Identification of Underlying Assumptions Is an Integral Part of Research: An Example from Motor Control

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ABSTRACT. Research is inherently subjective. It is conducted within a theoretical and methodological framework, the validity of which depends on underlying assumptions about the nature of reality and knowledge. The interpretation of one's own data, and the evaluation of the data interpretation of others, requires assessment of these underlying philosophical assumptions. We contend that while examination of philosophical assumptions is demonstrably an integral part of research, it is one which has largely been neglected in experimental psychology because researchers have rarely explicitly identified their ontological and epistemological assumptions. A contemporary debate in experimental psychology, that between representational and non-representational approaches to understanding the control of movement, is discussed to illustrate the influence such ontological and epistemological assumptions have upon methodological choices and upon the development and evaluation of theory.

It has been cogently argued by Toulmin (1961), Kuhn (1962) and others (e.g. Suppe, 1974) that all research is conceived, executed, analysed and evaluated within a conceptual framework, world-view or disciplinary matrix (Kuhn, 1974) and that this disciplinary matrix determines what questions are legitimate, how answers may be obtained, what are counted as facts and what significance is attached to these facts. Researchers with different world-views may see very different things in the same phenomenon. Research (as a search for further knowledge) is inherently subjective because observations and facts are theory-laden (Feyerabend, 1965; Hanson, 1958) and all knowledge is socially constructed (Berger & Luckmann, 1966).

An extreme version of this assertion, which makes all knowledge subjective and rejects the notion that there is a world that we can better understand through research (a relativist position), is obviously problematic. Rather than pursuing this course and rejecting objectivity we need to reconceptualize objectivity as a dialectical process (Keller, 1982). The process of critical self-reflection, of identifying one's preconceptions in the process of science, encourages a new vision of what it is to be objective. By continually stating carefully and critically what is done, and

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allowing no presuppositions to go unquestioned, both the researcher and others may be better able to evaluate the significance of experimental results.

Any theory developed within a particular world-view is embedded in a web of auxiliary hypotheses. These include more basic aspects of the theoretical framework, and methodological assumptions about, for example, appropriate operationalization, experimental design and data manipulation techniques. This is the basis of the Duhem–Quine holism thesis which concludes that the falsification of any inidividual hypothesis is impossible because a failure to obtain predicted results could be a result of a fault in an auxiliary hypothesis rather than in the hypothesis being tested (Duhem, 1914/1954; Quine, 1963, 1990—see Bechtel, 1988; Laudan, 1988; and Suppe, 1974, for commentaries).

The corollary is that auxiliary hypotheses can be modified to protect any hypothesis confronted with contradictory evidence. Decisions about whether the individual hypothesis should be retained or rejected are thus always subjective and depend on judgement of the appropriateness of the auxiliary hypotheses. The auxiliary hypotheses or theoretical framework are in turn dependent for their validity on assumptions about the nature of reality (ontology) and knowledge (epistemology). All researchers make such assumptions whether explicitly formulated and acknowledged or not. Thus empirical observations alone may not be sufficient to make informed decisions between competing theories, particularly if the theories are embedded in theoretical and methodological frameworks derived from different ontological and epistemological assumptions.

For a researcher or reader to make appropriate decisions about the validity of methodological assumptions, or other auxiliary hypotheses, the underlying ontological and epistemological assumptions need to be identified and their implications explored. In experimental psychology these assumptions have generally remained unexamined because, in the logical positivist paradigm which has dominated research, objective falsification by empirical means alone was considered not only possible but the primary aim of research (Popper, 1963). Metaphysical questions have been largely ignored because they were considered unscientific (Madsen, 1988).

A consequence of the dominance of logical positivism has been that an important step in the research process remains inaccessible to direct critique and thus revision. Accessibility to criticism is necessary for scientific progress and thus we agree with Tolman that 'questions of ontology and epistemology . . . are essential concerns of scientific practice that do not disappear when ignored' (1987, p. 211) and with Madsen that 'it is important that *all* philosophical preconceptions are made conscious and formulated explicitly' (1988, p. 30; original emphasis).

