Interactive Software for Evaluating Auditory Discrimination

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Received November 13, 1998; accepted December 11, 1998.

Outline

- Acknowledgments:
- References

Since 1992, we have been investigating the neurophysiologic bases of speech perception in a large-scale study of healthy school-age children and children with learning problems (see, e.g., Kraus, McGee, Carrell, Zecker, Nicol, & Koch, 1996). One of the test protocols in that study is evaluating just noticeable differences (jnds) for synthetic speech syllables. To make that protocol interesting and engaging for the subjects, an interactive software program was developed using an entertaining graphics interface designed especially for school-age children. The program consists of modules that control the sequence and delivery of auditory stimuli using an adaptive procedure based on the subject's response in a two-alternative forced-choice experimental protocol. Feedback and reinforcement are provided by an arcade-game-type graphics display. Specifically, the software program has the following characteristics.

PEST algorithm. The software uses a Parameter Estimation by Stimulus Tracking (PEST) algorithm to search for a jnd threshold. PEST was developed by Taylor and Creelman (1967) as an efficient method of measuring a point on a psychoacoustic probability function (see also Findlay, 1978). Although the PEST algorithm may be used with any discrimination trial structure, a four-interval two-alternative forced-choice same/different (4IAX) procedure is used in this design. This trial structure prevents response bias and minimizes certain memory effects (Pisoni, 1975).

In each trial, the listener is presented with two pairs of sounds where one pair is the same and one pair is different. The subject's task is to indicate whether the first or the second pair is different from each other. The order of same and different pairs within trials is randomized. Each block of trials yields one jnd measurement along a given stimulus continuum using the following procedure. The stimulus at one end of the continuum is designated the "anchor." The "same" pair is always two presentations of the anchor stimulus. The "different" pair consists of the anchor stimulus and another stimulus from the continuum. In accordance with the PEST algorithm, the software uses a Parameter Estimation by Stimulus Tracking (PEST) algorithm to search for a jnd threshold. PEST was developed by Taylor and Creelman (1967) as an efficient method of measuring a point on a psychoacoustic probability function (see also Findlay, 1978). Although the PEST algorithm may be used with any discrimination trial structure, a four-interval two-alternative forced-choice same/different (4IAX) procedure is used in this design. This trial structure prevents response bias and minimizes certain memory effects (Pisoni, 1975).

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algorithm, the stimuli in the "different" pair become closer together on the continuum and, therefore, increasingly harder to discriminate as the subject continues to make correct responses. The subject's jnd is defined as the distance between stimuli in the "different" pair when the subject reliably reaches an accuracy level of 69% correct. This level corresponds to a d' of 1 in terms of signal detection theory (Green & Swets, 1974).

Stimuli and stimulus control. The program reads stimulus files in the .adf format described by the Computerized Speech Research Environment system (AVAAZ Innovations, Inc., London, Ontario). To determine a jnd, a set of stimuli varying along an acoustic continuum are used. At the end of each test block, the jnd is provided in terms of a number of steps along the continuum. Those steps then can be expressed in physical units, such as msec or Hz. For example, in a 31-step speech-syllable continuum in which each stimulus differs from its neighbor by a 1 msec change in voice onset time (VOT), the PEST algorithm would yield a jnd between 1 and 31. A jnd of 7 would indicate that the subject could discriminate a 7-msec VOT difference. For a valid jnd estimation, there must be more than 30 stimuli in the continuum and it must be assumed that the true jnd is no smaller than three steps. Various stimulus timing parameters are under the control of the experimenter, including intertrial interval and interstimulus interval (within and between pairs).

Subject interface. In our experimental setup, the subject interface consists of a response box, a video display, and headphones, which are controlled by the software. During testing, the subject watches a video monitor depicting one of eight scenes, for example, an empty garden. At the bottom of the screen is a cue light and two response lights corresponding to the cue light and response lights on the response box. When a trial begins, the cue light comes on. Then the left light comes on while the first pair of stimuli are presented followed by the right light when the second pair of stimuli are presented. A response button is located under each of the stimulus lights. The subject indicates which stimulus pair was different by pressing the button under the appropriate light. If the response was correct, the light over the button comes on and the subject is reinforced by the appearance of a graphic on the screen. In the example, a flower appears in the empty garden. If the response was incorrect, the light over the correct interval comes on and no reinforcement graphic is presented. As the procedure progresses, the graphic reinforces fill the screen until the PEST algorithm determines a jnd. At that point, a congratulatory message appears. In the example, the flowers wave in the wind as the word "splendid" is spelled out.

Eight reinforcement scenes are available, including sports equipment on a gym floor, objects on a beach, bugs on a bathroom floor, fish in the sea, flowers in a garden, autumn leaves on a sidewalk, money in a bank vault, and stars in the night sky. Additional graphics can be added easily.

Hardware requirements. The software is available on compact disk and runs on an IBM-compatible personal computer using Windows 95 or higher. The computer must provide dual monitor support, and the second (subject) monitor must run at a screen resolution of 800 × 600. A TDT System II (Tucker Davis Technologies, Gainesville, Florida) is required that includes an array processor card (AP2), an optical interface (OM1), a data bus (XB1), a digital-to-analog converter (DD1), a smart port (PI2), and a low-pass filter appropriate to the sampling rate of the stimuli. The stimuli can be routed to the headphone buffer (HB6) and headphones or through an amplifier and loudspeaker. A user-provided two-button three-lamp response box is connected directly to the smart port.

Compact disk. The software is available on a compact disk, which contains all of the executable files required to administer the jnd protocol and to record results. In addition, a program is included that converts sound files in other formats (.wav, .dat, .stm, .aif, .pcm, .nsp, binary 12/16) to the required .adf format. (The most recent version of the file conversion and related programs also are archived online [Tice & Carrell, 1998].) The software comes with documentation describing the system setup and all user-controlled variables. The
compact disk can be obtained at cost by contacting Nina Kraus, Ph.D., Northwestern University, 2299 N. Campus Dr., Evanston, IL 60208 (E-mail: nkraus@nwu.edu).

The software can be used in any research and clinical setting where determination of an auditory jnd is desired. The flexibility of the program allows the experimenter to use any type of stimulus continuum and provides control of stimulus and feedback timing parameters. The reinforcement graphics are appropriate for both children and adults and can be supplemented if desired.

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Acknowledgments:

The software was developed with the support of the National Institute on Deafness and Other Communication Disorders (DC01510). We thank Bob Tice, Robert Gilkey, RedShift Software, Inc., and Ruth Schmidt for their contributions to the development and evaluation of these protocols.

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References


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