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# AR in Medical Auscultation Training

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**Abstract.** The aim of "AR in medical auscultation training" is to use digital media to support and supplement medical knowledge transfer for auscultation. The focus is on the usefulness and supplementing, not replacing, teaching through digitalization. The prototype, created in practice, is intended to give aspiring physicians the opportunity to compensate the lack of practice time to train their hearing.

## Introduction

Auscultation, a non-invasive and time-efficient technique, plays a key role in the diagnosis and monitoring of various medical conditions (Conn & O'Keefe, 2009). By listening to internal physiological sounds, healthcare professionals can quickly gather vital data to facilitate accurate diagnoses and therapeutic interventions, particularly in urgent clinical scenarios. Auscultation's simplicity, speed and broad cross-specialty applicability make it an indispensable tool in diverse medical settings and resource-constrained contexts. In recently conducted interviews one medical student said: "Honestly, we only learn this if we are lucky enough to end up in a pulmonary or cardiac clinic during our practical year [...]". Sentences like this came up often in interviews with medical students. The Federal Medical Ordinance requires a minimum of 5500 hours of study over six years to complete a medical degree. During this period, around 8 to 12 months are allocated for practical training, as stated in the Bundesärzteordnung (BÄO). Listening with a stethoscope is only a part of a three-hour course. Currently, practicing physicians often do not know how to listen (Mangione, 2001) because the differences between pathologic and physiologic heart murmurs are not easy to discern. Auscultation is not a simple procedure; it must be trained (Barrett et al., 2017). The application of augmented reality, "StethoSCOPE," was developed during this research and aims to provide assistance. This program will train students to identify the locations of auscultation points, different (heart) sounds, and provide an exercise module related to an anamnesis questionnaire.

# Theorie

The theoretical part of the paper deals with auscultation, teaching auscultation, e-learning and augmented reality.

## 1) Auscultation

The fact that auscultation with a stethoscope is not to be neglected even in the age of sonography, echocardiography and computed tomography is already mentioned in the preface of one of the standard works on basic diagnostics. "Basisdiagnostik in der Inneren Medizin" (Basic Diagnostics in Internal Medicine) by Martina Kahl-Scholz (2018). According to Kahl-Scholz (2018), a well-founded anamnesis combined with a structured physical examination, even without apparative diagnostics, can result in a tentative or main diagnosis. Physicians rely on auscultation during home visits or emergency situations. Due to the demographic development towards multimorbid elderly patients, auscultation is a non-invasive and gentle form of diagnosis (Kahl-Scholz, 2018). At a cardiological auscultation various points on the torso with different heart sounds can be perceived. After the pulse has been determined, the listening points are listened schematically in parallel with the stethoscope (Kahl-Scholz, 2018). Physiological heart sounds are all sounds emitted by a healthy heart. In contrast, pathological heart sounds indicate abnormalities. Four heart sounds can be differentiated from each other (Kahl-Scholz, 2018). Heart murmurs are divided during systole (ejection phase) and diastole, (filling phase). To interpret the murmurs caused by vitia (heart defects), a precise idea of the blood flow or cardiac hemodynamics in systole and diastole is essential (Kahl-Scholz, 2018).

## 2) Auscultation teaching

Although only 20% of findings from stethoscope listening by students and practicing physicians are correct (Mangione et al., 1993). Several studies demonstrate non-mastery of auscultation: among hospital internists from the United States, Canada, and England, correct auscultation findings are only 22, 26, and 20 percent, respectively (Conn & O'Keefe, 2009; Mangione, 2001). As described, the practical part in medical schools is underrepresented. "Medical teaching in Germany is characterized by a deficit of practical relevance."(Huwendiek et al., 2006) In addition to the books, which illustrate the theoretical part of auscultation well, there are partial extensions by audio examples. However, these are recorded only as individual audios and neglect the various auscultation points, which are of great importance for a tentative diagnosis as described in the chapter "Auscultation". Physical manikins are also sometimes used, but they are very expensive (the cost of a MATT - Simulator for Auscultation, MedVision Group; SAM II® - Student Auscultation Manikin, 3B Scientific ranges from 13,000 to 17,500 Euros, for example) (*MATT - Simulator für Auskultation, MedVision Group*, n.d.; *SAM II® - Studentische Auskultationspuppe, 3B Scientific*, n.d.) and provide only on-site access. Delocalization is not possible. There are also e-learning platforms such as Amboss (*AMBOSS*, n.d.) or Thieme via medici (*via medici*, n.d.); similar to the teaching by books. They combine text with audio examples. Therefore e-learning platforms neglect the physical location of the sounds. Also smartphone apps, like from the stethoscope manufacturer Littmann, have the same problem.

