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# DEAF AND HEARING CHILDREN'S PERFORMANCE ON A TACTUAL PERCEPTION BATTERY[1]

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*Summary.*—A battery of tactual sensitivity tests was administered to 300 deaf and hearing children and adolescents. The tests included vibrotactile and two-point sensitivity on several areas of the hand, gap-detection using two stimulation techniques, roughness discrimination, pattern discrimination, and cross-modal object identification. Measures included sensory thresholds, correct discrimination, errors, and in some cases, response latencies. Deaf youngsters were more sensitive than their hearing counterparts with vibrotactile and two-point measures. On most remaining tasks, deaf and hearing *S*s' performance accuracies did not differ, although hearing *S*s performed faster on all timed tasks. Improvements with age were evident with both speed and accuracy measures for several tasks. Results were discussed as to deaf/hearing differences, and reading achievement scores, active versus passive touch, developmental changes, and relations among the tactual tasks and measures of the battery. The findings strongly suggested that different measures of tactual sensitivity tap quite different sensory and perceptual abilities.

CONTENTS

Recent interest in skin sensitivity has centered around possibilities of using skin senses as primary or supplementary communication systems (Gilmer, 1966). Numerous studies have been attempted to discover the capacity of the skin for information transmission (e.g., Bliss, 1962; Geldard & Sherrick, 1965; Gilmer, 1966), the relationship between tactual and tactile[3] sensitivity and stimulus variables (e.g., Gibson, 1962; Gilmer, 1966), and the development of effective tactual information displays (e.g., Foulke, 1968; Hill & Bliss, 1968; Morris & Nolan, 1961; Schiff, Kaufer, & Mosak, 1966; Schiff & Isikow, 1966; Weidel & Groves, 1969). But, the relationships between various measures of skin sensi-

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[3] Although the terms tactual and tactile are used interchangeably throughout most of the literature, we suggest that *tactual* specify the active use of part of or the entire hand as a "sense organ system" (Gibson, 1966), including the obtaining of stimuli from muscles and joints as well as the skin, while *tactile* should specify skin sensitivity *per se,* implying "passive" touch (Gibson, 1962) in most cases. We have so used the terms in this paper.

tivity and tactual performance tasks are largely unknown, developmentally and otherwise.

Advantages of the skin as a sensory "channel" may lie in its ability to be sensitive to both spatial and temporal stimulus dimensions, in the relatively small amount of "noise" in the input system, and in its applicability to persons differing widely in sensitivity in other channels or loss of a channel (Gilmer, 1966). Since deaf persons have lost the capability of information pickup through a primarily temporal channel—the auditory system—the possibilities of using the skin for perceptual information pickup may be relevant for the deaf. The relationship between skin sensitivity and auditory sensitivity has, in fact, been noted previously (e.g., Gebhard & Mowbray, 1959).

The potential use of supplementary tactual and tactile information by deaf persons presupposes a knowledge of their tactile sensitivity, the course of its development, their discriminatory capacities, classification, and use of tactually presented information. It cannot simply be assumed that non-auditory information processing is necessarily similar in hearing and deaf persons, as there is evidence for cross-modal facilitation and inhibition (e.g., see Zubek, Flye, & Willows, 1964; Fox, 1965; Gilmer, 1966; Madsen & Mears, 1965; Ryan, 1940), in addition to other performance differences sometimes found with deaf and hearing *S*s (Furth, 1971). Recent studies of tactual performances of deaf persons relative to hearing persons do not present a clear picture of how deaf persons of various ages handle tactual or tactile information. Although there have been some attempts to study tactual and tactile abilities at several age levels in hearing children and adults (e.g., Abravanel, 1968; Pick, 1965; Pick & Pick, 1966), parallel studies have not been performed with deaf *S*s.

In those cases where both deaf and hearing children's performances have been compared, the tactual or cross-modal tasks used have not included a wide variety of tasks or stimuli with the same *S*s nor has a uniform set of findings emerged. Blank and Bridger (1966) found young deaf children superior to hearing counterparts in tactual information processing, whereas this difference did not hold with visual information. Larr (1955, 1956) found no significant difference between deaf and hearing groups' performances on tactual pattern perception tasks, with one exception where hearing children performed better. Using tactually applied rhythmic patterns, Rosenstein (1957) found that, while deaf children had initially lower vibrotactile thresholds than hearing children, they improved less with practice. Using tactual identification of letters as a task, Schiff and Dytell (1971) found no significant differences between deaf and hearing children and adolescents in either accuracy or speed of cross-modal matches.

Inspection of the deafness literature would lead one to expect that in tactual sensitivity tasks requiring a minimum of linguistic competence, deaf persons should perform similarly to hearing persons (Furth, 1964, 1971; Rosenstein,

1961) and possibly better, since auditory interference would be eliminated. But as linguistic/conceptual components of tactual tasks increase, hearing children and adults should perform relatively better than deaf *S*s. Since there is some evidence of deaf *S*s' superiority in tactile sensitivity, one might again expect a crossing of performance curves, with initial superiority of deaf *S*s yielding to superiority of hearing *S*s as linguistic conceptual factors become dominant in tactual information processing.

In terms of developmental trends in tactual perception, reports generally show variability and *errors* decreasing as age increases (e.g., James, 1965; Pick & Pick, 1966). However, there are virtually no data on perceptual performance *speed* changes in tactual tasks across age levels in deaf *S*s, although Olson (1967) found a perceptual speed factor using visual tasks with older (12 to 16 yr.) deaf children.

The present studies were performed to extend basic knowledge about sensory and perceptual tactual information processing, using a variety of tactile and tactual tasks and measures, and a relatively wide age-range of deaf and hearing children and adolescents.

## METHOD

### *Subjects*

*S*s were 179 deaf children and adolescents enrolled at the New York School for the Deaf, White Plains, and 121 children and adolescents with normal hearing enrolled in New York City Public Schools. The public schools were chosen to match the deaf school as closely as possible for socio-economic and racial composition. The *S*s ranged in age from 7½ to 19½ yr., $M = 13.61$.

IQs of the deaf *S*s ranged from 72 to 145, $M = 103.34$, $SD = 31.50$. Since IQs were not available for the hearing youngsters, Metropolitan Reading Achievement Test scores were obtained, and ranged from 29 to 110, $M = 62.28$, $SD = 47.50$. There were 112 boys and 71 girls in the deaf sample, and 61 boys and 60 girls in the hearing sample.

Degree of deafness ranged from 73- to 90-db loss (24 *S*s) to 101- to 110-db loss (82 *S*s).

### *Apparatus and Procedure*

1. *Vibrotactile sensitivity.*—An Electro-Medical Engineering Co. 61-2V vibrometer was used to measure vibrotactile thresholds. The instrument was calibrated using a microscope, micrometer caliper, and stroboscope.

The peak-to-peak displacement amplitude ranged from .0001 in. at approximately 40 on the instrument scale, to .0015 in. at 100 on the instrument scale, with a relatively smooth curve fitting the points between these.

