# EFFECTS OF METHODOLOGICAL PARAMETERS ON SIGNAL DETECTION AND FREQUENCY DISCRIMINATION

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## ABSTRACT

This experiment was undertaken to determine the effects of variation in three methodological parameters, namely paradigm (2IFC vs 4IFC), stimulus duration (50 ms vs 300 ms) and practice (1 vs 6 replications) on the auditory detection threshold and frequency discrimination limen for a 2kHz-pure tone, and the reaction time associated with each. The subjects were three normal-hearing listeners under the age of 30 years. In line with the predictions, an increase in the stimulus duration resulted in a significant decrease in the detection threshold and detection reaction time but did not affect discrimination. Also as expected, paradigm did not affect detection. However, the 4IFC paradigm reduced acuity for a change in frequency, possibly because the problem had changed to one of pattern recognition. Contrary to expectation, practice did not affect either sensory processing or choice reaction time.

## SOMMAIRE

Cette étude a pour but de déterminer les effets de la variation de 3 paramètres méthodologiques, à savoir le paradigme (2IFC vs 4IFC), la durée du stimulus (50 ms vs 300 ms) et l'entraînement (1 vs 6 repetitions) sur le seuil de détection auditive, le seuil de discrimination fréquentielle et le temps de réaction associé à chacune de ces tâches. Les trois sujets avaient moins de 30 ans et présentaient une audition normale. En accord avec les prédictions, une augmentation de la durée du stimulus a provoqué une amélioration significative du seuil de détection et du temps de réaction mais n'a pas affecté la discrimination. Tel que prévu, le paradigme n'affecte pas la détection. Le paradigme 4IFC a toutefois réduit l'acuité à un changement de fréquence, parce que le problème est possiblement devenu un problème de reconnaissance de structures. Contrairement aux attentes, l'entraînement n'a pas influencé l'un ou l'autre des processus sensoriels ni le temps de réaction.

## 1. INTRODUCTION

Auditory perception, particularly within the context of forced-choice signal detection and discrimination tasks, includes both a sensory processing stage and a decision-making stage (Swets, Tanner and Birdsall, 1961). The detection threshold and difference limen reflect sensory acuity. Decision-making may be accessed through such measures as response bias (Green and Swets, 1966) and also response latency (Welford, 1980).

The following experiment was undertaken to study the differential effects of variation in three methodological parameters on the sensory processing and decision-making stages for signal detection and frequency discrimination. The three parameters chosen were stimulus duration, psychophysical paradigm, and practice. The aim was to provide data for use in experimental design.

Stimulus duration has been shown to affect both signal detection and frequency discrimination, within limits. For normal-hearing listeners, increasing duration over the range of approximately 20-100 ms results in a decrease in the detection threshold at the rate of 3 dB/doubling of duration (Garner and Miller, 1947) or 8-10 dB/decade of duration (Florentine, Fastl and Buus, 1988). Below 20 ms, the rate may be as high as 4.5 dB/doubling of duration and from 100 ms - $\frac{1}{2}$ s, as low as 1.5 dB. This psychophysical phenomenon is known as temporal integration. Watson and Gengel (1964) explored the effect of stimulus frequency on temporal integration. Their threshold duration curves spanning the range of 16 -1024 ms were best fit by a negative exponential. As the stimulus frequency increased from 125 Hz to 8 kHz, the time constant decreased.

Like the detection threshold, acuity for a change in frequency (F), as measured by the frequency difference limen (DLF), improves with an increase in stimulus duration (Hall and Wood, 1984). The evidence suggests that the relationship will again depend on the stimulus frequency (Moore, 1973; Sinnott and Brown, 1993). In Sinnott and Brown's study, DLFs were shown to decrease for both 500 Hz and 4000 Hz, as duration increased from 12-400 ms, although less so for 4000 Hz. The effect appeared to level off after 40 ms. The Weber ratio DLF/F for durations equal to or greater than 100 ms at and above 500 Hz is approximately 0.003. Large individual differences due to psychophysical procedure and training have been documented (Green, 1976; Spiegel and Watson, 1984).

