Decision latencies of "same" and "different" judgments[1]

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When a subject is asked to judge whether two stimuli are "same" or "different," the time he takes to reach the decision same is frequently unequal to the time he takes to reach the decision different. We studied this discrepancy as a function of several variables, including stimulus modality, "codability" vs. "noncodability" of test stimuli, interstimulus interval, and discrimination difficulty. Results of four different experiments performed on a total of 171 subjects showed codability and discrimination difficulty to be the most important factors. Stimuli that are codable (i.e., which can be categorized by absolute judgment) yield a shorter latency for decision same, and noncodable stimuli (i.e., those requiring a reference stimulus for categorization) yield a longer latency for decision same. The modality of test stimuli, the prothetic or metathetic nature of the dimension to be judged, and simultaneous vs. successive presentation of the stimuli appear not to be crucial factors.

Judgments SAME and DIFFERENT are not obverse outcomes of a unitary decision process. This conclusion is suggested by the fact that in a given judgmental task the time taken to decide that two identical stimuli are the same may be widely divergent from the time taken to decide that two dissimilar stimuli are different. Investigators have reported both that the judgment SAME may have a longer (Bindra, Williams, & Wise, 1965; Walk, 1966; Nishisato & Wise, 1967), and that it may have a shorter (Egeth, 1966; Nickerson, 1965) decision latency than the judgment DIFFERENT. The aim of the present study was to isolate and define the factors determining the relative decision speeds of SAME and DIFFERENT judgments, and to employ this information in elucidating the nature of decision processes. We are concerned only with judgments based on stimulus comparison with respect to a single, specified dimension.

In our early experiments (e.g., Bindra, Williams, & Wise, 1965), the test stimuli were two similar but easily discriminable tones (1000 and 1060 cps), successively presented. The S's task was to press a key labeled "Same" if he thought the pitch of the second (comparison) tone was identical to that of the first (reference) tone, and to press a key labeled "Different" if he judged the two tones to be of different pitches. Decision latency, the time elapsing between the onset of the second tone and the indicator response (key pressing) was found to be longer for judgment SAME than for judgment DIFFERENT. Nickerson (1965), following a similar procedure but working with visual stimuli (English letters) found that the decision time for judgment DIFFERENT was longer than that for judgment SAME. As we searched for the reason for this discrepancy, various factors appeared to be of possible causal significance. The modality of test stimuli and discrimination difficulty were the first to strike us as two variables of potential importance; when these proved not to be crucial, we explored the significance of the "codability" of the test stimuli. Thus the present study consists of a series of somewhat isolated experiments aimed at discovering the factors contributing to the relative speeds of SAME and DIFFERENT decisions.

In this study, a trial on which the two test stimuli are identical is called a "SAME trial" and a trial on which they are dissimilar is called a "DIFFERENT trial," regardless of the response (SAME or DIFFERENT) made by S.

EXPERIMENT 1

Independently of Nickerson's (1965) work, we have also studied the relative latencies of SAME and DIFFERENT decisions in judgments involving visual stimuli. One of our experiments is described here. In this experiment we employed hue as the judgmental dimension. We also examined the influence of discrimination difficulty by varying the similarity of test stimuli and the interstimulus interval.

Method

Thirty-two men of the Canadian army served as Ss. They ranged in age from 17 to 35 years.

For one group of 16 Ss, the pairs of test stimuli consisted of red and blue circles (RB group), and for the remaining 16 the pairs consisted of blue and green circles (BG group). All circles were about 1 in. in diameter and of saturated colors. The blue and green circles appeared to be less dissimilar to each other than the red and blue circles; this difference in apparent stimulus similarity was one way in which discrimination difficulty was varied. The other way was to separate the (successive) presentation of the two test stimuli by either 0.5 sec or 5.0 sec; the latter interstimulus interval represented the higher level of discrimination difficulty.

The test stimuli were viewed by S at eye level from a distance of about 2 ft. The two stimuli to be judged by a group were combined with the order of presentation to yield four pairs (XX, XY, YX, and

YY); each pair was presented equally often. The first, reference, stimulus was presented for 2 sec. The second, comparison, stimulus, which was to be judged SAME or DIFFERENT, was turned on after the predetermined interstimulus interval had elapsed; it remained on until S responded. All Ss were given two 32-trial blocks, one with 0.5 sec and the other with 5.0 sec interstimulus interval. One-half of each group was tested with the 0.5 sec block first; the reverse order prevailed for the other half in each group.

Each 32-trial block consisted of equal numbers of SAME (XX, YY) and DIFFERENT (XY, YX) trials. Also, the number of SAME (or DIFFERENT) trials that were preceded by DIFFERENT trials was equal to the number of SAME (or DIFFERENT) trials that were preceded by SAME trials; that is, the frequencies of SAME and DIFFERENT *repeated* trials (e.g, XX preceded by XX or YY) was equal to the frequencies of SAME and DIFFERENT *changed* trials (e.g., XX preceded by XY or YX). The purpose of this was to balance for intertrial sequential effects, such as those reported by Bertelson (1961) and Williams (1966). Within these restraints, the order of presentation of the test stimulus pairs within a block of trials was randomized. All Ss were tested with an identical trial order.

A ready signal was followed about 1 sec later by the (successive) presentation of the two test stimuli. The S's task was to respond by moving the index finger of his preferred hand from a rest key and pressing either a key labeled "Same" or a key labeled "Different." The two response keys were equidistant (1.5 in.) from the rest key. To balance the effects attributable to direction of movement, or to any special characteristics of the keys, the key labels were interchanged for alternate Ss. Decision latency, the time elapsing between the onset of the comparison stimulus and S's response, was measured in milliseconds, and the type of response (i.e., SAME vs DIFFERENT key) was also noted. Intertrial interval varied between 5 and 10 sec. Each block of test trials was preceded by about 10 practice trials. The Ss were instructed to be both accurate and fast. No information was provided about the accuracy of their performance.

Results

Less than 2% of the responses were incorrect; they were not analyzed. For each S, means of decision latency were calculated separately for the correct SAME and DIFFERENT responses within each block of trials. These means, presented in Table 1, were treated as latency scores for statistical analysis.

Latency scores for the two groups were subjected to separate four-way analyses of variance (Judgment—SAME vs DIFFERENT by Interstimulus Interval—0.5 vs 5.0 sec by Trial Sequence—repeated vs changed trials by Ss). For the present purpose, we need merely note that both Judgment and Interstimulus Interval variables had significant effects on decision latency. None of the interactions was significant. In both groups, decision latencies were shorter for the judgment SAME than for the judgment DIFFERENT, and were longer for the longer interstimulus interval than for the shorter interval.

Table 1. Means of Decision Latencies for Judgments Same and Different Obtained with Two Sets of Stimuli, Red vs. Blue (Low Discrimination Difficulty) and Blue vs. Green (High Discrimination Difficulty) and Two Different Interstimulus Intervals (ISI)

Stimulus Set	Judgment	Decision Latencies in msec ISI: 0.5 sec Mean	ISI: 5.0 sec Mean	Overall for Two Intervals
Red-Blue	Same	410	482	446
	Different	437	513	475
Blue-Green	Same	543	574	558
	Different	564	641	602

The means of decision latency scores for the two groups (RB and BG) were compared by t test. As expected, the decision latencies of both SAME and DIFFERENT judgments of Group RB were significantly ($p < .05$) shorter than the corresponding latencies of Group BG.

