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OBSERVATIONS ON ACTIVE TOUCH[1]

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Active touch refers to what is ordinarily called *touching*. This ought to be distingushed from passive touch, or *being touched*. In one case the impression on the skin is brought about by the perceiver himself and in the other case by some outside agency. The difference is very important for the individual but it has not been emphasized in sensory psychology, and particularly not in the experimental literature.

Active touch is an exploratory rather than a merely receptive sense. When a person touches something with his fingers he produces the stimulation as it were. More exactly, variations in skin stimulation are caused by variation in his motor activity. What happens at his fingers depends on the movements that he makes—and also, of course, on the object that he touches. Such movements are not the ordinary kind usually thought of as responses. They do not modify the environment but only the stimuli coming from the environment. Presumably they enhance some features of the potential stimulation and reduce others. They are exploratory instead of performatory. In this respect, these touching movements of the fingers are like the movements of the eyes. In fact, active touch can be termed *tactile scanning,* by analogy with ocular scanning.

By means of active touch a great many properties of the adjacent environment can be perceived in the absence of vision. The blind must depend on it for most of their information about the world (Revesz, 1950). Nevertheless, despite its importance, the "sense of touch" (Boring, 1942, Ch. 13; Geldard, 1953, Ch. 9–12) has been studied by sensory physiologists only as a passive or receptive channel. It is treated as a part of cutaneous sensitivity. The sensitivity of the skin, which includes temperature and pain as well as touch, can be most easily investigated by the applying of stimuli to the cutaneous surface. At a perceptual level, Geldard (1957) has applied multiple stimuli to the skin and has thereby demonstrated some of the various "messages" that the skin will transmit but he is nevertheless concerned with a mosaic of receptors, not an exploratory organ. Katz (1925) and Revesz (1950) have argued, however, that the *hand* is a kind of sense organ as distinguished from the skin of the hand. Katz began the description of tactual experience as it occurs in life, and performed experiments on

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some of the remarkable discriminations that are possible. Revesz, observing the performances of the blind, proposed an unrecognized mode of experience called *haptics* which goes beyond the classical modalities of touch and kinesthesis. His interest is in philosophy and esthetics. These two seem to be almost the only investigators who have given much thought to what is here called active touch. Their work has not been followed up by experimenters and the term itself has never been widely used, perhaps because it does not fit with the established ideas of what constitutes a sense.

The relation of touch to kinesthesis. It seems to have been assumed by psychologists that active touch is simply a blend of two modes of sensation, kinesthesis and touch proper. That is, touching merely combines the data from the feeling of movement and the feeling of contact, the two sensations being fused into one experience. This assumption, however, can be criticized. First, it fails to take account of the purposive character of touching and, second, it fails to emphasize the multiplicity of so-called kinesthesis.

The first objection is that the act of touching or feeling is a search for stimulation or, more exactly, an effort to obtain the kind of stimulation which yields a perception of what is being touched. When one explores anything with his hand, the movements of the fingers are purposive. An organ of the body is being adjusted for the registering of information. The limbs and extremities are, of course, motor organs as well as sensing organs, whereas the eyes are only sense organs, but the function of motor performance can be subordinated to the function of exploratory adjustment in the case of the limbs.

Behavior theorists have recently been emphasizing the importance of what is variously called "feedback" from responses, or self-produced stimulation, or proprioception in general. They recognize that such inputs are necessary for the purposive control or steering of behavior. What they have not recognized is that some of the stimulation produced by responses yields objective information as well as subjective. The stimulation produced by sense-organ adjustment is of this sort. In active touch, as will later be suggested, the flow of stimulation contains two components, one *exterospecific* and one *propriospecific*. But these components are not the traditional sensations of touch and kinesthesis respectively. The hypothesis will be advanced that the purpose of the exploratory movements of the hand is to isolate and enhance the component of stimulation which specifies the shape and other characteristics of the object being touched.

A second objection is that the term kinesthesis itself means different things and should not continue to imply the existence of a unitary sense. Historically the word refers to movement of the body, and originally meant the "muscle sense." But it is known that there is sensitivity to the position of the body and of all its members relative to one another. This is an articular sense, not a muscle sense, and the joints yield information about joint position as well as joint rotation (Goldscheider, 1898). Probably there is no "sense" of muscle contraction as such, the joint initiating the spatial information and the muscle spindles having only reflex coordinating functions (Rose & Mountcastle, 1959). There is sensitivity for the upright posture of the head, the linear and angular accelerations of the head, and a general "sense" of the equilibrium of the body. There is sensitivity of some kind for the force exerted by an individual, whether or not this is accompanied by hypothetical "feelings of innervation" (Boring, 1942, Ch. 14). There is also, of course, *visual* sensitivity to the changes of position of one's body in space. And there is proprioception in general, however this may be defined, as well as somaesthesia.