Paradigm affects frequency discrimination to a greater degree than it affects detection. Jesteadt and Bilger (1974) and Jesteadt and Sims (1975) compared DLFs obtained using single interval yes/no (Y/N), two-interval forced choice (2IFC) and two interval same/different paradigms. The 2IFC paradigm yielded the smallest and Y/N, the largest, DLF. With respect to detection, the initial focus for research was the possible detrimental effect of clinical vs laboratory procedures. Marshall and Jesteadt (1986), for example, compared the outcomes for the standard audiological method of limits, and 2IFC paradigm in combination with an adaptive variation in intensity. The latter procedure yielded thresholds which were on average 6.5 dB lower than the former. Giguère and Abel (1990) found that thresholds derived from a Bekesy tracking procedure yielded thresholds which were 2-3 dB higher than those from a 2IFC with variation in stimulus intensity across trial blocks.

There is agreement that the 2IFC adaptive procedure will yield lower thresholds than the 2IFC fixed intensity procedure, although this may depend on the targeted probability of correct response used to estimate threshold (Kollmeier, Gilkey and Sieben, 1988; Schlauch and Rose, 1990). The literature suggests that the efficiency of the method, defined in terms of the accuracy and stability of the estimate of threshold, will increase with the number of observation intervals on a trial, 2 vs 3 vs 4IFC (Shelton and Scarrow, 1984; Green, Richards and Forrest, 1989).

Reaction time, which is considered to be a measure of cognition, will also be affected by the number of response alternatives. Simple reaction time is the time needed to respond to the presence of a single stimulus (detection). Choice reaction time, which requires a different response for each of a number of possible stimuli (discrimination), adds the times for identification and response selection (Smith, 1968; Welford, 1980). The time to respond will increase as the discriminability of the alternative stimuli decreases and as the number of alternatives increases and will decrease with practice. Detection reaction time will also decrease to a limited degree, as the stimulus duration (and hence, the total stimulus energy) increases (Brebner and Welford, 1980).

## 2. EXPERIMENTAL DESIGN

The present experiment was conducted to determine whether and to what extent the auditory detection threshold and frequency difference limen for a 2 kHz-pure tone, and their associated reaction times would be differentially affected by variation in the stimulus duration (50 ms vs 300 ms), psychophysical paradigm (2 vs 4IFC) and practice (1 vs 6 replications), in young, normal-hearing listeners. Based on our review of the literature, and envisioning perception as a 2-stage process of stimulus processing and decision-making, we predicted that an increase in stimulus duration would result in a decrease in the detection threshold and detection reaction time, while an increase in the number of forced-choice alternatives would result in an increase in both detection and discrimination reaction time. Practice was expected to impact positively on all four measures.

Each subject completed the experiment within a two-week period. There were six listening sessions (replications), each lasting approximately one hour. During a session, the detection threshold and frequency difference limen were measured for the four combinations of psychophysical method (2 vs 4IFC) and stimulus duration (50 vs 300 ms). The detection task preceded the frequency discrimination task. Within task, the order of the four combinations of stimulus paradigm and duration was randomly determined.

## 3. METHODS AND MATERIALS

### 3.1 Subjects

Three normal-hearing individuals, aged 20 to 26 years, participated in the experiment. All had previously served as subjects in auditory detection but not frequency discrimination studies.

### 3.2 Apparatus

The experiment was carried out in a double-walled IAC booth. The ambient noise level was less than the maximum allowed for headphone testing (ANSI S3.1-1977). The 2 kHz-pure tone used in the experiment was generated by a Hewlett-Packard Synthesizer/Function Generator (Model 3325A). A custom built attenuator and Luxman integrated amplifier (Model L-210) allowed for variation in amplitude over a range of 90 dB. Stimulus duration and envelope shaping (i.e., 10 ms-rise/decay time) were controlled by means of a Coulbourn Instruments Modular System. The system was controllable from an IBM XT PC via an IEEE-488 interface.

The auditory events on a trial were presented binaurally over a Telephonics TDH-39P matched headset. The stimulus intensities were calibrated using a Bruel & Kjaer artificial ear (Type 4153). Subjects responded by means of a custom-designed hand-held response box which comprised a set of five LEDs to cue the events on each trial and four microswitches for responding. The microswitches were accurate to within 1 ms.

