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A precision method for lingual vibrotactile threshold measurement

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This study was designed to evaluate the possible effect of two different psychophysical techniques on lingual vibrotactile sensory thresholds. Ten subjects were tested using the ascending psychophysical method of limits and the forced-choice signal detection technique of threshold assessment. Results indicated that both techniques provided consistent, reliable threshold data, but the forced-choice method yielded lower (more sensitive) lingual sensory thresholds. Results are discussed with respect to the appropriate utilization of both testing procedures.

A large body of research has shown that vibration can be used as a reliable stimulus for the assessment of peripheral and central oral tactile processes (Fucci & Crary, 1979). An early focus in vibrotactile threshold assessment was the development of appropriate psychophysical parameters for presenting the vibrotactile stimulus to the anterior surface of the tongue. In 1972, Hall, Fucci, and Arnst obtained lingual vibrotactile thresholds using the method of adjustment and the method of limits. They also compared the ascending and descending presentation of stimuli. Results of their study showed no significant differences in thresholds elicited by the different methods. Since that time, an ascending psychophysical method of limits has been adopted as the method of choice for the vibrotactile test paradigm employed to assess oral sensory thresholds.

One of the most serious concerns encountered with sensory threshold measurements is that of criterion shift (Bartoshuk, 1978). This shift occurs when a subject is free to adopt his own criteria as to how to respond to a presented stimuli. For example, when subjects are requested to indicate that they first feel the vibratory stimulus on the tongue (ascending method of limits), a conservative subject may be reluctant to immediately indicate the awareness of the stimulus, whereas a less conservative subject may respond more quickly. Another concern would be that subjects might actually shift threshold criteria over time when repeated measures are necessary.

Signal detection theory directly deals with the issue of criterion-based threshold measurement. This theory assumes that in the sensory channels there is the presence of random neural activity unassociated with external stimuli. This neural noise sums with that activity evoked by a stimulus (Green & Swets, 1966; Swets, 1964). Therefore, when an external stimulus is applied to the human sensory system, the subject must decide if the neural activity is above a certain baseline in order to indicate that an external stimulus has been applied. This necessitates that the subject adopt an internal criterion.

Closely associated with the signal detection theory is a psychophysical technique called the forced-choice method of threshold assessment (Gescheider, 1976). This method requires the subject to establish an absolute internal standard. The force-choice technique contains the criterion within itself. Two intervals are presented: one with a stimulus and one without. The subject compares the intervals and then chooses the interval eliciting the most neural activity. A few researchers have recently applied forced-choice detection theory to the absolute sensitivity of sensory systems, suggesting that it might describe data better than other threshold assessment methods (Bartoshuk, 1978; Eijkman & Vendrik, 1963; Potash & Jones, 1977; Sekular, Nash, & Armstrong, 1973; Thornbury & Mistretta, 1981).

Lingual vibrotactile research has progressed rapidly in recent years and is now beginning to enter into the exploration of thresholds in clinical case studies, as well as thresholds of different age groups (Fucci, Petrosino, Musto, & Townsend, in press; Fucci, Petrosino, & Robey, 1982; Petrosino, Fucci, & Robey, 1982). In the studies used to obtain lingual tactile thresholds, there has been no attempt made to control for subject response bias. Since it has been indicated that different groups may employ different criteria in psychophysical procedures, this is a critical concern (Potash & Jones, 1977; Sekular et al., 1973; Thornbury & Mistretta, 1981). The purpose of this investigation is to compare lingual vibrotactile thresholds obtained using a criterion-free psychophysical method (method of limits) and a criterion-based psychophysical method (forced choice) of threshold assessment.

METHOD

A group of 14 subjects having an age range of 22-30 years and a mean age of 24.6 years served as participants in this study. The subjects were recruited from a graduate course in speech

and hearing sciences, and they received extra credit for their involvement in this experiment. None of the subjects reported a past or present history of any sensory and/or motor impairments.

Lingual thresholds were assessed using vibrotactile instrumentation composed of a stimulus unit and a measurement unit. The stimulus unit consisted of a sine-wave generator, a 2-dB-step variable attenuator, two universal timers, an audio amplifier, a power amplifier, a preamplifier, and an electromagnetic minivibrator with a probe-contactor extension. The pulsed vibratory signal generated had a 50% duty cycle (on 500 msec and off 500 msec), with a rise and decay time of 100 msec. The measurement unit included an accelerometer, a cathode follower, a microphone amplifier, and a voltmeter. A more detailed description of the vibrotactile equipment can be found in a review by Fucci, Petrosino, Wallace, and Small (1982). A narrow-band noise generator was used to present auditory masking at 70 dB HTL to subjects through TDH-39 headphones.

All of the 14 subjects were treated in the same manner. Each subject was seated in an adjustable chair and asked to place his tongue flat up against the bottom of a rigidly mounted plastic disk. A hole in the center of the disk provided access for the probe-contactor extension of the vibrator to the anterior midline section of the dorsum of the tongue. The contactor area of the probe was .128 cm^2, and there was a 1-mm gap between the contactor and the rigidly mounted plastic disk. To maintain constant pressure of the vibrator on the tongue for all subjects, the vibrator assembly was lowered until a voltmeter recorded contact. The contactor was then lowered 1 mm further into the lingual surface.