The single term "kinesthesis" cannot carry the burden of all the meanings that have been added to its original meaning. It fails to do justice to different inputs, to different combinations of these inputs, and to different functions of these combinations.

Types and subtypes of anatomical receptors involved in active touch. Passive touch involves only the excitation of receptors in the skin and its underlying tissue, although the patterns may be elaborate. But active touch involves the concomitant excitation of receptors in the joints and tendons along with new and changing patterns in the skin. Moreover, when the hand is feeling an object, the movement or angle of each joint from the first phalanx of each finger up to the shoulder and the backbone makes its contribution. And these inputs occur relative to a continuous input from the vestibular organs, along with the cutaneous input from contact with the ground. Presumably the feeling of an object by the hand involves the feeling of the position of the fingers, hand, arm, body, and even the head relative to gravity, all being integrated in some hierarchy of positional information.

The total flux of stimulation is enormously complex, but lawful modes of combination occur. Presumably the modes of combination of these inputs specify the difference between touching and being touched. Also certain special combinations probably carry information about the *object* being touched. In short, the so-called sense of touch as it is most often employed by using the hands involves the play of inputs coming from the whole skeleto-muscular system. Whether it is one sense or many is therefore a matter of dispute. It depends on what one wishes to call a sense. There is no single organ or structure analogous to an ear or an eye. There is no unique quality of sensation analogous to warm, cold, pain, sour, sweet, or red. Active touch does not fulfill the supposed criteria for a single sense modality. Nevertheless it provides a quite definite channel of information about the external environment. It is a type of perception that is isolable from vision, audition, taste, and smell, and it needs to be studied in its own right.

Mechanics of cutaneous stimulation, proximal and distal. The literal or proximal stimulus for touch, the immediate cause, is some sort of deformation of the skin, not necessarily a simple depression of the surface as by a tactile "stimulator," but almost any deformation of the elastic tissue. Pulling on a thread glued to the skin is just as effective a stimulus as pushing it in. The stimulus has to be a change in time, that is, a motion of the skin. Since the work of Nafe and Wagoner (1941) it has been suspected that whenever the skin becomes absolutely motionless even in some abnormal conformation, the receptors cease firing and the stimulus becomes ineffective. Outside of the laboratory this situation would be rare. A precisely constant pressure of an object relative to the skin would not occur, if only by reason of tremor or body sway.

The cause of elastic change of the skin's surface can be almost any mechanical event. Some work must be done, even if slight, but the actual mechanical happenings are so various and complex that the textbooks of mechanics do not begin to describe them. A common event is impact with a solid substance, but a puff of air or a drop of water will do as well. In hairy regions of the skin, even the slightest bending of a hair gives a stimulus. Some of the types of mechanical events that stimulate the skin, in terms of everyday physics, may be exemplified as follows.

1. Brief events: pressure, push, slap, pat, tap, prick. Note that these vary in area as well as in duration.
2. Prolonged events without displacement: vibration, stretching, kneading, pinching.
3. Prolonged events with displacement: scratching, scraping, rubbing, sliding, brushing, rolling. Note that these moving deformations vary in the degree of friction between the two surfaces, and also in the degree of lateral stretching of the skin as well as the degree of vertical depression.

These are relatively large scale events as compared to the micro-events that excite the actual end-organs imbedded in the tissue. But the latter are also mechanically complex. The ways in which mechanoreceptors are made to fire nervous impulses need not be considered here. The facts, so far as they are known, are to be found in the physiological literature.

The external causes of these mechanical events, the sources of potential cutaneous stimulation, are the objects and surfaces of the environment. They are at the distal end of a sequence that leads to the excitation of nerve cells. An objective surface of some kind and the cutaneous surface must "touch," either by movement of an object with reference to the stationary skin or by movement of the skin with reference to a stationary object.