## 3.3 Procedure

### 3.3.1 Detection and Discrimination

For the *auditory detection task*, the subject was presented on each trial with a ½ s warning light, a pause of 300 ms followed by two (2IFC) or four (4IFC) listening intervals, separated by 300 ms. The duration of the listening intervals was either 100 ms or 300 ms, depending on whether the stimulus duration was 50 ms or 300 ms. These events were cued by three or five LEDs based on the choice of procedure. The 2-kHz stimulus to be detected was presented in one of the intervals randomly determined from trial to trial. The subject was instructed to depress the microswitch response key corresponding to the LED that was coincident with stimulus, as soon as the last LED in the series was extinguished. A maximum of 5 s was allowed for the response.

The intensity of the stimulus remained constant within a block of 32 trials but was varied across blocks, independently for each subject, so as to generate a psychometric function with the proportion of correct responses, P(C), ranging from 0.50 (chance) to 1.00 (perfect performance) or 0.25 to 1.00 for the 2IFC and 4IFC procedures, respectively. The detection threshold, the intensity that would generate a P(C) of 0.75 or 0.625, for the two procedures, was interpolated from a straight line fit to the data points. These critical values correspond to the midpoints on the theoretical psychometric functions. For either procedure, two data points were considered sufficient, as long as one was between a few percentage points above chance and the threshold P(C), and the other between the threshold P(C) and a few percentage points below perfect performance. In practice, three or four blocks of trials were usually required to satisfy this constraint.

The method for measuring the *frequency discrimination difference limen* was similar to that for detection. On each forced-choice trial, the standard frequency (F) of 2 kHz was presented in either one or three listening intervals, depending on whether the experimental condition specified 2IFC of 4IFC, and a comparison frequency ($F + \Delta F$) was presented in the remaining interval, randomly determined from trial to trial. The comparison stimulus, which exceeded the standard in frequency, remained the same within a block of 32 trials but was varied across blocks, so as to generate a psychometric function with P(C) ranging from either 0.50 to 1.00 or 0.625 to 1.00, depending on the procedure. The frequency difference limen (DLF) was interpolated as that value of $\Delta F$ that would result in a P(C) of 0.75 or 0.625, as for the detection threshold.

### 3.3.2 Choice Reaction Time

The method for obtaining the reaction times associated with correct and incorrect responses for the detection threshold and frequency difference limen is described by Abel and Armstrong (1992). For both tasks, subjects were instructed to respond as quickly as possible without sacrificing accuracy. Guessing was encouraged. For each experimental condition, the P(C) obtained for each block of trials was plotted against each of the median reaction times for correct and incorrect responses, taken separately. These corresponded to the time lag between the termination of the final LED and the microswitch closure signifying the response. The median was used in preference to the mean because of the skewness of the distribution of latencies within blocks. Straight lines were fit by eye to these reaction time psychometric functions. The correct and incorrect reaction times associated with P(C) equal to 0.75 or 0.625, depending on the paradigm, were interpolated to provide values associated with the detection threshold and difference limen.

## 4. RESULTS

The results of the experiment are presented in Tables 1, 2 and 3. Table 1 shows the detection thresholds and frequency discrimination limens obtained for each of the three subjects for the eight combinations of stimulus duration (50 ms vs 300 ms), paradigm (2IFC vs 4IFC), and replication (1 vs 6). The correct and incorrect reaction times (CRT and IRT) associated with each of these measures are presented in Tables 2 and 3. In the case of subject JT, the results of the detection task obtained on the first day were rejected because of equipment malfunction. These data were replaced by data from the second replication.

Repeated measures ANOVAs were applied to each of the six data sets given in the tables. Although the number of subjects was small, the trends observed for each were similar. In the case of detection, the only significant factor ($p < 0.05$) was stimulus duration. An increase from 50 ms to 300 ms resulted in a decrease in threshold of 6 dB SPL, averaged across paradigm, replications and subjects (see the left panel of Fig. 1). In contrast, the frequency discrimination difference limen was significantly affected by the paradigm ($p < 0.05$). The DLF generated by the 4IFC paradigm was 3.4 Hz greater than the DLF for the 2IFC paradigm, averaged across stimulus duration, replications and subjects (see the right panel of Fig. 1).

