OBSERVATIONS ON HAPTIC EXPERIENCE AND HAPTIC PERCEPTION

by

Gregory Thomas Banwell

B.A.(Hons.), Simon Fraser University, 1972

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Psychology

SIMON FRASER UNIVERSITY

November 1974

APPROVAL

Name: Gregory Thomas Banwell

Degree: Master of Arts

Title of Thesis: Observations on Haptic Experience and Haptic Perception

Examining Committee:

Lorne M. Kendall
Chairman

Christopher M. Davis
Senior Supervisor

Bruce K. Alexander

Roger Blackman

Robert B. Horsfall
External Examiner
Assistant Professor
Simon Fraser University

Date Approved: October 31, 1974

PARTIAL COPYRIGHT LICENSE

Title of Thesis/Dissertation:

OBSERVATIONS ON HAPTIC
EXPERIENCE AND HAPTIC
PERCEPTION

Author:

(signature)

G.T. BANWELL

(name)

November 20, 1974

(date)

Abstract

Haptic perception is defined as the integration of tactile and kinesthetic information. In psychological enquiry it has received little attention as an exploratory and perceptual process. Rather, much attention has been payed to 'touch' as a passive activity at the simple level of reception. The present paper discusses passive touch as a component of perception which may neither lead to perceptual response nor define the process. The importance of kinesthesis in haptic perception is discussed in terms of its essential involvement in perception both in relation to tactile sensation and to the kinesthetic aspects of exploratory behavior. The need for the concept of haptics centers on the complexity of tactile and kinesthetic integration and the need for study at the level of integration as such. The nature of some haptic percepts are discussed to show the much larger result of the integrative process. Like other perceptual systems, the issues which surround haptic perception have basically to do with what governs the availability of stimuli and stimulus information to perception. For example, the effects of visual dominance, past experience, motivation, and quality of the environment.

A study was carried out both to determine the effects of a dark, tactually rich environment on behavior and to determine something of the plasticity and abilities of the haptic modality. After investigating the phenomenology of the experience, measures of haptic perception were developed including form, texture, rigidity, size, and spatial discrimination measures, as well as a measure of the perception of the hand as the exploratory 'organ'. The measures were used to ascertain the effects of experience in the tactually rich environment on perceptual response. A group of 30 male subjects were tested on all the measures, then later retested; 15 of the subjects being retested immediately after exploring the environment for 2 hours. Multiple regression results indicated a lack of change in perceptual response. However, a significant change was noted on the hand perception measure which showed that experimental subjects performed very differently on the task after exploration. For these subjects there was a general trend toward greater accuracy although an apparent confusion of response was noted. Results are discussed both in terms of the hypothesized nature of the haptic system and the conditions for change as well as the nature of the exploratory experience for producing change.

Acknowledgment

I wish to give special thanks to Dr. Davis for his support, encourment, and constructive evaluation throughout the entire project. I also wish to thank Dr. Alexander and Dr. Blackman for their support as committee members. Much thanks to Dr. Koopman for his invaluable help in the planning of data analysis procedures and critical reading of results. Thankyou to the many students and faculty who enthusiastically responded to and took part in the project from its inception.

Table of Contents

List of Tables

List of Figures

Introduction

Haptic perception is defined as the perceptual integration of tactile and kinesthetic information. It is a little known, little studied area of perception which is of interest because of its involvement with motor behavior (Gibson, 1962) and its theoretical position as a primary component of human development (Flavell, 1963, Piaget's sensory-motor stage of cognitive development; Harlow, 1971, "contact comfort" and the development of early social relations). The word "haptic" was coined by Revesz (1950) in describing the experience of the blind and popularized by Gibson (1962) in psychological literature. The use of this descriptor reflects a need for a more encompassing conception of a perceptual modality which did not easily lend itself to more concrete concepts in the rubric of tactile perception. That is, in psychological research the 'sense of touch' has generally been treated as a passive component in human experience; something which exists only at the receptor level. In comparison to research on other perceptual modalities very little has been discovered and very little organization has emerged. The lack of knowledge in this area stems from the notion that tactual perception can be studied as if it were a more perceptually and physiologically discrete modality like vision and audition. This has led to a huge assortment of univariate studies which although directed toward the same topic, have very little theoretical and practical coherence. J. J. Gibson (1962) for example, suggests that there is a need for research into what he calls "active touch", "an exploratory rather than a merely receptive sense [p. 477]" which in its functions includes the integration of touch and kinesthetic information.

The Sense of Touch

Even as a passive component of experience the sense of touch is in many ways the most unique mode of perception which the individual has for interaction with the environment immediately outside his own body. Touch does not have one specific organ of reception like vision and hearing do, being defined by the activation of various receptor sites to some change near or on the surface of the body. Although the change may be one of temperature, pressure, or cell destruction, there are not necessarily thermal, pressure, and pain receptors which react only to specific change.

There are receptor sites, however, some incapsulated, bundled, mylinated and unmylinated, and differing in fibre size and threshold. The nature of this cutaneous reception and the associated processing of information is still under conjecture. At the peripheral level the most accepted argument is that presented by Uttal and Krissoff (1965) who state that "there is but one somatosensory stimulus, a mechanical distortion of any of the nerve endings making up the plexus of the nerve net in the skin and body" and "different stimulus energies [and patterns] are coded differentially [pp. 297-298]."

In general, cutaneous sensation is coded by two anatomical systems: the predominantly large fibre, medial lemniscal system with point to point projections to the anterior parietal cortex; /and the predominantly small fibre spinothalmic system without direct cortical projections. The best theoretical and experimental account of the coding functions of these systems requires that the medial lemniscal system mediates the spatial, intensitive, and temporal aspects of touch and kinesthetic stimulation. Reception and coding of rapid shifts in stimulation important for active touch are probably attributable to this system. An important property of the medial lemniscal system is its representation of body form at thalmic and cortical levels. Mountcastle (1961), for example, describes single neuron response patterns in the somatic-sensory areas of the cortex which are quite similar to those recorded from first order neurons innervating small regions of the body's surface. This regional specificity is apparently quite well preserved at cortical levels. But, the second system, the slow, small fibre spinothalmic system acts more diffusely in mediating tactile as well as thermal and pain stimuli. This system probably has more to do with the qualitative aspects of sensation, and its activities are most likely efferently modulated by the action of the medial lemniscal system on the cortex. That is, the fast system probably serves to modify the information input to the slow system (Head, 1920; Melzack & Wall, 1965; Simmel & Shapiro, 1969). Even though there are cortical projections of receptive fields this does not adequately account for the fantastic sensory discriminations that are possible (for example, reading Braille). A considerable amount of literature points to the existence of an inhibitory function which serves to increase the discriminative capacity of the organism (eg. Mountcastle, 1961). The research of von Bekesy (1957) and later Schmid (1961) suggests that an inhibitory mechanism serves to improve such things as localization by inhibiting surrounding activity to the stimulated point. Inhibition occurs when intensities are disproportionate or when there are small temporal separations between stimuli. Equally intense stimulation of two separate points produces a mutual facilitation by inhibiting the area between the two points.

As will be further shown, most evidence points to a validation of Gibson's (1966) statement that "a neat correspondence between the energy types of physics and the receptor types of physiology does not exist. There is no reason why it should, since the evoulution of sensitivity was governed by the need for the information in energy, not for the energy as such [p.105]." The need for the concept of haptic perception arises because, for example, things are at once warm, hard, rough, bulky, etc., and in the study of perception we should consider touch as a unified experience, very much unlike vision or audition with comparitively discrete channels of sensation. At the same time it is not unlike other modalities when we consider the necessity of movement and change in position over time. That is, to discriminate between velvet and paper, it is not enough just to touch — one must also stroke. Here as in other modalities, change and variety are essential to perception itself. This fact requires the involvement of kinesthesis.

Kinesthesis

The importance of kinesthesis (body movement and position) in the conception of haptic perception lies in its relation to cutaneous sensation. The body is always in some position relative to the environment and the muscles are always either relaxed or contracted in various combinations. Without movement there is limited reference of the individual to the spatial environment. To a great extent, without movement there can be no haptic perception of contour, shape, texture, and size. It is movement which most accounts for the difference between the perception of 'being touched' and the perception of 'touching' even if the same stimulus properties are involved. In general there are three kinds of kinesthetic information. Articular kinesthesis for the body framework, vestibular kinesthesis for the movements of the skull, and cutaneous kinesthesis for movement of the skin relative to what it touches (Gibson, 1966).

With regard to articular kinesthesis, or perception of body position, it is apparent that such perceptions arise not from muscle sensation but from mechanical receptors in bone joints (Rose & Mountcastle, 1959). That is, in order to perceive what position our body is in we detect the angles of our joints, not the lengths of our muscles. In fact, mechanoreceptors in the joints discharge at a given rate for a given angle of a joint, and the rate changes when the angle changes. Importantly enough, perception of body position varies with somatosensory input (Gross & Melzack, 1973).

Vestibular kinesthesis is primarily the system which provides information for balance by registering the position of the skull. Within the same bony cavity that contains the inner ear is the vestibular apparatus composed of hair-like receptors in three fluid filled semi-circular canals which mechanically register movement. The receptors themselves are moved by the inertia of the fluid as the head turns, a similar mechanical function existing in the vestibular apparatus for perceiving motion. The important characteristic of the apparatus that provides an understanding of haptic perception is that there is no sensation associated with the apparatus. This lends a problem to the study of tactile perception which has historically been founded on sensation. For example, as Gibson (1966) points out, a subject given a quarter turn in a chair with his eyes closed will perceive a quarter turn but cannot define the sensation which gave rise to the perception.

The third kind of kinesthetic information important for haptic perception is that which is associated with the movement of the skin relative to what it touches. This information is primarily derived from the combination of cutaneous contact, articular kinesthesis, and what Wood (1969) refers to as active kinesthesis, or rate of self-initiated movement. That is, any change in the pattern of contacts the skin has with the environment occurs simultaneously with a change in the branching of the bones and rate of activity of the muscles. Judgements of rates of self-made movements are of critical importance to active touch perception and it is probably the muscle spindles which provide active movement information quickly enough to cortical centers to allow judgements to be made (Paintal, 1962; Buchwald & Eldred, 1962). Whether judgements of muscle movements are conscious judgements or not is probably not critical in haptic perception since perception of touch stimuli and movement do not necessarily fuse at the cortical level but rather, according to Gibson (1966), "combine in one system to register one kind of invariant stimulus information [p.114]."

The Concept of Haptics

The need for the concept of haptics centers on the integration of cutaneous and kinesthetic information and the need for study at the level of integration as such. The need arises when we consider, for example, that when touching an object sensation varies but perception is comparatively invariant. More specifically, Gibson (1963) describes the invariance of perception in the following:

> "Rigidity . . . when pressing on a rigid object with a finger or squeezing it with the hand, there is an increase of sensation and then a decrease, or usually a flow of changing intensities. The perception, however, is of constant rigidity . . . Unity . . . when feeling one object between two fingers, only one object is felt, although two separated cutaneous sensations occur . . . Stability . . . [when moving the hand across the surface of an object] the perception is stable although the sensation is moving . . . [when one lifts an object] besides the end organs of the skin and the deeper tissue, the receptors of the finger joints, wrist joints, and arm joints are excited, and the whole neuromuscular feedback system of the arm is activated . . . but what the observer perceives is the mass of the object, unchanging despite the changing sensations . . . Shape . . . [when feeling the shape of an object] the phenomenal shape of the object is invariant although the phenomenal patterns of sense data fluctuate and vary from moment to moment [pp.4-8]."

The implication for a highly integrated process is further indicated by the striking difference between active and passive touch. Interestingly, active touch or tactile scanning serves to enrich the overall information input while making more exact the percept. The percept, however, not only becomes more exact but often becomes distinctly different. For example, the perception of pressure by itself is generally attributable to passive touch — say, the pressing of a blunt point on the skin. But, although one might actually grasp a hard object in active touch and therefore exert pressure on the skin, the perceptual response is generally not one of pressure but of hardness.

Most of haptic perception not only includes the integration of tactile and kinesthetic information but also the integration of spatially and qualitatively different tactile sensations to create both entirely new percepts and vary original percepts. For example, in the perception of thermal sensation, McFarland (1971) has shown that temperature estimates vary as a function of concomitant pressure, even when the pressure and temperature stimuli were separated spatially and temporily. Similarly, thermal sensation has an effect on surface perception since, for example, both wet and smooth surfaces will conduct heat away faster than dry or rough surfaces producing differential perceptual responses. Also, in haptic length estimations (Corsini & Pick, 1969), as texture varies from fine to coarse, length will be first over-estimated and then under-estimated while the actual length remains constant. It is certainly remarkable that we can touch an object with five fingertips and determine what the consistency of the object is instead of perceive five separate objects. It is remarkable that we are able to perceive dimension and size by touch. In this case perception apparently arises from kinesthetic length judgements, cutaneous pressure, and the articulation of bone joint combinations and distances.

Research and Issues

Like other perceptual systems, the issues which surround haptic perception have basically to do with what governs the availability of stimuli and associated information to perception. For example, it is held that man is primarily a visual animal basing most of his observations of the physical environment on visual perception. However the individual becomes exposed to tactile stimuli, being aware of the stimulation and making use of the associated information depends to a great extent on the biasing effects and dominance of the visual modality. A number of recent studies have purported to have shown that visual perception is stronger and more dominant than touch and influences performance in that respect. Shopland and Gregory (1964), for example, have shown that even while simultaneously touching and looking at a self-luminous three dimensional Neker cube in the dark, visual reversals still occured. Rock and Victor (1964) had subjects simultaneously touch and look at a shape which was optically distorted to appear visually different from the tactual shape. By having subjects match the perceived shape with a comparison they found that comparisons were closer to the visual shape than the tactual. Lobb (1965) studied transfer of training across touch and visual modalities and found vision to be more dominant for learning and transfer. Singer &

Day (1969) found in studies of haptically judged depth that apparent visual depth was more dominant. Whether such results should be necessarily interpreted as visual dominance was questioned by Lobb (1965) who suggested that "one possibility is tactual inexperience [p.186]." The question here is whether the visual dominance phenomenon is a biological - adaptive function (eg. non-lability of the visual system, lability of the haptic system) or whether it is for the most part dependant upon learning.

Developmental literature suggests that the issue of visual dominance is an important one in terms of how the newborn comes to 'know' its environment. Although the childs' ability to explore the environment visually is far more advanced from the beginning, it does not preclude the perceptual learning that might take place through passive contact with the environment. This possibility is not easily shown since it is much later with greater development of motor skills that the haptic parallel of visual search can be observed. Interestingly, at this later time haptic perception appears to be the dominant mode of learning. Zaporozhets (1960), for example, reported that three year olds tend to manually explore novel objects significantly more than they visually explore them. But, the same investigator shows that by the age of six or seven visual exploration becomes dominant suggesting a developmental shift. This makes sense when we consider the time and energy saving properties of visual perception. Once we learn to visually recognize objects which were originally established in tactile terms, vision becomes the dominant mode of perception. The capacity of vision to metamorphosize haptic information no longer requires the individual to recognize the tactual properties of the stimulus object which originally established its qualitative existence. One could suggest that it is in this fashion that we lose an 'awareness' of the dimension of haptic experience. The critical question within the context of the visual dominance phenomenon is whether haptic perception is stably inferior or whether it may improve with non-visual experience. A change in haptic ability would suggest lack of experience since one would expect no change if haptic perception had developed to the limits of an inferior potential.