If the metaphysical assumptions of the researcher and those of the reader differ fundamentally then critique must first be directed at the assumptions underlying the paradigm before considering the results derived within that paradigm. To pre-empt what follows, if the reader does not allow that any representation of the world exists in the mind, then the results of research that purports to examine this representation cannot be sensibly debated. Debate at the level of underlying assumptions may, however, be appropriate (see Glotzbach, 1992, for an example in visual perception).

The remainder of this note concerns an example from the field of motor control in which an appreciation of the underlying ontological and epistemological

assumptions is essential in evaluating the results of research and in understanding the fundamental nature of the differences between conflicting methodological approaches. Without this understanding, substantial effort may be expended in an attempt to develop a hybrid theory incorporating aspects of models from different theoretical frameworks (as Summers [1992] predicts will occur). Such a reconciliation is unlikely, in our opinion, if not impossible, because of the differences in underlying assumptions about the nature of reality and knowledge.

Motor control is that part of experimental psychology which is concerned with understanding how humans manage to produce complex patterns of movement accurately and reliably. The field is currently in a state of paradigmatic conflict (see Abernethy & Sparrow, 1992; Meijer & Roth, 1988; Whiting, Meijer, & van Wieriengen, 1990). The conflict is between conventional 'top down' theories of motor control which propose that a representation of movement exists in the mind before movement commences; and more recent 'bottom up', 'dynamical', 'action' or 'natural-physical' approaches in which coordination is not seen to be representationally driven, but is rather seen as a consequence of the physical nature of the body and its interaction with the environment. The latter view represents more than simply a different theory. It is, rather, a different approach (Beek & Meijer, 1988) which is distinguished from the conventional approach by the absence of a representation of movement in the mind (Schmidt, 1988). This theoretical difference is a consequence of different ontological assumptions about the relationship between consciousness (mind) and environment (body).

Conventional theories reflect an ontological belief that mind and body are independent and distinct. Mind and body are qualitatively different and so may only affect each other indirectly. This mind–body dualism is traceable from Plato through Cartesian thought to the present day and has been the dominant ontology in western civilization (Lombardo, 1987). By separating the mind and body in this way the mind cannot have direct contact with the outside world and the epistemological assumption follows that knowledge can only be gained from the outside world indirectly. This representational realist view (Hospers, 1956) assumes that an objective reality of the environment exists and is known to the mind through a *representation*; that is, 'nothing is directly present to the human mind except its own ideas' (Olson, 1967, p. 23).

A consequence of this epistemological assumption is that perception is viewed as a process of constructing a representation of the world in the mind by extracting meaning from static, informationally impoverished, retinal images. This construction involves intensive computation and reference to memory (e.g. Marr, 1982). The corresponding consequence of mind–body dualism for movement control is that if the mind does not directly contact the body then, for the mind to interact with the environment through movement, an intermediary or representation of movement must be involved. A representation of movement must exist in the mind before movement starts and prescribe the subsequent coordination of the body parts. Reaching to grasp an object, for example, is controlled through a representation in the mind of the desired movement pattern which, in turn, determines the necessary neural commands required for that movement. This is an 'a priori' (Kelso, 1981) or 'top down' approach in which the central nervous system

commands the muscles throughout execution of the movement. While authors of representational theories would perhaps not accept a dualistic metaphysics, their theories mirror the distinctions of dualistic philosophy. These theories typically make use of information-processing theory and include models of the human as an information processor (Fitts, 1954; Hick, 1952; Hyman, 1953), a feedback-dependent servomechanism (Adams, 1971, 1976), a computer running motor programs (Keele, 1976; Schmidt, 1976) or a hierarchical structure of reflexes, oscillators and servomechanisms (Gallistel, 1980).

Separation of the mind from the body and a Newtonian ontological belief in the existence of irreducible elements has led to reductionist methodological strategies and the auxiliary hypothesis that perception and action can be studied as distinct processes. Typically, action variables are studied using simple perceptual stimuli like a tone to signal the start of movement, or perceptual processes are studied using simple movement responses such as a button press. Thus, in both cases, the processes of perception and action are studied in relatively unrealistic situations.