With respect to reaction time, the outcomes of the ANOVAs indicated that the values associated with both correct and incorrect trials at the level of the detection threshold decreased with an increase in stimulus duration ($p < 0.05$), as for the detection threshold. The improvement was approximately 106 ms for each of the CRT and IRT, when averaged across paradigms, replications and subjects (see Fig. 2). The IRT associated with the frequency difference limen decreased significantly ($p < 0.05$) for the 4IFC compared with the 2IFC paradigm. As shown in Fig. 2, the difference was on average 35 ms. The CRT did not change significantly as a function of any of the variables manipulated. Two of the subjects showed a decrement for the 4IFC paradigm, and the third subject, an increment.

## 5. DISCUSSION

Based on our review of the literature, we predicted that increasing the stimulus duration from 50 to 300 ms would result in a decrease in threshold, according to the theory of temporal integration. We did not expect duration to influence frequency discrimination because a number of previous reports had concluded that it was not a significant factor for the range of durations tested. The results of the experiment confirmed the predictions. Across subjects, the threshold decreased significantly by 6 dB, as the stimulus duration increased from 50 ms to 300 ms for both the first and final replications. Duration did not affect the frequency difference limen. The observed value of DLF across the first and final replications, the two paradigms, two stimulus durations and subjects, was 7.8 Hz, yielding a Weber ratio of 0.0039, in line with previous reports.

Paradigm has previously been shown to affect detection, although in comparisons of various forced-choice procedures, the outcome was reported as a change in the stability of the estimates rather than sensitivity. Clinical procedures yield higher DLFs than laboratory estimates. A comparison of the outcomes for 2IFC and 4IFC procedures in the present experiment indicated that the detection threshold was not affected. However, the DLF was significantly greater for the 4IFC paradigm. Averaging across stimulus durations, first and sixth replications and subjects, the observed values for 2IFC and 4IFC were 6.1 Hz and 9.5 Hz, respectively. The smaller value yields a Weber ratio of 0.003, the value quoted in the literature. The larger value yields a Weber ratio of 0.005. One possible explanation for this difference is that the 4IFC paradigm may present the subject with a pattern recognition problem involving sequential processing across listening intervals, rather than a simple comparison of two frequencies.

We expected that practice would improve, that is reduce, both the detection threshold and frequency difference limen. Statistical comparison of the values obtained during the first and final (sixth) replications indicated that there were no differences in either measure. Collapsed across stimulus duration and paradigm, the mean within-subject change in the detection threshold from the first to the final replication was an improvement of 0.9 dB in the detection threshold and 3.5 Hz in the DLF at 2 kHz. For each subject, within each experimental condition, the function relating outcome to replication number, 1 through 6, was always non-monotonic. The lack of a significantly positive outcome may have been due to the fact that all three subjects had had experience as subjects and testers in psychoacoustic experiments, although not with the particular paradigms and measurements under study.

Apart from the traditional psychoacoustic measures of detection threshold and difference limen, the experiment was also designed to evaluate the effect of variation in methodological parameters on decision-making. The measure chosen was the reaction time associated with the same level of performance used to derive the two indices of sensory acuity, i.e., either $P(C) = 0.75$ or $P(C) = 0.625$, depending on whether a 2IFC of 4IFC paradigm had been used. According to the literature, there is some evidence for a decrease in simple reaction time with an increase in duration but only at the low end of discriminability (Brebner and Welford, 1980).

The results of the present experiment showed a significant decrease in both the correct and incorrect reaction times with an increase in stimulus duration for the detection task. The mean within-subject differences in the correct and incorrect reaction times due to duration (without regard to paradigm or replication) were 106 ms and 107 ms, respectively. Across the 24 conditions by subjects, the incorrect reaction time was 45 ms longer than the correct reaction time. We have noted a similar difference in previous studies and have pointed out its comparability to the duration of the alpha half cycle in EEG recordings (Abel, Rajan and Giguère, 1990; Abel and Armstrong, 1992). The average difference observed for the discrimination task was 64 ms.