Comment

(1) The results show clearly that in making judgments about the sameness or difference of hues, the decision latency for SAME is shorter than that for DIFFERENT. This is consistent with the findings of Nickerson (1965), whose test stimuli were also visual. However, the present results are the exact opposite of the results obtained with the judgment of pitch (tones), where the decision latency for SAME was longer (Bindra, Williams, & Wise, 1965; Nishisato & Wise, 1967).

(2) The two conditions of greater discrimination difficulty, namely, the higher similarity of the blue-green than of the red-blue stimuli and the longer interstimulus interval (5.0 sec), raised overall decision latency substantially while the number of errors still remained negligible. The difference between the SAME and DIFFERENT latencies was evident at all levels of discrimination difficulty.

(3) The fact that there was no significant interaction effect of the Judgment variable with the Interstimulus Interval variable means that the latter had no differential effect on the SAME and DIFFERENT latency. This finding is at variance with the result obtained with tones, where an increase in interstimulus interval increased the difference between the latencies of SAME and DIFFERENT decisions (Bindra, Williams, & Wise, 1965).

EXPERIMENT 2

Decision latency can be affected by many factors, such as the nature of instructions, strategies adopted, task difficulty, and the form of the required indicator response. Therefore, we wanted to be sure that the discrepancy between the results of experiments with auditory and visual stimuli was not the result of some peculiarities of experimental arrangements. The purpose of this experiment was to examine the decision latencies of SAME and DIFFERENT judgments obtained with auditory and visual stimuli in one and the same experimental arrangement, involving parallel procedural details.

Method

Twelve men of the Canadian army served as Ss; they ranged in age from 17 to 35 years.

Two tones (A, 1000 cps; B, 1060 cps) and two figures (X, a square; Y, a triangle) were used as test stimuli. All Ss, on each trial, were exposed first to a simultaneous presentation of a tone and figure followed by a second simultaneous presentation of a tone and a figure (AX—AY, AX—BY, BX—BX, etc.). The S's task was to judge the second, comparison, stimulus exposure (tone + figure) against the first, reference, stimulus exposure (tone + figure). Six of the 12 Ss (the tone group) were told to ignore the figure and to judge whether the pitch of the second tone was the same as, or different from, that of the first. The remaining six Ss (the figure group) were told to ignore the tone and to judge whether the shape of the second figure was the same as, or different from, that of the first.

The tones were presented through a loudspeaker placed 3 ft in front of S yielding a sound pressure level of about 65 dB (re .0002 dyne/cm^2). The figures were rear-projected on a transluscent screen, placed 2 ft from S. The projected figures (square and triangle) were saturated blue and occupied an area of about 3.5 in. in the screen. The two stimuli to be judged by a group, the relevant stimuli, were presented and were combined into four pairs (AA, AB, BA, and BB; or XX, XY, YX, and YY) and each pair was presented equally often. All possible pairs of the irrelevant stimuli were also used equally often. The number of SAME trials on which the two irrelevant stimuli were also identical was equal to the number of SAME trials on which the two irrelevant stimuli were dissimilar; the same held true for the DIFFERENT trials. The first stimulus exposure lasted for 2 sec; the second stimulus exposure was turned on after an interval of 5 sec, and remained on until S responded. Following 10 or so practice trials, each S was tested in a block of 32 trials, with the intertrial interval varying from 5 to 10 sec.

The sequence of SAME and DIFFERENT trials within the 32-trial block was balanced in the same way as in Experiment 1. The arrangement of the response keys, the measurement of decision latencies, and related procedural details were also similar to those employed in Experiment 1.

Results

For statistical analysis, the latency data were treated in the same way as the data of Experiment 1. The overall (SAME + DIFFERENT) mean of decision latency scores for the tone group (1501 msec) was greater than that for the figure group (995 msec). Also, while the mean decision latencies for SAME and DIFFERENT judgments were virtually identical in the case of the figure group (SAME = 981 msec; DIFFERENT = 1008 msec), the mean SAME latency was considerably longer than the mean DIFFERENT latency in the case of the tone group (SAME = 1644 msec; DIFFERENT = 1359 msec). A three-way analysis of variance (Judgment—SAME vs DIFFERENT by Modality—tone vs figure by Trial Sequence—repeated vs changed) showed the Modality and Judgment effects, as well as their interaction effect, to be significant. The significant interaction effect confirms that the overall longer SAME latency arose from the behavior of the tone group only.

Comment

(1) The results show that the previously reported discrepancy between the findings with auditory and visual stimuli are not attributable to peculiarities of experimental arrangement or procedure. Tonal stimuli, judged with respect to pitch, clearly yield a longer decision latency for SAME than for DIFFERENT, but figures, judged with respect to shape, do not.

(2) Visual stimuli have been reported to yield longer decision latencies for judgment DIFFERENT (Experiment 1 and Nickerson, 1965). In the figure group of the present experiment, the latency of DIFFERENT was somewhat longer than the latency of SAME, but this difference did not reach an acceptable level of statistical significance.

(3) The longer overall decision latency of the tone group suggests that different processes may be involved in the judgment of tones and figures of the types used in the present experiment. The latency differences between the tone and figure groups may mean that Ss found it harder to ignore the figures while judging tones than to ignore the tones while judging shapes.

EXPERIMENT 3

If the discrepancy between the findings with visual and auditory stimuli is not an artifact of the experimental arrangement or procedure, the question arises whether the discrepancy represents a true modality difference in the decision-making process or is attributable to certain properties of the particular auditory and visual stimuli used. Concerning the latter possibility, one of our hypotheses was that the discrepancy results from the fact that the visual stimuli hitherto employed (English letters, colors, shapes) were all individually identifiable in an absolute way, that is, they were readily codable (for example, as "C," "red," "square") while the auditory stimuli hitherto employed (tones), though easily discriminable, were not identifiable without a relational estimate with reference to each other, that is, they were not readily codable. This hypothesis prompted us to examine the relative decision latencies of SAME and DIFFERENT judgments with visual stimuli selected so that they would *not* be readily codable (this experiment), and with auditory stimuli selected so that they would be (next experiment). In Experiment 3, we required Ss to judge the length of lines as SAME or DIFFERENT, and also explored the influence of discrimination difficulty and of emphasis on accuracy vs speed. The experiment was run in two parts; in Part 1 the lines were presented simultaneously and in Part 2 successively. The two parts were conducted separately on different groups of Ss.

Method

Part 1 (simultaneous presentation). Fifty-five 17-23 year old, high school and college students served as Ss. There were 39 men and 16 women. They were paid on an hourly rate.

Test stimuli consisted of three sets of 40 slides each. When projected, each slide presented a pair of horizontal black lines; the left end of the lower line was centered beneath the midpoint of the upper line. Twenty slides within each set had line pairs with the two lines of identical length; the remaining half of the slides in a set had line pairs with the two lines of unequal length. The three sets of slides differed in the relative lengths of the lines in the unequal line pairs. The projected lengths (on the screen) of the lines of the high discrimination difficulty set were 3 in. and 3-1/8 in. (Set 1); those of the lines of the medium discrimination difficulty set were 3 in. and 3-3/8 in. (Set 2); those of the lines of the low discrimination difficulty set were 3 in. and 3-3/4 in. (Set 3). All Ss were tested on all three sets; the order of set presentation was randomly determined separately for each S. Within each set, two different random orders of slide presentation were used for each group; about half of the Ss in a group were assigned to one order and the remaining half to the other. All Ss were told to judge whether the two lines were SAME or DIFFERENT with respect to length and to indicate the decision by pressing one of two response keys.

