What utility is there in distinguishing between active and passive touch?

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Paper presented at the Psychonomic Society meeting, San Antonio, Texas, November 1984

Note: Since this paper was presented at the 1984 Psychonomics Society meeting, two publications have expressed some of the ideas presented here. The 1986 chapter by Loomis and Lederman has a section on categories of tactual perception and another on modes of touch. The essay by Loomis (1992) elaborates on the last section of this talk with its discussion of the necessity of an internal model in externalizing sensory experience (distal attribution). These two references are given at the end.

When we examine an object using the sense of touch, there is nothing in our experience that would indicate the operation of two distinct sensory subsystems, each with its own functional properties. These two subsystems are the cutaneous and kinesthetic senses. In functional terms, the cutaneous sense provides an observer with information about stimulation of the skin surface; whereas, kinesthesis provides static and dynamic information about the relative positioning of the head, torso, limbs and effectors used in touching. While J. J. Gibson acknowledged these two components of the sense of touch, he believed that analysis of the touching process in terms of them lost sight of the purposive nature of touch. In addition, he disdained the idea prevalent at the time and promoted by the then current research on cutaneous sensibility that perception was based on sensations. Rather, he believed that the perceiver seeks the invariant aspects of sensory stimulation over time and space that correspond to the properties of objects in the spatial field. Thus, he preferred to stress the function of the two subsystems working in concert. Far more important for him than the distinction between the two sensory subsystems was that between what he termed the active and passive modes of touch. This distinction has had much influence in the investigation of tactual perception. The purpose of our talk is to consider the utility in distinguishing between the two modes. In our evaluation we use a number of ideas that have expressed by others.

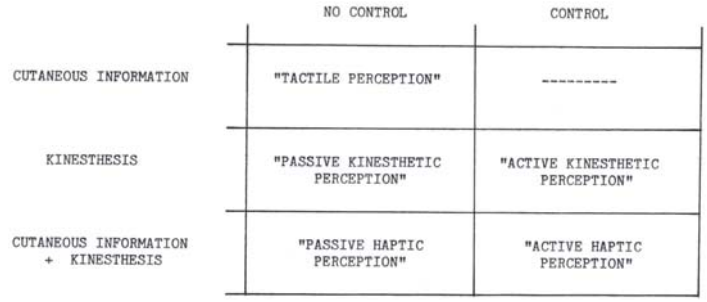
As we begin we immediately encounter a complication, for Gibson in fact did not distinguish between active and passive touch in a consistent fashion. One can identify in his writings two distinctions, which we shall refer to as the broad and narrow distinctions. First we introduce the broad distinction which is represented in the left column of the accompanying figure. In most of his writing including the discussion of his frequently cited experiment comparing the two modes, Gibson equated passive touch with what is more frequently termed "tactile perception". This is perception based solely upon stimulation of the cutaneous sense of an immobile observer. Active touch on the other hand meant purposive exploration of the stimulus field. Thus, in addition to the cutaneous information available to the passive observer, the active observer has the information provided by afferent and efferent kinesthesis as well as the ability to control the pickup of information.

	Broad	Narrow
Passive	Cutaneous information "Tactile perception"	Cutaneous information Afferent kinesthesis "Passive haptic perception"
Active	Cutaneous information Afferent kinesthesis Efferent kinesthesis Active control "Active haptic perception"	Cutaneous information Afferent kinesthesis Efferent kinesthesis Active control "Active haptic perception"

The narrow distinction represented in the right column is essentially that employed in the literatures dealing with kinesthesis, motor control, and perceptual adaptation. In a typical manipulation involving passive

touch as defined here, the observer's hand might be moved by the experimenter over the surface of a 2-dimensional pattern or 3-dimensional object. This definition of passive touch differs from the earlier definition, for the observer has information about static and dynamic posture available through afferent kinesthesis. Presumably the active observer, as before, is at an advantage over the passive observer, for he or she can control the sensing process and has the additional information provided by efference copy (or corollary discharge as it is sometimes called).