For the discrimination task, we had expected that the reaction time would increase with number of alternatives, i.e., that the 4IFC paradigm would generate longer values that the 2IFC. A significant difference of 35 ms was observed only for the incorrect reaction time but in the opposite direction. Outcomes across individuals were highly variable. Practice had no effect on reaction time in either task, possibly because the subjects were not experimentally naive.

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## REFERENCES

Abel, S.M. and Armstrong, N.M. (1992). "The effect of aging on reaction time in auditory detection and discrimination tasks." Canad. Acous. 20(4), 3-9.

Abel, S.M., Rajan, D.K. and Giguère, C. (1990). "Stimulus parameters in detection and reaction time." Scand. Audiol. 19, 229-235.

ANSI-S3.1 (1977). "Criteria for permissible ambient noise during audiometric testing." American National Standards Institute, New York.

Brebner, J.M.T. and Welford , A.T. (1980). "Introduction: An historical background sketch," in Reaction Times, edited by Welford, A.T. (Academic, New York), pp. 1-23.

Florentine, M., Fastl, H. and Buus, S. (1988). "Temporal integration in normal hearing, cochlear impairment, and impairment simulated by masking." J. Acoust. Soc. Am. 84(1), 195-203.

Garner, W.R. and Miller, G.A. (1947). "The masked threshold of pure tones as a function of duration." J. Exp. Psychol. 37, 293-303.

Giguère, C. and Abel, S.M. (1990). "A multi-purpose facility for research on hearing protection." Appl. Acous. 31, 295-311.

Green, D.M. (1976). An Introduction to Hearing. (Erlbaum, Hillsdale).

Green, D.M., Richards, V.M. and Forrest, T.G. (1989). "Stimulus step size and heterogeneous stimulus conditions in adaptive psychophysics." J. Acoust. Soc. Am. 86(2), 629-636.

Green, D.M. and Swets, J.A. (1966). Signal Detection Theory and Psychophysics. (Wiley, New York).

Hall, J.W. and Wood, E.J. (1984). "Stimulus duration and frequency discrimination for normal-hearing and hearing-impaired subjects." J. Sp. Hear. Res. 27, 252-256.

Jesteadt, W. and Bilger, R.C. (1974). "Intensity and frequency discrimination in one- and two-interval paradigms." J. Acoust. Soc. Am. 55(6), 1266-1276.

Jesteadt, W. and Sims, S.L. (1975). "Decision processes in frequency discrimination." J. Acoust. Soc. Am. 57(5), 1161-1168.

Kollmeier, B., Gilkey, R.H. and Sieben, V.K. (1988). "Adaptive staircase techniques in psychoacoustics: A comparison of human data and a mathematical model." J. Acoust. Soc. Am. 83(5), 1852-1862.

Marshall, L. and Jesteadt, W. (1986). "Comparison of pure-tone audibility thresholds obtained with audiological and two-interval forced-choice procedures." J. Sp. Hear. Res. 29, 82-91.

Moore, B.C.J. (1973). "Frequency difference in limens for short-duration tones." J. Acoust. Soc. Am. 54, 610-619.

Schlauch, R.S. and Rose, R.M. (1990). "Two-, three-, and four-interval forced-choice staircase procedures: Estimator bias and efficiency." J. Acoust. Soc. Am. 88(2), 732-740.

Shelton, B.R. and Scarrow, I. (1984). "Two-alternative versus three-alternative procedures for threshold estimation." Percep. & Psychophys. 35(4), 385-392.

Sinnott, J.M. and Brown, C.H. (1993). "Effects of varying signal duration on pure-tone frequency discrimination in humans and monkeys." J. Acoust Soc. Am. 93(3), 1541-1546.

Spiegel, M.F. and Watson, C.S. (1984). "Performance on frequency-discrimination tasks by musicians and nonmusicians." J. Acoust. Soc. Am. 76(6), 1690-1695.

Swets, J.A., Tanner, W.P. Jr. and Birdsall, T.G. (1961). "Decision processes in perception." Psychol. Rev. 68, 301-340.

Smith, E.E. (1968). "Choice reaction time: An analysis of the major theoretical positions." Psychol. Bull. 69, 77-110.

