Distal Attribution and Presence

1 Introduction

The perceptual world created by our senses and nervous system is so functional a representation of the physical world that most people live out their lives without ever suspecting that contact with the physical world is mediate; moreover, the functionality of perception impedes many reflective individuals from appreciating the insights about perception that derive from philosophical inquiry. Oddly enough, the newly developing technology of teleoperator and virtual displays is having the unexpected effect of promoting such insight, for the impression of being in the remote or simulated environment experienced by the user of such systems can be so compelling as to force a user to question the assumption that the physical and perceptual worlds are one and the same.

We begin by considering a person using a teleoperator system. In such a system, the user controls a slave device or robot that is typically situated at some remote location. In some teleoperator designs, the slave robot bears a strong resemblance to the human, both in terms of the functional properties of the torso, limbs, and effectors and the sensors for photic and acoustic energy. Thus, the limbs and effectors of the slave are moved in concert with those of the human user while video cameras and microphones mounted on the robot head provide signals to video displays and headphones worn by the human. With such highly anthropomorphic designs, the user often reports a compelling impression of "telepresence" or "remote presence"—of being at the location occupied by the slave device (Corker, Mishkin, & Lyman, 1980; Minsky, 1980). Similarly, virtual displays that provide the user with visual, auditory, and even haptic input, all generated by computer in response to movement of the user's body, head, and limbs, are said to convey an impression of "presence" within the simulated environment (Rheingold, 1991).

Although "presence" is just now becoming a familiar phenomenon in connection with teleoperators and virtual displays, a closely related phenomenon has received attention in the past by both philosophers and perceptionists (Epstein, Hughes, Schneider, & Bach-y-Rita, 1986; Gibson, 1962, 1966; Katz, 1925/1989; Koffka, 1935; Lotze, 1894; Polanyi, 1964, 1966; von Fieandt, 1966; Weber 1846/1978; White, 1970; White, Saunders, Scadden, Bach-y-Rita, & Collins, 1970). The phenomenon, which has been referred to as "externalization" or "distal attribution," is this—that most of our perceptual experience, though originating with stimulation of our sense organs, is referred to external space beyond the limits of the sensory organs.

2 Phenomenal and Physical Worlds

To avoid a lapse into naive realism whereby perceptual contents are conceived as being "projected" into the physical surroundings of the observer,[1] it is necessary to demand a strict separation between the phenomenal and physical worlds (e.g., Brain, 1951; Gogel, 1990; Koffka, 1935; Russell, 1948; Shepard, 1981). The phenomenal world is that of which we are perceptually aware, being a construction of our senses and nervous system; its high degree of functionality, as stated above, conceals its very nature to the unreflective person. The physical world, including our nervous systems, is not given directly in our experience but is inferred through

1. In an essay entitled "Towards a philosophy of colour," physicist W. D. Wright (1967) puzzled over how color, which he acknowledged to be a subjective response to spectrally varying light, is phenomenally attached to objects. His speculations led to the curious conclusion that part of the visual process must "represent the mental image being generated in colour in the visual cortex and then projected outwards into physical space" (p. 24). His conclusion illustrates the great difficulty all of us face in expunging naive realism from our thinking even after recognizing its fallacy; a particularly common error is to reject naive realism for vision and audition but not for touch.

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observation and critical reasoning (Campbell, 1966; Russell, 1948). Given this fundamental separation of the two domains, it is useful to recognize the "normal" division of the phenomenal world into "self" and "nonself" (the phenomenally external). The phenonemal self encompasses the phenomenal body (body schema) as well as those aspects of our experience considered private and subjective such as pain, hunger, thirst, and emotion. Ostensibly, the division between the phenomenal body and the phenomenally external, for most people, closely parallels the division in the physical world between the observer's body and everything else physical. However, the phantom limb phenomenon (e.g., Simmel, 1966; von Fieandt, 1966) is clear evidence that the phenomenal body need not always correspond with the physical body. Much broader support for the distinction between phenomenal and physical is provided by the literature dealing with brain damage, psychopathology, and intoxication with psychoactive drugs (e.g., Brain, 1959; Laing, 1965; Klüver, 1966, respectively); this literature makes it clear that the boundaries within the phenomenal world can vary tremendously among individuals, so much so that, for some, the boundaries between self and nonself cease even to exist.