Another factor associated with the obtaining of tactual information and its processing are the motivational properties of the situation; the adaptive consequences of seeking stimulus information and so on. Seeking stimulation necessarily requires an increase in the information available. As discussed, Gibson (1962) points out that there is a considerable difference between active and passive exploration; a more active process of perception enriches the information and results in more exact percepts. Thus, with regard to the continuum of activity-passivity of perceiving, degree of exposure is central to perception; activity producing greater exposure to information.

Another use of the term 'exposure' refers to the effects of previous tactile perceptual experience on present perception. For example, Roeckelein (1968) has shown that training in active touch perception increases perceptual acuity. Zubek, Flye, and Aftanas (1964) showed that after one week of visual deprivation the pain sensitivity and tactual acuity of subjects significantly increased, this facilitatory effect lasting for several days after darkness had terminated. In a similar experiment by Milstein and Zubek (1971), in attempting to define the temporal course of increases in sensitivity as a function of visual deprivation, it was clearly shown that only one measure of sensitivity (tactual fusion threshold) showed a significant increase. As in similar experiments, subjects were confined in a small room in which there could not have been a considerable amount of exposure to tactual information nor the necessity to rely on tactual information. To account for the results that were obtained, Zubek has suggested that a sensoristatic process exists which serves to keep the total sensory input at an optimal level. Thus, the loss of visual stimulation will result in an increase in sensitivity in other modalities. Alternatively, if changes do take place it might be due to the concomitant conditions of the darkness. For example, a greater dependence on tactile cues and therefore a greater exposure to and awareness of tactile stimuli. These conditions were not operationalized in the visual deprivation experiments. From a learning point of view, with only some necessity to rely on tactual information and with relatively restricted tactual and kinesthetic variation, one would expect a considerable amount of exposure to be required which was the case in these experiments. Again, the critical question appears to be whether haptic perception can vary as a function of haptic experience. That perceptual acuity depends on quantitative factors alone seems highly questionable since such qualitative factors as patterned sensory input are probably very important for integrated behavior.

That the haptic system is a highly integrated process which is potentially more useful for the sighted individual is supported by the literature on the blind. In particular, as Lowenfeld (1950) has shown, without some unifying process effected by learning, awareness, and 'cognitive motives', the blind would not have any workable knowledge of their environment. Unlike the relatively simultaneous nature of visual perception, haptic perception is successive and requires some form of construction to produce the 'wholes' that characterize visual perception. Sendin's (1960) review of the perception of space and shape for the blind shows clearly that the blind must be able to unify separate percepts into one total concept of the object. The necessary involvement of kinesthetic components in perception by the blind as well as the sighted and integration of these with object contact also requires a unifying process.

Most important with regard to the question of the effects of experience on haptic perception, as Lowenfeld (1971) points out, is the assumption that "the loss of one sense is compensated for by a more or less automatic improvement in the acuity of the other senses [p.220]." His review of the literature on the sensory acuity of the blind in comparison to the sighted suggests that there is no difference but that "any higher efficiency of the blind on interpreting the sensory data perceived must be the result of attention, practice, and increased use of remaining faculties [p.221]." Although the two statements tend to contradict one another the difference is apparently a sensory versus perceptual distinction. That is, the nature of perception for the sensorily restricted individual might be more adequately defined by exploring attention and the process of perceptual learning rather than trying to describe the sensory system.

Given the potentially broad scope of enquiry in the area of haptic perception and given the previous lack of a more rigorous theoretical ground from which to develop hypotheses, it seemed wise to carry out a general exploratory-descriptive study on the nature of haptic perception. In the development and study of an educational environment at Simon Fraser University and enquiry was conducted to ascertain the general effects of haptic experience on behavior or, in particular, on haptic perception. The study was conducted not so much to define as to describe areas of interest that might foreseeably establish the domain of haptic perception and thus, the frame of reference for the development of hypotheses.

The Tactile Environment

During the spring of 1971 an educational environment was constructed at Simon Fraser University. Named "The Tactile Environment", the purpose of the Environment was to expose the sighted individual to the dimension of haptic experience. The Environment was dark and tactually rich and developed solely on the basis of intuitive assumption. By the time the Environment closed to the public in 1972 over 10,000 individuals had explored it. The enthusiasm and reports of these individuals led to a further enquiry[1].

As an educational environment, the Environment was developed with concern for the cultural and possibly adaptive emphasis on other modes of perception other than touch. The sighted individual, then, was viewed as tactually blind and by implication, having the capacity to perceive through the haptic modality but making limited use of that capacity. The Environment was designed to increase 'awareness' of the dimension of haptic experience. For example, Deutsch, Katz, and Jensen (1968), have expressed the notion that an enriched environment enables the individual to better comprehend and deal with the world about him. Providing an enriched environment can either be a product of adding to the environment or adding to the individual's experience of the environment. As well, White (1959) notes that individuals constantly search for novelty to increase the impact of the environment. In this sense gaining an awareness of the dimension of haptic experience creates an awareness of something unfamiliar, of something yet to be found out, and increases the effect and quality of the everyday environment.

Conception and Design

Essentially the Environment was built in components, space and movement being dealt with first. Working within a 60 foot long, 12 foot by 12 foot concrete tunnel, a 260 foot multi-level maze was constructed which varied from cramped to open space within a haptic frame of reference (ie., in darkness).

---

[1] Construction of the Environment followed the interest generated from a colloquium presented by Dr. August F. Coppola on a similar project at California State College, Long Beach.

Diversity in movement was established by providing various angles of up and down, left and right, and so on. This then, provided the kinesthetic 'ground' of tactile sensation and the space within which tactile perception could be experimented with.

During the course of experimentation it was found that in order to exaggerate tactile sensation or to provide an awareness of it to the prospective visitor, a number of methods could be used with equal success depending upon the space and direction at that point. Firstly, a single stimulus array (i.e., single form, material, etc.) could easily be exaggerated by simply exposing the prospective visitor to a great quantity of it. For example, one need only compare the sensation of a handfull of millet (birdseed) to the sensation of crawling in a bin containing 600 pounds of millet to reach this conclusion. Secondly, a stimulus array could be exaggerated by presenting before it in the sequence of travel a phenomenologically opposite sensation or a material which produced a greatly different sensation on several dimensions. Thus, before the birdseed bin one encountered straw-like walls, a coarseness and form quite different from the silk-like millet seeds. Similarly, following the birdseed one encountered 100 pounds of unbound sisal which, unlike the birdseed, is a coarse, hair-like material which 'clings and catches'. Thirdly, the same rationale could be applied to a single point in the Environment rather than in some sequence. For example, by simultaneously providing opposing sensations for the feet and hands one could easily exaggerate the response to each. Thus, one section of the Environment consisted of a 10 foot walkway with a floor of wet foam (wet, soft) and walls of asphalt shingling (dry, coarse).

The disorienting effects of complete darkness were also experimented with not only to test each completed section of the Environment but also to determine the presence of enough cues which would actually allow the visitor to find his way in or out or, for that matter, find his way out too quickly. Thus, it was decided that although the Environment would not contain any 'dead ends', an attempt would be made to disorient the visitor by breaking down what might be called, his visual prediction system. That is, in the visual environment certain events and objects are relatively predictable, steps are generally of a uniform height, walls are generally vertical, floors are horizontal, and so on. Within the main structure of the Environment, then, were constructed 'unusual' events. In the wet, foam walkway, for example, the floor dipped down and back up again while the asphalt walls slanted away. A narrow tunnel, created to force to a standing position those who might be crawling at that point, spiraled to the right, the floor and walls raising and slanting. Near the entrance to the Environment a set of 3 foot high, foam and canvas steps provided great uncertainty as well as making one feel extremely small. These things were most effective in complete darkness.

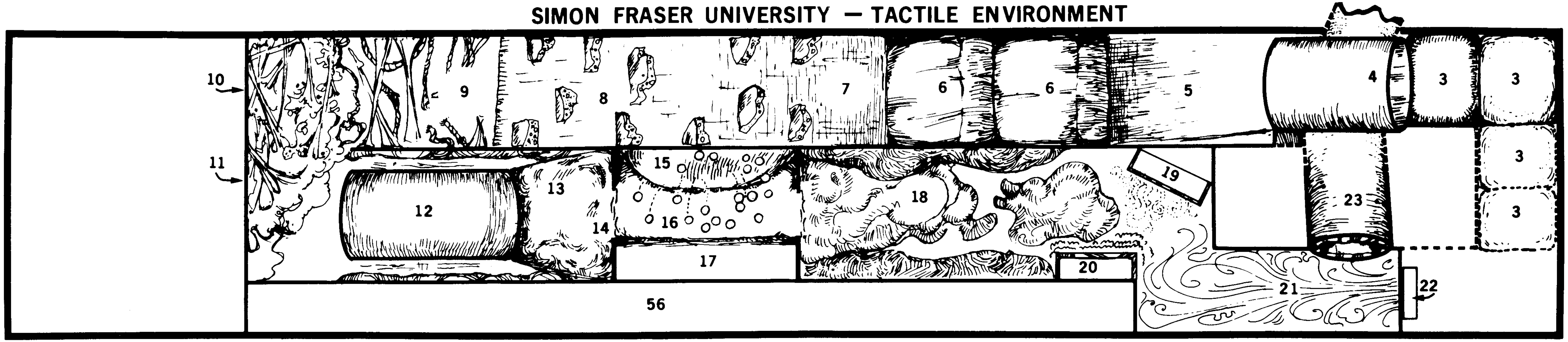
The uncertainty of movement in the dark was also experimented with. For example, two tube-like slides were constructed, the first slide having a 'slick' surface. One could not work up any amount of speed over the 8 foot surface and landed softly against an angled foam pad. In darkness though, sliding down the tube produced quite a different sensation. Visitors reported sensations of exaggerated speed accompanied by anxiety only to have their perception contradicted by a soft and passive landing. The second tube was less smooth, being lined with artificial fur and underlined with 4 inches of foam which afforded more control over movement. This slide was 12 feet long, turning slightly at 6 feet and then depositing the visitor into a 9 by 12 foot, water-mattress covered room. In darkness, the experience was one of being forwardly off balance as the individual went down the tube and then, upon entering the water-mattresses, an uncertainty of the upright for lack of solid reference after the sensation of falling.

The haptic experience of the movement of objects in relation to the movement of the individual was also explored. A section was created in which light plastic balls circulated in the air as the individual passed through and were only activated by the movement of the individual. Also, a sheet metal room was constructed in which the walls, floor, and ceiling produced a fine vibration which changed in quality as a visitor passed through, and a 6 foot horizontal tube rolled back and forth in accordance with individual movements.

These are a few examples then, of the conceptual approach to the consruction of the Tactile Environment. A layout of the space, direction of exploration (in sequence of numbering), and sensory components of the Environment is presented in Figure 1. Detailed description of each component and operation of the Environment is contained in the Appendix.

Figure 1

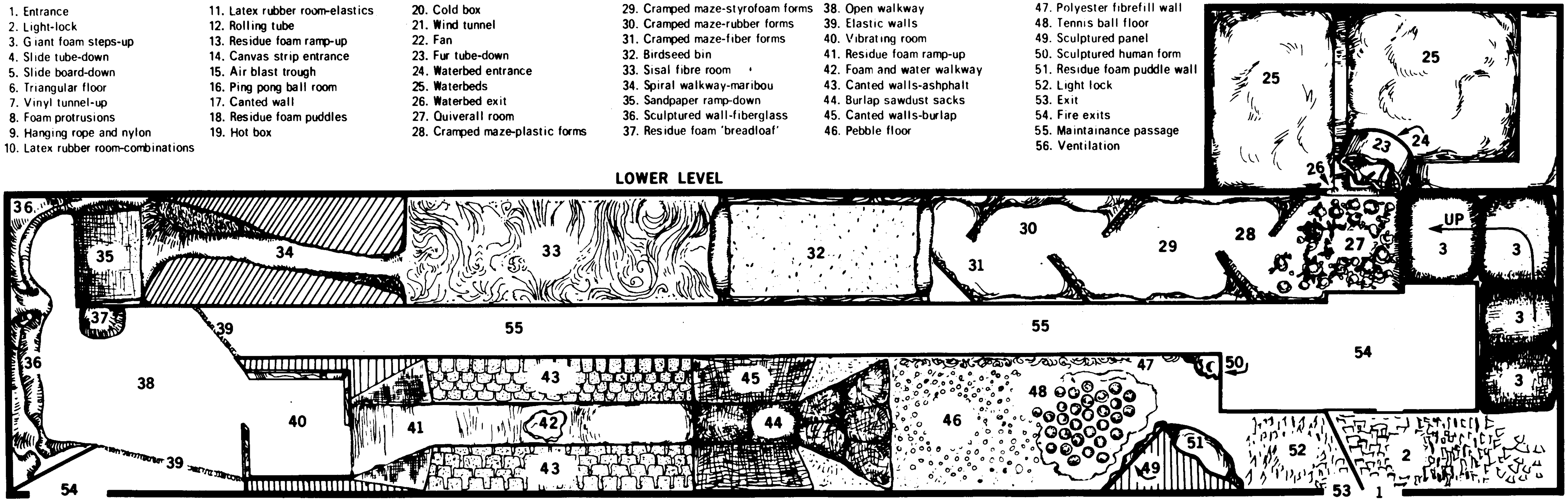
SIMON FRASER UNIVERSITY — TACTILE ENVIRONMENT



UPPER LEVEL

1. Entrance
2. Light-lock
3. Giant foam steps-up
4. Slide tube-down
5. Slide board-down
6. Triangular floor
7. Vinyl tunnel-up
8. Foam protrusions
9. Hanging rope and nylon
10. Latex rubber room-combinations
11. Latex rubber room-elastics
12. Rolling tube
13. Residue foam ramp-up
14. Canvas strip entrance
15. Air blast trough
16. Ping pong ball room
17. Canted wall
18. Residue foam puddles
19. Hot box
20. Cold box
21. Wind tunnel
22. Fan
23. Fur tube-down
24. Waterbed entrance
25. Waterbeds
26. Waterbed exit
27. Quiverall room
28. Cramped maze-plastic forms
29. Cramped maze-styrofoam forms
30. Cramped maze-rubber forms
31. Cramped maze-fiber forms
32. Birdseed bin
33. Sisal fibre room
34. Spiral walkway-maribou
35. Sandpaper ramp-down
36. Sculptured wall-fiberglass
37. Residue foam 'breadloaf'
38. Open walkway
39. Elastic walls
40. Vibrating room
41. Residue foam ramp-up
42. Foam and water walkway
43. Canted walls-ashphalt
44. Burlap sawdust sacks
45. Canted walls-burlap
46. Pebble floor
47. Polyester fibrefill wall
48. Tennis ball floor
49. Sculptured panel
50. Sculptured human form
51. Residue foam puddle wall
52. Light lock
53. Exit
54. Fire exits
55. Maintainance passage
56. Ventilation

LOWER LEVEL



General Response to the Environment

Since the Tactile Environment like other environments imposed constraints on the range of behaviors possible (Wohlwill, 1970), much of the response to the Environment was in relation to those constraints. The most obvious constraint was that of space which determined most movements of the individual. At a given time it determined whether the individual crawled, walked, moved quickly or slowly, or stopped. Also, particular qualities of the Environment such as the degree of stimulation it imposed, produced generalized effects on the total response of the individual. After exploration of the Tactile Environment most individuals experienced relaxation lasting up to several hours. Varied affective responses were instigated depending upon the physical qualities of particular points in the Environment. In general, most individuals experienced pleasure, excitement, and satisfaction. Of 141 individuals responding to a 82 adjective, 3-choice checklist (yes, no, or neutral) composed of both positive and negative items, over 100 of them described the Environment as "strange", "varied", "private", "unusual", "enclosed", "safe", "pleasant", "changeable", "mysterious", "inviting", "warm", "inspiring", "sensual", "invigorating", "refreshing", "challenging", "close", "exciting", and "soft". Of course, some individuals experienced a certain degree of displeasure and dissatisfaction. In general, the existence of some kind of arousal, either positive or negative as opposed to neutral, on the part of every individual, pointed out what happens when familiar environmental cues are partially withdrawn and replaced by new ones. Whether an individual responded positively or negatively overall apparently depended on their adaptation to the uncertainty and novelty of the situation. That is, all individuals on first entering the Environment experienced some anxiety and some displeasure associated with the situation while very few came out with the same affective response. The degree to which an individual could adapt to the initial stimulus situations which produced uncertainty and displeasure (i.e., darkness, disorientation, etc.) was directly related to the degree to which he responded positively later. Those who did not adapt easily generally tried to avoid the situation entirely by coming back out or by avoiding prolonged contact with the Environment by quite literally 'plunging' through.

