Publishable Summary for 15HLT03 Ears II
Metrology for modern hearing assessment and protecting public health from emerging noise sources

Overview

This project concerns two aspects of hearing assessment and conservation; the further development of the next generation of ear simulators that will provide measurement traceability for hearing tests on adults, children and neonates, and improvement in our understanding of human response to infrasound and ultrasound, including novel assessment methods for potential health risks. The project started in May 2016.

Need

Virtually everyone will have their hearing tested at stages throughout their life. It is essential for effective diagnosis that these tests are accurate and quality assured. Ear simulators provide the basis for measurement traceability, but in the past have been designed for adults only. The EMRP HLT01 EARS project made the first significant steps at specifying ear simulators for other age groups, and produced a prototype neonatal ear simulator. However the concept of a universal ear simulator needs further refinement and extending to cover all forms of audiological testing, before it can be adopted into clinical practice. One specific aspect is that new methods for transient calibration are needed, to replace the current, technically flawed methods. The move to the next generation of ear simulators is the ideal time to introduce new improved calibration methods for transient stimuli.

Another aspect of hearing conservation concerns environmental and industrial exposure to noise which represents a major public and occupational health issue. With urbanisation and industrial innovation often come undesirable consequences such as new types of noise hazard from infrasound and airborne ultrasound. Greater understanding of the human perception mechanisms is needed in order to tackle the risks posed by this emerging noise. Due to the inaudible nature of some of these noise sources, a multi-disciplinary approach is needed combining neuro-imaging and advanced audiological investigations. Alongside the development of this understanding, new methods and instrumentation are needed to measure and assess noise sources in both public and workplace environments.

Objectives

The overall objective of this project is the improvement and further development of strategies and methods of metrology and calibration for hearing assessment, hearing diagnosis and safety. The specific objectives of the project are:

1. To finalise the universal ear simulator concept to fulfil the whole range of audiological requirements for traceability to sound pressure, including the development of an alternative approach to transient calibration based on impulse response and adaptors for the most common devices. A demonstrator will be realised for the novel ear simulator.
2. To generate robust normative reference threshold data (transfer and input impedance), calibrate devices across partners, quantify the degree of equivalence with currently established practices and provide a user guide summarising features, calibration and handling for application of the novel ear simulator in practice.
3. To exploit neuro-imaging and audiology to further develop understanding of perception as well as response and loudness thresholds for ultrasound (16 kHz – 80 kHz), infrasound (4 Hz – 16 Hz), and the influence of infrasound on sound within the normal hearing range; together with the development

of instrumentation and measurement methods for the determination of noise and its hazards in those frequency ranges in both public and workplace environments.

4. To determine experimentally the impact of infrasound and ultrasound on hearing, mental health, cognitive abilities and general wellbeing, and their contribution to annoyance and loudness, including the study of individuals with particular sensitivity to noise.

5. To engage and work closely with stakeholders to establish the clinical protocols and international standards proposals for the use of the universal ear simulators in the calibration of audiometric equipment used for hearing assessment and hearing aid fitting for both children and adults; and to create the knowledge for future guidelines and policy framework to enhance the wellbeing of European citizens and protect them from health hazards associated with infrasound and ultrasound.

Progress beyond the state of the art

Having produced and tested a prototype of an ear simulator for neonates in the EMRP EARS project, this project will develop the concept further to become practically viable for all age ranges. This includes a reduction in the number of different designs, in conjunction with alternative criteria for matching the ear simulator to the patient, and an extension to allow the coupling of circumaural and supra-aural headphones.

Separately, the project will develop an innovative approach to the calibration of audiological transducers for transient stimuli, based on the impulse response of the ear simulator. Starting from the selection and characterisation of short-duration stimuli based on properties of the auditory system, novel methods for determining the impulse response of the ear simulator will be investigated and form the basis for a new calibration strategy for the transducer under test. Together these elements represent a significant departure from established practice and mark the first attempt to improve on the flawed method currently specified in international standards.

The EARS project developed the first primary measurement standard for airborne ultrasound measurements and made first attempts to develop exposure measurement techniques for use in laboratories. This project will design, assemble and validate practical ultrasound measurement devices and components.