For all tasks *S* was seated by the side of a desk. Tactual stimuli were presented behind an opaque screen. The tasks were administered in random orders. *S* was shown the apparatus and given written instructions. He or she was then touched lightly on the fleshy pad of the right index finger for about 2 sec. with the tip of the vibrometer, illustrating how a large amount (scale reading of 100) and a smaller amount (scale reading of 40) felt. The task was then demonstrated by touching alternately with the vibrometer "on" and "off" and requesting a report of whether or not he felt vibration. The task was then begun on the index finger, with repeated stimulation with decreasing amounts of vibration. Catch trials of zero vibration were included. The above procedure was duplicated on the inner distal inter-joint area ("bone") of the right middle finger.

2. *Two-point threshold.*—A Lafayette Instrument Co. Model 1712-S aesthesiometer was used to measure two-point thresholds.

Written instructions were given and the apparatus was shown. It was demonstrated that the aesthesiometer was not painful by touching *E*'s fingertips. *S*'s right index fingertip was touched lightly for about 2 sec. with two points spread apart ¼ in. and then with one point. Stimulation was repeated alternately, and *S* was asked to report whether he felt one or two points. The task was then administered on the index finger with repeated stimulation with decreasing sized 1/16-in. intervals between the two points. Catch trials of one point only were included. The above procedure was repeated on the palm of the right hand on the main crease produced in the center of the palm when the thumb is folded.

3. *Landoldt C-test.*—A tactile version of the visual Landoldt C circle adapted from Chan (1964) was used to test the ability to detect a gap in tactually scanned or pressed rings. The apparatus was identical to that shown in Chan (1964) except that the 10 rings containing 8 gaps were fitted to the slide bar. Gap sizes were as follows: .020-in., .030-in., .045-in., .060-in., .075-in., .105-in., .120-in. and .130-in. Two rings containing no gaps were used for catch trials.

Written instructions containing diagrams of the rings were given to *S*, who was then shown the bar with the rings on it. *E* then touched one of the rings lightly without moving the right index finger for about 2 sec. and instructed *S* to do the same, while cautioning against the moving of the finger ("passive" condition). *S* was asked to point to the diagram on the printed instruction sheet which was exactly the same as the ring touched. This practice was repeated on three of the rings. *S* was shown how to grasp the palm rest and then the bar was slipped into the holder. During the task, each of the ten rings was presented once in fixed order. In the "active" condition, the above was repeated with only one difference—with instructions to move the finger around, "scanning" the ring.

4. *Roughness discrimination.*—Four grades of sandpaper were reproduced in pairs on Brailon (a calendered semi-rigid vinyl) pages of a booklet so that each was paired with each other an equal number of times (4) on each side

of the pair. This provided a total of 20 pairs, including each sample paired with itself twice for "catch" trials. Each sample measured 1.5 in. × 1.5 in. The four grades of roughness included: 31M 1G3 Fine Emery Cloth (finest), Carborundum F Flint Paper—Medium, 3-M 60 LS4 D Wt., Closed Coat, and 3-M 40 IE$_3$D Wt., Open Coat (coarsest). The four grades had been previously found discriminable from each other well beyond chance.

Written instructions were given and a sample page in the test booklet containing squares of the finest and the coarsest grades was presented. *E* then moved her right index finger repeatedly over the two surfaces and pointed to the rougher surface. Practice time was provided to feel the surfaces and instructions were given to report whether the two surfaces were of the same roughness, or, to point to the *rougher* square. *S* was informed that he would be timed.

5. *Pattern discrimination.*—Ten pairs of patterns also found discriminable (Schiff, 1967) were reproduced on *Brailon* sheets in pairs. Sixteen patterns were used, including 1 and 6: Raised "bumps" differing in density, providing a frequency difference for active touch (Schiff, 1967); 2 and 3: Dotted vertical lines differing in spacing, providing frequency difference for a horizontal scan (2 sets); 5 and 8: Raised points differing in "sharpness" (2 sets) providing an intensity difference; 7: Parallel diagonal ribs, differing in direction; 9: Patterns containing raised units of different sizes, shapes and distributions, providing a complex set of differences; 10: Raised points distributed regularly or irregularly; 4: One set of identical patterns ("Vexierversuch"); and 1 and 6: One repeated pair of patterns (reliability test) with positions reversed. Each sample measured 1.5 in. × 1.5 in.

Written instructions were given and a sample page in the test booklet was shown. *E* demonstrated the task by scanning the two surfaces with the right index finger, allowing practice time for *S* to do the same. *S* was asked to report whether the two felt patterns were exactly the same or different and was further informed that he would be timed.

6. *Object identification.*—Two of each of the following objects were used for cross-modal object identification: 1. Large paper clip, 2. Small comb, 3. Rubber brush-type eraser, 4. Gum eraser, 5. Rubber band, 6. Small spool thread, 7. Matchbook, 8 ."Nonsense" object—made of twisted wire, 9. Penny, 10. Nickel, 11. Dime, 12. Quarter, 13. "Old" New York City Transit token (slightly smaller than a dime). In addition to two of each of the above, the following were also included in the visually displayed set of items, but *S*s never felt these items: small paper clip, large comb, large spool of thread. These served as additional confusion items (size transformation) of the object identification test.

Written instructions were given and a visual display of all objects was presented. The examiner explained that one object at a time would be placed in the right hand; *S* was to feel the object, and identify it as soon as possible by pointing to the object which was exactly the same as the one contained in the visual display. A stopwatch was used to measure response latencies on several of the sub-tests.

7. *Letter identification.*—A full description of this sub-test and the results obtained with it are reported separately (Schiff & Dytell, 1971).

The duration of each sub-test was 10 min. or less, and the total testing time was 1 hr. or less for each *S*. The nature, brevity, and variety of tasks apparently prevented boredom, and all but 6 *S*s (see below) completed the tasks with no major difficulty. The order of sub-test presentation was held constant, in the sequence indicated by number.

## RESULTS

Of the original sample of 300 *S*s, 294 provided usable data, although the number of *S*s in some sub-tests varied slightly. A *t* test between mean thresholds of boys and girls was initially performed for both groups with each set of measures. Since sex differences were not significant at the .05 level, scores of males and females were pooled for further statistical tests.

### *Task Performances*

1. *Vibrotactile sensitivity.*—Table 1 shows mean thresholds and *SD*s for finger and "bone" areas, in Deaf and Hearing groups. Table 1 also presents correlation coefficients between finger and bone thresholds and both age and IQ (reading achievement scores in the Hearing group). Only coefficients for age and finger thresholds in Deaf *S*s were significant. Two-way analyses of variance (Age × Deaf/Hearing) performed on bone and finger threshold data showed that Deaf and Hearing thresholds differed significantly in vibrotactile sensitivity on the finger *and* bone, while the Age factor and Age × Deaf/Hearing interaction were significant on the bone measure only.