As Wohlwill (1970) has predicted, qualities of the Environment also instigated behavior which was directed toward the Environment. Thus, more exploration could be expected from the individual who experienced excitement and satisfaction. Similarily, for a small number of people who responded negatively to the Environment, destructive behavior was directed at the Environment. For these individuals the Environment may have presented conditions of sensory overload since then hostility can be expected (Zuckerman, Persky, Miller, & Levin, 1969), and low tolerance of frustration (Glass, Singer, & Friedman, 1969). However, it is as likely that the dark conditions lowered inhibitions evidenced by the fact that, although most individuals knew the Environment was monitored, many sang, made pleasurable noises, and talked to themselves. From spontaneous comments and from responses obtained after exploration of the Environment, it was clear that one of the major responses to the experience was the attempt to possibly lower uncertainty and establish a visual frame of reference by guessing at and describing the materials and spatial characteristics in the Environment.

Since it was of interest to know whether the original purposes of the Environment were fulfilled, many phenomenological reports were collected. Other than those reports discussed above, there were many reports which seemed to reflect perceptual change. Specifically, these were reports of perceiving disconnection or loss of perimeter of body parts, of increased sensory awareness, and reports of spatial confusion. Surprisingly, because of the apparent visual bias in language, not a single individual questioned could describe the perceptual experience with reference to his own sensations without indicating descriptive inadequacy. As pointed out, there were general reports of relaxation and descriptions of positive and negative affect. But, the lack of parallel descriptors to such visual terms as focus, intensity, and so on, left a void in the phenomenological evidence. Under these circumstances it was not surprising that many used manual expression and inventive vocal sounds to provide reports. Though it was always apparent in reviewing these reports that there were broad individual differences in description, it was not descriptively clear whether there was a change in response to haptic information. Since many affective responses were obtained one could be sure that some increase in 'awareness', in the sense of knowledge, had been produced. Whether there was an increase in awareness in the perceptual learning sense was not clear. Even unsolicited reports of perceptual change could be suspected since it was well known what the purpose of the Environment was at the time. Evidence and theory were provocative enough, however, to hypothesize that change might have occured even over a short period of exposure.

The Conditions for Perceptual Change

The Tactile Environment as a novel and complex environment provided conditions of uncertainty. According to most theorists this is a sufficient and necessary condition for perceptual learning since perceptual learning itself is the "reduction of uncertainty" (eg., Garner, 1962; Berlyne, 1966; Gibson, 1969). That is, reducing uncertainty is viewed as consonant with obtaining information; the existence of uncertainty being sufficient to instigate perceptual 'search' in order to detect and retain that which will reduce uncertainty. It is hypothesized that uncertainty exists for the individual in the Tactile Environment merely because it is a changed environment, presents a new ecology, and presents information to be processed. The individual exposed to the changed environment "must learn in order to maintain an adaptive relationship [Gibson, 1969, p.128]."

Also essential for perceptual learning is the feedback from overt action, from exploratory movements, the main component of perceptual search. For example, movement is necessary to "isolate and enhance" tactual perception (Gibson, 1962, p.478) and certainly exploratory or self-produced movements are useful for learning (eg., Held, 1963; Holst, 1954). Even if the individuals who traveled through the Environment did not spend time conscientiously exploring, it was hypothesized that they would have learned from carrying out the adaptive function of finding their way out and thus encountering much information.

In general, it was hypothesized that perceptual learning would occur because the sighted individual in a dark environment is forced to attend (attention being defined as the directive aspect of perception) to haptic information. Since there was a great deal of information in the available stimulation as defined by the complexity and novelty of the Environment, and since there was also an increase in information due to hypothesized attentional changes, uncertainty would increase and coupled with exploration, perceptual learning would be expected.

If perceptual learning did occur as a function of exploration in the Tactile Environment, in what way would it be reflected in behaviour? According to Gibson (1969) perceptual learning involves the abstraction of invariant relationships and distinctive features which serve to reduce uncertainty or, in the jargon of communication theory, reduce information. Furthermore, perceptual learning can be "regarded as the development of a transfer of a previously learned set of responses to a new set of stimuli [Wohlwill, 1958, p.284]" and most importantly, "when the information that [the individual] is able to pick up in a given situation increases, perceptual learning has occured [Gibson, 1969, p.129]." Thus, we would expect that previous perceptual learning will improve later perceptual learning. For example, Zinchenko (1966) presents evidence that perceptual systems transfer input to make more adaptive further processing. If perceptual learning does occur as a function of experience in the Tactile Environment it should be reflected in changes in perceptual response.

To determine whether haptic experience in the Environment had the proposed effects, a way in which to observe changes in perceptual response was required. However, with little knowledge of the plasticity and abilities of the haptic modality, potential areas of measurement were limitless. Within the bounds of what was defined as haptic perception it seemed useful to explore a number of possibilities to ascertain both what perceptual responses were definable and which were measureable.

Measurement of Perceptual Change

The problem of the measurement of perceptual change in the haptic modality is conceptually approached from a 'cognitive reorganization' and perceptual learning view. That is, it is hypothesized that changes will result from attentional shifts, or shifts in the directive aspect of perception, from visual to haptic, and changes will result from learning through 'intrinsic' reinforcements transferable to new perceptual learning situations. Thus, in the development of measures there was no interest in the measurement of sensory acuity, per se, since such measures require only minimum attention and do not in themselves present the conditions for perceptual learning.

In most of the literature, perceptual change is seen in terms of threshold variation. For example, tactual fusion threshold (Shewchuk & Zubek, 1960), pressure sensitivity (Semmes, Weinstein, Ghent, & Teuber, 1960), finger acuity (Chan, 1964), and heat and pain sensitivity (Hardy, Wolff, & Goodell, 1952). In general, previous research is designed with the implication that better sensitivity produces better perception. However, as Gibson (1962, 1966) points out, tactile sensitivity measures are often unrelated to useful perceptual information. Typically there have been very few developments in measurement for active touch ar haptic perceptual abilities. Of those that have been developed most concern the discrimination of visually derived forms (eg., Pick & Pick, 1966) confounded with prior visual experience, or object recognition which involves little new learning (eg., Ahmad, 1971; Rubino, 1970). However, nonsense forms have been developed and used successfully as tasks for the study of individual differences in active touch discrimination. Also, a number of recent studies have used sandpaper roughness discrimination tasks and raised lines for pattern discrimination (eg., Nolan, 1960; Schiff & Dytell, 1972). There have been no developments in the measurement of the perception of rigidity, consistency, size, etc..

For the present purposes we are interested in measures which require the abstraction of invariants and distinctive features through exploration and require attention to relevant information. Thus, we require measures which tap the process of differentiation. However, the problem of measuring change in the haptic modality is a problem of circularity. Changes in the system define its functional nature but without first knowing the nature of the system as reflected in change, measures of the change cannot be defined. One can only hypothesize about the nature of the haptic system on the basis of univariate knowledge and if a particular measure based on the hypothesis is not successful we cannot know whether we have wrongly defined the system or simply have a poor measure of it. Thus, it was decided to intuitively develop and explore a number of potential areas of measurement to provide more generalizable information about haptic perceptual response rather than rigorously define a single measure at the cost of more pervasive information about the haptic system in general.

The following areas of measurement were developed in attempting to cover a number of perceptual abilities thought to be representative of the capabilities of the haptic modality. The selection was based on the need for new measures, hypothetically independent measures (but dependent enough to be measuring the same thing), measures which had some face validity with regard to their reflection of 'everyday' perceptual functioning, and measures which required tolerable time and energy in application. However, though there was a consideration of complex tasks such as tactile maze exploration which involved many abilities and much time in application, ultimately some tasks were selected which were more descriptively discrete and less time consuming. For exploratory purposes it was simply more interpretable to measure such things as form, texture, and spatial discrimination separately than to measure maze exploration which undefinably might have involved all such discriminations as well as a strong reasoning component.

Form Discrimination

The ability to discriminate form requires the integration of continually changing and multiply located cutaneous sensations with movement in three-dimensional space (Gibson, 1966). As a measure of form discrimination an attempt was made to construct a task which was completely novel, lacked any visual frame of reference, was difficult to mediate verbally, and thus, required learning for successful discrimination. Loosely modeled after the Gibson (1966) forms, the task consisted of 10 three-dimensional, nonsense forms, each of equal weight, with a convex back, concave front, and five protrusions. All shapes were made of cast polyestre resin and therefore, were of the same thermal and resilient properties. Forms varied only slightly in terms of relative curvature, position and size of protrusions, and relative convexity-concavity of front and back. Eight of the forms were finally kept for use as being of approximately equal difficulty in discrimination

Initial work with the measure showed that when Ss were first allowed to scan the forms while blindfolded, the forms all felt the same. Over repeated presentation of a standard form and then exploration of all forms to find the standard, Ss reported that only then did they come to know the forms as different. However, it remained difficult for all Ss to note the distinguishing features and make the correct discriminations. All Ss visualized the forms unsuccessfully and could only minimally attach verbal labels to discovered dimensions. One form might be perceived as more "pointy" or more "bent" but this was not apparently useful on a task which had multiple combinations of dimensions. Interestingly, most Ss relied on reproducing exploratory movements to match the 'consequences'.

In the final version of the task *Ss* were blindfolded and sat in front of a sorting tray which they first explored to know the boundaries of the area in which they would be working. The following instructions were given:

> "Before you on the tray are eight objects of the same weight and texture but each varying slightly in form. On each trial you will be given one of the objects to explore with both hands for 15 seconds, at which time it will be taken from you and mixed with the other objects. You will then have 30 seconds in which to explore all the objects and find the one you initially explored. As you sort through the objects keep possible choices in front of you and discard other objects to the side. If you should make a choice before I indicate that the 30 seconds is up, continue to explore the other objects to learn what distinguishes one from another."

Ss were not told of the correctness of their choices so as not to confound response learning with perceptual learning. Sixteen trials were run using each of the eight objects twice as a standard and maintaining the same order of presentation for each *S*. During exploration of the standard the other objects were kept slightly warm to counteract the effects of the *S*'s body heat on the standard object. The method of presentation maintained the same learning conditions across *Ss*. Earlier work with the measure using a 'trials to criterion' method produced test exposure times ranging from approximately 10 to 30 minutes making learning conditions uneven. For the present method *Ss* were scored on total errors for the 16 trials. Though the matching aspect of the task was not simultaneous and, thus, a memory component involved, it is assumed that discrimination precedes memory in this regard.

From the distribution and descriptive statistics of Figure 2, for

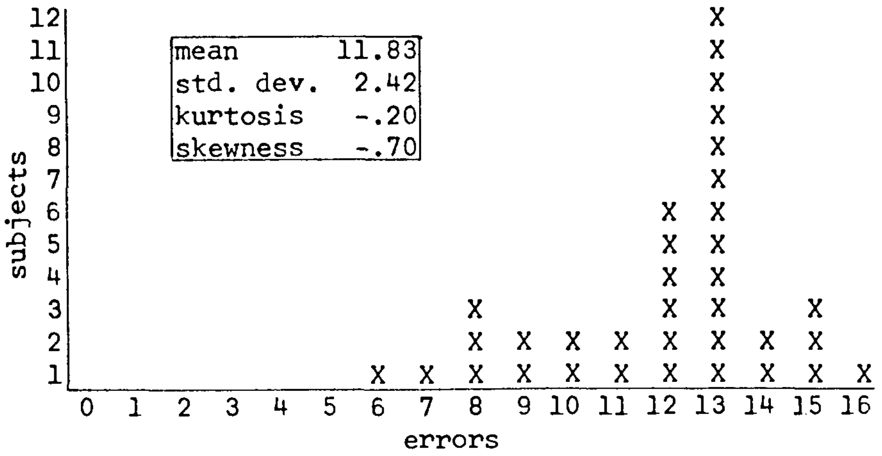


Figure 2. Frequency distribution for total errors of performance over 16 trials on the form discrimination task, N=35.

35 male Ss ranging in age from 18 to 30, the negative skewness shows that the task is somewhat too difficult, though there are significant individual differences reflecting the discriminant validity of the measure. Even though the measure is subject to practice effects, by definition, the performance of 15 of the Ss, retested as control Ss after a three week interval, correlated .54 with initial performance, reflecting minimum reliability. There was only a shift in the mean (from 11.3 to 10.1) and not in variance.

Size Discrimination

The inclusion of a size discrimination measure developed out of a consideration of sensory threshold measures which might lend themselves to 'active' use. The threshold measure in this case was developed by Vierch and Jones (1969) in order to show that the skin is more sensitive to size (area stimulated) than to distance (two-point threshold). For pilot investigation the measure was developed to consist of a series of 5 inch plexiglass rods varying in diameter by 1/32 of an inch. One end of each rod was polished flat and used as the stimulus. Upward and downward difference thresholds were obtained by maintaining one disc as the standard and presenting all others in ascending and descending order. Interestingly, though passive stimulation with the discs produced an average discrimination threshold of 1/8 of an inch on the palm of the hand, active discrimination of the rod diameters allowed Ss to discriminate all 1/32 inch differences. Although successful discrimination was imminent, the task was difficult since all pilot Ss reported that they did not know on what basis they made their discriminations and were surprised after being told of the correctness of their responses. Also, there were broad individual differences in exploratory time. The task was therefore used in its active form.

For the final task, 10 rods varying in diameter by 1/32 of an inch from 1/2 inch to 25/32 of an inch were placed on a sorting tray in front of the blindfolded S. The S was instructed to sort the rods in order of increasing diameter as quickly as possible by using the palm and fingers to note which rods were larger relative to the top of the tray or by grasping the rods on more difficult discriminations. This stategy of exploration was given since there was no desire to have size discrimination confounded with manner of exploration. On the basis of pilot work with this measure it was found simply less cumbersome for the S to leave all the rods on the tray during most of the task. Also, the rods varied slightly in weight which, though not perceivable in the more difficult discriminations (smaller size differences), may have produced cues if the rods were lifted regularly. The final version of the task used time to successful completion (rank ordering) as the measure of response strength.

