1064: CONTEXT AND USER REQUIREMENTS FOR DIGITAL SPEECH THERAPY FOR THE SEVERELY HEARING IMPAIRED – FIRST RESULTS (THERESIAH)

Markus Meis, Joerg-Hendrik Bach, Andreas Becker, Kerstin Bilda, Alev Erem, Tobias Feith, Stefan Goetze, Jonna Juers, Andreas Radeloff, Benjamin Tschuschke, Laura Tuschen

HörTech gGmbH, Oldenburg, DEU: Evangelisches Krankenhaus, Oldenburg, DEU
University of Applied Sciences, Bochum, DEU: KIZMO GmbH, Oldenburg, DEU
Fraunhofer IDMT, Hearing, Speech and Audio Technology, Oldenburg, DEU
Universitätsklinik für Hals-Nasen-Ohren-Heilkunde, Oldenburg, DEU

Goals: The aim of THERESIAH is to develop a digital therapy and documentation system for pronunciation and hearing training in at least severely hearing-impaired patients who suffer from speech and voice disorders due to insufficient auditory input (audiogenic speech disorders).

Motivation and approach: The THERESIAH project is developing a digital system consisting of the following modules: software modules for automated pronunciation evaluation using an automated speech recognition system (ASR), elements of adaptive training programs with listening and pronunciation exercises (PC or Tablet PC/Smartphone with headset), and the connection of electromyographic methods (EMG) for explorative investigation of articulatory muscle functions. Overall, tools are to be developed that continuously objectify articulation and pronunciation quality. Patients will have the opportunity to do exercises at home, self-determined and with a high training frequency. In addition, it is planned to support phoniatrists and speech therapists in the clinical environment and in postoperative outpatient therapy with new documentation functions.

Methods: N=12 medical experts (speech therapists, audiologists, and phoniatrists) were interviewed for the context and user analyses. N=50 patients with severe hearing loss (PTA > 60 dB at frequencies 0.5, 1.0, 2.0 + 4 kHZ better ear) and possible speech disorders were selected from a database of 1,700 hearing impaired patients. A total of N=23 patients were interviewed. Qualitative in-depth interviews and interviews with (partially) standardized questionnaires were conducted.

Context analyses: Data from disease-specific HrQoL questionnaires such as the Nijmegen Cochlear Implant Questionnaire (NCIQ, scale 'Speech production'; Hinderink et al., 2000) and the German version of the Articulation Handicap Index (AHI-12; Keilmann et al., 2017) showed that postlingually severe hearing impaired patients with a progressive or acute pattern reported a comparatively low severity of symptoms in terms of speech production and articulation. This was also supported by a study by Grundmann et al. (2019) with bimodal patients. Prelingually deaf / hearing impaired cochlear implant (CI) patients who were fitted with CI’s at a late stage were identified as the primary target group. It was found that the THERESIAH system should be primarily used in outpatient speech therapy and that clinical CI rehabilitation can initiate outpatient care. The trustworthy speech therapist-patient dyad was assessed as essential and is to be supported by a digital therapy system, but not substituted.

According to expert interviews and literature reviews, the most common abnormalities are replacements or omissions of phonemes, as well as backshifting of phonemes, an increased voice pitch, a disturbance of nasality, an increased speaking speed, low sentence melody and other disturbances of prosody. Extensive diagnostic measurements will be carried out with the planned patient group in order to quantify the suspected abnormalities and, if necessary, to qualify further speech disorders.

User requirements analyses: Initial analyses of user requirements towards THERESIAH showed that a serious gamification approach with a high-resolution display of learning progress was desired by the respondents and that the incorrect or correct pronunciation of the patient should primarily be reported visually due to the model-oriented intervention approach, based on the Speech Motor Control Model from Perkell et al. (2000). In addition, EMG measurements were accepted as an additional diagnostic and training option in the clinical environment. Measurements are currently being carried out with a THERESIAH prototype in order to iteratively further develop the system. First results of this second iteration involving further prelingually deafened patients will be reported and discussed with regard to further development.

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1066: BENCHMARK OF HEALTH-RELATED QUALITY OF LIFE QUESTIONNAIRES IN BIMODAL HEARING SYSTEM SUPPLY

Mareike Grundmann, Karsten Plotz, Andreas Radeloff, Gisela Schulze, Markus Meis
Institut für Sonder- und Rehabilitationspaedagogik, University of Oldenburg, Oldenburg, DEU
Medizinisches Versorgungszentrum Oldenburg MEVO, Oldenburg, DEU
Universitätsklinik für Hals-Nasen-Ohren-Heilkunde, Carl von Ossietzky Universität Oldenburg, Oldenburg, DEU
Institut für Sonder- und Rehabilitationspädagogik, University of Oldenburg, Oldenburg, DEU
Hörzentrum Oldenburg GmbH, Oldenburg, DEU