A different approach to the coordination of movement results if the fundamental assumption of mind–body dualism is questioned. Gibson's (1950, 1966, 1979) approach to perception involved a rejection of mind–body dualism, and has been the inspiration for the development of this approach. Gibson's underlying ontological assumption was that the animal and the environment are interdependent in evolutionary and functional terms, a 'reciprocally integrated ecosystem', as Lombardo (1987, p. 3) put it. The consequences of this animal–environment reciprocity (after Lombardo, 1987) are that knowledge of the environment is available directly to the animal, and that perception and action are reciprocally causal.

If (as in conventional approaches) mind is separate from body and cannot contact the outside world directly, then knowledge is obtained indirectly through the (fallible and subjective) process of perception. If, however, mind is assumed not to be separate from body, then the mind can contact the environment directly. This assumption leads to a position on the epistemological question of the acquisition of knowledge which Lombardo (1987) described as direct realism.

Smith and Jones (1986) argue that (a) the conventional position of representative realism postulates that perception involves pictorial representation; (b) this representation still requires interpretation; and (c) this view fails to explain the crucial question of how the interpretation occurs (see Turvey, Fitch, & Tuller, 1982, for a parallel criticism of representational approaches to motor control). Smith and Jones argue that the problem of interpretation is reduced if perception is viewed as the direct receiving of information. Direct contact between mind and body removes the need for representation and allows an attempt to understand both perception and movement coordination in physical (but not reductionist) terms.

An auxiliary hypothesis in much of science (and common in experimental psychology) has been the classical reductionist methodological assumption that knowledge (and consequently understanding) is gained by reducing the system of interest to its elements, and studying the elements and the interactions between them (Garfinkel, 1987). It is assumed that the behaviour of the whole system will be

predictable from a knowledge of the individual elements and the rules of interaction between them. This assumption is increasingly being challenged (e.g. Garfinkel, 1987; Soodak & Iberall, 1978; Yates, 1987). Non-linear relationships between elements in a complex system prevent prediction of systemic behaviour from a knowledge of the parts. This is the central methodological assumption of theories of self-organizing behaviour. These theories are particularly applicable to biological systems (Yates, 1987) and form the basis of the dynamical approach to motor control (e.g. Kelso & Schöner, 1988; Kugler & Turvey, 1987). In this approach, the coordination of movement is seen as an example of spontaneous pattern generation. Such forms of self-organization occur in numerous open multi-degree of freedom systems, many of which do not involve a nervous system, and thus self-organization can occur in the absence of cognitive control. This alternative approach to perception and action is characterized by methodological commitments to: (a) studying perception and action as a single system (e.g. Turvey & Carello, 1986); (b) ensuring ecological validity through the use of realistic experimental situations; and (c) anti-reductionism. The first two methodological assumptions are a consequence of the assumption of animal–environment reciprocity. Perception and action form an interdependent cycle and therefore it is not possible to study these processes separately. This, in turn, requires the use of relatively realistic situations. A recognition that the behaviour of open complex systems with non-linear elements cannot be predicted by focusing on the elements leads to the third methodological assumption—that the control of movement can only be understood by focusing on the behaviour of the system as a whole.

The contrasting methodological commitments of these different approaches are a direct consequence of the underlying philosophical assumptions held by the proponents of each approach, whether explicitly formulated or not. If these assumptions and their methodological consequences remain implicit and unexamined, then neither the researchers themselves, nor other readers, are able to make informed judgements about the validity of the methodological choices, or other auxiliary hypotheses, and this clearly limits rational assessment of the significance of experimental results. The identification of philosophical underpinnings is essential in this example because of the gulf that separates the world-views of different researchers. These philosophical differences can only be argued in philosophical terms; no amount of empirical evidence will result in falsification of either theoretical framework, and no amount of ad hoc theorizing will allow reconciliation of the competing approaches.

We contend that the metaphysical assumptions underlying theoretical frameworks within experimental psychology in general should receive greater attention during the evaluation of experimental results, and that discussion at this level should be encouraged in journals such as *Theory & Psychology*. This is not to suggest that all (or indeed any) scientific debates can be resolved solely by identifying and discussing underlying metaphysical assumptions, nor even that such resolution should be attempted. Theoretical pluralism may be necessary and even desirable (Feyerabend, 1965). However, the failure to identify and discuss underlying assumptions, and hence address the validity of the many auxiliary hypotheses, is a weakness in much experimental psychology research.

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