Since discrimination was inevitable on this task it was assumed that any individual differences in time required would not be due to ability to differentiate but rather ability to attend to already differentiated features. However, performance of six males on two trials with the measure showed a drop in mean time required from 207 to 134 seconds. Since there was no evidence that attention would have increased over trials, it was concluded that some learning had occured. As with other tasks no external reinforcement was given.

Like other measures in which time is the dependent variable, the distribution of raw scores (Figure 3) is abnormally skewed but reflects broad individual differences. Three week interval, retest data for 15 of the 35 male Ss correlated .28 with initial performance. As expected, the mean dropped (250.9 to 190.2) but the standard deviation for the 15 Ss also dropped (150.9 to 91.4), reflecting the general instability of the measure Much of the unreliability was due to the few individuals who took an unusually long time to reach criterion and then later showed normal response times. Similarly, other Ss who had previously performed within the normal range now took an excessively long time. Certainly differentiation could not have worsened and thus, attention may have varied. These Ss reported being aware of the unusual length of time involved but simply had difficulty making the discriminations they had made before. As one might historically predict for the use of time as a dependent variable, comparatively small 'psychological'

```
subjects
5|             X
4|     X   X   X   X   X   X   |mean      257.54  kurtosis  .37|
3|     X   X   X   X   X   X   |std. dev. 159.09  skewness 1.26|
2|     X   X   X   X   X   X                                           X   X
1|  X  X   X   X   X   X   X   X       X   X           X   X           X   X
 +--------------------------------------------------------------------------
  60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570 600
                                   seconds
```

Figure 3. Frequency distribution for size discrimination times, 30 second intervals, N=35.

changes produce large changes in response time.

Texture Discrimination

The development of a texture discrimination measure stemmed from an interest in an active task which would include a definable sensory acuity dimension as well as the requirement for differentiation. That is, other tasks assumed that useful sensory data was equally available for all individuals insofar as it need only be differentiated. The candidate for such a measure was texture since discriminating textures depends upon vibratory sensitivity (Katz, 1925; Krueger, 1970; Schiff & Dytell, 1972). To involve sensory acuity a measure was developed such that a scale of discriminations from 100% discriminable to 50% discriminable was included. On the smooth surface of a number of 2 and 1/2 inch square blocks, raised metal dots (1.5 mm. in diameter) were attached in a modified random fashion. That is, for the number of dots being applied, the surface of the block was equally devided into an equal number of areas and within each area a dot was randomly placed. This allowed for an equal distribution of dots while alleviating equal intervals between dots and avoiding simple gap-detection. On the basis of pilot work, 10 blocks were selected ranging from 30 to 120 dots with intervals of 10 dots. The discrimination between a block of 110 and a block of 120 dots (a ratio of 11/12) was approximately 50% probable, while the discrimination between a block of 30 and a block of 40 (a ratio of 3/4) was 100% probable. The only manner in which to discriminate between similar blocks was to judge the difference in overall texture of the surfaces. Thus, percepts were along the dimension of roughness - smoothness. On the average, two-point gap differences between adjacent blocks would be different but this only proved to be a distinctive feature (in gap-detection) between blocks some distance apart.

Most interesting in the development of this measure was the manner of exploration used. Clearly, all Ss as they progressed through the task, would maintain a constant rate and style of movement—scanning the surface of the blocks with their fingertips. It can be suspected that differentiation here is not dependent so much on noting the distinguishing features of the surfaces, per se, but of differentiating vibration produced through movement. This might have accounted for the fact that a paired-comparisons presentation of the blocks produced better discriminations than having Ss rank order the blocks (simultaneous paired-comparisons). That is, it was probably easier to maintain a differentiating frame of reference between two blocks than 10. In the final version of the task a rank order method was used merely to increase the range of variability of the measure and thus, the individual differences. However, since sensory acuity was also involved, discrimination was not imminent for some Ss while others could successfully rank the blocks. To alleviate the necessity of consolidating time and error, a test interval was sought which would force errors for the probable high acuity Ss while still allowing all Ss enough time to produce a rank order. A satisfactory time of 2 and 1/2 minutes was found and the dependent variable selected was error. Error was calculated as the sum of the number of places each block was removed from its natural rank.

Ss were given the following instructions:

"Here are two blocks on the surface of which are raised dots. One is the block with the least number of dots, the other has the most number of dots. There are 10 blocks altogether and your task is to put them in order from the least number to the most number of dots. The dots were applied at random to the surface so that detecting gaps between two dots will be misleading, especially between blocks which feel very much the same. The best approach is to scan the whole surface of each block with one or both hands and compare the relative amount of roughness - smoothness. You have 2 and 1/2 minutes to order them correctly."

Figure 4 presents the distribution of errors and descriptive statistics for 35 male Ss. Statistically, the distribution is positively skewed and leptokurtic, suggesting that the task was too easy. Surprisingly however, all Ss reported that the task was extremely difficult insofar as they could not judge their success. Like the form discrimination task, Ss reported not knowing on what basis they had made their discriminations, relying on some 'general feeling' that they were not able to verbalize. However, as required

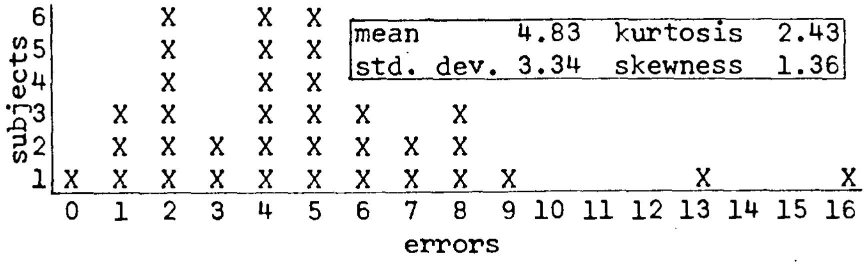


Figure 4. Frequency distribution of errors for the texture discrimination task, N=35.

they made very successful decisions in comparison to what one would expect from their judgements of success and in relation to the number of possible errors.

For 15 of the Ss the test-retest correlation after a three week interval, was .64. As expected, the mean dropped slightly (from 4.93 to 3.13) and due to the more regular performance of two previously high scorers, the standard deviation dropped from 2.93 to 1.86.

Rigidity Discrimination

In order to involve a larger kinesthetic component in a haptic perceptual task and to attempt to measure a previously unassessed ability, a measure of the discrimination of rigidity was developed. Of course, other measures also involved a kinesthetic component but largely one which was restricted to the movements of the hands in a manner which did not require much exertion. The hardness or softness of a substance is, according to Gibson (1966), "a property of the substance that is registered when forces are exerted on it by the hand [p.128]." Specifically, Harper and Stevens (1964) suggest that the hardness or softness of a substance is measured by the haptic system as the ratio of the force exerted to the amount of indentation made. Much of the variation between substances differing in rigidity are due to differences in size and density. Since in the development of a measure of rigidity an attempt was made to derive a definable scale, and since it was difficult to find a substance which could be varied solely in density (without varying texture, etc.), a measure was developed based on varying size. That is, it was assumed that using a material of the same density but varying thickness one could produce variations in rigidity. After many attempts a series of eight 4 and 1/2 inch square, polyethylene foam blocks of the same density were selected which varied in thickness by increments of 1/8 inch from 1 and 1/8 inches to 2 inches. Each block was secured in a 5 inch square wooden box with the base of each box varying in height such that 1 inch of the depth of each foam block was above the edge of its box. Thus each of the foam blocks were of equal height when exposed. The task for the S was to order the foam from thickest to thinest based on differences perceived by pressing into the center of the blocks with the fingers. Ultimately, the task involved exertion of the whole arm.

In pilot work with the measure, Ss reported that, while holding rate of movement constant, the task was one of noting which block was "harder sooner", or otherwise noting the amount of indentation made. Surprisingly, with only differences of 1/8 inch and with the utilization of rather gross motor functions, all Ss could order the blocks successfully. However, there were broad enough individual differences in time required to suggest differences in ability. It was also noted that the use of one hand in making discriminations consistently led to more difficulty than alternate or simultaneous use of both hands, suggesting the effects of fatigue. The simultaneous use of two hands (one on one block and one on another) was less effective than the alternate use of two hands. This suggested that the arms adapt differently to the exertion and thus, provide different information with regard to amount of exertion. Ss were therefore instructed in the alternate use of hands since there was no desire to measure fatigue or exploratory mode.

In the final version of the measure Ss were simply instructed to order the blocks in the correct order, according to thickness, as quickly as they could. Initially, they were given the ends of the dimension as examples and instructed in manner of exploration. Figure 5 presents the distribution of times to completion and descriptive statistics for 35 male Ss. As shown, two Ss took an excessively long time suggesting that for some

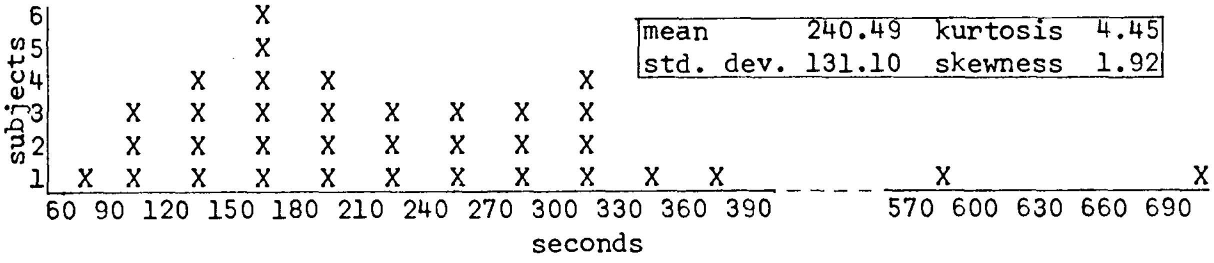


Figure 5. Frequency distribution for rigidity discrimination times, 30 second intervals, N=35.

it was difficult to attend to the relevant information. The distribution itself is extremely leptokurtic, and positively skewed like other measures requiring the S to 'speed'. For 15 of the Ss the test-retest correlation was only .21. Since the mean only varied downward slightly (224.9 to 207.2) and the standard deviation remained approximately the same (76.2 to 78.5), there is, apparently, intra-individual random variation.

Spatial Discrimination

A spatial discrimination task was selected in order to tap possible changes in spatial perception as reported by individuals who explored the Tactile Environment. Since no measure of haptic spatial perception had ever been developed, a visual measure was sought out which would lend itself to haptic perception. One such measure, the Ayres Space Test (Ayres, 1961, 1969), was selected and parts of it used for the present purposes. Ayres (1969) characterizes the measure as involving a perceptual ability in which the S is the origin or point of reference and which requires 'mental' manipulation of parts of the stimulus pattern. The test uses three-dimensional diamond and egg-shaped forms through each of which a hole has been placed. Corresponding form boards have a removeable peg which may be placed in a number of positions. On a given trial, the task is for the S to select a form which not only fits the shape of the form board but also has a hole in the correct position corresponding to the position of the peg. Depending on what orientation the choice forms are placed and on what orientation the form board and peg are placed, the S, before selecting, must mentally manipulate the choice forms on the horizontal plane to determine which would fit if actually placed in the form board. For haptic use, only familiar diamond shaped forms were used from the space test since successful manipulation of egg-shaped forms required skilled form perception. Although the visual test had a total of 60 different trials, only 10 were used since a haptic test with the 60 items required a testing time of approximately 50 to 60 minutes.

In the haptic version of the Ayres Space Test, on a given trial, two diamond shapes were placed on an adhesive surface in a predetermined orientation directly in front of the S. Ahead of the two shapes, the diamond form board was placed with both the position of the peg and orientation of the form predetermined. The S was first required to explore the form board for 10 seconds, noting the position of the peg in relation to the orientation and shape of the form. Then without referring back to the board, the S was required to explore the two shapes, noting the positions of the holes and orientation, and without moving the shapes, decide which would fit. Unlike the Ayres test the S was not told of his success. Two practice trials were given to familiarize the S with the task, noting to him that only horizontal manipulations were required. All Ss were given the same trials in the same order. Figure 6 provides visual examples of the kinds of manipulations required.

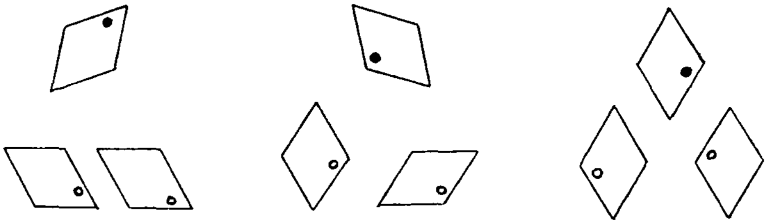


Figure 6. Top view of three trials of the kind used in the spatial discrimination task. Circles note position of the holes in the shapes (lower diamonds) and filled circles note the position of the peg in the form board (upper diamonds). On each trial the S was required to indicate which of the two lower shapes would fit the form board.

Initially, both decision time and error were determined and an adjusted score assigned on the basis of time conversion tables provided by Ayres (1969). That is, decision time was calculated for each trial as the time taken to arrive at a decision beginning after exploration of the form board. The sum of decision times over the 10 trials produced the time score which was converted on the basis of assigning one point per 25 second interval. The converted time score was then added to the total errors to produce the adjusted score. Of all possible arbitrary ways in which to combine time and error, the Ayres weighting scheme provided a precedent.

Figure 7 shows the adjusted score distribution and descriptive statistics for 35 male Ss, higher scores reflecting poorer performance. The distribution reflects substantial individual differences.

Very clearly, from the reports of Ss, some found the task extremely

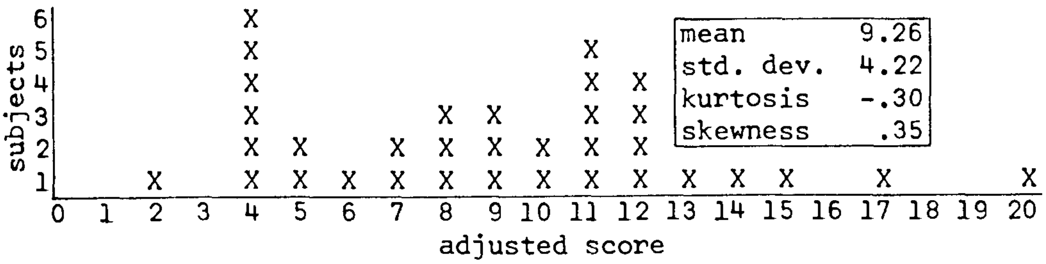


Figure 7. Frequency distribution of adjusted scores (time:error) for spatial discrimination, N=35.

difficult while others found it very easy. Unlike the other tasks, there was less frustration overall since it was easier for all Ss to judge their success without external reinforcement. Ss who did well were apparently able to verbally code the relevant dimensions (eg., left-below, narrow apex) but whether this resulted in, or resulted from better discrimination is not known.

Retesting 15 of the Ss after a three week interval produced a test-retest correlation of .81 with the mean improving (from 8.2 to 6.7) and standard deviation remaining substantially the same (from 3.9 to 3.5). Thus, taking into account expected practice effects, the measure appears very reliable. With regard to the consolidation of time and error, the correlation between the two was significant (.01 level) at .55. Both correlated equally highly with the adjusted score (time, .85; error, .90) suggesting that time and error were given approximately equal weight.