Contact with the substratum. The "sense of touch" is not ordinarily thought to include the feeling of cutaneous contact with the earth. Nevertheless, the upward pressure of the surface of support on some part of the body provides, for every terrestrial animal, a constant background of stimulation. It is covariant with the continuous input of the statocyst receptors of the inner ear already mentioned. Together they provide what the ordinary person calls the "sense of support." The axis of gravity and the plane of the ground provide the basic frame of reference for tactual space perception. Active touch, as will appear, yields clear perceptions of environmental space in the absence of vision.

The touching of the substratum is neither active nor passive touch as defined above, i.e., neither the touching of a stationary object nor being touched by a moving object. It is instead a means of registering the stable environment with reference to which *both* the movements of one's body and the motions of objects occur.

OBSERVATIONS OF THE ACT OF TOUCHING [2]

In the simple experiments to be described, vision was always excluded. This was usually accomplished by having the seated observer put both hands under a cloth curtain at the front of a table, not by blindfolding him, or working in darkness. His manual activity could thus be observed.

When an object of any sort is placed in the hand of the observer or when

[2] The collaborators in this work were Susan Stanley, Lewis Greenberg, and James Caviness. The report has profited from a critical reading by Jesse Smith.

his hand is placed on it, the following facts can be noted. He tends to bring the other hand to the object if allowed to do so. He tends strongly to curve his fingers around the object if permitted. He tends to move his fingers over the object in complex ways. Some of these are: tracing movements with one fingertip or several fingertips, opposition of the thumb and other fingers, and rubbing, grasping, or pressing movements of the fingers. Finally, he tends to name the object if he can do so, or to compare it with a familiar object if he cannot. Nonsense objects are almost necessary for such observations since the observer does not persist after recognizing something.

The observer seems to be trying to obtain mechanical events at the skin at various places in various combinations. The movements by which he obtains them do not ever seem to be twice the same, but they are not aimless. If the hand is conceived as a sense organ, he seems to be adjusting it. He appears to be searching for stimulus information.

So much for the manual activity. Reports of experience during active touch can also be obtained. They tend to be radically different from reports of experience during passive touch. The following facts, noted by the writer, are confirmed by other observers in this experiment, or are consistent with earlier observations.

Unity of the phenomenal object. When feeling a single object with two fingers, only one object is perceived although two separated cutaneous pressures occur. The separate "local signs" are not noticed. This holds true not only for finger-thumb opposition but also for other combinations of fingers. The unitary perception occurs when all five fingers are applied to an object, and even when two separate hands are applied to the object. In fact, 10 different digital pressures all at the same time yield a wholly unified experience. There are some limitations on this unity, as can be observed with Aristotle's illusion when a pencil is held between crossed fingers, but even then it is very hard to overcome, by the writer's introspection. This fact needs further investigation.

Stability of the phenomenal object. When sliding the skin over a corner or protuberance of an object, the displacement of the cutaneous pressure, the "tactile motion," cannot usually be noticed. The object seems to remain stationary even though the impression moves relative to the skin. Not only the object but also the whole space of the table, chair, floor, and room is felt as perfectly stable. This phenomenon has been studied in an experiment reported in the next section.

Rigidity or plasticity of the phenomenal object. When pressing a finger on a rigid surface or squeezing an object with the hand, it is difficult to notice the increase of intensity of cutaneous sensation; instead the observer is primarily aware of the substance and its resistance. Likewise, when pressing or squeezing a nonrigid object (a lump of modeling clay, a rubber ball, a handful of cloth) the observer is aware of the yieldingness, elasticity, or softness of the substance, not of the (very different) intensity of the back pressure on the skin. This fact deserves further study. Presumably the degree of force exerted is being registered by the joint-and-tendon receptors and the resulting degree of skin-pressure is being registered by the cutaneous and deep-tissue receptors, but the intensities are not experienced as such. Perhaps it is the *relation* between these different intensities that is registered. The proportion of one to the other, and the relative temporal buildup of these two, are different for rigid and for nonrigid objects. A possible hypothesis is that proportion and buildup are registered by the receptive system when it is operating in an exploratory fashion. They constitute stimulus-information about the object, whereas the intensities as such do not.

Shape of the phenomenal object. When the corners, edges, or other protuberances of a strange object are being felt, one can distinguish the pattern which these make to one another but one cannot distinguish the pattern which the various cutaneous pressures make to one another. One perceives the object-form but not the skin-form. The latter is, in fact, continually changing as the fingers move in various ways. It is almost completely unreportable, whereas the pattern of physical corners and edges seems to emerge in experience. This fact is extremely interesting and two experiments arising from it will later be reported.