A graphic plot of bone and finger vibrotactile thresholds as a function of age for both deaf and hearing groups showed Deaf *S*s were *more* sensitive (lower thresholds) to vibrotactile stimuli than Hearing *S*s at almost all age levels with both measures. This finding elaborates upon the generally lower mean thresholds for Deaf *S*s in the age-pooled data of Table 1. The bone measure proved more sensitive at almost every age level in both Deaf and Hearing groups.

2. *Two-point threshold.*—Since age *r*s were significant with both measures in the Deaf group, and with the palm measure in the Hearing group, two-way analyses of variance (Age × Deaf/Hearing) were again performed on threshold scores for finger and palm (see Table 1). Age and Deaf/Hearing factors were significant with both measures, while the Age × Deaf/Hearing interaction reached a significant level with the palm measure only. Fig. 1 presents the two-point threshold data as functions of age for Deaf and Hearing groups for both measures, and shows superior sensitivity in Deaf *S*s at most age levels, further elaborating the over-all mean difference between Deaf and Hearing thresholds.

TABLE 1

SUMMARY OF DATA: TACTUAL PERCEPTION BATTERY

| Tasks & Measures | Deaf *Ss* | | Hearing *Ss* | | Analysis of Variance: *F* | | | $r_{\text{Age}}$ | | $r_{\text{IQ}}$ | $r_{\text{Read}}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | A (Age) | B D/H | A × B | Deaf | Hear. | | |
| 1. Vibrotactile Sensitivity | | | | | | | | | | | |
| RL(F) | 11.20 | 3.25 | 15.04 | 8.71 | 1.25 | 26.79† | 1.05 | –.26* | –.07 | –.07 | –.01 |
| RL(B) | 10.16 | 2.45 | 12.92 | 4.12 | 1.91* | 78.50† | 2.01* | –.05 | .01 | –.15* | .00 |
| 2. Two-point Threshold | | | | | | | | | | | |
| RL(F) | 3.17 | .84 | 3.40 | .91 | 2.03* | 4.13* | 1.00 | .17* | .11 | –.02 | .07 |
| RL(P) | 9.20 | 2.85 | 12.49 | 2.82 | 2.16* | 76.37† | 2.36* | –.42† | .30† | –.21* | .16* |
| 3. Gap Discrimination | | | | | | | | | | | |
| Active | 6.31 | 1.40 | 6.48 | 1.21 | 23.68† | 2.15 | .22 | –.10 | .14 | .17* | .27† |
| Passive | 5.26 | 1.42 | 5.39 | 1.24 | 23.68† | | | –.14 | .05 | .10 | –.03 |
| 4. Roughness Discrimination | | | | | | | | | | | |
| Errors (+)‡ | 2.97 | 2.27 | 1.42 | 1.27 | 7.04† | 3.36 | .14 | –.41† | –.44† | .05 | –.34† |
| Errors (—)‡ | 2.12 | 1.40 | 1.48 | 1.56 | 3.82* | 9.08† | .80 | .28† | –.10 | –.05 | .08 |
| Latency | 112.91 | 39.41 | 95.87 | 29.52 | 2.46† | 5.68* | 1.15 | .08 | –.10 | –.24† | .01 |
| 5. Pattern Discrimination | | | | | | | | | | | |
| Correct | 6.81 | 1.46 | 6.64 | 1.68 | 3.50† | .29 | 1.99* | .37† | .31† | .00 | .19* |
| Latency | 79.88 | 38.35 | 68.25 | 23.42 | .92 | 4.89* | .47 | .20* | –.01 | .00 | .06 |
| 6. Object Identification | | | | | | | | | | | |
| Correct | 11.04 | 1.65 | 11.11 | 1.49 | 21.46† | .66 | .67 | .38† | .21* | .11 | .19* |
| Latency | 35.98 | 8.51 | 31.71 | 8.05 | 1.99* | 17.40† | 2.68† | .15* | –.41† | –.30† | .16* |

*Note.*—Factor A in Task 3 refers to Active/Passive, not Age.

*Code.*—$^*p < .05$. $^\dagger p < .01$. ‡False positive errors (+), false negative errors (—).

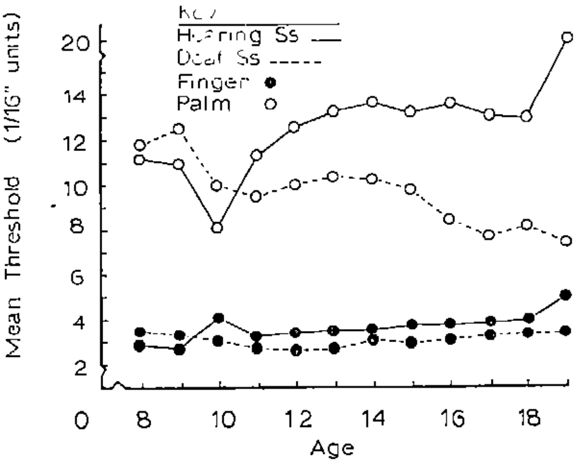

FIG. 1. Mean two-point thresholds of palm and fingertip regions as functions of age for Deaf and Hearing groups

The finger measure provided rather flat curves, with consistent values throughout the age range.

Inspection of Fig. 1 indicates that the source of the significant Age × Deaf/Hearing interaction is a tendency for increasing palmar sensitivity with age in the Deaf group, and irregularly *decreasing* palmar sensitivity with age in the Hearing group.

3. *Landoldt C-test.*—Table 1 shows low correlation coefficients between Age and IQ and gap detection thresholds. Since no significant age *r*s were in evidence, data were not analyzed further for developmental trends.

Fig. 2 presents percent correct discrimination as functions of gap size, plotted separately for Deaf and Hearing groups, and Active and Passive techniques. Inspection of Fig. 2 indicates a clear increase in the number of correct discriminations with increasing gap size beyond 1.5 mm., and that the active inspection techniques led to better performance in both groups at virtually every gap size. Since Fig. 2 also showed Hearing *S*s performing better at most points regardless of the technique used, Deaf/Hearing and active/passive differences were tested using a 2 × 2 analysis of variance, repeated measures on the second factor. The results (Table 1) indicate a significant active/passive condition.

4. *Roughness discrimination.*—Two-way analyses of variance (Deaf/Hearing × Age) performed on all three measures show the age factor significant with all measures, and the Deaf/Hearing factor significant with all measures except false positive errors. With this exception, the Deaf group performed significantly slower but with fewer errors than the Hearing group at most age levels.

