

## **Auditory Rehabilitation via an VR Serious Game for Children with Cochlear Implants: Bio-Behavioral Outcomes**

**Authors :** Areti Okalidou, Paul D. Hatzigiannakoglou, Aikaterini Vatou, George Kyriafinis

**Abstract :** Young children are nowadays adept at using technology. Hence, computer-based auditory training programs (CBATPs) have become increasingly popular in aural rehabilitation for children with hearing loss and/or with cochlear implants (CI). Yet, their clinical utility for prognostic, diagnostic, and monitoring purposes has not been explored. The purposes of the study were: a) to develop an updated version of the auditory rehabilitation tool for Greek-speaking children with cochlear implants, b) to develop a database for behavioral responses, and c) to compare accuracy rates and reaction times in children differing in hearing status and other medical and demographic characteristics, in order to assess the tool's clinical utility in prognosis, diagnosis, and progress monitoring. The updated version of the auditory rehabilitation tool was developed on a tablet, retaining the User-Centered Design approach and the elements of the Virtual Reality (VR) serious game. The visual stimuli were farm animals acting in simple game scenarios designed to trigger children's responses to animal sounds, names, and relevant sentences. Based on an extended version of Erber's auditory development model, the VR game consisted of six stages, i.e., sound detection, sound discrimination, word discrimination, identification, comprehension of words in a carrier phrase, and comprehension of sentences. A familiarization stage (learning) was set prior to the game. Children's tactile responses were recorded as correct, false, or impulsive, following a child-dependent set up of a valid delay time after stimulus offset for valid responses. Reaction times were also recorded, and the database was in Excel format. The tablet version of the auditory rehabilitation tool was piloted in 22 preschool children with Normal Hearing (NH), which led to improvements. The study took place in clinical settings or at children's homes. Fifteen children with CI, aged 5;7-12;3 years with post-implantation 0;11-5;1 years used the auditory rehabilitation tool. Eight children with CI were monolingual, two were bilingual and five had additional disabilities. The control groups consisted of 13 children with NH, aged 2;6-9;11 years. A comparison of both accuracy rates, as percent correct, and reaction times (in sec) was made at each stage, across hearing status, age, and also, within the CI group, based on presence of additional disability and bilingualism. Both monolingual Greek-speaking children with CI with no additional disabilities and hearing peers showed high accuracy rates at all stages, with performances falling above the 3rd quartile. However, children with normal hearing scored higher than the children with CI, especially in the detection and word discrimination tasks. The reaction time differences between the two groups decreased in language-based tasks. Results for children with CI with additional disability or bilingualism varied. Finally, older children scored higher than younger ones in both groups (CI, NH), but larger differences occurred in children with CI. The interactions between familiarization of the software, age, hearing status and demographic characteristics are discussed. Overall, the VR game is a promising tool for tracking the development of auditory skills, as it provides multi-level longitudinal empirical data. Acknowledgment: This work is part of a project that has received funding from the Research Committee of the University of Macedonia under the Basic Research 2020-21 funding programme.

**Keywords :** VR serious games, auditory rehabilitation, auditory training, children with cochlear implants

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