The 55 Ss were divided into three groups, Group A of 15, Groups B and C of 20 each. The number of women in Groups A, B, and C was 5, 5, and 6, respectively. For Group A, each slide was exposed for 0.15 sec, and S was told to take as much time as he wanted to decide whether the two lines were the same or different in length. This group was used merely to establish the discrimination difficulty in terms of error of judgment for the three sets of slides; decision latency was not measured. For Group B, each slide remained exposed until S responded; the instructions were to respond as rapidly as possible, taking care to be accurate. Continued exposure and emphasis on accuracy were calculated to induce an attitude of care in S. For Group C, each slide was exposed for 0.15 sec and S was instructed to respond as quickly as possible. Each S was seated about 2 ft in front of the screen; slides were rear-projected. A 3 sec tone, which S heard through earphones, served as a ready signal, its termination coinciding with the exposure of a slide. The arrangement of the response keys and related procedural details were similar to those employed in Experiment 1. Since the two test stimuli were simultaneously presented in this Part 1, decision latency on each trial was the interval between the onset of the slide exposure and the response.

Part 2 (successive presentation). Forty-eight Ss of the same description as in Part 1 were divided randomly into three groups, Group A of 18, and Groups B and C of 15 each. The number of women in the three groups was 10, 7, and 7, respectively.

Test stimuli consisted of three sets of 40 slide pairs each. In order to select and construct three sets of stimulus pairs of different difficulty levels in this successive presentation situation, the group of 18 Ss (Group A) was given the same instruction as Group A in Part 1. The three sets of 40 slide pairs each, selected on the basis of the performance of this group, were as follows: The projected lengths of the lines of the high discrimination difficulty set were 3/4 in. and 23/32 in. (Set 1); those of the lines of the medium discrimination difficulty set were 3/4 in. and 2/3 in. (Set 2); those of the lines of the low discrimination difficulty set were 3/4 in. and 5/8 in. (Set 3). The slides were viewed at a distance of 21.5 in. Each trial consisted of a 1 sec presentation of the first line, a 2 sec light-filled blank interval, and a 1 sec presentation of the second line; the lines were presented horizontally. Intertrial interval was about 6 sec. Groups B and C saw three sets of 40 line pairs, and the instructions to Ss in these groups were, respectively, to respond accurately and to respond as quickly as possible. In other respects the procedure resembled in all essentials that used in Part 1.

Results

Part 1 (simultaneous presentation). The data of Group A were analyzed to determine the relative discrimination difficulty of the three sets of slides. Each S's correct responses were tabulated separately for SAME and DIFFERENT trials for each set of slides. A percent correct score, representing correct SAME and DIFFERENT responses as a proportion of the number of, respectively, SAME and DIFFERENT trials, was then calculated for each S.

Table 2. Per Cent Correct Judgments (Column 3) and Corrected Accuracy Score (Column 4) for Three Sets of Slides Representing Different Levels of Discrimination Difficulty (Group A). Columns 5 and 6 Represent the Corresponding Decision Latencies for Correct Responses Obtained Under Accuracy (Group B) and Speed (Group C) Conditions

(1) Stimulus Set	(2) Type of Trial	(3) Mean Per Cent Correct Group A	(4) Mean Corrected Accuracy Score Group A	(5) Decision Latency in msec Accuracy Instructions Group B	(6) Speed Instructions Group C
1. High Discrimination	Same	58.5	0.90	6021	1300
Difficulty	Different	48.5	0.95	9758	1350
2. Medium Discrimination	Same	75.5	3.90	5676	1270
Difficulty	Different	62.0	3.85	4744	1140
3. Low Discrimination	Same	80.5	6.67	4484	1150
Difficulty	Different	93.0	6.77	3179	980

The means of the percent correct scores of Group A are presented in column 3 of Table 2. The overall mean percent correct scores ranged from about 50% for Set 1 (high discrimination difficulty set) to about 85% for Set 3 (low discrimination difficulty set).

When the number of errors is large, guessing or response bias (a preference for making SAME or DIFFERENT responses) can affect the estimates of relative accuracy of SAME and DIFFERENT judgments. Therefore, a "corrected accuracy score"[2] was calculated for each S of Group A separately for SAME and DIFFERENT trials. The means of the corrected accuracy scores for the three sets of slides are presented in column 4 of Table 2. Note that the corrected accuracy scores for SAME and DIFFERENT responses are virtually identical within each set. The corrected accuracy scores were subjected to a three-way analysis of variance (Discrimination Difficulty—high, medium, low by Judgment—same vs different by Ss). The analysis showed the Discrimination Difficulty variable to be significant ($p < .01$). Also, Scheffé's test (McNemar, 1962) showed that there was a significant ($p < .01$) decrease in accuracy scores between adjacent difficulty levels, from low to high. Thus, the three sets of stimuli may be said to define a meaningful discrimination difficulty variable.

The means of decision latencies for correct responses of Groups B and C are shown in columns 5 and 6, respectively, of Table 2. It is seen that the overall decision latency decreased with decreasing discrimination difficulty (from Set 1 to Set 3). In both groups, the mean decision latency for Set 1 was significantly longer than those for Sets 2 and 3 when tested by Scheffé's method (McNemar, 1962). Also, in both groups, the decision latencies for judgment SAME, as compared to those for judgment DIFFERENT, were longer with Sets 2 and 3 (low and medium discrimination difficulty), but shorter with Set 1 (high discrimination difficulty). Three-way analyses of variance (Discrimination Difficulty—high, medium, low by Judgment—same vs different by Ss), conducted separately on the data of Groups B and C, show Discrimination Difficulty, as well as its interaction with the Judgment variable, to have significant ($p < .01$) effects on decision latency. The overall (combining sets) mean decision latency for judgment SAME was significantly ($p < .05$) longer than that for judgment DIFFERENT in the case of Group C but not in the case of Group B. The extremely high latencies of Group B are probably due to the combined effects of emphasis on accuracy and the continued exposure of the stimuli until S responded; in Part 2, where the second test stimulus was presented for only 1 sec, the latencies of Group B were not so grossly exaggerated.

The error data of Groups B and C were analyzed in a different way. The number of errors was tabulated separately for the incorrect responses (error) of two types, E_{same} and E_{diff}. E_{same} is the error of calling dissimilar stimuli SAME, and E_{diff} is the error of calling identical stimuli DIFFERENT. The medians of latency for the two types of error at the three levels of discrimination difficulty were also calculated. These error and latency results are presented in Table 3. The following observations are pertinent: (a) If the six error means of Group B and the corresponding ones of Group C are considered as paired random samples from two populations that are not different in their tendencies to

Table 3. Mean Number of Incorrect Responses (Errors) of Two Types (E_{same} and $E_{diff.}$) and Medians of Error Latencies for Group B (Accuracy Instruction) and Group C (Speed Instruction) at Three Levels of Discrimination Difficulty. (E_{same} is the Error of Calling Dissimilar Stimuli Same, and $E_{diff.}$ is the Error of Calling Identical Stimuli Different.)

