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Journal of Neuroscience Methods 142 (2005) 131–136

JOURNAL OF NEUROSCIENCE METHODS

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A flexible auditory research platform using acoustic or electric stimuli for adults and young children

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Received 9 July 2004; received in revised form 11 August 2004; accepted 13 August 2004

Abstract

A user-friendly and versatile research platform for use in auditory experiments, referred to as APEX (Application for PsychoElectrical eXperiments), is described. The platform takes care of automatic stimulus presentation and collection of the subject's responses. Acoustical auditory, as well as electrical auditory experiments with CI recipients can be conducted. The platform currently supports LAURA, Nucleus CI22 and Nucleus CI24 cochlear implants. The graphical user interface for the subjects has been extended to allow for testing very young children, by embedding the psychophysical procedures in a computer game. The research platform is available free of charge.

Keywords: Research platform; Auditory; Acoustic; Cochlear implant; Child; Psychophysics; Speech perception

1. Introduction

The introduction of the PC as a regulator for experiments into the area of auditory psychophysics resulted in better-controlled experiments and as such to better science. The present article describes a PC-based research platform for controlling stimulus presentation and collecting subject responses that enables researchers to set up auditory experiments in a user-friendly way. The stimuli can be either acoustical or electrical for cochlear implants, and the graphical user interface for the subjects is adapted for testing both adults and young children.

Software running on digital hardware has enabled researchers to set up more complex test designs, controlling many different factors and varying more parameters than would be feasible for a human controller. Another benefit of software driven experiments is the high precision of stimulus presentation and response collection and the reduction of possible errors during an experiment.

Because of these advantages, psychophysical experiments are currently almost always controlled by software. Most of this software is specifically designed for one particular experiment, but some software packages enable the researcher to set up a large variety of experiments in a user-friendly way. This prevents the researcher from having to code new software for every new experiment. Recently, a number of commercial packages, consisting of software or hardware or both, have become available for performing psychoacoustical experiments.

However, there are still a number of shortcomings to the software that is currently available for auditory experiments. Firstly, most software packages are only capable of presenting acoustic stimuli, while with the increasing number of cochlear implant patients, more and more research is being devoted to electrical auditory perception (Zeng, 2004). Secondly, most existing packages are designed to test adults and provide the subjects with a relatively dull graphical user interface and limited reinforcement. This excludes testing of young children since their attention fades after a few trials.

The present article describes a software package called Application for Psycho Electrical eXperiments (APEX)

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doi:10.1016/j.jneumeth.2004.08.015

running under the Windows operating system for setting up and performing auditory experiments with acoustical stimuli or electrical stimuli for cochlear implants. The graphical user interface can be set up to a relatively sober mode for testing adults or a highly animated mode for testing children. The software was developed at the Laboratory for Experimental Otorhinolaryngology of the Katholieke Universiteit Leuven, based upon software by Geurts and Wouters (2000) for the LAURA cochlear implant. It is offered as a free service to the community for research or educational purposes. Information on how to obtain the research platform is given below.

2. Overview of the software

After defining the research hypothesis and the general outline of a particular study, the process of designing an auditory experiment can be divided into four steps: (1) stimulus creation, (2) definition of the experimental procedure, (3) running the experiment, and (4) analysis of the collected responses. Each step is supported by APEX software and will be briefly discussed below.

2.1. Stimuli

Currently APEX is capable of handling stimuli for four different devices: acoustical stimuli via a PC-soundcard, and electrical stimuli routed through three cochlear implant systems supported by Cochlear Ltd.: Nucleus CI22, Nucleus CI24, and LAURA.

- Acoustical stimuli consist of standard windows Pulse Code Modulation (PCM) wave files and are presented through the PC-soundcard. The stimuli can contain one or two channels (stereo) with 16 bit resolution and can be sampled at any sampling frequency supported by the soundcard.
- For electrical stimuli presented through the LAURA implant, a specific file format was designed taking into account the limitations of the implant (Geurts and Wouters, 2000). The amplitude of the current of LAURA stimuli is always defined relative to the dynamic range of the subject for the different channels and the mapping to the actual current intensity is done in real time by the APEX software. Presentation of electrical stimuli to the LAURA implant requires dedicated hardware mainly consisting of a DSP (TI C30) and a LAURA headset (Geurts and Wouters, 2000).
- For the nucleus implant two different file types are supported: NIC1 and NICStream (Cochlear Ltd., 2002). NIC1 files can contain arbitrary pulse trains (any pulse can be presented at any time) but the file format restricts the total length of the stimulus to approximately 15,000 pulses. The NICStream file format supports stimuli of virtually unlimited length but restricts the stimuli to monopolar mode with constant pulse rate and constant pulse shape. The stimuli for the Nucleus implant (of either file format) can be presented using the standard clinical Nucleus fitting hardware and a SPrint speech processor. The amplitude of the current of the pulses in the NICStream format can be stored directly in absolute current intensity or in a relative proportion of the dynamic range. When the amplitude of the stimuli is defined in a relative way, the stimuli can be presented to different subjects by mapping the amplitude of each stimulus between threshold and most-comfortable level of the patient for the particular channels. Mapping of current amplitude is done automatically in APEX by retrieving patient specific data through an SQL-connection to the clinical fitting software of Cochlear. For NIC1 file formats the amplitude is always defined in absolute current intensity.

All stimuli have to be created offline with APEX and are stored on hard disk. This allows for generating very complex stimuli, which may require relatively large computation times. This also enables the researcher to verify all stimuli before running the experiment. Before starting an experiment, APEX checks all stimuli for file-corruption and compatibility of the stimuli with the present hardware. An extensive list of Matlab functions is available for creating, visualizing and storing stimuli for all file formats.

2.2. Experimental procedure

APEX was designed to be user-friendly and not to require any programming skills for creating and setting up an experiment. Experimental procedures and parameter values are defined in simple configuration text files that are interpreted by the APEX program. The syntax of the experiment configuration is straightforward and easy to read.

Currently, APEX is capable of performing five different types of experiments: (1) constant stimuli experiments, (2) adaptive procedure experiments, (3) closed and (4) open set identification, and (5) adjustment procedure experiments. Both the constant stimuli procedure and the adaptive procedure present the stimuli in an N-interval, M-alternative-forced-choice paradigm where N and M are arbitrary with M being smaller or equal to N. Whereas the constant stimuli procedure presents every test trial a fixed number of times, the adaptive procedure uses the x-up, y-down procedure (Levitt, 1971) to reach a certain asymptotic level of performance. Closed set identification allows the researcher to set up a list of possible answers from which the subject has to select one after each trial. During open set identification the subjects can respond with any possible answer. With the adjustment procedure, the researcher can instruct the subject to adjust a property of the sound to match a predefined percept (e.g. matching the percept of a companion stimulus). During one step of an adjustment procedure the variable test signal is presented once in sequence with a fixed reference signal. The reference signal can optionally be repeated a number of times before and after the test signal. The subject then indicates how to adjust the variable test signal, direction and step size (for instance large step, normal step or small step) and