Prior to actual experimental data collection, all subjects received training to acquaint them with the nature of the stimulus and to familiarize them with the testing apparatus. The subjects were trained to detect the vibratory stimulus on the tongue at a frequency of 250 Hz. A training criterion requiring each subject to produce three threshold responses in which no two varied by more than 10 mV was used as an index of adequate training.

Subsequent to adequate training, lingual vibrotactile thresholds were collected using two different psychophysical methods of testing. Thresholds were measured using a temporal, forced-choice procedure with a staircase presentation of stimuli (Cornsweet, 1962; Thornbury & Mistretta, 1981) and also using the ascending method of limits, as is typically used in lingual vibrotactile testing. The order of presentation of the psychophysical methods was counterbalanced to offset a possible order effect.

In each trial of the forced-choice method, a 70-dB narrow-band masker was presented auditorily to signal the beginning of each of two consecutive stimulus intervals. When the masking noise was presented, the subject assumed the lingual test position (as previously practiced) and remained in test position until the noise was turned off. A vibratory stimulus was presented in one interval, and no vibratory stimulus was presented in the other interval, according to a predetermined random sequence. A 3-sec pause was employed after the stimulus condition of one interval. The subject was instructed to wait until after both auditory masking cues and report whether the vibratory stimulus followed the first or the second cue. If the subject was not sure when the stimulus was present, he was told to guess, thus always being forced to make a decision. The forced-choice trials were begun with millivolt presentations that were approximately 10 mV above threshold. Intensity was decreased on each successive trial until an incorrect choice was made. Thornbury and Mistretta (1981) referred to this change from a right to a wrong choice or a wrong to a right choice as a reversal point. The same definition of reversal was used in the present study. The stimulus intensity was increased until a correct response was made and then decreased until an incorrect response was given.

Lingual vibrotactile thresholds were also collected using the ascending psychophysical method of limits. The intensity of the vibratory signal was attenuated from below threshold and the subject was instructed to raise his hand as soon as he detected the stimulus on his tongue. The mean of three millivolt readings was accepted as the subject's threshold of sensitivity. Narrow-band noise of 70 dB HTL was used as a precautionary step to prevent the subject's responding auditorily instead of tactually to the stimulus, and also to match the test procedure used in the forced-choice method. The results for both experimental conditions were recorded in millivolts and then converted to displacement in microns re 1-micron peak RMS.

RESULTS AND DISCUSSION

Micron data were compiled and averaged across subjects for both experimental conditions. The mean threshold for the ascending psychophysical method of limits was 2.1 microns. The mean threshold for the forced-choice methodology was 1.5 microns. The standard deviations were .40 microns and .61 microns, respectively. A t test for related measures was applied to the means. A statistically significant difference was obtained [$t(13) = 4.87$, $p < .001$] (Bruning & Kintz, 1977). The results indicate that the mean threshold for the forced-choice methodology yields significantly lower (more sensitive) thresholds than the ascending method of limits. Standard deviations for both conditions were small and indicative of little variability within each condition.

The results of this study demonstrate that the most precise objective lingual sensory threshold measurements appear to be obtained using the forced-choice signal detection technique. This technique has advantages over the traditionally used ascending psychophysical method of limits in that it gives a true measure of the subject's sensitivity at a particular time that is unconfounded by psychological and/or behavioral factors. The forced-choice technique also insures that all subjects use the same response criteria for their decisions involving the presence or absence of an external stimulus.

The forced-choice methodology alleviates important differences in "cautiousness" seen in different subjects. It puts the conservative subject who approaches a psychophysical task with caution on an equal foundation with the less conservative, more risk-prone subject. Researchers have reported increased caution and distractability in older persons (Aiken, 1980). It has also been suggested that the elderly may use different response criteria than the young in psychophysical procedures (Potash & Jones, 1977). Therefore, a forced-choice methodology may be essential to investigate any changes in tactile sensitivity as a function of age.

Although the forced-choice method did provide more sensitive thresholds, there was a problem with respect to the time necessary to complete testing. With the ascending method of limits, accurate lingual vibrotactile thresholds could be obtained within 10 min. The average time required to obtain thresholds with the forced-

choice method was approximately 25 min. The extended time required for the forced-choice technique can lead to subject fatigue and sensory system adaptability. These factors in themselves, then, have the potential to negate the precision afforded by the forced-choice method of threshold assessment.

It appears that both psychophysical methods investigated in this study can be used to obtain reliable lingual vibrotactile thresholds, in that threshold consistency was apparent within each method. Since both methods do appear to provide consistent data, the final decision about the degree of precision required for threshold measures depends on what the measurements are to be used for. If subtle threshold changes within different subject groups are to be identified correctly, a sensitive criterion bias-free procedure such as the forced-choice signal detection technique should be the method of choice.

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