Hand Perception

Phenomenological reports of individuals exploring the Tactile Environment suggested the possibility of some change with regard to the sense of one's body position and parts. Some reported the apparent loss of visual connection of body parts. For example, the hand connected by the arm. Most reported a loss of a sense of body perimeter. That is, the body was perceived as diffuse or as no longer integrated into a whole. It seemed interesting, therefore, to develop a measure of body-perception. That included in a set of haptic perceptual measures should be a measure of hand perception is theoretically sensible. There is some evidence that body perception and tactile perception are integrated. For example, Wapner, Werner, and Comalli (1958) showed that tactile stimulation of the face changed the perception of its shape in terms of the perceived distance between parts. Many studies on the 'phantom limb' suggest that a neural representation of the body and tactile input are linked (eg., Weinstein & Sersen, 1961; Paillard & Brouchon, 1968). Furthermore, body perception seems involved with perception in general, for example, in perceptual adaptation (Harris, 1963; Wallach, Kravitz, & Lindauer, 1963). Whether body perception has much to do with active touch has not been directly studied but it seems clear that having a sense of position and parts of the body would add much to the perception of form, extent, size, etc., insofar as such perception must rely on some representation of the relationship of parts of the body in order to relate multiple points of stimulation. The interdependence of the perception of stimulus location and perceived body location is described in two recent studies (Gross & Melzack, 1973; Gross, personal communication). Firstly, these studies found that independent of stimulation, parts of a visually occluded limb were perceived as closer to the body than they actually were. Localizing points of stimulation also showed the same inward error. Furthermore, when the limb length was artificially shortened (by uncomfortable stimulation at some point) there were concomitant changes in errors of localization. The apparatus used in these studies is similar in intention to the one used here. Overall, it seemed wise to develop some measure of hand perception since on all the tasks the hand is involved as the "exploratory organ" (Gibson, 1962). However, unlike the other areas of measurement discussed, a measure of hand perception would not seem to fit the 'active' definition of haptic perception. The difference, though, is only in the nature of the task rather than a contradiction in the conceptualization of haptic perception. That is, it is assumed that body perception is a result of the integration of tactile and kinesthetic information. Unlike the other measures, as will be shown, in the development of the hand perception measure there was no intervention in the process of learning but rather a quantification of the percept itself. Thus, a measure of, say, form perception might have been developed by looking for a change in the percept of a single form (possibly through description) instead of looking for discriminatory advances. Though such a measure might well involve a 'passive' activity at the point of measurement it would be founded on an active process -- i.e., previous tactile and kinesthetic integration. For example, such a process must be involved in delayed matching tasks in which a memory representation of a percept is involved.

The apparatus used in the following procedure consisted of a plexiglass sheet, 1 foot by 2 feet, on which a square centimeter, XY coordinate grid was imposed. The sheet was placed over the S's dominant arm and was positioned close to, but not touching, the arm. The S's arm was positioned comfortably on a foam pad in front of him, but not fully extended such that the tip of the middle finger was on a line perpendicular to the sternum. The grid was positioned such that the y-axis was approximately centered over the midline of the length of the arm, and the x-axis over the wrist. As in other measures, the blindfolded *S* was not able to view the apparatus.

Before the onset of the task the *S* was instructed not to move any part of his hand or arm and to let his arm relax. During this time, the tip of the elbow, middle of the wrist, tip of the thumb, tip of the middle finger, tip of the little finger, and middle of the palm were sighted through the clear sheet and marked on the grid. During the task the *S* was instructed to point with his other index finger to points on the panel directly above where he judged the tip of the thumb,etc., to be located. On each pointing trial, the *S* was instructed to return his other arm to the table top and not to explore the apparatus. In random order, the *S* was required to point three times to the six locations. Each perceived point was marked on the grid.

For each of the points each *S*'s average coordinates were calculated and plotted with the corresponding plot of the 'real' arm and hand. In further work with the data the elbow coordinates were not used except for repositioning the arm on repeated testing and for drawing a schema of the real and perceived arm for *Ss*' later viewing.

As a measure of general accuracy of perception, the absolute distances between corresponding real and perceived points were summed. As a measure of the perception of lateral position of the hand, the sum of differences between corresponding x coordinates were summed, and the sum of differences between real and perceived y coordinates were calculated as a measure of error of extension. Since, for example, an unusually laterally displaced, perceived little finger and, say, contralaterally displaced thumb would produce an x-dimension score reflecting lack of x-axis displacement, a fourth measure was developed to note the dispersion of hand parts. Very simply, for both real and perceived points a figure was formed by joining with a line the wrist, thumb, middle finger, and little finger points. The inside area of these real and perceived, four-sided figures was measured with a planimeter. The measure of dispersion was taken as the difference between real and perceived areas.

Figures 8, 9, 10, and 11 present score distributions and descriptive statistics for the performance of 35 male *Ss* on accuracy, lateral displacement (x-scores), extension (y-scores), and dispersion, of perceived hand relative to the real hand. All but six *Ss* perceived their hand to be much

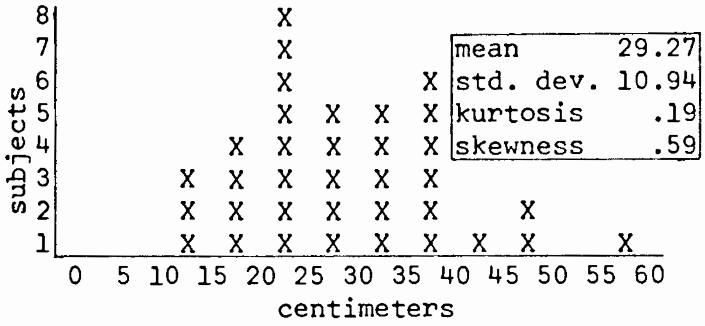


Figure 8. Frequency distribution for general accuracy scores for perception of the hand, 5 centimeter intervals, N=35.

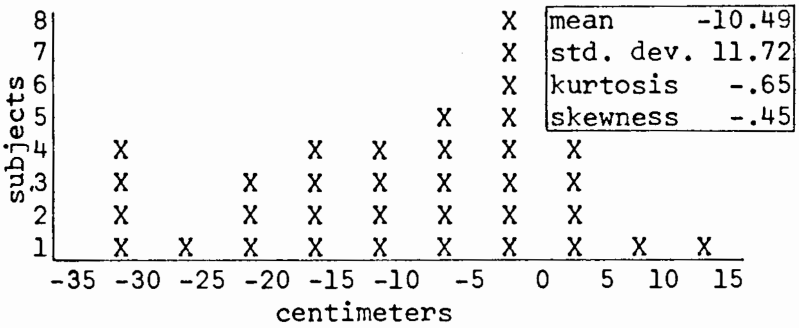


Figure 9. Frequency distribution for perception of lateral position of hand parts (x-scores), 5 centimeter intervals, N=35.

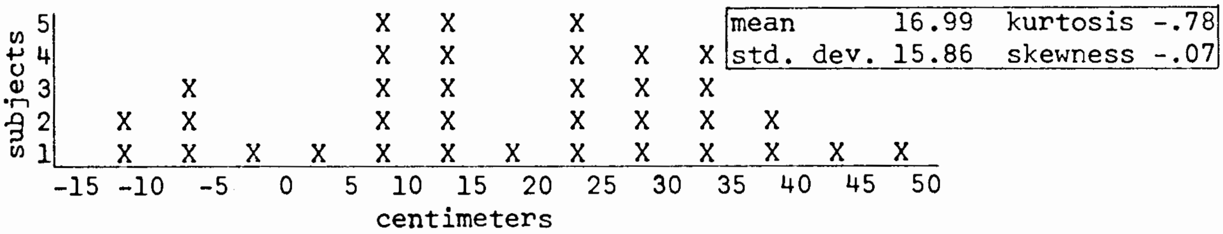


Figure 10. Frequency distribution for perception of extension of hand parts (y-scores), 5 centimeter intervals, N=35.

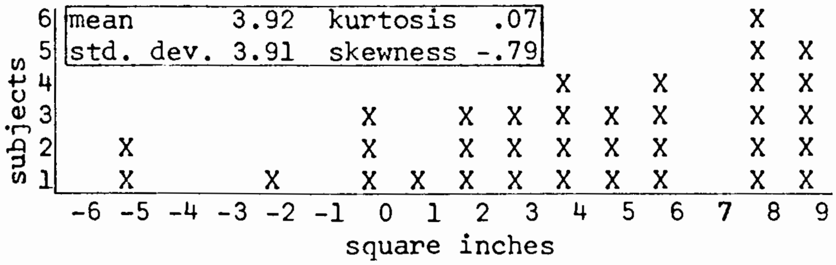


Figure 11. Frequency distribution for perception of the dispersion of hand parts (area score), square inch intervals, N=35.

less extended than it really was and all but six Ss (not the same six) perceived their hand to be smaller in area than their real hand (as reflected in positive scores), some as much as 8 to 9 square inches smaller.

Table 1

Correlations: Hand Perception Variables

	1	2	3	test-retest
1. Accuracy				.76
2. X-score	-.63			.71
3. Y-score	.72	-.17		.67
4. Dispersion	.11	-.17	-.18	.85

From the correlations of Table 1 can be noted the relationships of the four hand perception measures. The relationship of x- and y-dimension errors is non-significant suggesting that lateral displacement occurs independent of extension errors, and the relationship of dispersion to all the measures is also non-significant. Both x- and y-dimension scores are significantly related (.01 level) to the accuracy scores however, as one might expect. As shown in Table 1, test-retest correlations from 15 of the Ss (Ss' arms were replaced in the original position during the retest) indicate that the measures are generally reliable and show that body perception is a stable occurence.

To determine whether hand perception was dependent on actual hand parameters, a number of dimensions were calculated which approximately corresponded to the measures taken. Thus, whether actual breadth of the hand (thumb to little finger) might influence x-dimension perceptions, whether actual length of the arm (elbow to middle finger) might influence y-dimension perceptions, whether actual area of the hand might influence perceived dispersion, and whether all three might influence overall accuracy was of interest in order to insure that individual data would be approximately on the same scale. Of course, implied in the calculation of the dependent variables is a correction (through subtraction) for the real dimensions. Clearly, comparisons with corresponding parameters for x- and y-dimensions and for dispersion were non-significant (.05 level) with correlations of -.17, .31, and .14 respectively. To determine influences on accuracy scores, a multiple regression was computed with the accuracy scores as criterion and actual x, y, and dispersion parameters as predictors. None of the parameters significantly predicted the accuracy scores either individually or in combination (.05 level). Thus, the hand perception measure is apparently not dependent on actual body dimensions.

Relationships among Measures

Table 2 presents the correlation matrix for the data collected from

Table 2

Correlation Matrix: Haptic Measures

	Form	Texture	Space	Size	Rigidity
Texture	.23				
Space	.25	.27			
Size	.24	.27	.47		
Rigidity	.25	.57	.32	.31	
X-score	-.05	.06	-.15	-.35	-.05
Y-score	.10	.09	.23	.01	.11
Dispersion	.31	.24	-.07	.12	.08
Accuracy	.10	.16	.16	.16	.08

35 male Ss who were 18 to 30 years of age. Although discussed independently above, the measures were given together to each S under the same conditions and in the same order. The intercorrelations among hand perception variables were discussed above (Table 1) and are omitted from Table 2. From the results of Table 2 it is apparent that the measures are for the most part independent of one another. However, the internal consistency of the battery is .71 seemingly because they are independent measures of the same thing. Varimax rotated factor loadings were obtained which support this conclusion (Table 3), though the interpretation of the results is limited both by the number of Ss and variables involved as well as the possible predetermined nature of the separation of discrimination variables from hand perception variables into separate factors as shown in Table 3. That is, only one variable exists for each of the discrimination measures while four exist for the hand perception measure which possibly weights the results in favor of two separate factors. Factors retained for rotation were those with unrotated eigenvalues greater

Table 3

Two Factor Varimax Rotation:
Factor Loadings

Factor	1	2
Form	.57	-.05
Texture	.75	.01
Space	.57	-.27
Size	.63	-.23
Rigidity	.75	-.01
X-score	-.09	.71
Y-score	.00	-.78
Dispersion	.38	.06
Accuracy	.08	-.94
Internal Consistency	.62	.57

than unity (using unity in the diagonal) and internal consistencies greater than .40. Although four factors had eigenvalues greater than unity, the internal consistencies were only .23 and .07 for the last two factors. From these results and from the low correlations between hand perception and discrimination scores there is little evidence to suggest that they are related. Although only significantly correlated at the .06 level, the dispersion variable appears to bear some relation to form discrimination. It also loads more highly on the factor which represents discrimination measures. To some extent, the smaller the perceived hand is relative to the real hand, the worse the discrimination of form. At the .05 level of significance, hand x-dimension errors are negatively related to size discrimination scores. Since x-scores negatively increased, this is a direct relationship suggesting that the more laterally displaced the perceived hand, the worse the discrimination of size. A possible explanation for this occurence is the inadequacy of the size measure.

The significant correlation of texture and rigidity discrimination scores (.01 level) makes little sense from what is overtly required of the S, though the abilities required may share some higher level of processing. Both tasks involve ranking but if this accounted for the shared variance then one would expect both to be correlated with the size discrimination task. However, the size task involves the integration of finger positions and movements while rigidity and texture discriminations involve, among other things, noting differences in cutaneous pressure. The significant correlation of spatial and size discrimination (.01 level) is more accountable since separate correlations with the time and error scores of the spatial test revealed that only time significantly correlated with size discrimination scores (r=.50, .01 level). It was hoped that time would reflect discriminatory strength but since the size and spatial discrimination tasks probably do not require the same abilities, they seem only to be related with individual 'rates of activity'.

The Effect of Haptic Experience on Haptic Perception

In order to determine the effects of exploration in the Tactile Environment on haptic perception, the following procedure was initiated. Firstly, although it was important to apply measures of haptic perception to Ss after exploration, some frame of reference for determining change was required. The wide variability between Ss suggested that a comparison to a normative group would not be useful since a great number of Ss would be necessary to be sure that such a group was representative. As well, a simple between groups comparison (haptic versus normal experience) might certainly mask intra-individual changes. It was important, therefore, to arrange the procedure such that each S acted as his own comparison. This necessitated the application of baseline, or pre-experimental, measurements and the addition of a control group to provide information on variability due to practice. Also, since there may have been limits to the range of variability for the measures, initial application of the measures might be expected to produce some optimum change through practice. Therefore, initial measurement was carried out three to five weeks prior to experimental testing to allow for some extinction of acquired exploratory skill, etc.. However, since there is much evidence to suggest that perceptual learning is apparently not extinguishable (eg., Gibson, 1969), there may have been no loss in this regard.

The question, therefore, of whether experience in the Environment would produce perceptual change was answered by comparing a group with normal experience to a group with haptic experience in the Environment prior to a second testing. It was considered premature to experimentally isolate the many environmental variables that could be causally involved (for example, the effects of darkness alone or varied tactual stimulation alone) without first knowing whether there would be change at all. Also, the concern was with the effects of haptic experience which, as defined, is enhanced by the inclusion of all of the variables.

Subjects. Thirty male students from Simon Fraser University were acquired as Ss, who ranged from 18 to 30 years of age. Ss were randomly assigned to either experimental or control group, 15 in each group.

Procedure. Throughout the experiment Ss were not allowed to view the testing materials and were discouraged from having any expectations with regard to the results. They were told that the purpose of the study was to find out "what happens" and that there were no experimental expectations.