Discussion. For all four of the perceptions described above, it is possible to perform a sort of control experiment substituting passive touch for active touch. The experiences aroused are quite different. For the first, two different pressures applied to two different loci on the skin of the hand yield two sensory impressions, not one. For the second, translocation of the stimulus over the skin yields a perception of something moving. For the third, increase in the intensity of skin-depression is reportable as such. For the fourth, a pattern of simultaneous pressures is detectable when it is pushed into the passive skin. In all cases the sensory impressions can be aroused by an experimenter, but when the observer himself brings them about they seem to disappear.

Different Ways of Perceiving Motion of an Object by Touch

The objects of tactile perception considered so far have been essentially stationary, either resting on a table top or in one or both hands. How can the motion of an object be perceived, and how can this be distinguished from the motion of the hand relative to the object?

Translatory motion over the skin. The simplest case is that when the observer's hand lies passively supported behind the curtain and an object of some sort is made to trace a path of pressure across the skin. The path, direction, and speed of motion could always be described relative to the skin. They could equally well be described relative to the table top and to the space of the room.

For these observations various instruments were used, a sharpened point, a blade, a rounded stylus, a soft brush, and the wheel of a map-measuring instrument. The observer could identify the kind of instrument used without ever seeing it. He distinguished between brushing, rolling, and rubbing, and also between the blade, the point, and the rounded protuberance. There was always an objective component in the experience.

Friction at a single area of the skin. When a string is stretched over a region of the skin and then pulled in one or the other direction, the velocity is perceived. In order to study this phenomenon further, a yardstick sliding in a track was constructed on the table top, on which the observer could lower a fingertip, the hand being supported on an adjacent motionless block of wood. The yardstick could be moved laterally by a rack-and-pinion gear attached to a silent variable-speed clutch and a constant speed motor. When the observer lowered his finger on this surface, he could feel the stick and report whether or not it was objectively moving, and the direction of the movement. He could estimate the speed and the amount of displacement over a given interval of time with some success. A speed of less than 1 mm. per second was detectable under these conditions. In this case there was no path of movement over the skin but only directional stretching and friction of a single patch of skin. There was no change in the "local sign" of stimulated points. Nevertheless the perception was that of a moving object.

Passive rotation of the joints of the limb. With the apparatus described, when the wooden support for the hand was removed and the fingertip was allowed to rest on the yardstick, the observer could still report accurately whether or not it moved, the direction of movement, its speed and the amount of displacement. Such results are predictable from those of Goldscheider (1898, described in Geldard, 1953, Ch. 12. See also James, 1890, Ch. 20). Only the receptors in the joints of the limb are stimulated. In the situation described, the joints of the finger, wrist, elbow, and perhaps the shoulder are all involved. The perception, as before, was that of a moving object. A naive observer would assert that he perceived the movement "by touch" although in actual fact the only cutaneous stimulation was a deformation of the skin of the finger, unchanged except by reason of slight tremor. The whole forearm was invisible behind the curtain.

Evidently three anatomically different receptive systems, two in the skin and one in the joints, can be functionally equivalent for the experience of objective motion when they are passively stimulated by an external agency.

Friction on the skin combined with active movement of the arm. In active touch, one runs the fingers over the protuberances of the object. In this operation friction on the skin and rotation of the joints are combined, together with voluntary contraction of the muscles. But in this case what one experiences is the movement of the hand, not an illusory motion of the object. We wished to make an even stronger test of this fact of phenomenal stability. Hence the apparatus was used to determine whether the motion of the yardstick, or its stability, could be detected while the finger was being actively moved along its surface, i.e., rubbed over it.

The fingertip of the observer was placed at one end of the stick and he was required to move his hand slowly either toward the right or the left. During this active movement the object was, on occasion, put into slow motion in the same or the opposite direction. It turned out that the existence, direction, and approximate speed of the object could be perceived, as before. Introspectively, there appeared to be a distinct separation of the movement of the hand from the motion of the stick. Both of these separate displacements were perceived relative to the space of the invisible table top hidden behind the curtain, this being connected to the visible and tangible floor and chair. One can only conclude that the propriospecific component in the total stimulus input had been separated from the exterospecific component.

