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# Ear and hearing diagnostics in low-income settings

## Prospects for new eHealth supported solutions

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**Academic dissertation**

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## Abstract

Millions of people suffer from hearing loss globally. Otitis media and age-related hearing loss are the most common causes of hearing loss. Besides hearing loss, otitis media can lead to severe infections in the balance and hearing organs as well as the brain with serious complications. Long term consequences of both otitis media and hearing loss are preventable, but for prevention, available and reliable diagnostics is essential. South Africa is one of many countries where ear disease and hearing loss are prevalent and the studies in this thesis are conducted in low-income communities in the City of Tshwane in South Africa. The aim was to validate two new diagnostic tools based on eHealth for ear disease and hearing loss and to explore the prerequisites to implement the methods at clinics in the low-income communities.

The thesis includes two studies of smartphone-based audiometry and one study of image-based otitis media diagnostics using artificial intelligence. To explore the prerequisites for implementing these methods, the thesis also includes one study in which primary healthcare professionals working in low-income settings were interviewed about their perspectives of ear and hearing health today and for the future.

In study I and II, the accuracy and reliability of smartphone audiometry was investigated. The thresholds from the smartphone hearing tests were compared to the thresholds from conventional audiometry. When the test was conducted in an operator-controlled manner (study I), the mean difference between methods was in a soundproof booth 1.6 decibel (SD 9.9) and in a noisy primary healthcare environment -1.0 decibel (SD 7.1) (smartphone thresholds subtracted from conventional). When the hearing test was updated to a self-test (study II) and studied in a noisy environment, the mean difference compared to conventional audiometry was -2.2 decibel (SD 10.1) (smartphone thresholds subtracted from conventional). There were no significant differences between repeated measurements with the smartphone test, and smartphone audiometry was therefore considered reliable.

The third study compared the diagnosis from a convolutional neural network (one kind of artificial intelligence) to the reference diagnosis from an expert panel using otoscopic images of tympanic membranes. Accuracy was calculated and how modifications of data affected it (addition of more images, augmentation and normalisation). The accuracy was ≥88 % for all instances tested when the network was used to discern between normal ears, obstructing wax and pathological ears. The modifications of data had no apparent effect on the accuracy.

The interview study (study IV) is ongoing, and the results are therefore preliminary. Professionals from public primary healthcare clinics were interviewed about the prerequisite for ear and hearing healthcare today, their knowledge of and attitude towards artificial intelligence and the prerequisite to implement tools like the ones proposed in study I-III at their clinics. Some important components seem to be present, although there are several aspects necessary to consider before the tools can be incorporated in the everyday work. An openness to the technique and willingness to learn and being involved was considered beneficial together with critical thinking towards possible pitfalls. It was however seen that maintenance of facilities and equipment and basic medical treatment were at instances missing, which must be prioritised first.

Overall, the studies in this thesis showed that tools supported by eHealth for ear and hearing care can contribute to accurate and accessible ear and hearing diagnostics in low-income settings. They can thereby offer possibilities to prevent long-term consequences from ear disease and hearing loss, but the unique conditions at the clinics must be considered. Future studies of AI supported tools should be performed in clinical settings.

**Keywords:** Diagnostics, otitis media, middle ear disease, OME, AOM, CSOM, wax, audiometry, smartphone audiometry, hearing, hearing loss, tympanic membrane, global health, artificial intelligence, machine learning, convolutional neural network, deep learning, attitudes, AI-literacy, eHealth, mHealth

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