Test data were collected with Ss blindfolded and sitting comfortably before a table. Each S during each testing session received all of the measures in the same order to maintain constant learning conditions. Given no evidence as to the effect of order, the order of presentation was selected arbitrarily and was: hand perception, size, spatial, texture, form, and rigidity discrimination. Total testing time was 45 to 50 minutes for each session.

After the inter-test interval control Ss were simply retested under the same conditions. Experimental Ss were required to explore the Tactile Environment prior to retesting. Control and experimental Ss were matched with regard to length of inter-test interval. Experimental Ss were given the following instructions and were required to remove at least their footwear and shirt:

"In the Environment you will essentially experience blindness. It will be necessary for you to rely on other senses for direction and position. As soon as you enter the Environment you will have to 'feel' your way. It is completely safe. Although much of the Environment will require you to crouch, there is as much of the Environment in which you can walk freely. At any point in the Environment there is always an exit which is different in quality than the entrance to that point. Experiment with your position. Search out new sensations. Your purpose is to explore the Environment thoroughly."

Ss were also told that the Environment was monitored throughout and that they would only be talked to once at the beginning (to check whether the initial anxiety was overcome) and once at the end of the exposure time when they would be asked to return to the entrance. On the basis of earlier reports, two hours of exploration was selected as the maximum time required short of experiencing fatigue but long enough to allow each S to thoroughly explore the Environment. During this time Ss were instructed not to sleep and not to remain passive for more than a few minutes at a time, but certainly not to exert themselves. During exploration Ss were closely monitored to be sure that they explored every part of the Environment and didn't encounter any problems. At the end of the two hour period the S was instructed to return to the entrance where, before leaving the Environment, he was blindfolded. Thus, for the experimental Ss there was no visual experience from the time they entered the Environment to the end of the testing.

For both experimental and control Ss, at the termination of the retest session a series of questions were asked with regard to the motivational conditions surrounding the experiment. For example, questions were asked regarding outcome expectations, states of arousal, and general experience with the tests. This was done in light of evidence presented by Suedfeld (1969) who suggests that "anticipation, instructional set, and role playing by experimenter and by subject" may effect results especially in experiments where some form of deprivation is introduced.

Results. Data for each measure was analyzed separately and the analysis conducted within the framework of the general linear model (Mendenhall, 1968). That is, it is assumed that within each group (experimental and control) that a linear model is sufficient to account for the data. It is hypothesized that scores on the criterion test (retest) can be expressed as a linear function of the initial test. Therefore, for control (c) and experimental (e) groups,

$$\hat{Y}_e = \alpha_e + \beta_e X$$

and

$$\hat{Y}_c = \alpha_c + \beta_c X$$

where $\hat{Y}$ is the criterion score, X is the initial performance score, and α and β the slope and intercept respectively. Of major interest is whether the parameters of the linear relations differ between groups. That is, a comparison between α_e and α_c would ascertain the main effect for 'group' and a comparison between β_e and β_c would ascertain the effect of initial testing. This comparison can be made by assigning group membership values for each person and creating a group membership variable G. The model for the regression becomes:

$$\hat{Y} = \beta_0 + \beta_1 G + \beta_2 X + \beta_3 (GX)$$

where $\alpha_c = \beta_0$

$\alpha_e = (\beta_0 + \beta_1) = \alpha_c + \beta_1$

$\beta_c = \beta_2$

$\beta_e = (\beta_2 + \beta_3) = \beta_c + \beta_3$

where β_0 is a constant

and β_1, β_2, β_3 are weights

applied to G, X, and GX variables respectively,

where G = 0 for controls
= 1 for experimentals

GX = interaction (group by initial performance).

A test of β_1 (a test of the significance from 0) is thus a test of the difference between α_e and α_c, and β_2 is a regression weight applied to initial performance for all Ss, and a test of β_3 is a test of the difference between β_e and β_c or a difference above and beyond the control group. Although this is the full model for the regression of y on x, it may not be the best model since some of the terms in the regression may not be significant. That is, one looks for a model in which all regression weights are significantly different from 0 and, given other models in which all terms are significant, then selects the model which has the minimum estimated sum of squared errors as reflected in, say, a higher estimated multiple correlation. For example, the best model may only include the initial performance term such that $\hat{Y} = \beta_0 + \beta_2 X$. Since there is no interaction term then $\beta_3 = 0$ and where in the full model $\beta_e = \beta_2 + \beta_3$, now $\beta_e = \beta_2$, and the model is interpreted as the regression of y on initial performance for both groups.

The purpose of the multiple regression in the following was to determine for each of the measures which model best accounted for the data and thus, which interpretation could be placed upon performance. Tables 4 through 12 contain t-scores for the significance of regression weights for all possible models and their degrees of freedom. Also shown are 'corrected' multiple correlations (single-shrunken multiple correlations) which represent a better estimate of population multiple correlations corrected for degrees of freedom to allow for more accurate comparison of models varying in number of terms. Beta weights for experimental group regression (β_e) are shown only where relevant since, as discussed above, such a weight does not differ from β_c when the interaction term (β_3) is not significant (not included in the model). Table 13 contains descriptive statistics for all comparisons.

For form discrimination data Table 4 shows that only the initial performance term is significant in the evaluation of the full model (all three terms included). Deleting the interaction term as the lowest non-significant term and evaluating the new model shows that the group membership term remains non-significant. Deleting the group membership term and then evaluating the model with only the initial performance term included shows that it remains significant and is the best model for the regression of y on x. The same is true for texture and rigidity discrimination data (Tables 5 and 6) showing that there were no significant differences in criterion performances between experimental and control Ss taking into account initial performance and differences between groups in initial performance. However, the best model in each case indicates that initial performance

Table 4

Multiple Regression: Form Discrimination

Predictors	t-values						
Group membership	.16	1.93	.69			.15	
Initial performance	2.27*		3.15*	3.13*	3.11*		
Interaction	.12	1.93		.70			.36
Corrected multiple r	.43	.25	.46	.46	.48	.00	.00
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 5

Multiple Regression: Texture Discrimination

Predictors	t-values						
Group membership	.80	.62	.72			.73	
Initial performance	2.10*		2.65*	1.95	2.69*		
Interaction	.49	1.67		.33			1.74
Corrected multiple r	.37	.21	.40	.39	.42	.00	.26
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 6

Multiple Regression: Rigidity Discrimination

Predictors	t-values						
Group membership	.18	1.53	.52			.14	
Initial performance	.87		2.14*	1.77	2.10*		
Interaction	.20	1.91		.49			1.14
Corrected multiple r	.22	.24	.29	.28	.33	.00	.10
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 7

Multiple Regression: Size Discrimination

Predictors	t-values						
Group membership	.73	.60	.96			.13	
Initial performance	.88		1.18	1.06	1.19		
Interaction	.14	.79		.16			.52
Corrected multiple r	.00	.00	.00	.00	.12	.00	.00
Degrees of freedom	26	27	27	27	28	28	28

significantly predicted criterion performance.

For the analysis of size discrimination data the results of Table 7 indicate that no model is sufficient to account for the data. That is, criterion performance is unpredictable.

The results of Table 8 for the analysis of spatial discrimination data indicates that only initial performance is significant in the evaluation of the full model. In deleting either non-significant term, initial performance remains significant; the best model being the one which includes only the initial performance term. That is, though the model with group membership and interaction terms and the model with only the interaction term are significant, it is clear that these predictions were primarily due to the initial performance component since the inclusion of this term in the regressions produced non-significance of the other terms. This is supported by the fact that the multiple correlation is higher for the model including only the initial performance term. Thus, for spatial discrimination data initial performance significantly predicts criterion performance.

For the y-dimension, hand perception data the results of Table 9 also show that, although criterion performance is predictable from initial

Table 8

Multiple Regression: Spatial Discrimination

Predictors	t-values						
Group membership	.52	3.54*	.17			1.06	
Initial performance	5.08*		8.92*	7.13*	9.33*		
Interaction	.58	5.22*		.27			3.47*
Corrected multiple r	.86	.70	.86	.86	.86	.07	.53
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 9

Multiple Regression: Hand Perception, Y-dimension

Predictors	t-values						
Group membership	.51	1.56	.12			.24	
Initial performance	3.88*		5.03*	4.42*	5.13*		
Interaction	.17	2.48*		.20			1.89
Corrected multiple r	.65	.36	.67	.67	.68	.00	.29
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

performance, there is no significant difference between control and experimental criterion performance taking into account previous performance. Though x-dimension data appears similar in Table 10, from a comparison of multiple correlations the model which includes both initial performance and interaction components is the best regression. That is, the multiple correlation for the regression with two components is larger than for the regression with only the initial performance component which, according to the significance of t-values, should be the best regression. In support of the conclusion, the significant difference between correlations for within group initial and criterion performances (Table 13) suggests that there is a major difference in criterion performance even though the interaction component fell short of significance in the better model. Distinctly, experimental criterion scores are unpredictable from experimental group initial performance scores, indicated by the non-significance of experimental group regression (β_e).

Table 10

Multiple Regression: Hand Perception, X-dimension

Predictors	t-values						
Group membership	.49	1.31	1.18			1.31	
Initial performance	2.60*		2.13*	3.02*	2.24*		
Interaction	1.47	.37		2.00			.31
Inter. + Init. (β_e)				.19			
Corrected multiple r	.41	.00	.37	.45	.35	.16	.00
Degrees of freedom	26	27	27	27	28	28	28

*$p<.05$

The results of Table 11 on hand dispersion indicates that not only is criterion performance predictable from initial performance but also predictable from the group by initial performance interaction when both are included in the model. Since the group membership term is not included in the model, experimental and control groups significantly differ in slope of the regression. Calculation of the experimental group beta weight (β_e) was significant indicating overall that, although both experimental and control criterion scores were predictable from initial performance, performance was different between groups on the criterion test. In fact the within group initial and criterion correlations (Table 13) are significantly different (z=2.01); the experimental group correlation being lower. To further characterize the difference in performance, the ratio of variances for group criterion scores (control, 53.86; experimental, 19.06) was calculated and indicated a significant difference in variance (F=2.83, .05 level, one-tailed). In looking at the descriptive statistics of Table 13 and considering that standard error for both groups was approximately equal (control, 3.85; experimental, 3.95) it is suggested that unsystematic or absolute error remained the same while systematic error has been significantly reduced for experimental Ss. That is, experimental criterion scores are less dependent on initial performance thus reducing the regression component.

Table 11

Multiple Regression: Hand Perception, Dispersion

Predictors	t-values						
Group membership	.74	.25	1.16			1.17	
Initial performance	5.80*		5.33*	5.80*	5.40*		
Interaction	2.12*	1.16		2.35*			1.63
Inter. + Init. (β_e)				3.74*			
Corrected multiple r	.75	.14	.71	.75	.70	.09	.23
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 12

Multiple Regression: Hand Perception, Accuracy

Predictors	t-values						
Group membership	2.76*	.33	1.48			1.17	
Initial performance	4.57*		2.67*	3.28*	2.52*		
Interaction	3.54*	.79		2.44*			1.39
Inter. + Init. (β_e)	.61						
Corrected multiple r	.65	.00	.44	.53	.39	.11	.18
Degrees of freedom	26	27	27	27	28	28	28

*p<.05

Table 12 presents the results for general accuracy scores in hand perception. The best model in this case includes all three terms. Thus, there is a significant difference between control and experimental performance. Interestingly, the experimental group regression weight was not significant indicating that experimental criterion scores were unpredictable

Table 13

Descriptive Statistics for Comparison Groups

Test	Group	Initial Performance Mean	Initial Performance S.D.	Criterion Performance Mean	Criterion Performance S.D.	Within Group Correlation
Form	Control	11.33	2.39	10.13	2.39	.54*
	Experimental	12.13	2.39	10.00	2.42	.50*
Texture	Control	4.93	2.93	3.13	1.86	.64*
	Experimental	5.13	3.78	3.80	2.89	.36*
Space	Control	8.20	3.85	6.67	3.48	.81*
	Experimental	10.20	4.78	8.27	4.44	.90*
Size	Control	254.93	150.90	190.20	91.40	.28
	Experimental	278.13	176.64	189.67	124.61	.19
Rigidity	Control	224.87	76.20	207.20	78.47	.21
	Experimental	271.87	172.21	203.27	68.29	.53*
Hand X	Control	-10.51	11.23	-11.56	8.83	.71*
	Experimental	- 8.43	10.48	- 6.74	10.59	.09
Hand Y	Control	16.98	16.69	14.19	22.71	.67*
	Experimental	19.73	14.06	15.95	16.00	.75*
Dispersion	Control	1.79	3.94	1.79	7.30	.85*
	Experimental	5.58	2.98	1.78	4.37	.43*
Accuracy	Control	28.83	11.74	31.73	12.76	.76*
	Experimental	30.29	8.11	27.12	7.27	-.30

$^*p < .05$

from initial performance. The correlations as indicated in Table 13 support the regression results by showing that experimental group initial and criterion performances are uncorrelated. Thus, as a function of the experimental condition, Ss have performed very differently on the criterion tests. Since the full model was the best model, then there is also a difference in mean performance in the direction of improved accuracy for at least some experimental group Ss.

Post-experimental questioning of both experimental and control Ss revealed that, in general, there was little difference between groups with regard to expected results. Sixteen of the Ss "didn't think about" what was expected while eight control and six experimental Ss thought they were to "do better." Decidedly, when asked if they could have done better if given some incentive, most (21 Ss) reported that they could not have for all the tasks while the rest thought they could have done better on the timed tasks (i.e., size and rigidity). Seven control Ss reported that they had worked harder on the tasks during the second testing, while five said they had worked less hard and three "the same." However, for experimental Ss 10 reported having worked harder while five reported having worked less hard. With regard to arousal, only two control Ss indicated that there was a difference between first and second testing. For experimental Ss however, all reported some change. In particular, when asked if they were anxious or relaxed all reported being relaxed, eight extremely so. When asked whether there was fatigue, three experimental Ss responded affirmatively. Overall, spontaneous comment indicated that most found the tasks frustrating for lack of a frame of reference for success or failure, but found the tasks interesting and involving because of the 'novel' mode of perception.

Discussion

From the results of the analysis of performance on the discrimination measures it is apparent that for the duration studied, experience in the Tactile Environment did not produce measurable change in perceptual response. Whether there was actually no change or whether there was a failure to measure it remains as a question. Though articulation of the hand changed, it is unknown whether this should predict change on measures of discrimination involving the hand since in the present study there is, generally, no statistical relation. If there was actually no change in perceptual response then the individual differences on three of the measures (form, texture, and spatial discrimination) must surely reflect 'abilities' -- something that is relatively stable over time. It is suggested that the size and rigidity discrimination measures are uninterpretable since there was no systematic variation noted. The dependent variable on the two tasks is time and apparently is subject to unsystematic changes in individual rates of activity. The two measures cannot be regarded as reliable and will be omitted from discussion.

Considering the descriptive data of Table 13, there was a consistent improvement in mean scores on all measures indicating that learning had occured. Perceptual learning is defined as "an increase in the ability of an organism to get information from its environment as a result of practice with the array of stimulation provided by the environment [Gibson,1969,p.77]."

Thus, with regard to practice with the measures, perceptual learning occured. However, practice with the array of stimulation in the Tactile Environment which is not directly related to task requirements, apparently did not produce perceptual learning. This result suggests that experience with only modality-specific (as opposed to task-specific) information did not increase the ability to abstract information in other perceptual learning situations. Although exposed to variations in form, texture, and space, the conditions were not present for Ss to learn to better differentiate such dimensions. In light of the results of post-experimental questioning it is possible that the relaxation produced by the experience may have rendered them less attentive to distinctive features even if they were better able to abstract the features. Nevertheless, the overall experience which included its relaxing effects, did not produce an improvement on the measures above that expected from practice.

