Stimulus duration effects on vibrotactile magnitude estimation for the tongue and hand

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The present study was designed to investigate the effect of stimulus duration on vibrotactile sensation magnitude for the lingual dorsal surface and the thenar eminence of the right hand through use of the psychophysical scaling method of magnitude estimation. Magnitude estimation values for the tongue and hand were derived from 20 normal young adults. Measurements were made at a frequency of 250 Hz with stimulus durations of 100, 500, and 1,000 msec. Results showed the upper power function exponents to be steeper at all three stimulus durations for the lingual dorsal surface than for the thenar eminence, and the exponents for both the tongue and hand were smaller for 1,000 msec than for 100 msec. Pearson product moment correlations were performed on the subject magnitude estimation responses for the three stimulus durations. The durational correlations were performed independently for both test structures. Correlation coefficients for both test structures at all three stimulus durations tended to increase as stimulus intensity was increased. The correlation coefficients did not reflect changes in the relationship between individual subject responses as a result of stimulus durational changes at any of the sensation levels tested. Results are compared to previous research and discussed in terms of internal scaling mechanisms and learning effect.

Von Békésy (1959b) investigated the effect that stimulus duration has on hearing and skin sensations. He suggested that for vibratory stimulation of the skin, there is an initial increase in sensation magnitude during the first second of stimulation, followed by a gradual decline thereafter. Verrillo (1965) explored the effect of stimulus duration on vibrotactile thresholds of the hand and determined that vibrotactile thresholds decreased with increasing duration up to about 600 msec. Verrillo (1968) did not find a similar stimulus duration effect for vibrotactile thresholds of the tongue.

Berglund, Berglund, and Ekman (1967), using a direct scaling method, studied the effect of stimulus duration on the subjective magnitude of suprathreshold vibrotactile stimuli delivered to the finger. They found that subjective intensity of a 250-Hz signal was a logarithmic function of stimulus duration up to 1 sec. These researchers reported power function exponents that decreased from .70 for a duration of 30 msec to .40 for durations of 220 msec or longer. Gescheider (1976) reported

suprathreshold magnitude estimation exponent values for the hand of .43 for durations of 200 and 50 msec, and .40 for a duration of 600 msec. Verrillo and Smith (1976) used the method of magnitude estimation to study stimulus duration effect on the thenar eminence of the right hand. They reported power function exponents of .50 for 10 msec, .49 for 80 msec, and .47 for 600 msec. Although the methodologies varied considerably among these investigations, in each, a stimulus duration effect was noted whereby the suprathreshold power function exponent decreased with an increase in stimulus duration.

The test sites for vibrotactile stimulation used in the research described above were selected from various locations on the hand. To date, the possible effects of stimulus duration at suprathreshold levels has not been investigated for other body locations. The purpose of the present study was to extend the research on vibrotactile sensation magnitude by investigating stimulus duration effect on the dorsal surface of the tongue and the thenar eminence of the right hand through use of the psychophysical scaling method of magnitude estimation. A comparison of sensation magnitude scaling data between these two test sites may provide additional information concern-

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ing temporal summation at body locations which vary in overall neurophysiological characteristics (Bosma, 1967).

METHOD

Subjects

Twenty subjects, 10 men and 10 women, aged 18–27 years (mean = 20.45 years), were selected randomly from an introductory course in speech and hearing sciences at Ohio University. All subjects had normal speech and hearing and reported no known sensory and/or motor impairments. None of the subjects were experienced in vibrotactile testing.

Apparatus

The vibrotactile instrumentation consisted of a stimulus unit and a measurement unit. The stimulus unit was composed of a sine-wave generator, an experimenter-controlled variable attenuator, a rise/fall gate, two universal timers, an audio amplifier, a power amplifier, and an electromagnetic minivibrator with a probe-contact extension. The pulsed vibratory signal generated had a frequency of 250 Hz, with a rise-decay time of 5 msec. Three signal durations of 100, 500, and 1,000 msec were selected, with a constant interstimulus interval of 2 sec. The measurement unit consisted of an accelerometer, a cathode follower, a microphone amplifier, and a voltmeter. A narrow band generator was used to present auditory masking at 70-dB HTL to the subjects in order to prevent them from hearing the vibratory stimulus. A detailed description of the vibrotactile equipment and procedures can be found in a review by Fucci, Petrosino, Wallace, and Small (1982).

Procedure

All 20 subjects participated in two test sessions with an interval of 1 week between sessions. A split-half design was used in which half of the subjects were tested on the lingual dorsal surface during the first test session and the thenar eminence of the right hand during the second test session. The remaining subjects were tested on the thenar eminence of the right hand during the first test session and the lingual dorsal surface during the second test session. During each session, three signal durations of 100, 500, and 1,000 msec were randomly presented in a two-trial series to the structure being tested. In each session, the subject was seated in an adjustable chair and positioned so that the test structure was placed in contact with the lower side of a rigidly mounted plastic disk. A hole in the center of the disk provided access for the contactor extension of the vibrator to the test structure. The contactor had a surface area of .128 cm², and there was a 1-mm gap between the contactor and the plastic disk. Each subject's vibrotactile threshold was determined by the ascending method of limits. The accepted threshold was the mean of three successive readings within a 5-mV range. The psychophysical method of magnitude estimation was used to obtain a subjective magnitude function for the tongue and hand (Stevens, 1955). The subjects were required to assign numbers to a randomly presented series of eight stimulus intensities ranging from 6 to 40 dB SL. To minimize possible biases in the results, no reference standard was provided during the task (Hellman & Zwislöcki, 1963). Each subject was instructed to assign a number to each stimulus intensity such that his or her impression of how large the number was matched his or her impression of how intense the vibration was. Whole numbers, decimals, and fractions were designated as permissible selections (Zwislöcki & Goodman, 1980). The geometric means of the two trials of the eight stimulus intensities were taken as the magnitude estimation responses.