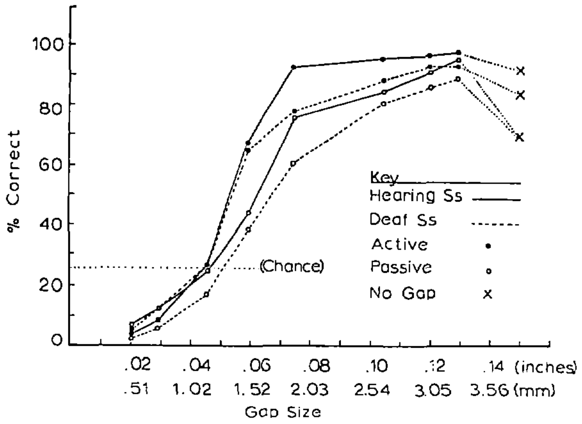

FIG. 2. Percent correct gap detections as functions of gap size for Deaf and Hearing groups using both "Active" and Passive" techniques

Fig. 3 presents both error measures plotted as functions of age, and shows that for both Deaf and Hearing groups, false negatives ("same" errors) generally increased with age, whereas false positives ("different" errors) generally decreased with age, but that the trends were clearer in the Deaf group than in the Hearing group.

Since the age factor proved significant in the analysis of variance of latency scores, mean latencies were plotted as functions of age for Deaf and Hearing groups delineating differences in performance speed at several age levels (10, 13, 14, 15, 18), with the Hearing group generally performing the task faster—

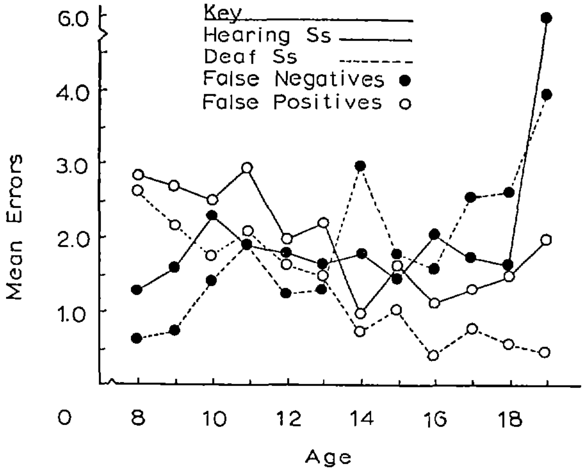

FIG. 3. Mean false positive and false negative errors of roughness discrimination as functions of age for Deaf and Hearing groups

especially at the higher age levels. Although the age-latency *r*s did not reach significance there was a tendency for older Deaf *S*s to perform slower, with the opposite tendency in Hearing *S*s.

5. *Pattern discrimination.*—Since age *r*s for patterns correct were significant in both groups and for latency in the Deaf group, two-way analyses of variance were performed; these show that the Age factor and Deaf/Hearing × Age interaction reached significant levels with "error" scores, whereas only the Deaf/Hearing factor proved significant with the latency measure. As Fig. 4 indicates, Hearing *S*s performed with fewer errors at all but three age levels—the mean number of correct discriminations increasing with age. They also performed rapidly at all but three age levels. The latency/age correlation coefficients in Table 1 show a tendency for older Deaf *S*s to perform more slowly, whereas older Hearing *S*s were about as fast or faster than their younger counterparts.

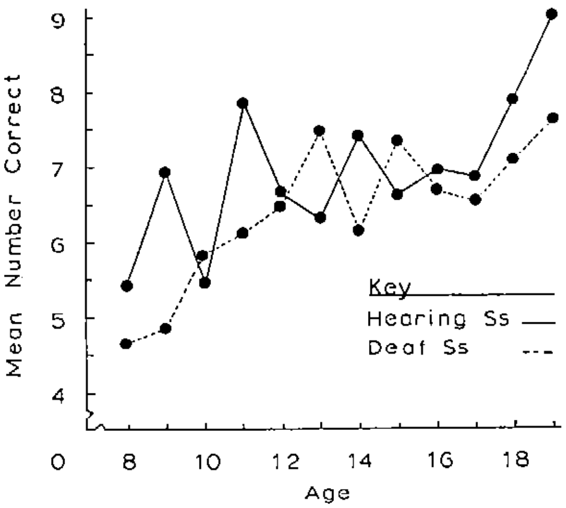

FIG. 4. Mean patterns correctly discriminated by Deaf and Hearing groups as functions of age

6. *Cross-modal object identification.*—Since all *r*s between age and accuracy and latency measures were significant, two-way analyses of variance were performed on both sets of data. Neither Age nor Deaf/Hearing factors were significant for errors, but both Age, and Deaf/Hearing factors and their interaction were significant with the latency measure. The age curve for the error measure is shown in Fig. 5. Improved performances as functions of age were evident in both Deaf and Hearing groups for objects correctly matched, but again, decreased speed of performance was evidenced by the Deaf group with increasing age,

while older *Ss* in the Hearing group performed faster than younger *Ss*. These relationships are corroborated by the age *rs* shown in Table 1.

From the number of correct identifications and mean latencies for each of the 13 objects tactually inspected in the cross-modal task, it was found that with the exception of the nickel, the coins were the most difficult to match across modalities, while the erasers, rubber band, matchbook and nonsense object were easiest to match. Pooled correct identifications were almost identical for these classes of objects. Other objects having possible *size* confusions (comb, clip, and thread) provided more confusions than objects having no size-differentiated counterparts.

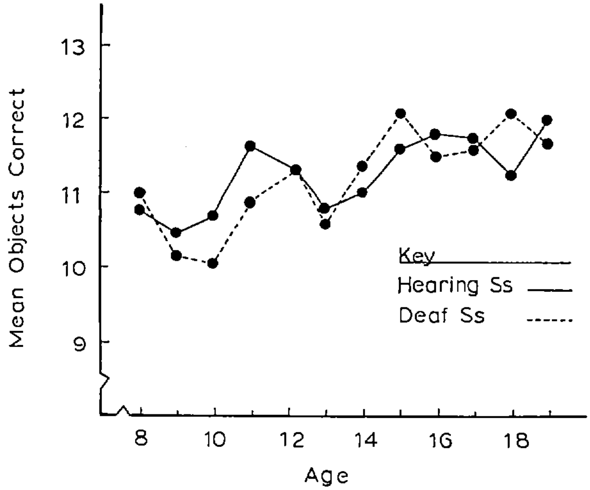

FIG. 5. Mean objects correctly matched (vision and touch) as functions of age for Deaf and Hearing groups

### *Factor Analyses*

Principal component factor analyses and varimax rotations were performed separately for Deaf and Hearing groups' tactual battery scores. Table 2 presents intercorrelation matrices for the entire battery, calculated separately for each group. Although 7 factors were extracted for each group, Factors 1, 2, and 3 in the Hearing group, and Factor 1 in the Deaf group appeared to be the only ones of major importance, each accounting for just between 12% and 14% of the variance.[4]

For both Deaf and Hearing groups, latency measures of several tasks loaded heavily on one factor, implying a "speed" factor across the different tasks. A second major factor involved the inability to identify differences in patterns, roughness samples, letters and also objects in the Deaf group only. This factor

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[4] Tables of factor loadings are available from the authors upon request.

