection of educational challenges relevant to rational drug prescription and tools for the literature review.

We selected the appropriate educational challenges as following: first we investigated the existing educational processes for improving prescription behaviors, in which the healthcare professionals participated. Next, we reviewed the literature to find learning objectives that have an influence on improving prescription behaviors. For the literature review we used the databases: PubMed, Web of Science, CINAHL, for medical and healthcare material, by using the keywords: resistance, antibiotics, antibiotic education, educational tools in antibiotic education, antibiotic guidelines, antibiotic policies, virtual patients in antibiotic education, clinical pharmacology. For the technological material IEEE and Scopus databases were used. A significant number of papers found by the keywords: mobile, mobile educational tools, augmented reality, mixed reality, augmented reality and education, mixed reality and education, augmented reality integration, contextual learning.

1.2. Pedagogical framework

We reviewed several educational theories to find the best approach for the pedagogical design. Three dominant theories have been reported as relevant in healthcare education: authentic learning [13], situated learning [14] and experiential learning [15]. The theories informed the design iterations.

1.3. Participants and context of the study

We focused on healthcare professionals with prescription experience ≤ 2 years, to reach the recently graduated students that have been in contact with contemporary educational methods. The participants' role was to provide their insights in the design of the research and potential solutions to the educational problems. We used a room at the Medical Simulation Department at Karolinska University hospital, Stockholm as the context of our study. We conducted two ''think aloud'' groups with nine Resident Practitioners.

1.4. Development of the vpAR prototype

The design process aimed at developing the vpAR prototype. The specific characteristics of digital patient were drawn from the typology of Huwendiek [15]. We used Metaio AR platform to develop the digital artifacts and to track the learning context. Metaio platform is based on AREL (Augmented Reality Experience Language) and is structured on a JavaScript binding in combination with XML content.

2. Results

The design based research iterative methodology resulted in three outcomes: the educational challenges that may be addressed using vpAR, the technological and pedagogical designs for the vpAR application.

2.1. Educational aims that may be addressed using vpAR

Table 1 shows the educational goals that are important to address by the combination of VP and AR with a vpAR application.

Table 1. Educational aims that can be targeted with each type of technology

Competency addressed	Educational goal	VP only	AR only	vpAR (VP+AR)
Knowledge	Prescribing antibiotic therapy according to national/local practice guidelines	Clinical Reasoning	Visualization of objects and guidelines real-time	Examination of VP and real-time visualization of related guidelines
Skills	Definitions and indications of empiric/directed therapy vs. prophylaxis	Student's Assessment		VP and object visualization in real context for student's assessment
Attitude	Clinical situations when not to prescribe an antibiotic	Clinical Reasoning		Real-time feedback

2.2. Technological affordances of vpAR

Figure 1. Shows the different components of the vpAR application

Fig. 1 shows the user interface of our prototype, which was deployed in a tablet device. Two trackable drugs were used as markers. Additional information was visualized when the objects scanned by the augmented reality software (Junaio) which was installed in the tablet device. From the prototype's evaluation process it was observed that the user understood completely the process and the educational purposes. The data for the VPs and for pharmacology were unsupervised, anonymized and collected from an IT-system.

The Metaio platform includes the following components that allowed the integration of VPs into augmented reality: XML to load VP data and antibiotic information data; an HTML5 layer to provide a graphical user interface. The user interacts with the VPs and the context by the using the camera (Fig. 1).

2.3. Pedagogical affordances of vpAR

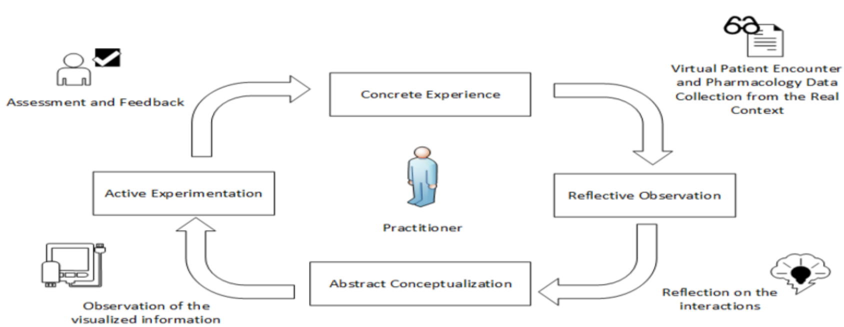

Figure 2. The educational process that is driven in vpAR application

The experiential theory was [15] used as the blueprint for the educational design. *Concrete experience:* The practitioner encounters a VP and collects pharmacology data from the real context. *Reflective observation:* The practitioner reflects on the effects of his interactions. *Abstract conceptualization:* The user runs assessment based on his/her choices and gets feedback; the user also examines the changes of the predicted outcome when we change the variables of VP.

3. Discussion

We presented the vpAR application from the technological and pedagogical perspectives. VpAR is the result of an iterative design based methodology, where the practitioners were involved and combines the best of both modalities. An observed limitation of this prototype is the need to use a tablet device; as AR technology improves, the findings of this study will be instantiated in new solutions (e.g. wearable devices, google glasses) to improve the usability of the interaction. This study needs to extend the research of the educational outcomes that VP and AR provide and explore the educational dynamics of this integration. We plan to conduct more think aloud groups with healthcare professionals to improve the testing prototype and to explore how this solution could be implemented in different medical departments to enrich the educational process of inter-professional skills and behavioral change. Finally, VP scenarios should be created for antibiotics' education, considering the fact that they will be used in real context.

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