Stimulus Set	Type of Error	Group B Mean No.	Group B Latency (msec)	Group C Mean No.	Group C Latency (msec)
1. High Discrimination	E_{same}	8.33	6093	11.15	1246
Difficulty	$E_{diff.}$	1.80	9870	7.55	1300
2. Medium Discrimination	E_{same}	4.07	3792	5.20	1244
Difficulty	$E_{diff.}$	.93	8671	5.15	1135
3. Low Discrimination	E_{same}	.27	2097	1.35	1236
Difficulty	$E_{diff.}$	1.13	6785	3.10	1243

make errors, then the mean number of errors of Group C is found to be significantly ($p < .02$) greater than that of Group B. (b) Under the same assumption, it can be said that the median of the latencies of errors of Group B is significantly ($p < .02$) greater than that of Group C. (c) The error means of Group B were multiplied by 15 to recover the total numbers of errors to be subjected to a chi-square analysis. The chi-square for the 2 by 3 contingency table (Judgment by Discrimination Difficulty) was significant ($\chi^2 = 42.46$, $df = 2$, $p < .01$), suggesting an interaction. It is noted from Table 3 that the mean number of E_{diff} was fairly constant for all the levels of discrimination difficulty, but that the mean number of E_{same} increased markedly as discrimination difficulty increased from low to high. The number of E_{same} was significantly greater than that of E_{diff} when the levels of discrimination difficulty were pooled ($\chi^2 = 70.26$, $df = 1$, $p < .01$), and there was also a significant difference in error means among the three levels of difficulty, when the two types of error were pooled ($\chi^2 = 104.86$, $df = 2$, $p < .01$). (d) The same types of analyses for Group C also showed a significant interaction between judgment and discrimination difficulty ($\chi^2 = 25.86$, $df = 2$, $p < .01$), a significant effect of discrimination difficulty ($\chi^2 = 182.57$, $df = 2$, $p < .01$), but no significant difference between E_{same} and E_{diff}. (e) Regarding the latency of error responses, median tests were employed to examine the effects of difficulty and the types of error. None of these effects, however, was significant in Group B or Group C. (f) Comparison of the medians of latencies of error responses with the corresponding mean latencies of correct responses (Table 2) reveals no reliable difference between the two sets of latencies.

Part 2 (successive presentation). The data of Group A revealed that the successive task of Part 2 was easier than the simultaneous task used in Part 1, presumably owing to the shorter duration of exposure in the latter case. The raw percent correct score for Set 1 (high discrimination difficulty) was 74.3 compared with 58.5 for Set 1 in the simultaneous experiment. However, when the raw scores are corrected for response bias and chance by the formula described earlier (see Note 2), the pattern of results (Table 4) is seen to be similar to that obtained in the case of simultaneous presentation.

The corrected accuracy scores were calculated for each S separately on SAME and DIFFERENT presentations for each stimulus set. As expected, the average corrected accuracy score was lower in Set 1 than in Set 2, and lower in Set 2 than in Set 3. Correct response latencies of Groups B and C were analyzed with the same type of analyses of variance as were conducted on the data of Groups B and C of Part 1. In Group B (accuracy instructions), there was a significant difference among reaction latencies for the different stimulus sets, and a significant interaction between the set and judgment condition (SAME or DIFFERENT). In Group C (speed instruction), there was a significant difference among latencies for the different stimulus sets, but no significant interaction between judgment and stimulus set. Table 4 shows that the pattern of results (higher latencies for SAME than for DIFFERENT at the easiest level of discrimination difficulty, order reversed at the higher levels of difficulty) is similar in both groups to the results of corresponding groups in the simultaneous presentation condition (Part 1). The only SAME-DIFFERENT latency difference which was significant in Group B was in Set 3 ($t = 2.33$, $df = 14$, $p < .05$). Using Scheffé's test (McNemar, 1962), the differences between Sets 1 and 3 were found to be significant for both Groups B ($p < .02$) and C ($p < .05$).

Regarding errors, it was found in the simultaneous presentation condition (Part 1) that the mean number of times a SAME pair was called DIFFERENT (E_{diff}) varied little across difficulty levels when compared to the mean number of times a DIFFERENT pair was called SAME (E_{same}). The present successive presentation condition gave the same result (Table 5). In the accuracy conditions (Group B) E_{diff} varied from a mean of 4.26 at low difficulty to a mean of 5.13 at high difficulty, while E_{same}

Table 4. Per Cent Correct Judgments (Column 3) and Corrected Accuracy Score (Column 4) for Three Sets of Slides Representing Different Levels of Discrimination Difficulty (Group A). Columns 5 and 6 Represent the Corresponding Decision Latencies for Correct Responses Obtained Under Accuracy (Group B) and Speed (Group C) Conditions

(1) Stimulus Set	(2) Type of Trial	(3) Mean Per Cent Correct Group A	(4) Mean Corrected Accuracy Score Group A	(5) Decision Latency in msec: Accuracy Instructions Group B	(6) Decision Latency in msec: Speed Instructions Group C
1. High Discrimination	Same	70.2	2.42	1560	781
Difficulty	Different	54.4	2.42	1669	826
2. Medium Discrimination	Same	70.0	5.93	1458	791
Difficulty	Different	81.6	4.43	1488	761
3. Low Discrimination	Same	89.3	8.80	1444	748
Difficulty	Different	87.4	8.80	1187	698

Table 5. Mean Number of Incorrect Responses (Errors) of Two Types (E_{same} and $E_{diff.}$) and Medians of Error Latencies for Group B (Accuracy Instruction) and Group C (Speed Instruction) at Three Levels of Discrimination Difficulty. (E_{same} is the Error of Calling Dissimilar Stimuli Same, and $E_{diff.}$ is the Error of Calling Identical Stimuli Different.)

Stimulus Set	Type of Error	Group B Mean No.	Group B Latency (msec)	Group C Mean No.	Group C Latency (msec)
1. High Discrimination Difficulty	E_{same}	11.33	1568	10.46	801
	$E_{diff.}$	5.13	1676	5.73	924
2. Medium Discrimination Difficulty	E_{same}	3.87	1795	5.93	826
	$E_{diff.}$	2.67	2107	4.06	993
3. Low Discrimination Difficulty	E_{same}	.87	1549	2.93	781
	$E_{diff.}$	4.26	1513	2.13	1001

varied from 0.87 to 11.33 over the difficulty range. In the speed condition (Group C), E_{diff} varied from a mean of 2.13 at low difficulty to a mean of 5.73 at high difficulty, while E_{same} varied from 2.93 to 10.46. In other words, both E_{same} and E_{diff} tended to increase with increasing discrimination difficulty ($p < .05$, nonparametric test), but the increase was much more extreme for E_{same} than for E_{diff} ($p < .05$, nonparametric test). In Group B, there were significantly fewer E_{diff} in Set 2 than in either Set 1 or Set 3, but the E_{same} increased regularly and significantly from the low (Set 3) to the high (Set 1) difficulty condition. At low difficulty there were significantly more E_{diff} than E_{same}, but at high difficulty there were significantly more E_{same} than E_{diff}. In Group C, the results are even more regular. The number of E_{diff} increased regularly but gradually from low to high difficulty, while the number of E_{same} increased regularly but much more rapidly. In Group C, the number of E_{same} and E_{diff} were not significantly different at low difficulty, and there were significantly more E_{same} than E_{diff} at high difficulty ($p < .05$, nonparametric test).

The mean error latencies for each set in the case of Group C (speed instruction) were always shorter than the corresponding latencies of Group B (accuracy instruction). This was also true for the latencies of correct responses. Also, the mean latencies for E_{same} were shorter than the corresponding latencies for E_{diff} within each stimulus set in each group except for Set 3 in Group B. Many Ss in both groups made no errors, so there are not enough data to permit statistical evaluation of these differences; however, they are almost completely consistent across sets and groups.