TABLE 2

INTERCORRELATION MATRIX FOR 15 TACTILE MEASURES FOR DEAF AND HEARING *Ss*

| Measure | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deaf *Ss* | | | | | | | | | | | | | | | |
| 1* | | 49 | 16 | 31 | –24 | 17 | 02 | 07 | 05 | 15 | 00 | 06 | –01 | –13 | 04 |
| 2 | | | –09 | –01 | –09 | 20 | 26 | 03 | 10 | 14 | 04 | 02 | –15 | –10 | 10 |
| 3 | | | | 11 | –04 | 02 | 16 | 02 | 13 | 06 | 17 | –05 | –08 | 03 | 13 |
| 4 | | | | | –13 | 21 | 15 | –12 | –02 | 28 | 15 | 02 | –01 | –09 | 03 |
| 5 | | | | | | –20 | –04 | 13 | –03 | –08 | –03 | –09 | –25 | –04 | 02 |
| 6 | | | | | | | 08 | –28 | –03 | 24 | 02 | 09 | –02 | –45 | 06 |
| 7 | | | | | | | | –01 | 44 | –07 | 48 | –15 | –10 | –09 | 44 |
| 8 | | | | | | | | | 02 | –24 | –01 | 03 | –01 | 19 | 03 |
| 9 | | | | | | | | | | –13 | 18 | 28 | –11 | –01 | 38 |
| 10 | | | | | | | | | | | 16 | –17 | –08 | –19 | 00 |
| 11 | | | | | | | | | | | | –16 | 02 | 00 | 36 |
| 12 | | | | | | | | | | | | | 18 | –04 | –03 |
| 13 | | | | | | | | | | | | | | 08 | –13 |
| 14 | | | | | | | | | | | | | | | –03 |
| 15 | | | | | | | | | | | | | | | |
| Hearing *Ss* | | | | | | | | | | | | | | | |
| 1 | | 56 | 44 | –25 | 01 | 15 | 37 | –19 | 04 | –05 | 04 | 01 | –18 | –15 | –03 |
| 2 | | | 18 | 00 | 07 | 15 | 25 | –14 | 12 | –05 | 03 | –06 | –24 | –08 | –07 |
| 3 | | | | 10 | 08 | 17 | 36 | 21 | 02 | 03 | 16 | –09 | –24 | –26 | –01 |
| 4 | | | | | –01 | –12 | –09 | 18 | –11 | –16 | 01 | –07 | –11 | 05 | 01 |
| 5 | | | | | | –02 | 04 | –02 | 00 | 06 | 02 | –08 | –10 | 07 | –12 |
| 6 | | | | | | | 08 | –45 | –13 | 41 | –07 | –23 | –26 | –32 | 16 |
| 7 | | | | | | | | –10 | 52 | 00 | 46 | 12 | 26 | –01 | 35 |
| 8 | | | | | | | | | 07 | –27 | 06 | 17 | 17 | 17 | –14 |
| 9 | | | | | | | | | | –22 | 29 | 01 | 03 | 28 | 37 |
| 10 | | | | | | | | | | | 09 | –31 | –34 | –27 | 17 |
| 11 | | | | | | | | | | | | –06 | 00 | –18 | 42 |
| 12 | | | | | | | | | | | | | 31 | 15 | –09 |
| 13 | | | | | | | | | | | | | | 09 | –06 |
| 14 | | | | | | | | | | | | | | | –10 |
| 15 | | | | | | | | | | | | | | | |

*Note.*—Decimals omitted. *1, Vibrotactile sensitivity [RL(F)]; 2, Vibrotactile sensitivity [RL(B)]; 3, Two-point threshold [RL(F)]; 4, Two-point threshold [RL(P)], 5, Roughness discrimination, same error; 6, Roughness discrimination, different error; 7, Roughness discrimination, latency; 8, Pattern discrimination, patterns correct; 9, Pattern discrimination, latency, 10, Letter discrimination, errors; 11, Letter discrimination, latency, 12, Gap discrimination, correct detections, passive; 13, Gap discrimination, correct detections, active, 14, Object discrimination, correct; 15, Object discrimination, latency.

seemed to involve the ability to discriminate differences in surface and object characteristics. A third major factor involved insensitivity to vibration, whether delivered via the vibrometer, or obtained through fingertip scanning of sandpaper samples of Landoldt C-gaps. This factor was quite specifically vibratory in nature for the Deaf group, but was broader in the Hearing group, where two-point insensitivity, slow performances in roughness discrimination, errors in pattern discrimination, letters correctly identified, and active gap detection errors also loaded significantly on the factor. The factor was purer within the Deaf group.

In summary, the results of the factor analyses yielded several factors common to both Deaf and Hearing groups, including perceptual speed, pattern perception, and vibratory sensitivity. Several factors unique to each group were also extracted. The only tasks consistently loading on the same factors were vibrotactile thresholds and roughness discrimination.

## DISCUSSION

### *Findings with Specific Tasks*

1. *Vibrotactile sensitivity.*—The present findings confirm extensive literature (see Gilmer, 1966) concerned with vibrotactile sensitivity with regard to differential sensitivity of areas of the hand (fingertip vs inter-joint region of the index finger), and stability of the measure. The relatively stable thresholds with age further confirm the notion of vibration sensitivity as a "basic" sensitivity measure.

The fact that vibrotactile sensitivity constituted factor groupings in both Deaf and Hearing groups—especially the former—and was *not* correlated with any battery measure other than roughness discrimination (and two-point fingertip threshold for Hearing group only) is a theoretically provocative finding. First the relationships between vibratory sensitivity and roughness discrimination provide broad empirical support for the notion that differentially rough surfaces are discriminated through the differences in vibration they produce (Katz, 1925; Krueger, 1970). Furthermore, Gibson's (1962, p. 490) suggestions that sensory sensitivity measures are often unrelated to the useful perception information provided by sense organs or "sense organ systems" (Gibson, 1966) received support from *independence* of the vibratory measures from most other spatial and spatio-temporal measures of the battery.

2. *Two-point threshold.*—The findings with two-point thresholds (aesthesiometer) also confirm previous work with this classical measure, although values obtained were 1 to 2 mm. greater than those found in the literature (e.g., Major, 1898; Ringel & Ewanowski, 1965; Ruch, 1951) probably due to our use of naive *Ss* rather than the trained observers used in classical psychophysical experiments.

An earlier developmental study (ages 12 to 17 yr.) with two-point thresholds (Brown & Stratton, 1925) produced values averaging about 2 mm. as compared to the 4-mm. values of the present study but used an *active* touch technique —to be discussed later.

The differences found between areas measured (fingertip and palm) also confirm similar findings in the above studies.