## 3) E-Learning

The advantages of e-learning in the medical field are also decentralization and permanent access to learning content plus the integration of various media for improved retention. The design of such programs should consider didactics with meaningful learning objectives and media use, frequent interactions, appropriate complexity and information density, helpful feedback, high authenticity, user-friendliness and timeliness (Huwendiek et al., 2008). Digitization of teaching alone, as with asynchronous e-learning courses, have only moderate popularity among radiology students according to a survey. This dissatisfaction was based in part on the lack of practice (Volmer et al., 2021). As described in the constructivist approach to teaching, one learns by doing (Schulmeister, 1997). Therefore, the

StethoSCOPE application is intended to be highly interactive, as required by the quality criteria for e-learning programs (Huwendiek et al., 2008). Frequent didactic interactions promote active learning and critical thinking (Huang, 2005). According to Kulik, Kunert, Beck, and Fröhlich (2017), learning is largely driven by interaction with fellow students. Especially when it comes to interpreting complex and ambiguous information, "Direct student exchanges can help to consider multiple perspectives and confirm the likely interpretation."(Greenwald et al., 2017). In addition, face-to-face interaction and mixed-initiative communication promote ongoing discourse about a topic (Greenwald et al., 2017).

## 4) Augmented Reality (AR) and developed system

Augmented reality (AR) creates a closeness to reality that is not possible in classic textbooks (Barrett et al., 2017). As Karl Gerstner (2020) suggests in his book " Programme entwerfen" (Designing Programs), the third dimension, spatiality and depth of an object is opened up, thus the depicted is extended by another level of information (Gerstner, 2020). This third level of the StethoSCOPE application can help to assign and understand the anatomy and the sound signals emanating from it. What has already been written in a yet to be published paper on digitization in medicine, specifically electrocardiography, is equally applicable to auscultation: "So why should we continue to reduce the representation of such a complex organ to two dimensions when there is now also the possibility of representing the heart in 3D and anatomically correct? With the application, we want to give students the opportunity to learn directly on the anatomically correct heart. That would be a step in the right direction and a digitization where digitization is necessary. Merely putting the content of a book online should not be seen as progress or even digitization. It has never been easier to improve, or at least supplement, teaching methods such as electrocardiography with the help of programs."(Goetz, 2021) Augmented reality opens new collaborative scenarios in the course, while its flexible use allow students to train their hearing and expand their knowledge.

Our concept is based on auscultation on a virtual torso, very close to reality. For real heart sounds and murmurs, a recording procedure has to be developed for all six auscultation points simultaneously in order to exclude time delays between systole and diastole at the different listening points. The simultaneous recording of physiological heart sounds and pathological heart murmurs also serves to visualize the pulse. As described in the chapter "Auscultation", this is important for distinguishing between systole and diastole. As this cannot be felt in humans, a visualization method must be used here. The visualization should also offer the possibility to understand the cardiovascular system and the resulting flow sounds of the blood (Kahl-Scholz, 2018). With the application, a situation should be created, complemented and enhanced by digitality. To ensure this convergence, the torso must behave in its dimensions and physical properties (sounds of the heart) like patients. Through the digital layer of AR, two- or three-dimensional information can be inserted into the real space. Thanks to the technology of spatial mapping via infrared sensing, AR glasses, such as the HoloLens can virtually map real space and thus place objects on real surfaces (like on a table) (Zeller, 2023). Distances and proportions can estimated more easily, which is a basic prerequisite for auscultation with a virtual stethoscope. Beside tracking the room, the movements and gestures of the hands can also be tracked. Thanks to the improved tracking of the HoloLens 2, users can grasp and move objects naturally. (*HoloLens 2—Overview, Features, and Specs | Microsoft HoloLens*, n.d.). The user interface (UI) can operate directly without detours via controllers. Gestures are necessary for some interactions, such as for selecting objects/UI that are further than an arm's length away or for closing an application. Voice control also makes it possible to perform interactions simultaneously. Users could, for example, fade in the auscultation points or fade out the body shell of the virtual torso by voice command while placing the virtual stethoscope. Glasses such as HoloLens have the advantage of reduced motion sickness (the effect often occurs due to temporal delay of the organ of balance and virtual projection), which can be explained by a higher relation to reality. This allows for greater comfort and thus longer wear time, for a longer learning experience (Vovk et al., 2018).