The benefit assessment of hearing systems is usually carried out by determining clinically relevant parameters, such as speech comprehension. In addition to such parameters addressing efficacy, the assessment of everyday benefits by means of questionnaires on health-related quality of life (HrQoL) is of increasing relevance. It is important to demonstrate the effectiveness over time, see the Medical Device Regulation (MDR) of April 5, 2017 (EU, 2017/745) and '522 Postmarket Surveillance Program' of the FDA as well as the cochlear implant (CI) rehabilitation phase. To assess the benefit of hearing systems over time, the questionnaires must be suitable to demonstrate sensitivity to changes. Sensitivity to change was tested across a range of functional, disease-specific, and generic questionnaires with N=40 bimodal patients (average age M = 64.7 years (SD = 11.0; 55% female), who switched from bilateral hearing aids (HA) provision to a bimodal supply (HA and CI). The participants stated that they suffer from hearing loss since M = 28.2 years (SD = 18.5). Since M = 20.5 years they were aided with HA's and in the last M = 8.5 years (SD = 11.4). The results of the speech test (Freiburg monosyllabic test at 65 dB) showed a significant improvement compared to the baseline before implantation (M = 12.2; SD = 14.2) and six months later (M = 64.1, SD = 25.3). The following questionnaires with selected sub-scales were examined: 'Speech, Spatial and Qualities of Hearing Scale' (SSQ-12; Noble et al. 2013), 'Nijmegen Cochlear Implant Questionnaire' (NCIQ; Hinderink et al. 2007), 'Oldenburg Inventory' (Excellence Centre for Hearing Research HörTech 2004), 'Hearing Handicap Inventory for adults' (HHIA; Newman et al. 1991), 'Nottingham Health Profile' (NHP; Hunt & McEwen 1980), 'Glasgow Health Status Inventory' Questionnaire (GHSI, Robinson et al. (1996), and 'Indicators of the Rehab-Status' (IRES-3; Frey et al. (2007). The subjects answered 166 items of a large questionnaire battery at four measuring time points (before implantation and three to nine months after implantation). Some of the questionnaire scales were change sensitive (Cohen's d) from baseline and nine months later. So, they and can be used for evidence-based evaluation in the field of CI and bimodal rehabilitation. According on this, we selected the functional questionnaire SSQ-12 (all items) with d=1.55, a disease-specific 'social subscale' from the HHIE with d=1.11, as well as the generic 'general sub-scale' from the GHSI with d=0.82. For rehabilitation purpose we suggest to add the 'coping with illness' sub-scale from the IRES-3 with d=0.53. Though, the here proposed reduced test battery consists of 38 items and seems to be suitable for an economic to handle test battery in prospective longitudinal studies to evaluate the patients' benefit in everyday life to meet different regulatory recommendations.

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1144: AN ELECTRODOGRAM-TO-AUDIO WAVELET VOCODER THAT USES MACHINE LEARNING TECHNIQUES TO SOLVE INTERFERENCE PROBLEMS

Bradford C Backus, Kamil Adiloglu, Jorg-Hendrik Bach, Tobias Herzke
Oticon Medical, Vallauris, FRA
HörTech gGmbH, Oldenburg, DEU

We introduce a gammatone wavelet vocoder that can take an electrodogram and a CI user's fitting data and produce an audio output for normal hearing users. The vocoder generates a single gammatone-shaped wavelet for each pulse in the electrodogram and then combines these into a continuous sound output, similar to the function of the Bräcker vocoder [1]. The goal was to develop a 'universal' vocoder that could take any electrodogram input and mimic as much as possible a particular CI user's experience and performance—and work in real time. The main challenges with this type of vocoder are: (1) achieving correct loudness percepts when wavelets constructively and destructively overlap, (2) being able to simulate electrical current spread, (3) dealing with the place and temporal pitch cues which are always coupled by the action of the basilar membrane for NH listeners but are not coupled for CI users.

Loudness was adjusted by first assigning the magnitude of the wavelets to the intensity of their corresponding pulses in the electrogram. Since the output loudness can be reduced by destructive overlaps of consecutive wavelets, this effect was corrected using a combination of phase rotations and gains adjustments computed by a machine learning approach based on Gaussian process regression [2]. This is a new approach.

Since each wavelet was attributed to a pulse on a specific electrode, current spread could be controlled by changing the spectral bandwidth of all wavelets assigned to that electrode. The more current spread, the wider the wavelet bandwidth--and the less overlap of wavelets.

For electrodograms with a fixed stimulation rate, the vocoder produces a pitch percept corresponding to the stimulation rate. We found that by adding jitter, we could degrade this pitch percept. It was possible to add enough jitter to achieve similar pitch performance to CI users, albeit via manipulating a combination of mechanisms—primarily via the basilar membrane--that are not available to CI users.

Finally, we attempt to compare the strengths and weaknesses of this wavelet vocoder to other classes of vocoder.

References

[1] T. Bräcker, V. Hohmann, B. Kollmeier, M. Schulte, Simulation und Vergleich von Sprachkodierungsstrategien in Cochlea-Implantaten [Simulation and comparison of speech coding strategies in cochlear implants]. Zeitschrift der Audiologie / Audiological Acoustics, 48(4), 158–169, 2009.
[2] C. E. Rasmussen and C. K. I. Williams, Gaussian Processes for Machine Learning, MIT Press, 2006, ISBN 0-262-18253-X.