Watson, C.S. and Gengel, R.W. (1969). "Signal duration and signal frequency in relation to auditory sensitivity." J. Acoust. Soc. Am. 46, 989-997.

Welford, A.T. (1980). "Choice reaction time: Basic concepts," in Reaction Times, edited by Welford, A.T. (Academic, New York), pp. 73-128.

**Table 1. Detection thresholds (Det) and frequency difference limens (DLF) for a 2 kHz-pure tone. Effects of paradigm, stimulus duration and replication in three subjects.**

| | | Paradigm/Stimulus Duration | | | |
|---|---|---|---|---|---|
| | | 2IFC | | 4IFC | |
| Measure | Sub | 50 ms | 300 ms | 50 ms | 300 ms |
| Det | JT | -1.2 (-0.2)* | -5.6 (-8.6) | -0.3 (0.5) | -4.8 (-6.4) |
| (dB SPL) | VH | 7.9 (5.7) | 4.2 (3.5) | 8.8 (7.4) | 3.7 (1.2) |
| | FS | 10.0 (10.3) | -0.2 (-0.8) | 8.6 (7.3) | 2.1 (2.6) |
| DLF | JT | 3.4 (3.2) | 1.0 (2.0) | 7.5 (6.0) | 4.0 (2.7) |
| (Hz) | VH | 6.0 (8.4) | 6.0 (1.7) | 20.0 (10.8) | 6.2 (4.2) |
| | FS | 17.4 (8.2) | 10.1 (6.0) | 19.0 (12.8) | 14.3 (6.4) |

* First (sixth) replication

**Table 2.** Correct (CRT) and incorrect (IRT) detection threshold reaction times. Effects of paradigm, stimulus duration and replication in three subjects.

| | | Paradigm/Stimulus Duration | | | |
|---|---|---|---|---|---|
| | | 2IFC | | 4IFC | |
| Response | Sub | 50 ms | 300 ms | 50 ms | 300 ms |
| CRT (ms) | JT | 810 (375)* | 600 (385) | 800 (485) | 600 (275) |
| | VH | 625 (615) | 550 (475) | 620 (505) | 510 (450) |
| | FS | 295 (270) | 345 (160) | 365 (285) | 250 (175) |
| IRT (ms) | JT | 830 (425) | 660 (450) | 942 (515) | 750 (330) |
| | VH | 655 (620) | 672 (460) | 740 (610) | 565 (460) |
| | FS | 327 (319) | 395 (150) | 365 (245) | 230 (190) |

* First (sixth) replication

**Table 3.** Correct (CRT) and incorrect (IRT) frequency discrimination reaction times. Effects of paradigm, stimulus duration and replication in three subjects.

| | | Paradigm/Stimulus Duration | | | |
|---|---|---|---|---|---|
| | | 2IFC | | 4IFC | |
| Response | Sub | 50 ms | 300 ms | 50 ms | 300 ms |
| CRT (ms) | JT | 505 (510)* | 520 (350) | 380 (350) | 330 (225) |
| | VH | 545 (500) | 355 (310) | 560 (525) | 385 (345) |
| | FS | 705 (235) | 305 (190) | 400 (300) | 340 (145) |
| IRT (ms) | JT | 505 (460) | 545 (375) | 560 (395) | 435 (340) |
| | VH | 575 (770) | 527 (330) | 640 (590) | 430 (445) |
| | FS | 715 (250) | 325 (260) | 475 (390) | 325 (190) |