# Methods

The current prototype was implemented with Unity for the Hololens2. In the application, emphasis is placed on natural interactivity. The students can approach the virtual torso with a virtual stethoscope head and auscultate – like in reality. To increase the collaborative approach of the application, ideally multiple learners should be able to interact with StethoSCOPE together, strengthening their understanding of auscultation. The content developed collaboratively in the course can be reinforced through self-study; it serves as a knowledge base beyond the course. The prototype StethoSCOPE created for auscultation on the heart, depicts the functions to be implemented. These were discussed, evaluated and elaborated in several interviews with medical students. For now, auscultation is limited to the heart because it is much more complex to listen to than other organs. To reproduce the sounds as realistic as possible, a technique for simultaneous audio recording of heart sounds was developed. During the practical implementation, it shows that the Hololens2 is ideally suited for the implementation of the StehtoSCOPE application, as these augmented reality glasses can be used to display a virtual body in full life size. Another reason for the augmented reality implementation is to open up new collaborative scenarios in the course, while the flexible usage options allow students to train their hearing and expand their knowledge. To ensure the accessibility of the application for students outside the university, a smartphone application will also be implemented. This will include an AR mode, similar to the Hololens, in order to also be able to train listening via smartphone and to deepen the knowledge acquired in the course. Another digital extension is needed for the localization of the auscultation points. The points are determined using the intercostal spaces or ICS (the spaces between the ribs). These cannot be palpated in the virtual one and must therefore be displayed in another way.

# Conclusion

The concept of the StethoSCOPE allows medical students to practice auscultation. Users can acquire knowledge and develop skills in cardiology auscultation through case-based examples. Auscultation can be practiced on a virtual torso using a virtual stethoscope. To support the process of diagnosing, users can request various tools. Apart from the anamnesis sheet that provides information on gender, age, and medical history including medications, the application also displays skeleton, heart, and auscultation points. Highlighting of locations where pathological heart murmurs are heard can be enabled when required. This feature enables users to locate the origin of the murmur. Identifying systole and diastole is an important factor in making a preliminary diagnosis, which the animated heart helps with. Thanks to a database of heart murmurs, users can "listen" to various heart diseases. The next step involves representing the blood flow at the open heart, which will help interpreting the origin of heart murmurs more effectively. The StethoSCOPE application will animate the anatomically correct heart simultaneously with the recorded heart sounds. In the future, the application will be established as a platform for heart sounds and tones. As a result, a continually expanding audio library of recorded audio examples can be created, revealing new cases to all users. Furthermore, integrated machine learning will identify frequently made errors to provide optimized assistance. The data obtained can be utilized in teaching to identify sources of error from the outset. The AR app prototype was programmed for easy expansion to include additional listening points such as blood vessels, lungs, and intestines. The intention of multiple iteration cycles of usability testing and re-testing is to ensure that the application conforms to all usability criteria and other requirements. As HMDs like HoloLens are currently not widely available, a smartphone app is recommended as a transitional/supplementary measure. This could be structured in the same way, except for the mode of interaction.

The potential positive effects of knowledge transfer from the StehtoSCOPE AR app will be determined by utilizing a randomized controlled trial. Two groups (A/B) of medical students will receive auscultation training over a specific period. Group A (control group) will receive classical training material, while group B will receive the app StehtoSCOPE in addition to the classical training material. Before and after the implementation, the students' knowledge will be assessed through an auscultation test scenario.

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