The form discrimination measure was consistently difficult for all Ss. Though there was a mean improvement the task may have remained too difficult to reflect possible variation due to changes in perceptual response. For the texture discrimination task there were also probable limits to improvement based on the limits of information input. That is, there may not have been sufficient sensory information on the upper end of the scale of textures to allow differentiation. Mean criterion performance for both groups is extremely high and may have reached an optimum since it was expected that the end rank positions would be difficult for all. If there was learning for experimental Ss, there may not have been room for improvement above the effects of practice. In general, the overall quality of most of the measures in terms of their minimum reliability suggests that they may not have been sensitive enough since large effects would be required to produce noticeable change.

It is surprising that reported confusion with spatial discrimination was not measureable. Although one would expect the spatial measure to be affected by perceptual learning (differentiating the position of objects in space), the main use of the measure was to note any quantifiable basis for the phenomenological reports. This was not the case since performance remained very stable. The broad individual differences with this measure and the reliability of these differences, defines a valid measure useful for further enquiry.

With regard to the hand perception measures, the stability of performance for control Ss represents a surprising fact concerning the perception of body 'articulation'. Not only is this 'sense of body' non-veridical, but it is reliably so. More provocative is the finding that although the perception of extension of the hand (y-dimension) did not significantly change as a function of the experimental condition, lateral displacement, general accuracy in locating parts of the hand, and perception of the size or dispersion of the hand did change. From the results, it is apparent that for experimental Ss performance became confused or reorganized. The phenomenological reports of confusion and loss of a sense of body-perimeter support this result and suggest that Ss lost a frame of reference for articulation of body locations. Since Ss seemed to simply 'operate' differently on the tasks it is also possible that a kind of cognitive reorganization took place as there was a significant increase in accuracy for experimental Ss. Regardless of which interpretation is placed upon the change, the results are in direct contradiction to studies of body-schema (eg., Gross & Melzack, 1973; Weinstein & Sersen, 1961) which imply that body-schema (body representation independent of stimulation) is a stable neural representation. Hypothetically, it is suggested that such a representation is particular to sighted Ss who have a primarily visual frame of reference for hand perception. Exploration in a dark environment engenders a loss in the visual frame of reference as attention is shifted to 'felt' hand from 'visualized' hand. The mean improvement (toward veridicality) for experimental Ss but not for controls suggests that a haptic representation of the hand is the veridical representation. However, with regard to the present results there is only evidence of reorganization or confusion. Since the accuracy scores are related to both x- and y- dimension errors while x and y are unrelated to each other, the unpredictability of experimental x-dimension criterion performance suggests that overall accuracy unpredictability is most due to changes in the perception of lateral locations. Perception of the extension (distance away from the body) of hand locations remains stable for both groups and thus, confusion primarily lies in the left - right articulations.

Although uncorrelated with other hand perception measures, perception of the size of the hand also becomes confused for experimental Ss but shows no significant mean improvement. This result fits well with Gibson's (1962) concept of the hand as an exploratory organ which given experience will acquire new characteristics. The change that takes place for the perception of the hand is at least initially one of disorganization, suggestive of the general results of 'sensory deprivation' (Kubzansky, 1961). That is, initially disorganization occurs possibly as the first step in a reorganizing process; reorganization being possible since, unlike deprivation research, the present study allowed the S to maintain an 'optimum' level of stimulation through non-visual modalities. The present results then, may only reflect the early stages of adapting to a new environment. From the earliest formulations of perceptual learning (eg., Murphy & Hochberg, 1951) the organism is considered as progressively altering its modes of perception to more useful modes in coping with the environment.

Since performance on the reliable discrimination measures was not affected by prior experience as reflected in a lack of significant mean change or change in predictability, it has been suggested that perceptual functioning is stable. However, in noting the ratio of two hours of haptic experience to a life duration of apparent visual dominance, it may also be suggested that the amount of experience was simply not enough. Yet the same experience was enough to render hand perception unpredictable or less predictable from initial performance. Since hand perception and haptic discrimination are generally unrelated it is possible to conclude that the later represents stable abilities and the former an independent labile system. Possibly if the hand perception measure had been more directly related to the haptic tasks by requiring the S to note 'stimulated' locations there would have been a greater relationship indicated since this would provide a stimulus frame of reference as is necessarily involved with the discrimination measures. From the present results, the concept of a haptic system which involves the integration of a 'body sense' with discriminative functioning is not upheld. But, it is probable that the present measure of body perception is unrealistic since in haptic perception there is, by its active definition, no haptic perception of the body independent of stimulation. Certainly the results of the present study of hand perception are theoretically provocative with regard to the lability of some neural representation of 'body' but bear little relation to the integrated activity of haptic perception.

Overall results suggest that experience in the Tactile Environment produces change only in affective response and in body articulation. Increasing 'awareness' of quantity and quality of stimulation and providing conditions for exploration did not improve the ability to discriminate. As an alternative to other explanations of this lack of improvement, something may have been missing in the experimental condition. For all the tasks Ss were blindfolded and in a quiet room where they were expected to carry out the instructions of the experimenter. Thus, it is assumed that they were maximally attentive to haptic information and that it was adaptive for each S to try to learn. Since they were also provided with previously or partially undifferentiated stimulus dimensions in the tasks, then conditions for perceptual learning were present. If attention, adaptive requirements, and undifferentiated stimulus arrays were also present in the Tactile Environment, why then did this not improve their ability to differentiate? Transfer of learning is a fact of perceptual learning (Gibson, 1969) such that if learning had taken place it should have been reflected in later perception. In the Tactile Environment much potential information was present, and since Ss were forced to attend because of the darkness, only the adaptive requirements seemed lacking. To find one's way through the Environment the individual was required to discriminate certain kinds of stimulus information but, strictly speaking, this may have been the only adaptive requirement. For the individual to find his way through the Environment he needed only to discriminate empty from 'full' space. Though as a result of his exploration he would be forced to encounter a great deal, there may at least have been no externally imposed reason for differentiating the stimulus information. However, all Ss found their way through the Environment and all re-explored a number of times. Most spent a great deal of time exploring objects, textures, and so on, not only because they were instructed to, but apparently for 'intrinsic rewards'. Given more exposure this may have sufficed to produce learning since this is an adaptive process in which the individual wants to 'find out' about his environment in general (Gibson, 1969). What is more likely is that in light of the unrelatedness of discrimination measures that abstraction from, say, an array of complex stimulations involving texture, consistency, hardness, etc., was not discrete enough to be applied to the differentiation of, say, form only. In the Tactile Environment, as in most visual environments, there was a lack of 'pure' dimensions.

That is, in order to better differentiate form, for example, it is likely that short term experience with that dimension in particular was required. Also, the development of the Tactile Environment was based primarily on presenting many kinds and contrasts of stimulation rather than variations of phenomenologically similar arrays. In general, an attempt was made to increase quantity of stimulation rather than the quality of patterning of stimulation. Thus, the results suggest the conclusion that quantity of stimulation may not be an important variable in perceptual change. These things combined with a lack of strong adaptive requirements, of the kind Gibson (1969) describes as keeping the individual from "barking his shins," likely hindered measurable learning with regard to form, texture, and orientation.

In light of the inconclusive results in the present study, to learn more of the nature of haptic perception it would be useful to explore the effects of haptic experience in other ways. For example, though discrimination may not change as a function of haptic experience, exploratory activity might. Thus, it would be interesting to note whether the nature of exploratory movement changes possibly making the acquisition of information more parsimonious. Also, for the sighted individual one might suspect that haptic experience produces a shift in modality preference given some later choice in exploration. Furthermore, the effects of haptic experience may not produce perceptual change, per se, but produce some change in the use of haptic information through cognitive reorganization as possibly reflected on more complex tasks involving reasoning with haptic information.

The phenomenological results of the present study also suggest some interesting questions for further research. In particular, it would be important to discover whether the affective responses to the experience in the Environment and its relaxing effects were peculiar to haptic experience both in magnitude and in quality. Since the present results strongly support this possibility it would be more interesting to know what particular variables or combination of variables led to these effects. For example, is there some characteristic of tactual exposure in particular which 'relaxes' or is it simply an affect of experience in darkness?

It would be enlightening in further research to study the performance of blind S̲s on the present discrimination measures. Although one might expect a mean difference in comparison to the sighted, it would be interesting to note differences within groups for repeated measurements. That is, given novel stimuli we might expect the blind to acquire more information from practice than the sighted since, according to the present hypothesis, the blinds' experience with an ecology that requires haptic exploration would render them more capable of perceptual abstraction. Previous studies of differences between the blind and sighted present no conclusive evidence for better sensory capacity or perception in terms of object recognition and discrimination of previously learned dimensions (Lowenfeld, 1971; Nolan, 1963). There has been no study of differences in the 'process' of perception. With regard to the hand perception measure, it would be interesting to learn of the mean difference between the sighted and the blind as well as know something of the reliability of repeated performance. Is confused 'articulation' of the body a general state of affairs for the blind or is it stable over time and also more veridical in comparison to the sighted?

References

Ahmad, S. M. The difference between the haptic perception of the sighted and blind person. American Foundation for the Blind Research Series, New York, 1971, 23.

Ayres, A. J. Space Perception and Visualization in Cerebral Dysfunction, Unpublished PhD dissertation, University of Southern California, 1961.

Ayres, A. J. Ayres Space Test, Los Angeles: Western Psychological Services, 1969.

Berlyne, D. E. Curiosity and exploration. Science, 1966, 153, 25-33.

Buchwald, J. S. & Eldred, E. Activity in muscle spindle circuits during learning. In D. Barker (Ed.), Symposium on Muscle Receptors, Hong Kong: Hong Kong University Press, 1962.

Chan, D. An apparatus for the measurement of tactile acuity. American Journal of Psychology, 1964, 77, 489-491.

Corsini, D. A. & Pick, H. D. The effect of texture on tactually perceived length. Perception and Psychophysics, 1969, 5, 352-356.

Deutsch, M., Katz, M., & Jensen, A. R. Social Class, Race, and Psychological Development, New York: Holt, Rinehart, & Winston, 1968.

Flavell, J. H. The Developmental Psychology of Jean Piaget, Princeton, N. J.: Van Nostrand, 1963.

Garner, W. R. Uncertainty and Structure as Psychological Concepts, New York: Wiley, 1962.

Gibson, E. J. Principles of Perceptual Learning and Development, New York: Appleton-Century-Crofts, 1969.

Gibson, J. J. Observations on active touch. Psychological Review, 1962, 69, 477-491.

Gibson, J. J. The useful dimensions of sensitivity. American Psychologist, 1963, 18, 1-15.

Gibson, J. J. The Senses Considered as Perceptual Systems, Boston: Houghton-Mifflin, 1966.

Glass, D. C., Singer, J. E., & Friedman, L. N. Psychic costs of adaptation to an environmental stressor. Journal of Personality and Social Psychology, 1969, 12, 200-210.

References (cont.)

Gross, Y. & Melzack, R. The interaction between body schema and somatosensory input in producing body image. Paper presented at the Canadian Psychological Association convention, Victoria, B. C., June, 1973.

Harlow, H. F. Learning to Love, San Francisco: Albion Publishing, 1971.

Harper, R. & Stevens, S. S. Subjective hardness of compliant materials. Quarterly Journal of Experimental Psychology, 1964, 16, 204-215.

Harris, C. S. Adaptation to displaced vision: visual, motor, or proprioceptive change? Science, 1963, 140, 812-813.

Head, H. Studies in Neurology, Volume 2, Oxford: Henry Frowde, 1920.

Held, R. Plasticity in human sensori-motor control. Science, 1963, 142, 455-462.

Holst, E. V. Relations between the central nervous system and the peripheral organs. British Journal of Animal Behavior, 1954, 2, 89-94.

Katz, D. Der Aufbau der Tastwelt, Leipzig: Barth, 1925. (Reported in J. J. Gibson, The Senses Considered as Perceptual Systems, Boston: Houghton -Mifflin, 1966).

Krueger, L. E. David Katz's "Der Aufbau der Tastwelt": a synopsis, Perception and Psychophysics, 1970, 7, 337-341.

Kubzansky, P. E. The effects of reduced environmental stimulation on human behavior: a review. In A. D. Biderman & H. Zimmer (Eds.), The Manipulation of Human Behavior, New York: Wiley, 1961.

Lobb, H. Vision versus touch in form discrimination. Canadian Journal of Psychology, 1965, 19, 175-187.

Lowenfeld, B. Psychological foundation of special methods in teaching blind children. In P. A. Zahl (Ed.), Blindness, Princeton, N. J.: Princeton University Press, 1950, 89-108.

Lowenfeld, B. Psychological problems of children with impaired vision. In W. M. Cruickshank (Ed.), Psychology of Exceptional Children and Youth, Englewood Cliffs, N. J.: Prentice-Hall, 1971.

Melzack, R. & Wall, P. D. Pain mechanisms: a new theory. Science, 1965, 150, 971-979.

Mendenhall, W. The Design and Analysis of Experiments, Belmont, Calif.: Wadsworth, 1968.

References (cont.)

McFarland, R. A. Enhancement of thermal estimates by concomitant pressure stimulation. Journal of Experimental Psychology, 1971, 88, 20-25.

Milstein, S. L. & Zubek, J. P. Temporal changes in cutaneous sensitivity during prolonged visual deprivation. Canadian Journal of Psychology, 1971, 25, 336-348.

Mountcastle, V. B. Some functional properties of the somatic afferent system. In W. A. Rosenblith (Ed.), Sensory Communication, New York: Wiley, 1961.

Nolan, C. Y. Roughness discrimination among blind children in the primary grades. International Journal for the Education of the Blind, 1960, 9, 97-100.

Nolan, C. Y. The visually impaired. In S. A. Kirk & B. B. Weiner (Eds.) Behavioral Research on Exceptional Children, Washington, D. C.: The Council for Exceptional Children, 1963.

Paillard, J. & Brouchon, M. Active and passive movements in the calibration of position sense. In S. J. Freedman (Ed.), The Neurophysiology of Spatially Oriented Behavior, Illinois: Dorsey Press, 1968.

Paintal, A. S. Responses and reflex effects of pressure-pain receptors of mammalian muscles. In D. Barker (Ed.), Symposium on Muscle Receptors, Hong Kong: Hong Kong University Press, 1962.

Phelps, J. & Zubek, J. P. The effect of prolonged visual deprivation on various cutaneous and auditory measures. Psychonomic Science, 1969, 14, 194-195.

Rose, J. E. & Mountcastle, V. B. Touch and kinesthesis. In J. Field (Ed.), Handbook of Physiology, Volume 1, Washington, D. C.: American Physiological Society, 1959, 387-430.

Revesz, A. Psychology and Art of the Blind, Longmans-Green, 1950.

Rock, I. & Victor, J. Vision and touch: an experimentally created conflict between the two senses. Science, 1964, 143, 594-596.

Roeckelein, J. E. The effect of set upon length estimation in active touch perception. Psychonomic Science, 1968, 13, 193-196.

Rubino, C. A. Psychometric procedures and the detection and exploration of behavioral deficits due to cerebral dysfunction in man. The Canadian Psychologist, 1970, 11, 239-260.

References (cont.)

Senden, M. Space and Sight, Glencoe, Ill.: The Free Press, 1960.