Discussion. The ability of an individual to distinguish objective motion from subjective movement is a theoretical puzzle of long standing in visual perception (Gibson, 1954). A movement of the eyes is never confused with a motion of an object even though both involve what seems to be the same retinal stimulus. Evidently the problem is analogous in tactual perception, although the solution can hardly be quite the same. When an individual actively moves his hand relative to his body, and thus relative to gravity and the surface of support, he is in contact with the earth as well as with the object, whether it be moving or motionless. A receptive system of higher order is excited during activity than the system during passivity. Hence the stimuli which have one excitatory capacity for a receptive subsystem in passive touch will have a different excitatory capacity in active touch—a different specificity. The relations between stimulation of the subsystems become significant. A lawful covariation of the inputs carries information different from that carried by isolation of the inputs, and yields different perceptions. Johannes Müller's law of the specific conscious quality of each excited nerve is evidently much too simple.

To lump one set of receptive systems together as *touch* and another as *kinesthesis,* then, is to obscure the function of the systems in combination. If both had their own unique quality of experience there would be some justification for the traditional belief in separate senses, but they do not. Anatomically different receptors may serve the same function and arouse the same experience, and, moreover, may serve different functions in different combinations. It might be better to drop the term sense and speak instead of "esthesic systems."

It should be noted that nothing has been asserted about *performatory* movements of the hand, as when an object is relocated or a tool is wielded. The perception is then subsidiary to action and the receptive systems take on still another function not here considered.

PERCEPTION OF THE TEXTURE, SUBSTANCE, AND SHAPE OF AN OBJECT BY TOUCH

Katz (1925) showed that the texture of a solid substance could be perceived by touch if there was relative motion between the surface and the skin. Ordinarily this means rubbing the fingers over the surface; perpendicular motion was very much less effective than lateral motion. A substance could be identified by its texture; the observers could distinguish a dozen kinds of paper including blotting paper, wrapping paper, and writing paper. Katz also demonstrated the perceptibility of other physical properties of a surface besides rough-smooth, including soft-hard, and various kinds of plasticity, elasticity, or viscosity.

Katz was primarily interested in the fine structure of the surface of an object, and the substance of which it was composed. He had less to say about the *shape* of a substance, which is perhaps the main characteristic of an object. Active touch, however, is an excellent channel of spatial information in that the arrangement of surfaces is readily picked up. The solid geometry of things is best got by feeling them. A number of observations illustrate this assertion.

Curvature as against planarity of a surface. Departure of a surface from the plane can be judged by an observer either by holding his hand against the surface or by running his fingers over it. The opposite qualities of convexity and concavity are immediately given. On a smaller scale, protuberances or indentations on a plane surface are identified, and this acuity is taken advantage of in Braille. Moreover a surface with positive curvature on one axis and negative curvature on the other is perceived as saddle-shaped.

The accuracy of all these judgments could be but has not been measured.

Slant of a surface with respect to gravity. When the observer's hand is placed on an adjustable palm-board outside the field of view, it is found that he can judge its slant with precision. He can nullify this slant and adjust it to a normal plane. This holds for all three planes of space, the frontal, the saggital, and the horizontal. Variable and constant errors for settings to the normal plane seldom exceed 2°–3°. Furthermore, the slant of a surface that is visible only can be equated to the slant of a surface that is tangible only. The cross-modal matching of slant is accepted as natural by all observers, and the manual judgment can be used as a criterion of visual perception (Gibson, 1950).

When the palm-board is maintained at a slant from the frontal upright plane for some time, "normalization" seems to occur, and a negative aftereffect ensues. In this respect, the tangible slant of a surface behaves like the visible slant of a surface (Bergman & Gibson, 1959).

Parallelity of two surfaces. If a pair of adjustable palm-boards is held between the two hands, behind a curtain, they can be adjusted to the parallel position with small errors. The divergence or convergence of the two planes are felt as opposite qualities of a simple spatial experience. This dimension is also susceptible to normalization; after a few minutes of feeling divergence (say) the setting accepted as parallel is found to have shifted several angular degrees toward divergence. This fact has been studied in detail (Gibson & Backlund, 1963).

Distance between two surfaces. The span of the hands holding an object between them is experienced vividly. The tangible extent can be matched with a visible extent or vice versa. Likewise the distance between the thumb and one or more of the opposable fingers is perceived, and is accurately matched with the width of a visible object. According to Kelvin (1954) the cross-modal size comparison is made with no less accuracy than either unimodal size comparison alone. The finger-span of one hand can be immediately felt as equal or unequal to the finger-span of the other hand, and this comparison has been utilized by Köhler and Dinnerstein (1949) in studying a phenomenon they termed the kinesthetic figural aftereffect. In the many repetitions of this experiment the equivalence of the two hands for perceiving a spatial extent seems to have been taken for granted without its being studied in its own right.