Comment

(1) The results of this experiment (Parts 1 and 2) are consistent with the hypothesis that when visual test stimuli are such as not to be readily codable the decision latency for correct judgment SAME may be longer than that for correct judgment DIFFERENT. This is seen at the low levels of discrimination difficulty under both the simultaneous and the successive conditions. These facts indicate that even visual stimuli, when they are not readily codable, tend to make for a longer decision latency for SAME than for DIFFERENT. However, it is also clear that codability is not necessarily a decisive factor, for at the higher levels of discrimination difficulty in the present experiment the relation between the speeds of SAME and DIFFERENT judgments was reversed.

(2) At the higher levels of discrimination difficulty (Set 1) and with increased emphasis on accuracy (Group B), the overall decision latencies were higher, but the latency of DIFFERENT relative to that of SAME increased. It should be noted that discrimination difficulty was varied by varying stimulus similarity (length of lines), and the three levels of difficulty were defined in terms of error rate. In a previous study we found that an increase in discrimination difficulty tended to increase the latency of SAME relative to that of DIFFERENT (Bindra, Williams, & Wise, 1965). But in that study the test stimuli, though they were not readily codable, were so dissimilar that few errors were made even at the higher difficulty level. Thus the present finding does not necessarily contradict our earlier finding.

(3) The lower error rate and the higher latencies of the accuracy instruction groups (Group B) as compared to the speed instruction groups (Group C) were expected; they confirm that Ss can trade off accuracy for speed when instructions demand it. The increase in both errors and latencies with increasing discrimination difficulty was also expected. Of greater interest is the finding that the number of E_{same} increased with an increase in discrimination difficulty, but the number of E_{diff} remained roughly constant.

(4) No systematic difference seems to exist between the latencies of correct responses and error responses under the conditions of the present experiment.

(5) On the whole, simultaneous and successive presentations of the stimuli yielded very similar results.

EXPERIMENT 4

The purpose of this experiment was to examine the relative decision speeds of SAME and DIFFERENT judgments when auditory test stimuli were readily codable. In our previous experiments with auditory stimuli S judged two tones. In the present experiment a tone and a click served as the test stimuli; we assumed that each of these stimuli would be immediately identifiable without requiring a relational estimate. The effects of an instructional variable, emphasis on speed vs emphasis on accuracy, was also studied.

Method

Twenty college students, 14 males and six females, served as Ss. Their ages ranged from 19 to 21 years.

The stimuli, presented to S through earphones, were a 1000 cps tone (T) and a series of 15/sec clicks (C). The sound level of each stimulus was approximately 66 dB (re .0002 dyne/cm^2).

A ready signal (illumination for 1 sec of a red 7.5 W lamp) was followed 1 sec later by the sequential presentation of a pair of stimuli (T-T, T-C, C-T, or C-C). The duration of the first, reference, stimulus was 4 sec; the comparison stimulus was presented after a 1 sec interval, and it terminated with S's response. The S's response consisted of pressing one of the two response keys. The arrangement of response keys and the related procedural details were similar to those described under Experiment 1.

There were two 32-trial blocks, each consisting of equal proportions of SAME (T-T and C-C) and DIFFERENT (C-T and T-C) trials. For one block of trials, S was instructed to concentrate on speed at the expense of accuracy (Condition S), and, for the other block, S was instructed to concentrate on accuracy at the cost of speed (Condition A). Each S was tested under both conditions; half the Ss (7 males and 3 females) were tested under Condition A first (A-S group) and the other half were tested under Condition S first (S-A group). Between the two conditions there was a 2-3 min interval during which E gave instructions for the next condition. The first and second blocks were preceded by 12 and eight practice trials, respectively.

Results

Only 31 errors were made in the total of 1280 responses, that is, less than 3%; data for error trials were not analyzed. The mean decision latencies of correct responses were calculated for each S separately for the two instructions (speed and accuracy) and judgments (SAME and DIFFERENT); the group means are presented in Table 6. A three-way analysis of variance (Judgment—SAME vs DIFFERENT by Instructions—speed vs accuracy by Order of Instructions—S-A vs A-S) was conducted on the mean decision latencies of Ss. The following findings are worth noting. The Judgment variable had no significant effect on decision latency. The effect of the Instruction variable was significant at the .01 level; decision latency under the speed instruction was significantly shorter than that under the accuracy instruction. Instruction Order had no significant effect on latency, but the interaction between the Instruction and Instruction Order did ($p < .05$). When the accuracy instruction was given first, the decision latency under the speed instruction decreased markedly, on the average by 265 msec; when the speed instruction was followed by the accuracy instruction, the speed decision latencies were shorter by only about 25 msec. Note, however, that the Order effect was confounded with practice effect as well as individual difference effect in the present experiment.

Table 6. Means of Decision Latencies for Judgments Same and Different with Two Auditory Stimuli (Tone and Click) Under Two Types of Instruction (Accuracy vs Speed) and Different Instruction-Orders (Accuracy-Speed vs Speed-Accuracy)

Instruction-Order	Judgment	Latency in msec: Instructions Accuracy	Speed	Overall Means
Accuracy-Speed	Same	589	463	526
	Different	624	485	555
Speed-Accuracy	Same	594	604	599
	Different	637	579	608

Comment

(1) The fact that the click and tone employed in the present experiment did not yield longer decision latencies for the judgment SAME than for the judgment DIFFERENT is consistent with the hypothesis that the longer decision latencies for SAME are obtained only when the test stimuli are not immediately codable. That is, when S must compare the two stimuli (e.g., tones of 1000 and 1060 cps) before he can identify either one, the decision latency for SAME tends to be longer. But when, as in the present experiment, the stimuli are readily codable, S can identify each stimulus (as a click or a tone) without comparing it with the other, the decision latency for SAME is not longer than that for DIFFERENT. Thus, codability of test stimuli is important in determining the relative speed of SAME and DIFFERENT decisions regarding both visual and auditory stimuli; modality per se would appear to be unimportant.

(2) The results of Experiment 1 showed that the decision latency of judgment SAME was shorter when readily codable visual stimuli (red vs blue, or blue vs green) were used. But the result of the present experiment, as well as that of Experiment 2, showed no significant difference between the latencies of SAME and DIFFERENT judgments. The reason for this discrepancy is not obvious. We might note, however, that in the present experiment there was a tendency for Ss to give shorter latencies for judgment SAME.

(3) The instructions emphasizing speed clearly reduce decision latency, but the lack of a significant Instruction by Judgment interaction effect suggests that the type of instructions used in this experiment

ulus positions on each hand. For convenience the vibrators were numbered 1-10 from the left little finger to the right little finger. If vibrators 1, 2, 3 (left hand), and 6, 7, 9 (right hand) were energized in the first pattern and vibrators 2, 3 (left hand), and 6, 7, 9, 10 (right hand) were energized in the second pattern, a 1/6 or 16.7% shift would occur, since one element had changed hands and there were six elements involved.

It appears that not only are there more errors made with the finger than with the body sites, but also there are peculiarities associated with the hand-to-hand shifts which are not apparent on the body. These results are perhaps not surprising in view of the reports given by Os who had observed in both the body and finger experiments. For example, one O described the finger patterns as "two handfuls of vibration," whereas the body patterns were characterized as comprising more isolated vibrations. When the focus of loudness of the "handfuls of vibration" shifted within a pattern pair, however, discriminations between same and different were easily made.

EXPERIMENT 2

A decision was made at this point to set aside temporarily the peculiarity of shift and to concentrate on the larger problem of why the fingers had done so poorly in relation to the body. It seemed reasonable as a starting point to carry out a series of pilot experiments by manipulating major stimulus variables one at a time and noting their effects on discriminability.