* First (sixth) replication

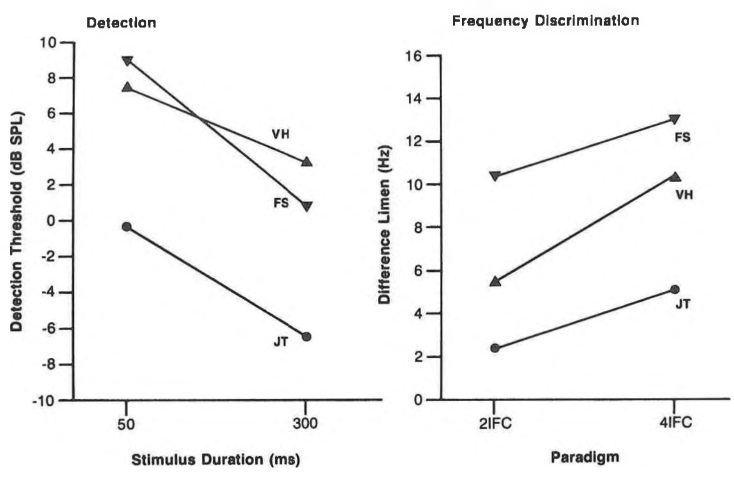


Fig. 1 Detection Threshold and Frequency Difference Limen for a 2-kHz Pure Tone

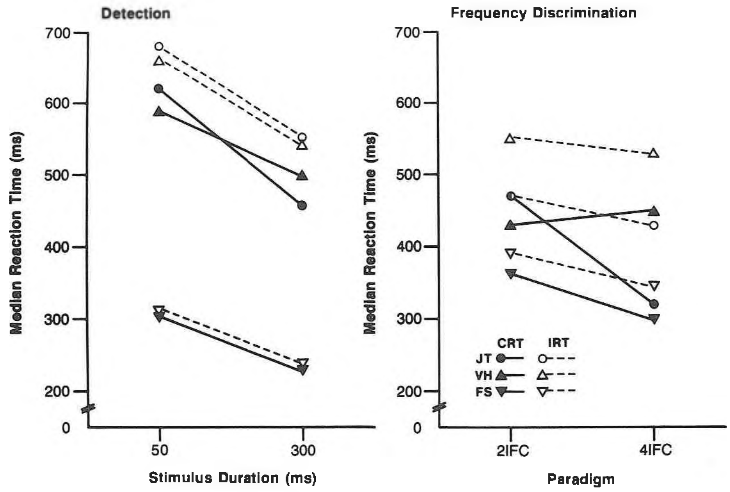


**Fig. 2 Correct and Incorrect RTs Associated with the Detection Threshold and Frequency Difference Limen for a 2-kHz Pure Tone**

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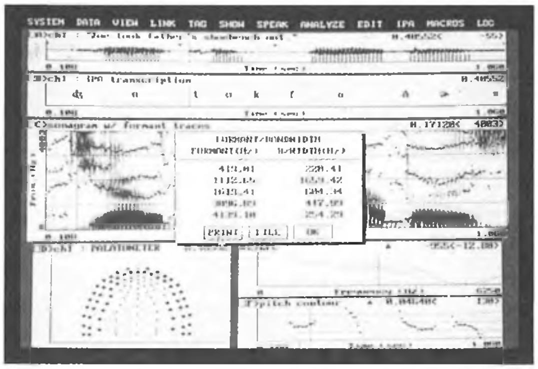


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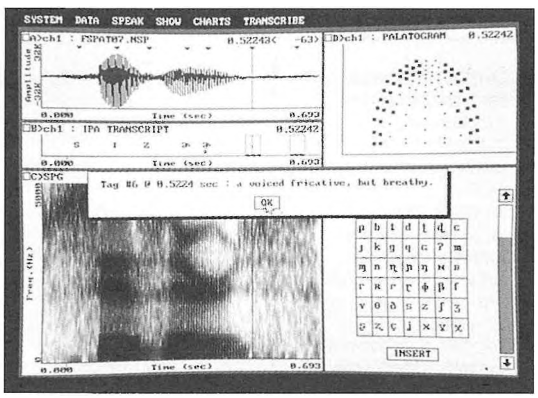


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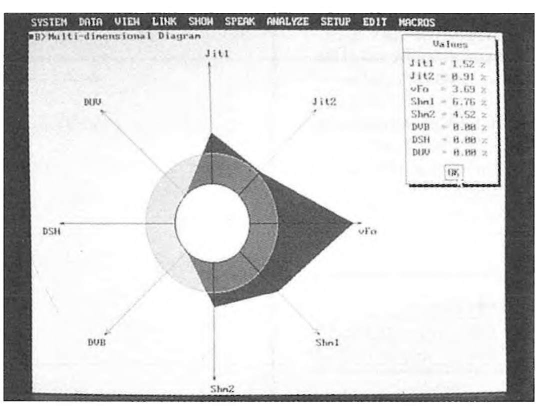


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