Results of the EARS project showed that infrasound leads to a hearing sensation and indications exist that an emotional response is activated in brain. This project will pursue these findings further with new more comprehensive study designs including other indicator modalities as frequency-following techniques in magnetoencephalography (MEG).

Results

The key technical achievements against each of the project objectives described above are:

Objective 1

A concept has now been developed for practically implementing a universal ear simulator. The current proposal is for three ear simulators to provide three discrete calibration points for test instrument used in hearing assessment, which will be supplemented by an in-test procedure to match actual ear characteristics to those of the ear simulators. A further process for interpolating between the calibration points will then be implemented automatically. In this way an optimum arrangement of fewer ear simulators and better calibration for individual test subjects is achieved. The range of earphones for which the ear simulators can be used is also being expanded by designing adapters and couplers for all of the commonly used transducer types.

The innovative concept for calibration of audiological transducers for transient stimuli has now been defined and experimental validation is underway. The new calibration method will be used in conjunction with the results of studies of the short-duration stimulus characteristics relevant to auditory perception and loudness. Together they form the new strategy which is a completely new approach.

Objective 2

Once the technical development of the new ear simulator is completed it will be tested and validated and used to define robust normative data. First steps for preparation of measurement have started.

Objective 3

First steps have been completed towards developing practical measurement tools for determination of airborne ultrasound in the public and at working places. A set of requirements and a specification for a single-sensor ‚ultrasound level meter' has been prepared and the first assembled systems are under laboratory evaluation. A multi-element beam-forming array of MEMS microphones acting as an acoustic camera, has also been specified and designed, and the first practical implementations are now being prepared for evaluation. The calibration methods for these devices have also been developed to allow measurement with these systems to be traceable to the primary measurement standards. In anticipation of these new measuring instruments becoming available, reviews have been carried out of workplaces and public spaces where ultrasound measurements are needed. First tests measuring an ultrasound machine have already been completed successfully.

Objective 4

New specific sound sources have been designed to support the planned studies, allowing modulation signals and audible sounds to be mixed with infrasound, ready for new experiments on the infrasound detection threshold when audible sounds are also present. A high power ultrasound source combined with an in-ear monitoring was developed allowing the reliable presentation of ultrasound at the ear entrance with a reliably and precisely known sound pressure at fMRT or MEG machines for the first time. Hearing experiments have been designed and are about to start.

A questionnaire for the determination of psychoacoustic information to investigate the annoyance of infrasound and ultrasound was developed and implemented in different languages.

Impact

The objectives and outputs outlined above have been formulated to meet the declared needs. Therefore delivery of these outputs will enable a significant impact in key areas to be created.

In standardisation, several new proposals are envisaged that, in the case of the ear simulator, will enable the new technology to gain recognition and ultimately be taken up in clinical practice to yield quality assurance and reliability improvements in hearing assessment, particularly for children and neonates. In noise control applications, vital new information, for example on human response and measurement capability will enable problems such as airborne ultrasound to be quantified and tackled for the first time.

While benefits from standardisation will flow to stakeholders, the consortium will also work with industry and clinicians directly, to enable early adoption ahead of the standards being established. Clinical users will be given access to the ear simulators emerging from the project, to assess their impact alongside established protocols. New measurement services for infrasound and ultrasound also developed in the project and the new understanding of human factors such as perception and annoyance will begin to assist industry and local authorities in mitigation of noise hazards in a systematic way with scientifically robust approaches.

A virtual centre of excellence in metrology and measurement capability for infrasound and airborne ultrasound will emerge from the project activities, providing an open resource for the metrology and scientific communities across Europe, and making duplication in this highly specialised area unnecessary.

A Stakeholder Advisory Group has been formed to extend the reach of dissemination from the project.

<table>
<tr><td colspan="2">Project start date and duration:</td><td>1 May 2016, 36 months</td></tr>
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<tr><td>Internal Funded Partners:
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7 UCL, United Kingdom</td><td>Unfunded Partners:
12 METAS, Switzerland</td></tr>
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3 DFM, Denmark 4 NPL, United Kingdom (withdrawn from Sep-2016) 5 TUBITAK, Turkey	8 UKE, Germany 9 UL, Slovenia 10 Uni-Oldenburg, Germany 11 UoS, United Kingdom	