One of the first questions asked was: What effects, if any, do nonspecific factors in the psychophysical situation have on discriminability? These factors include presentation rates and display periods. It was possible that the 2 sec interval between pair presentations (the intertrial interval) did not allow enough time for O to report and be ready for the next presentation. It was also possible that pattern duration or the interval between onsets within pairs (the interstimulus onset interval) produced some kind of spatiotemporal interactions affecting discriminability.

The results showed, however, that none of the changes made, at least within the range of variation, produced any significant alteration of discriminability as reflected by the mean number of errors. The variations included intertrial intervals of both 2 sec and unfixed time intervals based on O's readiness for the next presentation, three interstimulus onset intervals from 300 to 1000 msec, and three pattern durations of from 50 to 400 msec.

These findings contrast with those of Bliss, Crane, Link, and Townsend (1966), who showed variations in errors made on absolute identification tasks with interstimulus intervals and stimulus durations. The widely variant observational tasks, stimulus conditions, and orientation of the Bliss et al study relative to that of the present one, however, may account for the apparently conflicting results.

Another factor possibly influencing pattern perception appeared to be vibration conduction between fingers. It was mentioned earlier that the reports of Os in Experiment 1 characterized the stimuli as diffuse vibratory patterns within or "surrounding" the hands. Augmenting these reports was the more formal observation that when all 10 finger loops were energized simultaneously at 15 dB SL and 60 Hz, a strong propagation of vibration throughout the hands into the forearms of one O could be felt by a second O.

Two practicable ways of testing this hypothesis would be to: (1) reduce intensity and hence loudness of all stimuli, or (2) increase frequency, and measure the changes in discriminability. In relation to (2), Békésy (1955) has shown that propagation of traveling waves on the skin of the arm decreases with increasing frequency. This presumably also occurs on the fingers as well in spite of the more complex tissue structure. Indeed, Békésy (1957) has also indicated that perception of mechanical vibration on the fingertip is localized more sharply with increasing frequency.

As to (1) above, the effect of intensity was investigated at 3, 7, 21, and 28 dB SL. A plot of mean errors at each level with the inclusion of the data at 15 dB SL from Experiment 1 showed a roughly linear function with its slope approximately parallel to the abscissa. Moreover, analysis of the data with the Friedman test (Siegel, 1956, p. 168) at the .05 level showed no significant difference among levels.

With regard to (2) above, increase of frequency from 60 Hz to 300 and 500 Hz, although not yielding a significant difference in errors at the .05 level by the Friedman test did, however, produce a small but consistent decrease in error rate. This is shown in Fig. 3. Several alternative hypotheses could explain this effect. Among the more plausible is that relating to vibration propagation and sharpness of localization (vide supra). If errors on pattern pairs were the result of confusions arising from vibratory conduction between fingers, or from poor localization at 60 Hz, or of a combination of the two, it would follow that increasing frequency would reduce confusions and therefore the error rates.

Such an explanation is not incompatible with the findings for intensity, because with changes in intensity the relative vibratory interaction between fingers remains constant in relation to the signal. That is, the signal-to-noise ratio remains constant. For example, consider one vibrator as the signal and all other vibrators as contributing to the noise because their energies get conducted to the signal locus. When the level of the noise is reduced by decreasing intensity, the signal loudness goes down at the same rate, since all the vibrators were initially adjusted to equal loudness. The relationship between the signal and the noise background therefore remains the same and, according to Gibson (1966, pp. 293-6), there should be no changes in clarity when this relationship is maintained. This is not the case for frequency variations, however, because although the noise level decreases with increasing frequency as a result of reduction of propagation, the signal level remains at 15 dB SL by virtue of the initial loudness match.

From the foregoing discussion a reduction in error rate should be realized with any method of vibratory stimulation that reduces the propagation of vibration to a minimum while maintaining a high signal level at the stimulus site. On this basis a pilot experiment was set up to compare three methods of stimulation for extent of propagation: (1) the vibrating finger stalls, as previously described; (2) a contactor vibrating within a fixed surround; (3) a concentric vibrator in which both the inside contactor and the ourside surround vibrate 180 deg out of phase. The latter two methods were suggested by Békésy (1957, 1959) as being capable of reducing propagation and sharpening localization.

The procedure for determining extent of propagation consisted of an O comparing the alternation in loudness at the test contactor to the loudness at the middle knuckle of a subject whose finger was placed on the test contactor. That is, O first matched the loudness with his finger on the test contactor to a standard vibrator. Then a subject placed his finger on the test contactor and the O placed his finger on the subject's middle knuckle. The loudness of the standard vibrator was then adjusted to match the vibratory loudness at the subject's middle knuckle. The difference in dB between the two readings in voltage across the standard vibrator coil measured the attenutation of vibration from the point of contact with the vibrator to the middle knuckle, for that particular method of stimulation. The attenuation was taken as the measure of propagation.

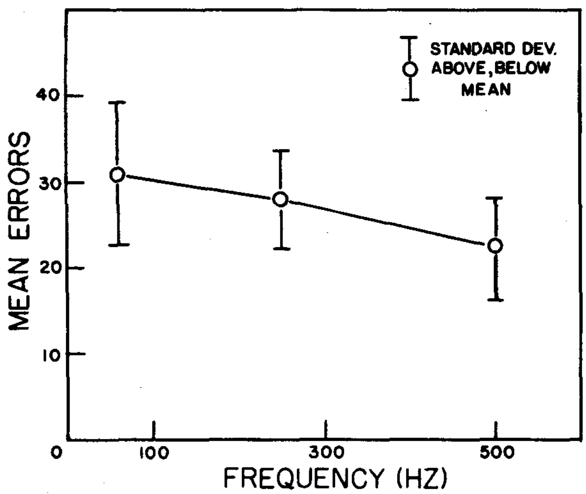

Fig. 3. Mean errors for five Os presented with three tapes at three different signal frequencies.

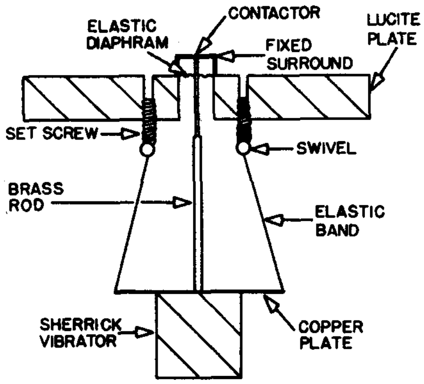

Fig. 4. Details of small vibrator suspension system.

Comparison of the three methods of stimulation showed that both the fixed surround and the concentrically vibrating systems afforded equally great reductions in vibratory propagation relative to the finger loops. Because of the relative simplicity of design of fixed as compared to vibrating surrounds, a complete system of 10 finger vibrators was constructed with contactors vibrating within fixed surrounds. The modified system is shown in Fig. 4.

In each of two Lucite plates five holes 1.2 cm in diameter were cut to correspond to the average placement of the fingertips, with relaxed hands of the Os who were to observe. Three elastic bands were attached at one end to three suspensory screws placed around each hole. Attached at the other ends of the elastic bands were Sherrick vibrators. The hanging vibrators were staggered in distance from the plate (15 and 20 cm) to prevent contact with each other. A brass rod 3 mm in diameter extended upwards from each vibrator through the holes in the Lucite plates and through a rubber diaphragm over the hole. The latter prevented the rod from contacting the sides of the hole. The last 2.5 cm of the rods were tapered to 1.5 mm diameter. A spacing ring was placed over the diaphragm upon which was attached a surround of 2.5 mm inside diameter and 15 mm outside diameter. Centering and height adjustments for each rod were accomplished by means of the three suspensory screws.