3. *Landoldt C-test.*—The results obtained with the gap detection task (passive method) closely parallelled Chan's (1964) findings in that the .045-in. gap (somewhat larger than the 1-mm. gap size used by Chan) was identified with only chance success, the .060-in. gap (about 1.5 mm.) was correctly identified about 45% of the time, the .075-in. gap (about 1.8 mm.) was detected with about 75% accuracy, and the .105-in. gap (about 2.5 mm.) was detected with about 90% accuracy. The present findings provide further evidence of a smooth threshold function for the ability to detect such gaps in that gap sizes smaller than and between those used by Chan yielded smoothly spaced intermediate values, and demonstrated that gaps as small as 1.52 mm. are identified beyond chance accuracy. This was the case with both relatively "passive" touching method used by Chan, and the "active" touching method, which yielded about 65% correct responses. The lack of relationship between two-point and gap-detection thresholds (see Table 2) on the same skin area (fingertip) suggests that different sensory or cognitive factors are involved in even these spatial resolution tasks (see Vierck & Jones, 1969).

It is clear that Chan's technique is applicable to *S*s as young as 8 yr. and that threshold values are enhanced considerably by an active tactual scanning technique. This enhancement is especially evident near threshold levels, as inspection of Fig. 2 demonstrates.

4. *Roughness discrimination.*—Of the 20 pairs of reproduced sandpaper samples, *S*s on the average correctly discriminated about 18 pairs of the set. Whereas this level of accuracy indicates *S*s understood the task and were able to pick up the information required to make the decision, the findings are provocative with regard to the decision-making process.

False positive ("different") errors were more frequent than false negatives ("same") errors with younger *S*s, while older *S*s' elimination of false positive errors reversed the situation—especially in the Deaf group. In making a decision as to whether two samples differ in degree of roughness, it appears that *S*s younger than 12 yr. tend to "guess yes." Whether this apparent change in decision strategies is due to declining acquiescence and/or increasing negativism (an altered attitude toward what *S* believes the *E* is looking for), or to changes in search/decision strategies or concepts is unclear. Other researchers in sensory, perceptual, and conceptual areas (Caldwell & Hall, 1969; Gibson, 1969; Ricciuti, 1963) have relied upon the second explanation however. The question posed is an interesting one for future research.

5. *Pattern discrimination.*—Of the 10 pairs of reproduced patterns, *S*s on the average correctly discriminated about 7. The number of patterns correctly discriminated averaged about 5 with 8-yr.-old *S*s and about 8 with the oldest *S*s.

Examination of the high- and low-error pairs showed that density or frequency differences of bumps, intensity differences, and the "Vexierversuch" (same pattern), were dimensions relatively *easy* to discriminate, whereas density or frequency differences of lines within a scan, and regularity of distribution differences were relatively difficult to discriminate.

These differences in discriminability of pattern elements indicate that differences in element density *per se*, producing differential frequency of skin deformation in scanning, are not necessarily good or poor dimensions for maximizing discriminability; raised bumps (easy to discriminate) allow for frequency differences regardless of direction of scan, whereas vertical lines differing in spacing (difficult to discriminate) provide adequate information for discrimination only with a horizontal scan. Also, the sharper elements of the latter may have produced a distracting dimension of stimulation, resulting in a loss of efficiency.

Although Bauer (1952) used a "passive" touch method rather than active scanning, he also found parallel vertical grooves (straight or wavy) to produce high error rates, as did Morris and Nolan (1961).

The general finding that varying orientation, size, distribution regularity, and shape of pattern elements does not provide highly discriminable tactual patterns, further confirms earlier findings (Schiff, 1967). Therefore, Fillipov's (1965) conclusions with regard to optimal pattern variables must be relevant only to the "passive touching" techniques he used, since he found that a number of elements and their orientation were optimal features for pattern discrimination.

6. *Cross-modal object identification.*—Most objects were accurately matched across modalities despite the novelty of the task, and the inclusion of *S*s as young as 7½ yr. This finding lends further support to the notion of amodal perception allowing for the identification of objects, forms, patterns, or substances in different modalities (see Gibson, 1969, pp. 215-231; Gibson, 1962, pp. 488-490; Gibson, 1966; Schiff, *et al.*, 1966; Schiff & Dytell, 1971).

Only those objects for which there were *size*-confusable alternatives produced 10% or more errors (i.e., all coins but the nickel, the large clip, small comb, and small thread). Apparently, modest size differences are difficult to distinguish in spite of a high degree of *intra*sensory sensitivity of the cutaneous system for sizing (Vierck & Jones, 1969), and equally efficient simultaneous and successive visual-tactual matching (Balter & Fogarty, 1971). Failure to find differences in simultaneous versus successive visual-tactual matching may be a consequence of using relatively insensitive *shape* matches (Balter & Fogarty, 1971) as compared with *size* matches.

### *Age Trends*

*General findings.*—Most of the tasks and measures incorporated in the tactual battery manifested improved performance accuracy with age. Errors of letter identification, pattern discrimination, object identification, and false positive errors of roughness discrimination all decreased significantly with age; and Deaf *S*s' palmar two-point thresholds similarly showed increased sensitivity with age contrary to Peters' general statement that two-point thresholds *increase* with age (Wohlwill, 1960).

*Letter identification and spatial resolution.*—The fact that letter identification accuracy improved markedly with age in both groups (*r*s between errors and age ranged from –.47 to –.61), while gap detection thresholds and two-point fingertip thresholds did not, indicates that improved abilities to identify letters tactually as age increases are *not* due to increased sensory sensitivity, but to the improvement in discovering information critical to letter identification—whether knowledge of critical features of letters, or superior search strategies (Schiff & Dytell, 1971). Since 8- to 12-yr.-old children have a functional knowledge of the alphabet, yet, improvement of tactual letter identification occurs as late as 15 to 17 yr., familiarity with letters seems an unlikely explanation for the improvement. Improved accuracy of letter identification with age substantiates Thompson's (1964) findings with deaf and hearing children and visual matching of letter-like forms, extending the findings to tactual and cross-modal identification, and older *S*s.

*False positive and false negative errors.*—Increased elimination of false positive ("different") roughness discrimination errors with age, was, after letter identification, the strongest age-related effect in the battery results. This finding with intra-modal errors conforms to similar findings with inter-modal errors (Birch & Lefford, 1963). James (1965) found that between ages 7 and 11 only male children improved in a roughness discrimination task, although females improved earlier, and adults' performances were superior to those of younger *S*s. Graphic plots of boys' and girls' roughness discrimination data in the present study failed to demonstrate this effect. Inspection of Fig. 3 will demonstrate that James' (1965) failure to distinguish between false positive and false negative errors was also unfortunate, since the two indices show markedly different age trends with roughness discriminations, as shown previously with cross-modal form matches (Birch & Lefford, 1963). Whereas false *positive* errors decreased moderately with increasing age in Deaf ($r = -.41$) and Hearing ($r = -.44$) groups, false *negative* errors showed no significant age trend in the Hearing group ($r = -.10$), and increased significantly with age in the Deaf group ($r = .28$).