Plane-angle, or edge of a surface. To exploratory touch, a junction of two planes constituting an edge is very noticeable. The angle is perceptible as varying from sharp to dull. At the extreme case of a knife-edge, sharpness is more accurately judged by touch than by vision.

Edge-angle, or corner of a surface. Where two edges intersect, or where three or more planes adjoin, a corner is produced. In the case when the angles of a convex corner are acute it is apt to be called a point. Corners and edges seem to be the main identifying feature of many objects. The fingers appear to seek them out and explore them.

Discussion. Planarity, curvature, slant, parallelity, span, edge, and corner may be conceived as variables of solid geometry. They are all perceptible to active touch, and appear to be simple qualities of experience. Since they are amenable to physical measurement, psychophysical experiments would be possible, but few have been performed.

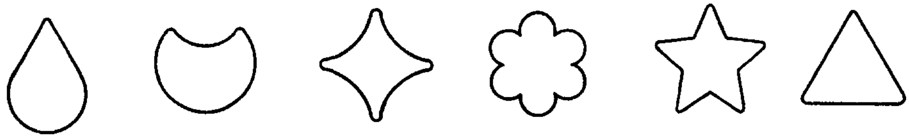

FIG. 1. The six forms to be identified by touch.

TACTUAL FORM PERCEPTION: A COMPARISON OF ACTIVE AND PASSIVE TOUCH

The study of the perception of objects by touch has been largely confined to investigations of two dimensional form or pattern on the skin, with passive stimulation (e.g., Zigler & Barrett, 1927). They are in the tradition of experiments on cutaneous localization and the two point threshold, the assumption being that the skin is first of all a receptor mosaic with patterns of excitation being projected to the brain. The forms pressed into the skin were called *solid* or *outline* depending on whether the edges of a surface or the edges of a metal strip were used; the latter gave better discrimination. The identification of forms in this manner is not very accurate, and there is some uncertainty even about circles, squares, and triangles.

Everyone knows, however, that a better way to perceive a thing of this sort is to run one's fingers over the edges. The fact is often taught to beginning students, and is even demonstrated in laboratory exercises (Langfeld & Allport, 1916) but a search of the experimental literature failed to locate its source. Lashley (1951), for example, asserts as if it were common knowledge that the same shape which can scarcely be distinguished with passive touch "can readily be distinguished when explored by tactile scanning" (p. 128). An experiment was performed to quantify this assertion, since no authority for it could be found. Each of a set of tactual forms had to be matched to its visual equivalent. The accuracy with which this could be done was compared when the form was pressed into the palm of the hand and when it was held above the palm and explored by the fingertips.

Method

The sources of stimulation were bent metal strips with handles, the edges having the forms shown in Figure 1. They were in fact small "cookie cutters" with a mean diameter of 1 inch. The six used were chosen for being mutually different in about the same degree. No two had the same number of corners or points. Each subject was shown the set of stimulators and the equivalent set of numbered drawings hung on the curtain in front of him. He then put his hand palm up on the table behind the curtain and was either touched by the object or was allowed to touch it for several seconds. In the one condition, he was instructed to open and relax his hand; in the other to cup the fingers upward and prepare to feel the edges. He then had to identify the form by number. The stimulator was not necessarily presented in the same orientation as the drawing.

The six forms were presented five times each (but the subject was told not to expect equal frequencies) and under two conditions, making a total of 60 trials. The order was random. No preliminary practice or knowledge of results was given. Twenty subjects were tested.

Results. A chance level of judgments would be 1/6 or 16.7%. For passive touch the mean frequency of correct matches was 49%. For active touch the mean frequency was 95%. The difference is significant.

In the active condition, the subject was permitted to explore the edges in any manner he chose. One style was to use all five fingertips simultaneously, another was to move the tip of the index finger around the edge, and others were intermediate. All subjects, however, actively moved their fingers and thus obtained relative motions between the skin and the object.

In the passive condition, the form was pressed down on the palm by manual action of the experimenters so that a certain amount of unsteadiness was inevitable. When subsequently, with 20 different subjects, a mechanical lever system was used to apply the stimulation the mean frequency of correct matches fell to 29%.