This system of stimulation was compared for discriminability to the vibrating finger stalls under the same conditions as in Experiment 1 (60 Hz vibration with 200 msec bursts at 15 dB SL). The comparison was made on the basis of five tapes presented to each of six Os who had observed in Experiment 1.

Results and Discussion

The Os uniformly reported upon first feeling this system that the finger patterns were much more "distinctive" with the small fixed surround vibrators than with the finger stalls. The individual vibrations were described as bright, sharply localized sensations, in close agreement with Békésy's (1957) observations with a similar five-vibrator system on the arm. The phenomenal reports anticipated the results. A comparison of the data with those obtained on the finger stalls for the same Os and tapes showed a 27% reduction in mean errors. This was significant at the .05 level by the Wilcoxon signed-rank test. It appears that a reduction in propagation or the accompanying sharpening of localization improves discriminability.

The effect of hand-to-hand shift, although somewhat reduced, still remained when the data were analyzed for shift in the same manner as in Experiment 1. It appears that shift still has an effect even with a minimum of vibratory interaction between fingers.

EXPERIMENT 3

In an attempt to investigate shift further, an analysis of the occurrences of shifts between large sections of the body was made on the raw data obtained by Geldard and Sherrick (1965). An upper-lower split was made, including body loci Nos. 1-5 in the upper section and loci Nos. 6-10 in the lower section. A bilateral split was also made, including body loci Nos. 2, 3, 6, 7, and 9 in one section and 1, 4, 5, 8, and 10 in the other (see Fig. 1). The results of the analysis showed that, unlike the hands, neither the upper-lower split nor the bilateral split showed variations in error rate (at the same per cent communality) with per cent shift between two sections. It appears that changes of locus within the hand are less discriminable than changes in locus (shifts) between the hands even with a minimum of vibratory interaction between fingers (Experiment 2). In contrast, however, all changes in locus or shifts on the body seem to be equally discriminable. One difference between the loci on the body and those on the fingers is that corresponding points on the body were avoided while on the fingers they were not.

Bender (1952) has described various types of neural interactions that take place with simultaneous stimulation of bilateral homologous regions of the body. Sherrick (1964), moreover, has shown vibrotactile masking with double simultaneous stimulation of corresponding fingertips.

At this point an inductive leap was made. It was conceivable that the effect of shift was the result of some kind of neural interaction between corresponding fingertips. The reasoning is as follows. If there is an interaction, in all probability it would interfere with rather than improve perception of a pattern. With increased shifting of elements across hands, the probability of stimulating corresponding fingertips and thus obtaining interaction is less in one of the two patterns in a pair. Therefore, with increasing shift the discriminations should be easier. It would be expected that reducing these interactions by stimulating at noncorresponding points should increase the ease of discrimination at low per cent shifts, where errors are greatest, and thereby increase overall discriminability. Experiment 3 was an attempt to test this hypothesis by stimulating noncorresponding points on the fingertips.

Apparatus and Procedure

The instrumentation was the same as in Experiment 2 with the small vibrators, with the one exception that O was instructed to place his right fingers further up on the vibrators. The point of contact for each finger of the right hand was, on the average, 2.5 cm more proximal than for the left. Each of six Os, all of whom had observed in Experiment 2, was presented with the 20 original tapes under the same conditions as described in Experiment 1.

Results and Discussion

An analysis of the data showed a 20% reduction in mean errors, when compared to those data obtained for the same five tapes in Experiment 2. This difference was significant at the .05 level by the Wilcoxon signed-rank test. Furthermore, an analysis of the 20 tapes for the shift effect did indicate a reduction in prominence of the effect. This is shown in Fig. 5. These results lend some support to the belief that there is some kind of neural interaction taking place between corresponding fingertips.

A comparison between the original body data and the present data on the 20 tapes revealed that, although the fingers still made about 25% more errors than the body, this difference was not significant by the Wilcoxon two-sample test ($p > .05$).

It appears that the combination of small finger vibrators with application to noncorresponding finger sites can improve discriminability to within the range

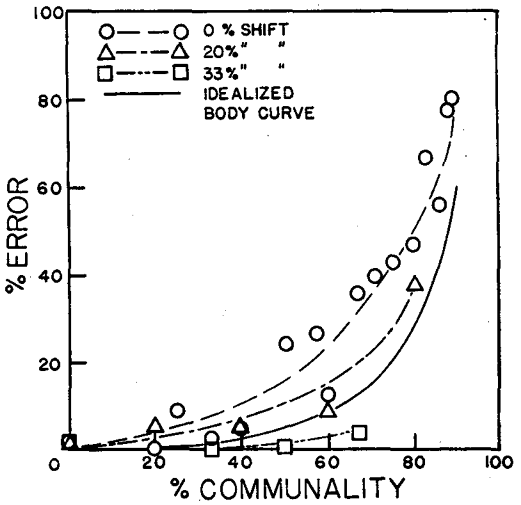

Fig. 5. Separation of shift and communality for pattern discrimination with the small vibrators on the fingers at non-corresponding points, together with the idealized curve for the body.

of that described by Geldard and Sherrick for the body. This is perhaps not surprising if one considers that the course of improvement in the method of stimulation at the fingers progressively approached a parallel to the method of stimulation on the body. For example, the first significant improvement occurred when the extent of propagation was reduced. This propagation reduction decreased the ratio of the skin area stimulated relative to the distinct skin area designated as one locus (i.e., the finger). As a result the ratio for the fingers approached the ratio for the body, a relatively small one owing to the large size of the areas designated as one locus. The second significant improvement came when noncorresponding points were stimulated on the fingers. This again approached the situation on the body in which corresponding points were avoided. Thus, as the method of stimulation approached that for the body, from the finger loops, to the small vibrators, to the small vibrators on noncorresponding points, the results all approached those for the body. It is clear that a major test of such thinking remains to be performed. It would be desirable to repeat the Geldard-Sherrick experiment utilizing bodily loci intentionally selected to occupy neurologically corresponding sites. The prediction would be that discrimination should falter considerably under such conditions. If it does not, the mystery of the great improvement with noncorresponding finger loci deepens.

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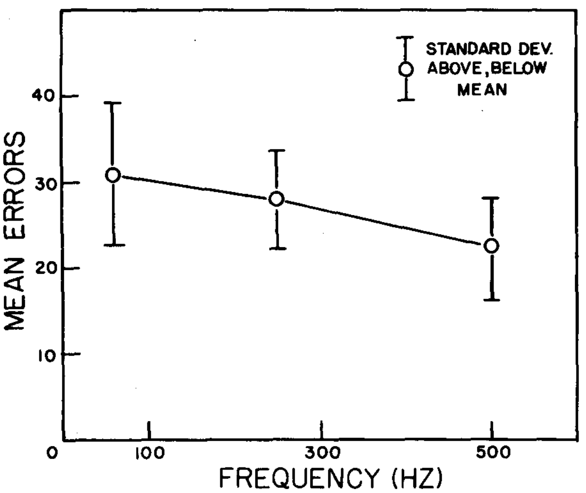
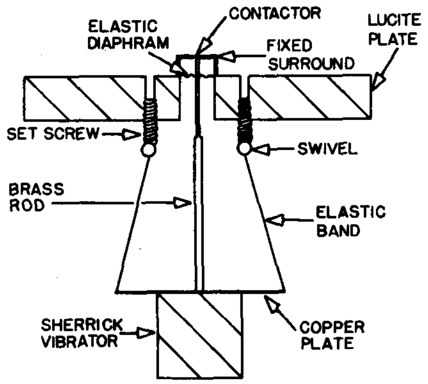


Fig. 3. Mean errors for five Os presented with three tapes at three different signal frequencies.