The explanation for the above findings may be related to young children's difficulties with the concepts "same" and "different" (Caldwell & Hall, 1969; Ricciuti, 1963). Younger children may have more difficulty detecting what features of stimuli are critical for non-identity ("different") responses (see Gibson, 1969, pp. 122-123; Warm, Clark, & Foulke, 1970). The view that younger children have special and asymmetrical difficulty with "same" and "different" concepts received strong support and should be carefully considered in various sensory and conceptual investigations incorporating one or both indices.

### *Deaf and Hearing Ss' Performances*

*Sensitivity and accuracy.*—The expectation that Deaf *S*s would perform better than Hearing *Ss* on only those tasks relatively free from linguistic/conceptual components was, at first glance, supported by the findings with the various battery tasks. Deaf *Ss*' vibrotactile and two-point thresholds were significantly lower than those of Hearing *Ss* in all locations tested, and at most age levels. However, whereas Deaf *Ss* were clearly more sensitive than Hearing *Ss* on these tactile sensitivity tasks, no significant differences between Deaf and Hearing groups were found on the remainder of the tasks, with the exception of false negative errors on the roughness discrimination task—where Hearing *Ss* made significantly fewer errors.

It is tempting to conclude that either the task distinction (active/passive) is critical to differential group performance—Deaf *Ss* having greater passive sensitivity; or that the linguistic/conceptual factor is critical—Deaf *Ss*' potentially superior performances being depressed as tasks come to involve more conceptual decisions or complex multidimensional discriminations. On the basis of either of the above contentions, it would have been expected that each of the two task groupings would be intercorrelated. However, the only consistent relationship of even moderate strength between sensitivity and accuracy measures of the various tasks was between the two vibrotactile measures, which comprised factor groupings in both Deaf and Hearing groups.

With the exception of a moderate correlation between vibrotactile sensitivity and two-point thresholds in the Hearing group, the passive sensitivity classification did not hold together. In the Hearing group there was a significant *negative* relationship ($r = -.25$) between vibrotactile fingertip thresholds and palmar two-point thresholds despite their both being passive sensitivity tasks, and no significant relationship between fingertip and palmar two-point threshold despite the fact that the two tasks were identical. In the Deaf group the correlation between vibrotactile and two-point thresholds of the fingertip was only .16, despite the fact that the loci were identical. Two-point fingertip thresholds were not related significantly to passive gap detection in either group despite the fact that both measures are purportedly concerned with spatial sensitivity of the same skin areas, and both involve vertical (relative to the bone) deformations of the skin. Therefore, the view that passive sensitivity versus active information extraction accounts for Deaf/Hearing differences on some tasks, but not on others, appears untenable, as does the view that linguistic/conceptual deficits of Deaf *Ss* were responsible for their "merely" comparable performance on the more complex tasks in the battery. The two groups of tasks were not sufficiently intercorrelated to support the above contentions.

How, then, can the partial superiority of Deaf *Ss* be explained? Regarding vibrotactile sensitivity, it is well known that deaf children are attuned to vibration in their everyday lives (Katz, 1925), and furthermore, have been found to be more sensitive to vibration in laboratory experiments (Blank & Bridger, 1966; Rosenstein, 1957). They are typically required to feel vocal vibrations in speech training and often enjoy music via vibration. Since there was no significant correlation between age and vibrotactile thresholds of Hearing *S*s, but there was a low but significant increase in fingertip sensitivity of Deaf *S*s with age, if such attunement of the vibrotactile system does occur, it continues, in part, past age eight. Augmentation of vibrotactile sensitivity due to lack of interference from audition cannot be ruled out as an explanation for the phenomenon (see Krueger, 1970).

Why Deaf *S*s were also more sensitive than Hearing *S*s on two-point threshold measures is less apparent, especially since this superiority was task-specific, not appearing as a general spatial sensitivity factor operating in gap-detection, pattern discrimination, object identification, or even letter identification, where many distinctive features of some letters involve the detection of gaps (Schiff & Dytell, 1971). Inspection of Fig. 1 shows different courses for fingertip and palmar two-point thresholds. The significance of these trends is indicated by the Deaf/Hearing × Age interaction. The sensitivity difference between these skin areas has been documented previously (e.g., Major, 1898; Ruch, 1951), and the increasing and decreasing functions for the palmar area may reflect the initially lower sensitivity of that area, although the fingertip values obtained in the present study were not nearly so low as those obtained by Ringel and Ewanowski (1965) and Ruch (1951) using trained adult observers.

Although there is evidence for inferior performances of deaf *S*s on tasks involving sequential visual information processing (Hartman & Elliott, 1965; Withrow, 1963, 1968), there was little evidence for this effect in those tactual tasks in the battery involving sequential short-term memory processes (roughness discrimination, pattern discrimination, and object identification). Perhaps the "overloaded" visual system of deaf persons is a necessary condition for the appearance of this difference in performance, and tactual tasks circumvent the difficulty (Austin & Sleight, 1952a, p. 246).

The *untimed* aspects of the Deaf/Hearing results, then, support the previous findings of Blank and Bridger (1966) and Rosenstein (1957) who both found superior tactile performances of deaf *S*s using vibratory stimuli—extending the findings developmentally and over different skin areas. Larr's (1955, 1956) findings that deaf children are for the most part the equals of their hearing counterparts in tactual tasks (figure-ground form perception) were generally supported.

*Performance speed.*—In contrast to the findings that Deaf *S*s performed better than or equal to Hearing *S*s on almost all tasks with the exception of the letter identification task, on which Deaf *S*s were nonsignificantly faster (Schiff & Dytell, 1971). The rather unitary aspect of the speed of performance was shown by high intercorrelations among latency measures in both groups and in the "speed" factor emerging from the factor analyses—accounting for the most variance of factors in both groups. The importance of a speed factor in deaf children's performances has been noted previously in *visual* tasks (Elliott, Hirsh, & Simmons, 1967; Elliott & Vegely, 1969; Hartung, 1968; Olson, 1967), and the present findings strengthen the generality accorded perceptual speed factors.

*Speed vs Accuracy of Responses*

The relationship between speed and accuracy measures has received considerable empirical investigation and comment (e.g., see Foulke & Warm, 1966; Schiff & Isikow, 1966). Whereas Austin and Sleight (1952b) and Foulke and Warm (1966) found moderate to high negative correlations between response time and accuracy (rapid and accurate performances being associated in tactual letter and pattern identification tasks), Schiff and Isikow (1966), Schiff, *et al.* (1966) and Zigler and Barrett (1927) found no significant relationship between the two measures, although they used rather similar tasks. However, the present authors found a low but significant negative relationship between time and accuracy measures in the letter-identification task of the present battery (Schiff & Dytell, 1971).

With the exception of the last mentioned finding, the consistently nonsignificant *r*s between accuracy and latency measures within the tasks of the battery suggest that time and accuracy measures on tactual perception tasks are more often independent than related, further stressing the need for *both* measures (Schiff & Isikow, 1966, p. 9).