Some subjects reported that they tried to count the number of corners or points they could feel, and that this was easier with the active than with the passive condition.

Discussion. A common belief has been verified but, in a sense, no claim can be made for the conclusiveness of the comparison. It could be argued that the fingertips are more "sensitive" than the palm of the hand, meaning that localization is better and the two-point threshold lower. This is true. The comparison is not very meaningful. The real point of the experiment is that tactual form perception in one meaning of that term does not depend on the pattern of local signs on the skin. If any number of fingertips from one to five can be used indifferently, the chaotic pattern of local signs resulting can hardly be the sole basis of the perception. With active touch no forms existed on the skin, but only a changing pattern of pressures. Evidently the registering of "form" by touch is not as straightforward a process as experimenters have supposed. Another experiment may help to clarify the matter.

TRANSPOSABILITY OF FORM ON THE SKIN

Gestalt theorists have emphasized the fact that a form can be moved over the retina, completely changing the set of receptors stimulated, without changing the perception. The contribution to perception of the anatomical pattern of excitation becomes a puzzle. The same is true of the skin.

Along with the experiment just described, another was carried out at the same time in order to compare passive static form perception with passive moving form perception. In these trials the "cookie cutter," instead of simply being pressed into the palm of the hand, was pressed and continually rotated clockwise and counterclockwise with a twisting motion. The same area of skin was stimulated in both cases and the same anatomical receptors were available, but in the latter case the form of stimulation changed from one instant to the next.

Judgments of the form of the object were more accurate when it was rotated than when it was not, the mean frequencies of correct matches being 72% and 49%, respectively. The difference is significant at the 2% level. To the writer's introspection, the corners of the object seemed to "stand out" better when it was twisted. In short, the form of the object seemed to become clear when the form of the skin-deformation was most unclear.

Discussion. Continuous change of the proximal stimulus with no change of the rigid object constituting the source of the stimulus is an old problem in visual perception. Why does the perception correspond to the form of the object instead of to the form of the stimulus? Evidently a quite similar problem arises for tactual perception. The paradox is even more striking, for tactual perception corresponds well to the form of the object when the stimulus is almost formless, and less well when the stimulus is a stable representation of the form of the object. A clear unchanging perception arises when the flow of sense impressions changes most.

It might be that the skin does not have as its primary function the registering of form as this has usually been conceived. Impressions of form and location relative to the skin might be quite separate from and incidental to the use of the extremities as sense organs. The informative stimuli might well be incorporated in the seemingly complex motions and transformations of the skin. There must exist relations of separation and proportion which remain invariant over time, and which are specific to the object. They do not represent the shape of the object but they specify it. The solution to the problem of object perception in touch would then be that continuous change in the proximal stimulation is accompanied by nonchange, that is, the set of invariant relations. The former is not noticed; the latter is separated out and attended to.

The role of exploratory finger movements in active touch would then be to isolate the invariants, that is, to discover the exterospecific component in the flux of stimulation. Only thus could the above paradox be resolved.

Relation between Touch and Vision

A number of similarities and differences have been noted in the course of these observations between active touch and visual perception. Many of these have been pointed out before by other observers such as Katz (1925, 1935) but a few of them have not previously been emphasized.

Surface perception. Solid surfaces are tangible and visible. This can only be because they have mechanical inertia in the first place, and because they reflect light with scattering in the second place. (A few visible surfaces such as smoke are not tangible and a few tangible surfaces such as plate glass may not be visible, but most surfaces are both.) The physical texture of a surface, the various kinds of roughness, can be observed either by vision or by touch. The color of a surface is visible only, not tangible, and consequently the pigment-texture of a surface (the differential coloring of marble or of a picture) is the same. On the other hand, if color is intangible temperature is invisible. Each sense has its special sensitivities to the properties of a surface but they also have some in common. The bark of a tree looks rough without touching it and feels rough without seeing it. The expert can identify the tree by either sense alone.

The visible array of surfaces extends for miles of course, and the tangible array only to the length of man's arm. But if surfaces determine space perception, both touch and vision are spatial senses.