Schiff, W. & Dytell, R. S. Deaf and hearing children's performance on a tactual perception battery. Perceptual and Motor Skills, 1972, 35, 683-706.

Schmid, E. Temporal aspects of cutaneous interaction with two point electrical stimulation. Journal of Experimental Psychology, 1961, 61, 400-409.

Semmes, J., Weinstein, S., Ghent, L., & Teuber, H. L. Somatosensory Changes after Penetrating Brain Wounds in Man. Cambridge: Harvard University Press, 1960.

Shewchuk, L., & Zubek, J. P. A technique of intermittent stimulation for measurement of tactual sensitivity: apparatus and preliminary results. Canadian Journal of Psychology, 1960, 14, 29-37.

Shopland, C. & Gregory, R. L. The effect of touch on a visually ambiguous three-dimensional figure. Quarterly Journal of Experimental Psychology, 1964, 16, 66-70.

Simmel, M. L. & Shapiro, A. The localization of non-tactile thermal sensations. Psychophysiology, 1969, 5, 415-425.

Singer, G. & Day, R. H. Visual capture of haptically judged depth. Perception and Psychophysics, 1969, 5, 315-316.

Suedfeld, P. Theoretical formulations: II. In J. P. Zubek (Ed.), Sensory Deprivation: Fifteen Years of Research, New York: Appleton-Century-Crofts, 1969.

Uttal, W. R. & Krissoff, M. Response of the somesthetic system to patterned trains of electrical stimuli. In Kenshalo, D. R. (Ed.), The Skin Senses, Springfield, Ill.: Thomas, 1965.

Vierch, C. J. & Jones, M. B. Size discrimination on the skin. Science, 1969, 163, 488-489.

Von Békésy, G. Sensations on the skin similar to directional hearing, beats and harmonics of the ear. Journal of the Acoustic Society of America, 1957, 29, 489-501.

Wallach, H., Kravitz, J. H., & Lindauer, J. A passive condition for rapid adaptation to displaced visual direction. American Journal of Psychology, 1963, 76, 568-578.

References (cont.)

Wapner, S., Werner, H., & Comalli, P. E. Effect of enhancement of head boundary on head size and shape. Perceptual-Motor Skills, 1958, 8, 319-325.

Weinstein, S. & Sersen, E. A. Phantoms in cases of congenital absence of limbs. Neurology II, 1961, 905-911.

White, R. W. Motivation reconsidered: the concept of competence. Psychological Review, 1959, 66, 297-333.

Williams & Wilkins Co., Pain Sensations and Reactions (Hardy, Wolff, & Goodell), Baltimore, Md., 1952.

Wohlwill, J. F. The definition and analysis of perceptual learning. Psychological Review, 1958, 65, 283-295.

Wohlwill, J. F. The emerging discipline of environmental psychology. American Psychologist, 1970, 25, 303-312.

Wolff, P. The role of stimulus - correlated activity in children's recognition of nonsense forms. Journal of Experimental Child Psychology, 1972, 14, 427-441.

Wood, H. Psychophysics of active kinesthesis. Journal of Experimental Psychology, 1969, 79, 480-485.

Zaporzhets, A. V. Origin and development of conscious control of movements in man. In The Central Nervous System and Behavior, Bethesda, Md.: National Institute of Health, 1960, 1005-1022.

Zinchenko, V. P. Perception as action. In Perception and Action, Proceedings, 18th International Congress of Psychology, Moscow, 1966, 64-73.

Zubek, J. P., Flye, J., & Aftanas, M. Cutaneous sensitivity after prolonged visual deprivation. Science, 1964, 144, 1591-1593.

Zuckerman, M., Persky, H., Miller, L., & Levin, B. Contrasting effects of understimulation (sensory deprivation) and overstimulation (high stimulus variety). Proceedings, 77th Annual Convention, American Psychological Association, 1969, 319-320.

Appendix

Tactile Environment: construction and operation

In the same sequence of travel as shown in Figure 1, the material components and their applications are as follows:

(1, 2, 52, 53) Entrance-exit light-locks: In order to keep the Environment in total darkness during operation, light-locks were constructed which served to block any light from filtering in through the exit and entrance. Both light-locks had walls and ceilings which were lined with black felt and canvas to cut down on reflection. Light was effectively blocked with the use of 4 inch wide, hanging strips of variously textured fabrics. By staggering the strips behind one another, all light was blocked while passage was not. Thus, as the individual entered the light-lock the strips would part and then flow behind leaving the individual in total darkness by the end of the light-lock.

(3) Giant foam steps: The steps consisted of four wooden boxes varying in height. Each box was covered with 4 to 6 inches of polyfoam held in place by loosely stretched canvas. In sequence, the steps were 2, 3, 5, and 7 feet high. The walls of the stairwell were covered with canvas and 2 inches of polyfoam.

(4) Slide tube: Approximately 1 and 1/2 feet above the top-most foam step was the entrance to the slide tube. The tube itself was 6 feet long and 42 inches in diameter and, like other tubes in the Environment, was of the kind used for concrete forms. Lined with thin foil and slanted approximately 30 degrees down from the entrance, it provided an excellant sliding surface.

(5) Slide board: From the end of the slide tube another slide was constructed which consisted of waxed chipboard. The purpose here was to suddenly remove the walls from the visitor as he exited from the slide tube. The slide board was 4 feet wide and flat.

(6) Triangular floor: To reinforce the disorienting effects of the foam steps and the slides, two triangular-like shapes were built into the floor. Each triangle consisted of a foam and canvas pad angled up with a short drop down.

(7) Vinyl tunnel: At approximately 4 feet above ground floor level,

where the slides and triangular floors ended, the floor was constructed so as to slant upward at approximately a 25 degree angle. At this point the walls and floor were covered with heavy vinyl while the ceiling consisted of loosely hung vinyl.

(8) Foam protrusions: To provide a kind of obstacle course in the angled section beyond the vinyl tunnel, 'chunks' of polyfoam were randomly placed and securely fastened to the floor and walls. In an area which was completely open, these provided a kind of startling encounter in the darkness.

(9) Hanging rope and nylon: At this point the floor was constructed to level out at about 4 feet from the ceiling. Here, a hanging maze of contrasting nylon mesh shapes and 1 inch jute was constructed.

(10) Latex rubber room, combinations: At a point where the upper level of the Environment was constructed to turn left, sawdust, styrofoam, sisal cord, chipboard, and polyfoam were combined with latex rubber to form variously textured shapes and surfaces.

(11) Latex rubber room, elastics: In its liquid form as applied in section 10, latex rubber was poured onto a concrete surface in long strips. After drying, these strips were peeled up and stretched over walls and ceiling in a cobweb-like fashion.

(12) Rolling tube: A 6 foot, 42 inch diameter, concrete form tube was placed after the latex rubber cobwebbing. With approximately 1 foot of space on each side of it, the tube could be displaced as an individual passed through it. The tube was lined with polyfoam and covered with polyestre fibrefill.

(13) Residue foam ramp: Walls and floor were covered here with a leather-like substance which is obtained when, in the production of polyfoam, the foam nearest the air cools too quickly to expand. This foam 'slag' was 1/4 inch thick having been cut away from the expanded foam.

(14, 15, 16, 17) Ping pong ball room: From the top of the residue foam ramp to the end of this 7 foot room was constructed a 2 foot wide crawlway covered with 2 inches of foam and tightly stretched canvas. A wall on the right of the crawlway, which sloped away at a 70 degree angle, was covered with residue foam. To the left of the crawlway, an inverted pyramid trough lead down to an air hole through which compressed air was forced. Thus, the room was constructed so that when the hollow plastic balls were displaced from the crawlway surface into the trough, they would immediately be blown into the air. The result was a continuous circulation of balls through the air. Heavy canvas strips covering both exit and entrance to the room prevented the balls from flying out of the room.

(18) Residue foam puddles: As a waste product of polyfoam production, left over polyfoam liquid is often poured into containers such as paper bags and boxes. When the foam cools and expands out of the containers it forms bulbous, crater-like puddles. Up to 10 inches thick and 7 feet long, the puddles are extremely buoyant and contain inumerable pockets, bubbles, and textures. In this section puddles were placed on both the floor and walls.

(19, 20) Hot and cold boxes: To provide the sensations of hot and cold at the same time, two boxes were constructed, one of which contained a heating element and the other of which contained ice packs. Both boxes had sheet metal plates on the exposed surface and were placed in a narrow area where the individual would be forced to encounter them.

(21, 22) Wind tunnel: At the end of an extremely small tunnel, approximately 3 feet high and wide, a 22 inch industrial fan was placed behind a wire mesh wall. The fan blew air into the small tunnel making the space feel less constricting and cooling the visitor.

(23, 24) Fur tube: Two 6 foot, 36 inch diameter, concrete form tubes were placed end to end, angled at approximately 45 degrees down from the wind tunnel to the water mattresses. Both tubes were first lined with 4 inch polyfoam and then covered with artificial fur to form a single tube.

(25, 26) Waterbed room: The fur tube was placed so as to pass through the top half of a door leading to the waterbed room and stand just over the first of two king-sized waterbeds. Each waterbed was framed in by walls covered with 1 inch foam such that the whole floor of the room had no standing space. The waterbeds were filled with water at room temperature and the vinyl left bare, giving the distinct sensation of wetness. An exit from the waterbed room was constructed just under the entrance tube in the lower half of the doorway.

(27) Quiverall room: A small chamber was consructed just outside the waterbed room in which the floors, walls, and ceiling were covered with a flesh-like rubber commonly called 'quiverall'.

(28, 29, 30, 31) Cramped maze: A 4 foot high crawling maze was constructed to maximally expose the individual to a variety of textures and forms within a short period of time. This was done by constructing a series of flanged panels which would force the individual to encounter as many surfaces as possible by continually changing the direction of the maze. Most of the forms and textures placed in the maze were man-made, consisting of plastics, rubbers, and various fibres.

(32) Birdseed bin: A 3 foot high bin was constructed in which was placed 600 pounds of millet. The bin was approximately 7 feet long with the surrounding area covered in felt. The individual had to crawl over foam and canvas panels to get in and out of the bin.

(33) Sisal fibre room: In contrast to the birdseed, a 12 foot long square tunnel was constructed which contained 100 pounds of sisal fibre. The sisal, which was unbound, hung from the ceiling and covered the floor.

(34) Spiral walkway: In order to force to a standing position those who might still be crawling, 1 and 1/2 foot wide walkway was constructed. To disorient the person in the standing position, the left wall of the tunnel was constructed to twist to the right with a concave shape. The right wall also twisted to the right but with a convex shape while the floor was constructed to raise and slant to the right. The thin walkway was lined with thick, coarse, residue foam and contained hanging strips of maribou, an extremely soft, fur-like material.

(35) Sandpaper ramp: From the end of the spiral walkway to the lower floor of the Environment, a ramp was constructed which was lined with coarse sandpaper. On the left of the ramp the wall dropped away leaving the individual with no left hand reference.

(36) Sculptured wall: Beginning on the right wall beside the sandpaper ramp and continuing around the end wall of the Environment, a 12 foot long, 8 foot high, fibreglass sculpture was constructed. As the base for the sculpture, a wood frame was erected on which heavy fence wire was shaped and

fastened. The wire was covered first with a plaster maché on the surface of which successive layers of fibreglass mat and resin were placed. Several coats of resin finished the sculpture to a smooth, plastic finish which was shaped to contain troughs, pockets, and protrusions.

(37, 38, 39) Open area and elastic walls: The Environment at this point was constructed so as to direct the individual into an open space. By stretching rayon elastic vertically on the sides of the open area, an attempt was made to produce an apparent loss of a fixed vertical reference.

(40) Vibrating room: Four 4 foot by 8 foot galvanized steel sheets were used in the construction of this section. Two full sheets were used for the left and right walls, one sheet cut in half lengthwise served as the exit and entrance walls, and one sheet cut in half widthwise served as the floor and ceiling. Edges were crimped and fastened with pop-rivetts. Vibration was produced with a 1/4 horse power motor with a concentric cam.

(41, 42, 43) Foam and water walkway: To raise the individual up to a height of 1 foot above floor level, a ramp was constructed and lined with canvas and residue foam. Following the top of this ramp a walkway was constructed which was 10 feet long and 1 and 1/2 feet wide. The walkway dipped down to floor level in the center and then raised back up again to the end. The center of the walkway was lined with polyethylene and 4 inch thick foam was placed over the entire surface of the walkway. Enough water was poured into the center of the walkway so that only depression of the foam would expose the water at that point. Beginning at the sides of the walkway, walls were constructed which slanted away to a height of 7 feet. The walls and ceiling were covered with asphalt roofing tile.

(44, 45) Burlap room: In an area approximately 7 feet in length from the foam and water walkway, burlap, sawdust filled sacks were placed on the floor. The slanted walls from the previous section were continued and covered with burlap and were constructed to widen and become vertical by the end of the burlap room.

(46) Pebble floor: The floor in this section was covered with smooth, clay pebbles held in place by setting them in a thin layer of latex rubber.

Appendix (cont.)

(47) Polyestre fibrefill wall: The left wall of a large area following the burlap room was covered entirely with polyestre fibrefill. The cotton-like material was attached to the wall with a rubber cement.

(48) Tennis ball floor: Tennis balls were cut in half and set with curved side up into latex rubber on the floor.

(49, 50) Sculptures: To block any light that might seep through the exit, a panel was erected at an angle in front of the exit light-lock. The face of the panel, which was 7 feet by 4 feet, was composed of a tactile relief sculpted with everything from tin foil and paper mache to cotton batton and plastic. A second sculpture, a 5 foot human form, was cast in resin and fibreglass and finely sanded. The sculpture was set into plaster with only the front surface exposed thus contrasting the smooth plastic surface of the form with the rough plaster.

(51) Residue foam puddle wall: As another means of blocking off light at the exit and also presenting a contrasting surface, a 7 foot long, 4 foot wide foam puddle was suspended at the exit.

(54) Fire exits: Provisions were made for escape routes in case of emergency, the first consisting of a canvas curtain near and and as an alternative to the exit and entrance. The second route consisted of two rayon elastic walls, section 39, which allowed access to the maintainance passage, section 55, or to a second door near the sculptured wall. In the dark though, by backing the rayon elastic with canvas curtains, access was 'felt' to be constricted and therefore the individual was directed elsewhere.

(55) Maintainance passage: In order to quickly gain access to any area of the Environment in case of emergency and to provide access for maintainance, a 3 foot wide tunnel was incorporated in the construction to run between lower level tunnels and directly underneath the upper level. Leading to this area were constructed a number of maintainance hatches located near sections 5, 11, 19, 27, 32, and fire exits. As well, all electrical equipment was contained in this area.

(56) Ventilation tunnel: Ventilation for the Environment was provided by a large metal air duct with four outlets open to the upper level.

Appendix (cont.)

Since construction of the Environment was an anticipation of how the prospective visitor would react to the various parts of it as well as the total experience, provisions were made for those individuals who might react adversely to the experience. Thus, in case of accident or in case an individual wished to be taken out of the Environment once in, there was a lighting system connected to a main switch in the entrance office. An intercom was set up to monitor all areas of the Environment and the lights could be turned on at short notice. As well, with the use of the intercom, any individual could be talked to or located and guided out through the nearest maintainance hatch and fire exit. In case of fire, the lights could be turned on revealing a series of clearly marked exits as well as a number of small fire extinguishers.