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Comparison of the three methods of stimulation showed that both the fixed surround and the concentrically vibrating systems afforded equally great reductions in vibratory propagation relative to the finger loops. Because of the relative simplicity of design of fixed as compared to vibrating surrounds, a complete system of 10 finger vibrators was constructed with contactors vibrating within fixed surrounds. The modified system is shown in Fig. 4.

In each of two Lucite plates five holes 1.2 cm in diameter were cut to correspond to the average placement of the fingertips, with relaxed hands of the Os who were to observe. Three elastic bands were attached at one end to three suspensory screws placed around each hole. Attached at the other ends of the elastic bands were Sherrick vibrators. The hanging vibrators were staggered in distance from the plate (15 and 20 cm) to prevent contact with each other. A brass rod 3 mm in diameter extended upwards from each vibrator through the holes in the Lucite plates and through a rubber diaphragm over the hole. The latter prevented the rod from contacting the sides of the hole. The last 2.5 cm of the rods were tapered to 1.5 mm diameter. A spacing ring was placed over the diaphragm upon which was attached a surround of 2.5 mm inside diameter and 15 mm outside diameter. Centering and height adjustments for each rod were accomplished by means of the three suspensory screws.

This system of stimulation was compared for discriminability to the vibrating finger stalls under the same conditions as in Experiment 1 (60 Hz vibration with 200 msec bursts at 15 dB SL). The comparison was made on the basis of five tapes presented to each of six Os who had observed in Experiment 1.

Results and Discussion

The Os uniformly reported upon first feeling this system that the finger patterns were much more "distinctive" with the small fixed surround vibrators than with the finger stalls. The individual vibrations were described as bright, sharply localized sensations, in close agreement with Békésy's (1957) observations with a similar five-vibrator system on the arm. The phenomenal reports anticipated the results. A comparison of the data with those obtained on the finger stalls for the same Os and tapes showed a 27% reduction in mean errors. This was significant at the .05 level by the Wilcoxon signed-rank test. It appears that a reduction in propagation or the accompanying sharpening of localization improves discriminability.

The effect of hand-to-hand shift, although somewhat reduced, still remained when the data were analyzed for shift in the same manner as in Experiment 1. It appears that shift still has an effect even with a minimum of vibratory interaction between fingers.

EXPERIMENT 3

In an attempt to investigate shift further, an analysis of the occurrences of shifts between large sections of the body was made on the raw data obtained by Geldard and Sherrick (1965). An upper-lower split was made, including body loci Nos. 1-5 in the upper section and loci Nos. 6-10 in the lower section. A bilateral split was also made, including body loci Nos. 2, 3, 6, 7, and 9 in one section and 1, 4, 5, 8, and 10 in the other (see Fig. 1). The results of the analysis showed that, unlike the hands, neither the upper-lower split nor the bilateral split showed variations in error rate (at the same per cent communality) with per cent shift between two sections. It appears that changes of locus within the hand are less discriminable than changes in locus (shifts) between the hands even with a minimum of vibratory interaction between fingers (Experiment 2). In contrast, however, all changes in locus or shifts on the body seem to be equally discriminable. One difference between the loci on the body and those on the fingers is that corresponding points on the body were avoided while on the fingers they were not.

Bender (1952) has described various types of neural interactions that take place with simultaneous stimulation of bilateral homologous regions of the body. Sherrick (1964), moreover, has shown vibrotactile masking with double simultaneous stimulation of corresponding fingertips.

At this point an inductive leap was made. It was conceivable that the effect of shift was the result of some kind of neural interaction between corresponding fingertips. The reasoning is as follows. If there is an interaction, in all probability it would interfere with rather than improve perception of a pattern. With increased shifting of elements across hands, the probability of stimulating corresponding fingertips and thus obtaining interaction is less in one of the two patterns in a pair. Therefore, with increasing shift the discriminations should be easier. It would be expected that reducing these interactions by stimulating at noncorresponding points should increase the ease of discrimination at low per cent shifts, where errors are greatest, and thereby increase overall discriminability. Experiment 3 was an attempt to test this hypothesis by stimulating noncorresponding points on the fingertips.

Apparatus and Procedure

The instrumentation was the same as in Experiment 2 with the small vibrators, with the one exception that O was instructed to place his right fingers further up on the vibrators. The point of contact for each finger of the right hand was, on the average, 2.5 cm more proximal than for the left. Each of six Os, all of whom had observed in Experiment 2, was presented with the 20 original tapes under the same conditions as described in Experiment 1.

Results and Discussion

An analysis of the data showed a 20% reduction in mean errors, when compared to those data obtained for the same five tapes in Experiment 2. This difference was significant at the .05 level by the Wilcoxon signed-rank test. Furthermore, an analysis of the 20 tapes for the shift effect did indicate a reduction in prominence of the effect. This is shown in Fig. 5. These results lend some support to the belief that there is some kind of neural interaction taking place between corresponding fingertips.

A comparison between the original body data and the present data on the 20 tapes revealed that, although the fingers still made about 25% more errors than the body, this difference was not significant by the Wilcoxon two-sample test ($p > .05$).

It appears that the combination of small finger vibrators with application to noncorresponding finger sites can improve discriminability to within the range

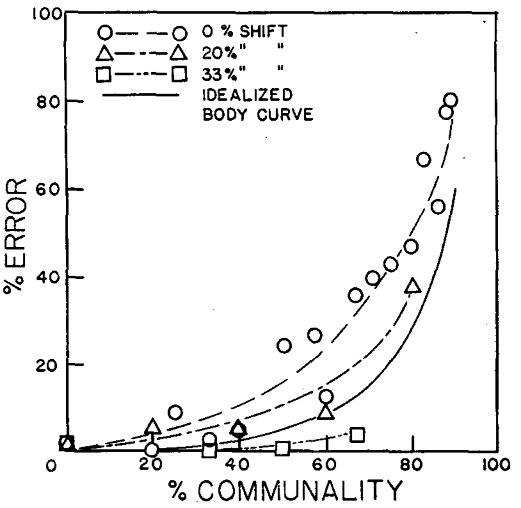

Fig. 5. Separation of shift and communality for pattern discrimination with the small vibrators on the fingers at non-corresponding points, together with the idealized curve for the body.

of that described by Geldard and Sherrick for the body. This is perhaps not surprising if one considers that the course of improvement in the method of stimulation at the fingers progressively approached a parallel to the method of stimulation on the body. For example, the first significant improvement occurred when the extent of propagation was reduced. This propagation reduction decreased the ratio of the skin area stimulated relative to the distinct skin area designated as one locus (i.e., the finger). As a result the ratio for the fingers approached the ratio for the body, a relatively small one owing to the large size of the areas designated as one locus. The second significant improvement came when noncorresponding points were stimulated on the fingers. This again approached the situation on the body in which corresponding points were avoided. Thus, as the method of stimulation approached that for the body, from the finger loops, to the small vibrators, to the small vibrators on noncorresponding points, the results all approached those for the body. It is clear that a major test of such thinking remains to be performed. It would be desirable to repeat the Geldard-Sherrick experiment utilizing bodily loci intentionally selected to occupy neurologically corresponding sites. The prediction would be that discrimination should falter considerably under such conditions. If it does not, the mystery of the great improvement with noncorresponding finger loci deepens.

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Note

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