The taxonomy of tactual modes that we propose recognises three important factors, two of which we presently discuss. They are (1) the type of information available to the observer and (2) the degree of control exerted by the observer in picking up stimulus information. The accompanying figure gives labels to the tactual modes in the taxonomy defined by these first two factors. "Kinesthetic perception" is perception mediated by variations in kinesthetic information, whereas, "haptic perception" is perception mediated by both cutaneous and kinesthetic information. In connection with cutaneous sensing, it makes little sense to speak of active tactual perception based solely on cutaneous information. For this reason we leave the cell at the upper right unlabeled.



It is important to realize that the control factor is conceptually separate from the availability of information factor, for one can conceive of the following experiment. After one observer has examined, say, a two-dimensional pattern using active scanning, a passive observer is presented with precisely the same scanning information but with the sequence of scans randomly reordered. The reason that the active observer might be expected to perform better is that he or she would search for information to confirm or disconfirm the concurrent hypotheses about the patterns; whereas, the passive observer would receive information not germane to his or her concurrent hypotheses. It is true that even in such an experiment the efferent kinesthesis is still experimentally confounded with the observer's control over sensing. Some investigators such as Landrigan and Forsythe (1974) have suggested distinguishing between the control of movement planning and the control of movement production, but it has not proven easy to operationalize these two separate distinctions in any natural way.

There are basically two classes of evidence upon which the active-passive distinction has been brought to bear: facts of tactual performance and phenomenological observations. In connection with the latter, it was observed by David Katz that descriptions of perceptual experience are expressed largely in terms of tactile sensations when objects are impressed upon the skin of a passive observer; whereas, the descriptions are expressed in terms of objects when the observer actively explores them. Observations such as these have been used on occasion to argue that studying tactile perception is irrelevant to the goal of understanding haptic object perception; clearly this criticism makes no sense, for phenomenological observations have no necessary bearing on the performance obtained in a given tactual task. In addition to these two types of evidence, we note that the discussion of tactual modes comes up in several different contexts. The first is ordinary touching where the sensing surface of the body comes essentially into direct contact with the stimuli of interest. The second is tactual exploration using tools that extend the sense of touch. One obvious example is feeling an object with a rigid probe. A more exotic example would be using a teleoperator system with touch sensing to "feel" objects perhaps miles away. Lastly, there is touch using prosthetic devices, either limb prostheses or sensory aids like the Optacon which permit one to feel patterns that are not otherwise tangible.

Is there any utility in the broad distinction proposed by Gibson? Although this and other ideas of Gibson have been extremely valuable in causing researchers to think about touch in terms other than receptor excitation and tactile sensations, we question whether the broad distinction by itself has much utility as a scientific idea. The problem is that it is much too broad to be diagnostic about the reasons for variation in performance in tactual tasks. If one finds that active touch is better than passive touch on a given task, the reason for the difference in performance can be ascribed either to the availability of kinesthetic information or to the observer's control over sensing. Only in those cases where performance is essentially the same in the two conditions is anything definitive learned.

Table 1 summarizes many of the studies that have investigated performance in both active and passive conditions; in all of the studies except several at the bottom, the distinction being considered was the broader one. The table indicates whether cutaneous information was used in performance of the task, and if so, the body locus and the tactile mode of stimulation. These two variables are included, for both have potent effects on tactile pattern perception. The table also indicates whether kinesthetic information was available, and if so, which body part was moved. Finally it indicates whether the observer had control over sensing and gives the basic result of the comparison.