3 Distal Attribution and Attribution to Nonself: An Initial Hypothesis

In view of this distinction between the phenomenal and physical, externalization is not a matter of projecting experiential contents into physical space but one of identifying those contents with the phenomenally external or nonself (distal attribution). What then are the conditions under which distal attribution occurs? A possible answer revolves around the correspondence between (1) the efferent commands issued by the central nervous system to the musculature and (2) the ascending input from the sensory apparatus.

As our point of departure, we assume the concepts expressed by von Holst (1954), some of which are represented in Figure 1. "Efference" consists of commands issued to the muscles of the body, which constitute the effectors of our action; the central nervous system

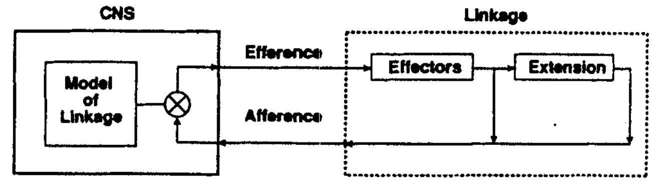

Figure 1. *Representation of sensorimotor interaction.*

(CNS) is assumed to retain a record ("efference copy") of the efference for comparison with the information ascending the sensory pathways. Von Holst conceived of sensory input ("afference") as having two components: "reafference," that which is contingent on action of the observer, and "exafference," that which is not. Because such a sharp distinction is problematic, we assume here only that afference is jointly determined by the external environment and actions of the observer. Thus, for example, as an observer moves about within the environment, retinal stimulation depends on the objects present and their motions and transformations as well as on rotations and translations of the observer's eyes.

We begin with White's (1970) suggestion that distal attribution results when afference is lawfully related to efference (see also Bach-y-Rita, 1972; Epstein et al., 1986). We first consider the opposite result—attribution to self. In the spirit of White's suggestion, we hypothesize that attribution to self occurs when afference and efference are completely unrelated or independent. (This notion of independence presumes that efference is not constant over time.) The interoceptive sensations of hunger and thirst are good examples for us to consider. Because variations in the afferent signals to which these sensations correspond are quite independent of efference issued to the musculature, such as when one moves about within the environment, the sensations define, in part, what is meant by "self." (Under this hypothesis, the epoch over which the correlation of efference and afference is "computed" must be a critical factor, for ingesting food and liquid does, over the longer term, diminish sensations of hunger and thirst without causing their externalization).

At the other extreme of attribution are the ordinary percepts of visual objects and sound sources, which are experienced as part of the phenomenally external; that is, these percepts define in part what we experience as "nonself." According to the hypothesis being considered, distal attribution occurs when efference and afference are lawfully related. Given the ambiguity of the term "lawfully related," however, it is clear that a more explicit hypothesis is required. At this time we are unable to offer a hypothesis of such specificity. However, what we will do in the remainder of this article is to note some of the additional complexity surrounding distal attribution and attribution to self and to respond to some of this complexity with a modification of White's original suggestion.

4 Complexity Surrounding Attribution to Self and Nonself

First, it is important to recognize that the distinction between self and nonself involves more than just the totality of efference and afference of the particular moment. Rather, the self/nonself distinction is a more stable and enduring one involving long-term memory; presumably, it arises out of the individual's accumulated experience. Piaget (1954) dealt extensively with this issue. He theorized that during infancy and childhood, cognitive structure progresses from a primitive egocentric awareness to one that increasingly differentiates between self and nonself; his primary concern was with the development of intellectual knowledge of the external world that transcends perceptual experience. Nevertheless, much of his thinking about the child's increasing awareness of the external world revolves around the interaction of perception and motoric activity and thus has many parallels with the ideas being expressed here. Inasmuch as our concern is more with attribution of perceptual experience, the point we wish to make here is simply that the structure of self and nonself is far more extensive than any momentary attribution.

A second complexity is that sensory stimulation cannot always be clearly identified with the subjective or objective poles, to use the terminology of David Katz (1925/1989). Visual experience of one's body is neither as private and subjective as pain and thirst nor as objective as objects in the physical environment. Likewise, a positive afterimage has a partly subjective and partly objective character, probably because the perceiver is confronted with constant stimulation issuing from the retina while the eyes and head move about. A similar example from the auditory realm is "intracranial localization" or "lateralization"—when a binaural sound is delivered through headphones, one localizes it within the phenomenal limits of the head (Yost & Hafter, 1987), presumably in part because the binaural stimulation is independent of head movements; however, when the same binaural stimulation is coupled to rotations of the head and displacements of the body, observers report an increase in distal attribution (Loomis, Hebert, & Cicinelli, 1990).