1168: A VR-BASED ENVIRONMENT ENABLING BICI SPATIAL SOUND RESEARCH - DEVELOPMENT AND EXPERIMENTAL VERIFICATION

Kacper Kosikowski, Bradford C Backus, François Patou, Tobias Herzke, Jeremy Marozeau, Søren Kamaric Riis
Technical University of Denmark, Kongens Lyngby, DNK
Oticon Medical, Vallauris, FRA
Oticon Medical, Smørum, DNK
HörTech gGmbH, Oldenburg, DEU

This project investigated the feasibility of using Virtual Reality (VR) to improve the auditory localization performance of bilateral cochlear implant (BiCi) users. The real-time VR setup we developed allowed us to introduce novel auditory spatial cues in a dynamic environment, and to use a subject's visual system to train his or her auditory system about those cues. We hypothesized that spatially-oriented coding strategies can enhance the scarce spatial auditory cues normally available to BiCi users and that immersive audio-visual training can help them learn new those new cues efficiently.

The project had three tasks: (1) develop of a VR-based dynamic BiCI simulation system, (2) design and implement a few example spatial enhancement coding strategies, and (3) evaluate the auditory localization performance of simulated BiCI (vocoder) users using the example strategies.

We first developed a Virtual Reality-based dynamic auralization framework for BiCI users. The system allows for simulating listening environments by chaining software-based virtual acoustics (using BTE-HRTFs) within the Oticon Medical Research Platform (OMRP) and can include custom binaural processing strategies implemented in software using the Master Hearing Aid (MHA) [1].

Next, three coding strategies involving different types and amounts of spatial information were implemented: (1) BTE-HRTF-based ILD-only mode (ITDs fixed to 0), (2) a mode with physiologically relevant ITDs added (in addition to ILDs) and, (3) a mode where an additional 'artificial coloration cue' was added. This cue was a simple low-pass filter used for sources behind the listener.

Finally, the system was used to assess auditory localization performance of 9 NH individuals (3 per coding strategy) exposed to simulated (wavelet vocoder) BiCI signals in a pilot experiment involving audio-visual localization training (4 sessions of 30 minutes in a span of 2 weeks). The data showed that audio-visual training improved both vertical and horizontal localization precision of most of the subjects. The results between strategies suggested that for continuous broadband stimuli restoring ITD cues may not add much for horizontal localization precision in cases where ILDs are maintained.

The developed dynamic VR system has proven promising for investigating spatial-information-centric algorithmic innovation, as well as improving auditory localization abilities through training in simulated BiCI users. Future developments will involve experiments with real bilateral cochlear implantees.

[1] Giso Grimm, Tobias Herzke, Daniel Berg, and Volker Hohmann, The master hearing aid: a PC based platform for algorithm development and evaluation, Acta acustica united with Acustica, vol. 92, pp. 618-628, 2006

1154: A BINAURAL CI RESEARCH PLATFORM FOR OTICON MEDICAL IMPLANTS ENABLING ITD/ILD AND VARIABLE RATE PROCESSING – AN UPDATE

Bradford C. Backus, Adama Treguier, Fabien Berrettoni, Tobias Herzke, Kamil Adiloglu, Soren Kamaric Riis
Oticon Medical, Vallauris, FRA
HörTech gGmbH, Oldenburg, DEU
Oticon Medical, Copenhagen, DNK

We present an update to the The Oticon Medical Research Platform (OMRP) and invite researchers to see a working demo of the system. The OMRP is designed to be a safe, portable, binaural, real-time research platform for Oticon Medical cochlear implants. The platform is a software programmable behind the ear processor (BTE) capable of processing signals from 4 ear-worn microphones simultaneously and producing synchronized binaural outputs capable of driving two (bilateral) implants. Subject safety is achieved by loading the subject's CI fitting data directly into the hardware where a hardware limiter module automatically limits outputs in real-time. The platform consists of hardware and software parts. The hardware is responsible for: (1) digitizing the 4 microphone signals typically coming from ear-worn microphone systems and (2) generating the final electric outputs needed to drive two antenna coils. The Master Hearing Aid (MHA) software [1] is responsible for processing the four audio input signals and then generating two synchronized electrodograms as stimulation outputs. The platform can control electrode timing to better than 1 microsecond accuracy and supports simultaneous CI/vocoder output allowing investigators to compare CI user's performance to normal hearing listeners' performance or to preview stimulation strategies while working on them. Several PC-based control panels are now available to support various types of experiments and a full API that enables real-time binaural control will be made available to researchers working with the platform.

[1] Giso Grimm, Tobias Herzke, Daniel Berg, and Volker Hohmann, The master hearing aid: a PC based platform for algorithm development and evaluation, Acta acustica united with Acustica, vol. 92, pp. 618-628, 2006.