RESULTS AND DISCUSSION

The mean magnitude estimation functions produced by the 20 subjects for the three stimulus durations presented to the thenar eminence of the right hand are shown in Figure 1. For the hand, the upper slope values for the durations of 100, 500, and 1,000 msec were .46, .48, and .42, respectively. The mean magnitude estimation func-

Figure 1. Magnitude estimation functions for three stimulus durations performed on the thenar eminence of the right hand.

Figure 2. Magnitude estimation functions for three stimulus durations performed on the dorsal surface of the tongue.

tions produced by the 20 subjects for the three stimulus durations presented to the lingual dorsal surface are shown in Figure 2. For the tongue, the upper slope values for the durations of 100, 500, and 1,000 msec were .66, .62, and .50, respectively. The lower slope values for the magnitude estimation functions produced by the 20 subjects for the three stimulus durations for both test structures approached unity. These lower slope findings are in agreement with Zwislöcki's theory of temporal summation (Zwislöcki, 1960, 1965; Hellman & Zwislöcki, 1961),

which states that sensation magnitude is directly proportional to stimulus energy near threshold of sensitivity.

The upper slope values for the three stimulus durations for the thenar eminence were similar for 100 and 500 msec, and showed a slight decrease for 1,000 msec. These findings are compatible with those reported by other researchers (Berglund, Berglund, & Ekman, 1967; Gescheider, 1976; Verrillo & Smith, 1976). The upper slope values for the thenar eminence were lower than those for the lingual dorsal surface at all three stimulus durations. This finding is in agreement with those of von Békésy (1957, 1959a), Stevens (1959), and Verrillo and Chamberlain (1972). These researchers noted that body locations of lower neural density yield steeper slopes of subjective magnitude than those of higher neural density. The upper slope values for the lingual dorsal surface, like those for the thenar eminence, showed an overall decrease with an increase in stimulus duration.

In order to compare the relationship between individual responses at each of the eight stimulus intensity levels, Pearson product-moment correlations were performed on the subject magnitude estimation responses for the three stimulus durations. These durational correlations were performed independently for both test structures. These findings are shown in Table 1. It can be seen that correlations for both test structures tended to increase as stimulus intensity level was increased. This trend was evident for the correlations between all three stimulus durations.

The magnitude estimation power function exponents obtained in this study suggest that the subject responses for the lingual dorsum and thenar eminence were similar over the three suprathreshold vibrotactile stimulus durations. In both instances, the upper slope values were smaller for 1,000 msec than they were for 100 msec. This finding agrees with the results obtained by Verrillo and Smith (1976), who concluded that subjective magnitude functions are directly proportional to energy near threshold but become compressed at higher intensity levels. In the present study, additional amounts of stimulus intensity did not elicit proportional subjective responses at the higher sensation levels, and this compression of magnitude functions became slightly more noticeable with stimulus duration increases (Figures 1 and 2; Verrillo & Smith, 1976).

The Pearson product-moment correlations obtained in the current investigation indicated that the relationships be-

tween individual subject magnitude estimation responses showed little change over the three stimulus durations at any of the sensation levels tested (Table 1). The correlations were generally higher for the higher sensation levels than for the lower ones, and this trend was consistent for all three stimulus durations. This pattern of correlations suggests that a wider range of numerical responses was used between subjects at lower sensation levels. At higher sensation levels, the range of numeric responses was narrowed between subjects. It appears from the data that the subjects in the present study used similar scaling behaviors for all three durations. This consistent behavior might be reflective of an internal absolute scaling mechanism that is established early in life and applied to all types of numerical scaling behavior (Zwislocki & Goodman, 1980).

The nature of the design for the present study was such that all three duration sequences (100, 500, 1,000 msec) were presented in the same experimental session for both the tongue and the hand. Because of this arrangement, it is possible that the consistent behavior across durations was the result of a learning effect that took place during exposure to the first sequence of eight stimulus intensity levels. This learning effect could have influenced the subjects' scaling behavior on the subsequent stimulus duration presentations. R. Teghtsoonian (1973) and Teghtsoonian and Teghtsoonian (1983) reported that a learning effect can take place in psychophysical scaling experimentation. For scaling responses to be independent of this learning effect, these researchers suggest that a minimum of 24 h should be required between scaling sessions.

In conclusion, the results of this study suggest that the effects of suprathreshold vibrotactile stimulus duration on magnitude estimation functions for the tongue and hand are similar. At lower sensation levels, subjective magnitude appears to be approximately proportional to stimulus intensity for both structures. At the higher sensation levels, compression of magnitude functions for the lingual dorsum appeared to increase with increases in stimulus duration. This pattern of upper slope compression agrees with data previously obtained for vibrotactile stimulation of the hand and suggests that the effects of temporal summation on sensation magnitude may be similar for the tongue and the hand.

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Table 1
Summary Table of Pearson Product-Moment Correlations
for Subject Magnitude Estimation Responses

Sensation Level in dB	100/500 msec		500/1,000 msec		100/1,000 msec	
	Hand	Tongue	Hand	Tongue	Hand	Tongue
6	.56	.64	.57	.46	.39	.71
10	.55	.72	.55	.77	.40	.76
16	.52	.50	.70	.72	.37	.48
20	.67	.71	.62	.66	.46	.78
26	.54	.74	.86	.81	.60	.70
30	.49	.89	.78	.83	.83	.86
36	.69	.73	.90	.68	.88	.73
40	.82	.80	.97	.80	.86	.88

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