Other examples of mixed attribution are those associated with the sense of touch involving stimulation of the skin. Because the receptive layer of the skin, unlike the retina and basilar membrane, comes to be represented within the observer's phenomenal world, there is an interesting duality associated with touch experience (Katz, 1925/1989). Often when the observer is passively touched, he/she experiences the contact as stimulation of the phenomenal body, but when the observer actively explores an object with the hand, the experience is that of an externalized object (Gibson, 1962, 1966; Katz, 1925/1989; Weber, 1846/1978); under some circumstances, both subjective and objective aspects prevail.

The most interesting examples of distal attribution of tactual stimulation involve indirect manipulation. A familiar example is exploring an object with a hand-held probe (Gibson, 1966; Katz, 1925/1989; Lotze, 1894; Polanyi, 1966; Weber, 1846/1978). Subjects describe the experience as contact between the probe and object rather than as vibrations felt in the hand. A less familiar example is that reported in connection with the Tactile Vision Substitution System (Bach-y-Rita, 1972; White, 1970; White et al., 1970), a system consisting of a television camera that provides video signals to a matrix of vibrating stimulators placed against an observer's back or abdomen. By actively manipulating the camera themselves, subjects could scan a high contrast object, the images of which were converted to vibrotactile patterns. Although, initially, subjects reported experiencing only changing patterns of vibration on the torso, extensive practice led some of them to experience stationary objects in front of the camera.

The impression of distal attribution of felt contact is even more compelling when tactual stimulation is supplemented with compatible visual and/or auditory stimulation. One example is that offered by Kaila (cited in von Fieandt, 1966), who noted that a person shaving in the mirror refers touch impressions to the face seen in the mirror. Another example is the experience that skilled technicians have when working under a microscope with dissecting tools (Loomis & Lederman, 1986). The impression of "directly touching" the tissue being dissected, despite the optical magnification, is accompanied by the impression that the tools are mere extensions of the hands and fingers. This is essentially the same phenomenon reported by skilled users of a teleoperator system (Corker, Mishkin, & Lyman, 1980).

The fact that we tend to attach greater import to distal attribution when feeling with a probe than when feeling directly with the hand is to be explained by the difficulty we have in eliminating the remnants of naive realism from our thinking. In fact, direct touching between bare skin and object is no less a constructive process of the central nervous system than is indirect touching. The same can be said for vision and audition; whether or not these senses are "extended" by optical, acoustic, or electronic devices, the resulting perceptions are always mediate, never direct, for the central nervous system constructs what is perceived. Thus, whether the senses are "extended" or not, the question remains—under what conditions does distal attribution occur? Our tentative answer has been White's (1970) conjecture that externalization occurs when there is a lawful relationship between efference and afference. However, even beyond the need for greater specificity, the idea requires modification, for as White (1970) and others (Bach-y-Rita, 1972; Epstein et al., 1986; White et al., 1970) have recognized, distal attribution with the Tactile Vision Substitution System and systems like it was achieved only after extensive practice. Similarly, distal attribution is most fully experienced by users of teleoperators and dissection microscopes after they have become skilled. This means that distal attribution is not a necessary consequence of systematic covariation between efference and afference but requires as well that the observer be able to model the lawful relationship by which efference governs changes in afference.

5 A Modification of the Initial Hypothesis: Modeling the Linkage

Figure 1 is an attempt to represent sensorimotor interaction in the general case (Loomis & Lederman, 1984). The block labeled "linkage" represents the connection between efference and afference. In the simplest case, the subject contracts a muscle and observes the sensory consequence; this is represented by the direct connection between the effectors and afference. When the observer controls more than his/her own body, the external system is represented by the block labeled "extension." In the simplest case, the extension might be a probe that is being wielded in the hand, a tool such as a pair of pliers, or an optical telescope mounted in front of the eye. An instance of a more complex extension would be a teleoperator system. The block within the central nervous system labeled "model of linkage" represents the observer's "representation" of the linkage (musculature, extension, and sense organs) intervening between afference and efference. By no means is it intended that this representation is cogitative or even accessible to conscious awareness. Rather, it is intended to be a representation more along the lines of Piaget's (1954) notion of "sensorimotor schema," a functional organization that operates independently of thought.