Task	Study	Condition	Cutaneous Information?	Sensing Surface	Tactile Mode	Kinesthetic Information?	Moving Body Part	Active/ Passive	Result
Estimation of Texture Roughness	Lederman 1981,1983	1	Yes	Finger	Moving	No	--	Passive	1=2
		2	Yes	Finger	Moving	Yes	Hand	Active	
Discrimination of Texture Roughness	Lamb, 1983	1	Yes	Finger	Moving	No	--	Passive	1=2
		2	Yes	Finger	Moving	Yes	Hand	Active	
Braille Reading	Grunwald, 1966	1	Yes	Fingers	Moving	No	--	Passive	1=2
	Day & Dickinson unpublished	2	Yes	Fingers	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Gibson, 1962	1	Yes	Palm	Static	No	--	Passive	1<2<3
		2	Yes	Palm	Static	No	--	Passive	
		3	Yes	Fingers	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Schwartz, Perey & Azulay, 1975	1	Yes	Palm	Static	No	--	Passive	1<2=3
		2	Yes	Finger	Moving	No	--	Passive	
		3	Yes	Finger	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Cronin, 1977	1	Yes	Palm	Static	No	--	Passive	1<2=3
		2	Yes	Palm	Moving	No	--	Passive	
		3	Yes	Palm	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Heller & Meyers 1983	1	Yes	Palm	Static	No	--	Passive	1=2<3
		2	Yes	Palm	Moving	No	--	Passive	
		3	Yes	Palm	Moving	Yes	Hand	Active	
2-D Pattern Reproduction	Heller, 1980 (unlimited exploration time)	1	Yes	Palm	Static	No	--	Passive	1<2<3<4
		2	Yes	Palm	Moving	No	--	Passive	
		3	Yes	Palm	Moving	Yes	Hand	Active	
		4	Yes	Fingers	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Heller, 1984	1	Yes	Fingers	Static	No	--	Passive	1=2<3
		2	Yes	Fingers	Moving	No	--	Passive	
		3	Yes	Fingers	Moving	Yes	Hand	Active	
2-D Pattern Recognition	Katori & Natori 1967 (Exp. 1)	1	Yes	Finger	Moving	No	--	Passive	1<2
		2	Yes	Finger	Moving	Yes	Hand/Finger	Active	
2-D Pattern Recognition	Magee & Kennedy 1980 (Exp. 2)	1	Yes	Finger	Moving	Yes	Hand/Finger	Passive	1>2
		2	Yes	Finger	Moving	Yes	Hand/Finger	Active	
2-D Pattern Recognition	Magee & Kennedy 1980 (Exp. 3)	1	Yes	Finger	Moving	No	--	Passive	1<2
		2	No	--	--	Yes	Hand/Finger	Passive	
2-D Pattern Reproduction	Bairstow & Laszlo, 1978	1	No	--	--	Yes	Arm/Hand	Passive	1=2
		2	No	--	--	Yes	Arm/Hand	Active	
2-D Pattern Tracking	Bairstow & Laszlo, 1979	1	No	--	--	Yes	Arm/Hand	Passive	1<2
		2	No	--	--	Yes	Arm/Hand	Active	

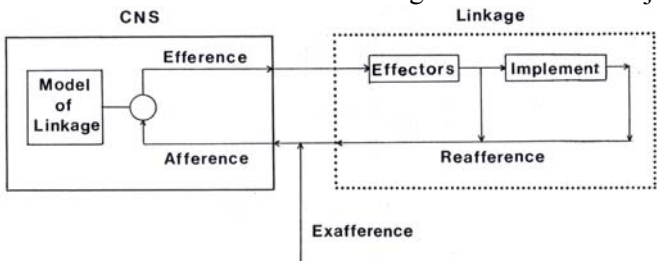
The experiments on estimation and discrimination of roughness clearly show that roughness perception depends only upon cutaneous information. This means that kinesthetic information is unimportant. This is not a patently obvious result, for in its absence, one could easily hypothesize that kinesthesis provides information about the frictional force impeding movement of the finger as it moves over a surface.

Similarly, the experiments on braille reading indicate that active control and kinesthetic information are quite unimportant for the sensing of braille characters. Similarly, anecdotal evidence suggests that the reading of print using the Optacon is no better when the reader has control of the camera than when the reader passively receives text presented by computer.