Object perception. A detached solid substance with a topologically closed surface is perceptible as such to both the hands and the eyes. By virtue of physics, the eyes can encompass the closed contour of a very large object (depending on its distance) while the hands can explore only the surface of an object of limited span. The unity of the visual perception is said to be based on the "figure-ground" phenomenon, the simultaneous registering of the whole contour, whereas the unity of the tactual perception has to be based on either cutaneously separated impressions or on successive impressions. Vision is said to register only the front surface of an object while touch registers the front and the back at the same time. In these respects vision and touch seem to differ. Nevertheless these contrasts are exaggerated; succession enters into the operation of both senses. The eyes normally fixate in succession just as the fingers explore in succession. With two eyes, and by changing one's standpoint, more of an object than its front surface is perceived. As regards the unity of separated impressions from the two hands, there is a visual analogy in the unity of separated impressions from the two retinas.

Spatial properties of objects. Certain variables of the shape of a detached object, slant, curvature, edge and corner are independently visible and tangible. The equivalence of the two modes of perception for judgments of the object is such that differences got by one sense are equated to differences got by the other. The stimulus information for these cross-modal judgments, one depending on mechanical and the other on luminous energy, might seem hopelessly discrepant, but the fact is that the judgments can be made.

Whether both vision and touch can register form is an ambiguous question, as the experiments showed. The answer depends on what is meant by form. Drawings and pictures on a flat surface are sensed only by vision. The conformation of the edges of an object, however, is sensed by both vision and active touch. The tangible and visible features of things abstracted by solid geometry (slant, curvature, edge, corner) did not seem any more complex to introspection than the solely visible features of things abstracted by plane geometry (triangle, square, circle).

A new set of shapes has now been devised for the study of object-perception by active touch. They consist of ten solid sculptures, or free-forms, made of plastic, the surfaces being curved, with no planes, edges, or corners. They are intended to be felt with two hands (and are called "feelies"). Approximately one-half of each surface (the "rear") is convex; the other half (the "front") consists of six convexities with intermediate saddles or concavities. In general, there are five protuberances around a central protuberance, but no object is symmetrical, either radially or bilaterally. They cannot, therefore, be distinguished from one another by counting. Each is readily discriminated from every other by vision of the "front" surface. They are also mutually distinguishable by feeling, although with some error and hesitation for an unpracticed observer.

Replicas of the ten objects are available, made from the same molds. It is therefore possible to present one object to the hands and the same or a different object to the eyes simultaneously. Preliminary results indicate that the cross-modal matching of these novel preceptions is possible even for a naive observer, and that practice can bring about errorless judgments in all observers so far tested.

Passivity and activity in touch and vision. In passive touch the individual makes no voluntary movements. Similarly, in passive vision he makes no eye movements, which means that he must voluntarily fixate his eyes on a point specified by the experimenter. Neither state is natural to an individual. In a tactual situation, the observer will explore with his fingers unless prevented and, in a visual situation, he will explore the focussable light, fixating, accommodating, converging and pursuing. Both senses are normally active. The passive stimulation of the skin or the retina is necessary for the study of the receptor-cells in the skin or the retina, but the experiences resulting are atypical.

In active touching and looking the observer reports experiences of a quite different order. They correspond to the environment instead of to the events at the sensory surface. The experiences noted with passive stimulation can scarcely be noticed, if at all. The effective stimuli are presumably different, being relations and combinations selected from a flux of potential stimuli. Moreover, the experiences of active touching and looking are more nearly equivalent; they are more alike to introspection than those of passive touch and vision.

In general, the foregoing survey suggests that vision and touch have nothing in common *only when they are conceived as channels for pure and meaningless sensory data.* When they are conceived instead as channels for information-pickup, having active and exploratory sense organs, they have much in common. In some respects they seem to register the *same* information and to yield the *same* phenomenal experiences.

Conclusions and Summary

A series of observations, both introspective and behavioral, confirms the distinction between *touching* and *being touched.* The former is a channel for a great variety of information about the environment, but whether it should be considered one or several senses is a matter of definition. The simple formula that it consists of passive touch plus kinesthesis is insufficient. The hypothesis of two components of stimulation, one exterospecific and one propriospecific, is more promising.

Many properties of surfaces and objects can be registered by active touch. The accuracy of such judgments can be measured and formal experiments are needed. The observations suggest that the variables of solid geometry can be more profitably studied than those of form. Object constancy is characteristic of tactual perception. In several respects, tactual and visual perception are alike.

In general, experimenters have not realized that to *apply* a stimulus to an observer is not the same as for an observer to *obtain* a stimulus. Obtainable stimuli can be controlled and systematically varied, just as applied stimuli can be. Psychophysical experiments are possible for tactual perception as well as for cutaneous sensitivity if appropriate methods are devised for controlling the obtainable stimuli.

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