To the extent that the subject can successfully model the linkage, either because the extension is natural and simple (e.g., a rigid probe attached to the finger) or because the subject has learned it through extensive training, the observer experiences "transparency" of the linkage (including the extension) and a consequent externalization of the distal environment with which the subject is put into contact by the extension (Corker et al., 1980; Loomis & Lederman, 1984). If, however, the observer is unsuccessful in modeling the linkage, perhaps because of extreme complexity, the observer will fail to experience distal attribution as well as transparency of the linkage. To give some concreteness to the argument, suppose that a user of a teleoperator system is controlling the slave robot by means of a complex and unnatural but determinate interface (e.g., a musical keyboard). Until the user is able to represent the way in which the interface controls the robot, the user will fail to experience externalization of the environment within which the robot is situated.

6 Focal and Subsidiary Awareness: The Response to Conflicting Information

The philosopher Polanyi (1964, 1966, 1970) expressed many of these ideas, albeit for a different purpose.[2] He noted that prior to full achievement of a skill (e.g., learning a new language), the observer's awareness focuses on the components of the skill (e.g., recognizing the sounds and translating the words). As skill develops, the observer eventually develops a "focal awareness" of the distal (here the meaning of the transmitted speech) as "subsidiary awareness" of the mediating chain subsides to the point that the chain becomes transparent. His notion of two levels of awareness, especially as elaborated within his essay "What is a Painting" (Polanyi, 1970; see also Pirenne, 1970, and Kubovy, 1986), has direct application to the meanings of presence and distal attribution.

We begin with the case where there is only sensory information signifying the distal environment and none signifying the medium. Were it possible to provide the user of a teleoperator with exactly the same stimulation that he/she would receive if located in the remote or simulated environment, we would expect "telepresence" to be the result, for one's self-localization is primarily determined by the locations of the sensory organs (in this case, the sensors of the slave robot). The entertaining and provocative essay by Dennett (1978) makes this point very effectively.

Because the ideal of "equivalent stimulation" is not attainable, however, it must be the case that the perceiver is presented with conflicting sensory information, some signifying the remote or simulated environment, and some the actual physical environment within which the observer is present. Presumably, when the stimulation is insufficient to fully support "telepresence" (the awareness of being somewhere else), the observer experiences "subsidiary awareness" of the actual environment and a "focal awareness" of the remote or simulated environment (see Polanyi, 1964, 1970). Speaking with someone on the telephone is an example, for we have both subsidiary awareness of being in one location communicating through a device and focal awareness of the person at the other end. Similarly, a person using a teleoperator that is connected to the slave robot via a very noisy data link would have greater subsidiary awareness of the teleoperator system and reduced focal awareness of the remote environment than a person for whom the data link is noise free. Still another example is that discussed earlier of normal tactual sensing of an object, where the perceiver has both focal awareness of the object and subsidiary awareness of the skin surface being stimulated (Loomis & Lederman, 1986). As was noted, tactual perception differs from visual and auditory perception in that the receptive surface is part of the phenomenal world.

In the view we are presenting, presence and distal attribution beyond the limits of some extending device (probe, teleoperator, virtual display) are not fundamentally different phenomena. Rather, they differ only in that true presence occurs when the sensory data support *only* the interpretation of being somewhere other than where the sense organs are located; whereas, distal attribution to a remote location occurs when the sensory data represent both the remote location and that device or linkage that connects the observer with that remote location.

2. Polanyi and others (Campbell, 1966; Piaget, 1954; Russell, 1948) are less concerned with distal attribution of perceptual experience than they are with its intellectual counterpart, the transcending of perceptual experience to a knowledge of physical reality through scientific reasoning and observation. An idea common to all is that the attainment of scientific knowledge is made possible by convergence on a given facet of reality through diverse sensorimotor and intellectual operations; for Polanyi, many of these essential operations on which knowledge is constructed are not accessible to conscious scrutiny. These operations parallel the notion of linkage used here in the treatment of externalization of perceptual experience.