The most interesting studies to date dealing with the active-passive distinction involve the perception of two-dimensional raised patterns, usually of a size to require significant movement of the fingers, hands, and sometimes arms. The first of these was reported by Gibson. Because he confounded body locus and the type of tactile stimulation with the active-passive manipulation, several of the subsequent studies have replicated this study while attempting to better control for tactile mode and body locus. In most of the 2-dimensional pattern recognition studies, active touch has resulted in superior performance than passive touch, but in all such studies the passive touch condition involved only cutaneous stimulation. Thus one does not know if the superiority of active touch resulted from the control over sensing or the availability of kinesthetic information. Only in the first study by Magee and Kennedy and the two by Bairstow and Laszlo was the comparison between active and passive conditions, in both of which afferent kinesthesis was available. With the availability of afferent kinesthetic information controlled for, it is apparent that quite different result obtain. Taken together the two studies of Bairstow and Laszlo indicate little difference in performance between the active and passive touch. The finding of Magee and Kennedy's first study is even more decisive, for the condition in which the subject's finger was passively moved along the pattern's raised contour resulted in significantly more correct identifications than did the condition in which the observer actively tracked the contour. Based on the evidence so far, there seems to be no advantage in permitting the observer to control the pickup of information. Perhaps experiments involving the perception of 3-dimensional objects or complex two-dimensional patterns will show some superiority of active sensing. For the time being, the narrow distinction seems of sufficient potential value to be retained in our taxonomy of tactual perception.

The third important factor defining the taxonomy we are proposing is best expressed in terms of the next figure. It applies only in the case of active sensing.

The figure represents the central nervous system of an observer as the controller of a system external to it. The overall system is referred to here as the linkage, for it links the observer's efferent commands to the effectors with the reafference coming in through the senses. At a minimum this linkage would consist of just the observer's effectors, such as the hand. A slightly more complex linkage would consist of the effectors and a single object being manipulated. Still a more complex linkage would be some implement used by the observer to extend the tactual exploration beyond the range of ordinary touch. Skillful manipulation comes about as an internal model of the linkage develops.



Referring back to our earlier discussion of phenomenology, recall that perceptual experience generally is in terms of external objects when the observer is active, whereas experience is referred to events at the phenomenal surface of the body when the observer is passive. This diagram helps to make the point that the externalization of experience (distality of awareness) depends upon something other than whether sensing is active. If the observer has not internalized the linkage, then manipulation involves allocating much attention to control of the linkage with consequent awareness of more proximal levels of the linkage, such as the boundary between effector and implement. On the other hand, if the observer has a fully internalized model of the linkage, then little or no attention need be allocated to controlling the linkage. The consequence is that the system, which generally would be the object or objects being manipulated. It is this awareness of the phenomenal object corresponding to the physical object at the most distal point in the linkage that has been termed telepresence in the context of teleoperator systems by Minsky and by Corker, Mishkin, and Lyman. Another way of expressing telepresence (or "focal awareness of the distal object"-- Polanyi, 1962) it is to say that the linkage has become phenomenally transparent.

In summary we have questioned the utility of Gibson's broad distinction between active and passive touch and have shown that, as yet, there is little evidence that in the narrow sense active touch is better than passive touch. Retaining the narrow distinction, we propose a taxonomy of tactual modes in terms of this distinction and two other factors: type of information available to the observer and the transparency of the linkage between efference and reafference.

Publications presenting some of the ideas of this talk:

Loomis, J. M. & Lederman, S. J. (1986) Tactual perception. In Boff, K., Kaufman, L., & Thomas, J. (Eds.), *Handbook of Perception and Human Performance*, Volume II, Chapt. 31.

Loomis, J. M. (1992) Distal attribution and presence. *Presence: Teleoperators and Virtual Environments*, 1, 113-119.