With the exception of the letter identification task, latencies were significantly and negatively correlated with IQ, although the magnitudes of the relationships were modest. That is, IQ was positively related to rapid performances. Accuracy or error measures on the same tasks were *not* significantly related to IQ, however, although in both roughness discrimination and object identification tasks, performance accuracy was significantly correlated with reading achievement (Hearing group only). The sum of these relationships corroborates earlier findings that IQ and tactual performance speed are related not only in blind *S*s (Morris & Nolan, 1961; Schiff, *et al.*, 1966), but in deaf youngsters, and those with normal vision and hearing. It may be that timed components of IQ measures—especially performance on non-verbal IQ measures—are the basis for the relationships. It is evident from the low or zero-order correlations between IQ and error measures that some simple perceptual performances are relatively independent of intelligence as measured by typical IQ tests. Asking *S*s to perform simple psychophysical tasks may or may not eliminate intellective factors from perceptual data. For example, the different correlations between IQ and "tactual" error scores for letter identification (–.32; Schiff & Dytell, 1971, p. 156) and pattern discrimination (.00) suggest that the nature of perceptual objects is related to the degree to which intelligence relates to their discrimination.

### *Sex Differences*

In contrast to a number of tactual studies finding significant sex differences in sensitivity or performance accuracy (e.g., Chan, 1964; Garfinkel, 1965; Ghent, 1961; James, 1965; Vaught, 1968), the present study yielded *no* significant differences in mean sensitivity, accuracy, or speed, when data were summed across age groups. Since *t* test procedures might have obscured sex-related differences in developmental trends (Ghent, 1961; James, 1965) boys' and girls' data were also plotted graphically for each task as functions of age, but no systematic or large differences were noted.

Whereas the above mentioned research has shown females superior on such tactile and tactual tasks as punctuate pressure sensitivity (Garfinkel, 1965; Ghent, 1961), gap-detection (Chan, 1964), form discrimination (Vaught, 1968), and roughness discrimination (James, 1965), no significant differences in males' and females' performances have been noted in tactual letter-identification tasks (Austin & Sleight, 1952b, Schiff & Dytell, 1971), intrasensory and intersensory matching tasks (Balter & Fogarty, 1971; Birch & Lefford, 1963), and Solomons (1957) found that boys made fewer errors in tactual discrimination of size, weight, texture, and form. The generalization that tactual sensitivity is sex-related (Frank, 1957, p. 249) apparently requires qualification.

### *Active vs Passive Touch*

The role of haptic or tactual activity and resulting self-produced stimulation in touch sensitivity has received theoretical attention for some time (e.g., Katz, 1925, p. 58; Frank, 1957; Gibson, 1962, 1966), although empirical comparisons between active and passive touch have been few, and stimulus conditions have remained relatively unspecified.

Katz reported increased accuracy of tactual perception when the hand and fingers were active in the examination of surface *textures* (Katz, 1925, p. 93). Note that active touch in this case involved perception of textures, and self-produced, primarily *lateral* deformations of the skin and supporting tissues of the fingertips, resulting from back-and-forth scanning, while passive touch involved primarily *vertical* deformations of the same areas of tissue. Gibson (1962, pp. 486-487) reported active touch superior in *form* discrimination studies, in which outline shapes were pressed into a passive palm, or were actively examined with the fingertips. Using different materials and methods, Birch and Lefford (1963) similarly found active (haptic) matching of forms superior to passive kinesthetic tracing. In both studies the two types of stimulation were different in characteristics other than active vs passive (lateral and vertical deformation), and additionally, the skin area was quite different in the active and passive conditions. In a related experiment, Gibson compared form identification accuracy using the same area of the skin (palm), while varying the type of deformation (vertical vs lateral "twisting") (Gibson, 1962, p. 487). The latter provided significantly greater accuracy. Austin and Sleight (1952a), Bauer (1952) and Vaught (1968) compared active and passive *form* or pattern discrimination using the fingertips primarily, the active condition producing fewer errors, and the effect increasing with task difficulty. In Vaught's study, deformation of the skin of the fingertips was apparently vertical rather than lateral as it was in Bliss, Crane, and Link's (1966) study, in which relative motion of the skin relative to the stimulus source enhanced the accuracy of identifying patterns representing letters, the stimulus *applied to* the skin via tiny air jets. Also, Brown and Stratton (1925) using an *active* two-point threshold technique found fingertip thresholds averaging 1.7 to 1.8 mm. for 12- to 17-yr.-old children, whereas the present comparable thresholds were about 4 mm. using an "applied" or passive stimulus.

In the present gap-detection task, the *same* skin area (index fingertip) was used in both "active" and "passive" conditions, but the active condition actually involved lateral deformations on the same areas. Thus, although both procedures involved some movement on the part of *S*, the active condition involved the type of deformation (primarily lateral) typical of active perception of surface textures or patterns but not necessarily of the sort involved in form or shape perceived with the hand(s) (Gibson, 1962).

The present study provided a clear indication that "active" *scanning* with the fingertips produces fewer gap identification errors than "passive" *pressing* with the same skin area. Either the type or degree of skin deformation is critical in the superiority of the active condition, since both active *and* passive stimuli were self-produced, or "active" in the usual sense of the term. Along with Austin and Sleight's (1952a) similar findings with letters and forms, Bauer's (1952) with patterns or textures and Birch and Lefford's (1963) with visual-tactual matches, it is apparent that active touch provides more accurate performances. The likely source of such superiority is the role of lateral skin deformations in edge or particle detection (the edge of the ring at the gap, the ridges of pattern elements, etc.), which may be components of tactual identification of forms or patterns on planar surfaces (see Gibson, 1962, p. 485; 1966, p. 125).

The failure to find any strong relationships between active and passive gap-discrimination, or between measures of passive sensitivity and active perceptual exploration provides clear support for the contention that the classically studied *cutaneous sensitivity,* and functionally useful *tactual perception* are often relatively independent of each other (Gibson, 1962, 1966).

In summary, the various findings with the specific battery tasks indicate that a set of relatively independent tasks and measures were chosen to assess tactile sensitivity and tactual performances. The lack of strong or even moderate relationships between most accuracy and latency measures on the same tasks, and between most tasks involving the use of the "same" information extraction system, implies that tactile/tactual performances are far from unitary; that age, intelligence, and sensory impairment are related to some, but not to others. Not only can it be suggested that the two-point threshold should be discarded as a standard measure of spatio tactile resolution (Vierck & Jones, 1969), but that one cannot accurately speak of tactile sensitivity or tactual performance without specifying *which* sensitivity, which performance, and which measure. The factor analyses indicated that no major factor could account for the varied findings with the battery tasks and measures; no factor accounted for more than 14% of the battery variance. Therefore, one must conclude that the battery tapped a wide variety of abilities having minimal overlap and not a simple cutaneous sensitivity.

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