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Reductionism

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Synonyms

Mind-body problem; Mind-brain problem

Introduction

To set the stage for writing about reductionism, it may help first to review briefly the history of philosophy associated with, as it was known historically, the mind-body problem. However, mind-brain will be used here instead of mind-body. The four basic views are diagrammatically summarized in Fig. 1.

As may be seen in Fig. 1, there are two forms of monism, namely, either the brain alone exists (Thomas Hobbes's Materialistic Monism) or the mind alone exists (George Berkeley's idealistic monism, where *idea* not *ideal* is the root word). There are also two forms of dualism where both the mind and the brain exist. With dualism the question becomes that of how they relate to each other. Descartes believed that both the mind and brain exist, and they interact at the conarium (pineal gland). He also believed that the brain was material and had a boundary and that the mind was immaterial and had no boundaries; it permeated the universe. This form of dualism was known as interactionism. Gottfried Wilhelm Leibnitz believed that the mind and brain both existed independently and that they functioned in perfect parallel, a view known as parallelism.

There is no way to prove the truth or falsity of any of these positions regarding the mind and the brain. All that one can do is choose the one that is most useful or most comfortable personally. Many behavioral scientists are clearly materialistic monists, but many others write in ways that indicate that they are mind-brain dualists. This writer believes that science functions best with materialistic monism, and he cannot in good conscience write about any of the other viewpoints.

Returning to reductionism, two sources were examined for contemporary definitions of reductionism, *The Oxford Guide: Philosophy* (T. Honderich, Editor, 2005) and Turner's (1967) *Philosophy and the Science of Behavior*. The *Oxford Guide* included five definitions pertaining to reductionism by three authors, and Turner provided four definitions. One of the five in the *Oxford Guide* had minimal, if any, relevance for animal cognition and behavior, and it will not be considered further here.

Explicitly or implicitly, the eight definitions emphasized material reductionism. The following selected portions of the eight definitions are quoted to validate this conclusion.

Ontological reductionism (Ruse 2005, p. 793): *"All organisms are reducible ultimately to molecules," but often the claim is meant in*

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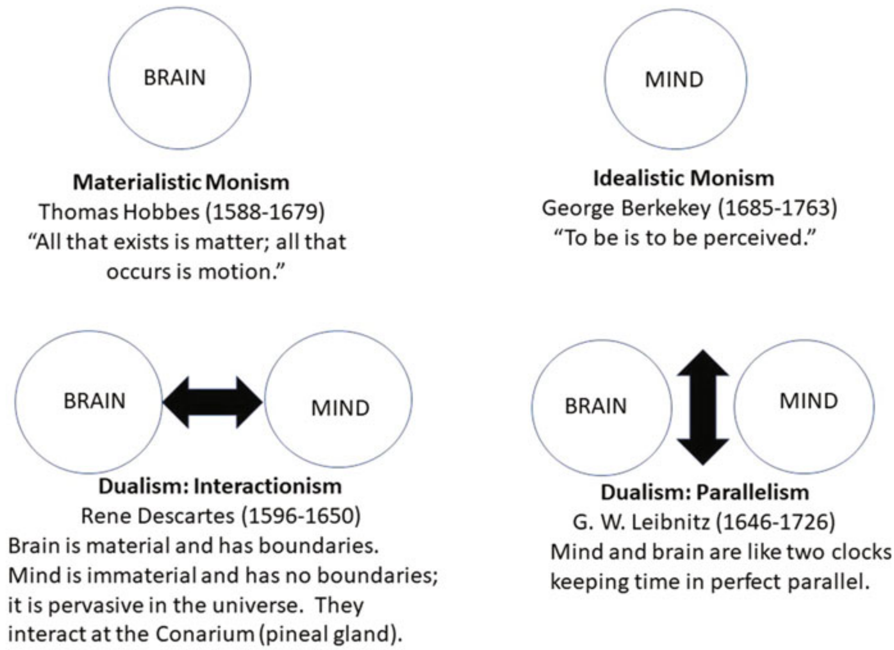


Reductionism, Fig. 1 Diagrammatic representation of the mind-brain relationship problem

the more metaphysical sense that there is but one substance or "world stuff" and that this is material.

Methodological reductionism (Ruse 2005, p. 793): *The best scientific strategy is always to attempt explanation in terms of ever more minute entities. It has undoubtedly been the mark of some of science's greatest successes and not just in physics.*

Theory reductionism (Ruse 2005, p. 793): *Theory reductionism raises the question of the relationship between theories in a field, as between Newton's theory and that of Einstein.* [Given the examples from physics, material reductionism is implicit.]

Reductionism, mental (Kim 2005, p. 794): *Reductionism in philosophy of mind is the claim that facts about mentality are reducible to physical facts,* i.e., *facts about matter and material processes.*

Constructual reduction (Turner 1967, p. 302): *The existential status of an object derives from it being empirically real and not inferred.*

Theoretic reductionism (Turner 1967, p. 304): *The laws of the reduced science are hereby explained by the laws of the reducing science* [e.g., behavioral science is reduced to physiology].

Methodological reductionism (Turner 1967, p. 309): *For psychology, this would mean restricting its theoretical constructs to terms in principle to the language of physiology.*

Metaphysical reductionism (Turner 1967, p. 309): *It asserts that for psychology ultimately all questions of theory are to be resolved by physiological reductionism.... This compares with a metaphysical behaviorism which assumes all sentences in the mental language are really translatable into sentences in the physicalistic language; the language presumably of pure mental content is meaningless.*

Of course, there are those who may accept material reduction in principle but who believe one can be a good scientist and work, for example, only at the behavioral level. B. F. Skinner was a good example of this type of behavioral scientist, and he will be considered further below.

In a material reduction scheme, where is behavioral science among the social, biological, and physical sciences? To illustrate the answer, the down arrow symbol "↓" means "reduces to":

Sociology
↓
Behavioral Science
↓
Biology (includes Evolutionary Biology, Genetics, Physiology)
↓
Biochemistry (includes Neurochemistry)
↓
Physical Chemistry
↓
Newtonian Physics
↓
Quantum Physics

Limitations of Measurement that Affect All Sciences

It is important to recognize that, regardless of reductionism, all sciences are affected by limitations of measurement and that reductionism itself can contribute to such limitations (see Figure Legend and discussion associated with Fig. 4 later in this entry). Werner Heisenberg (1901–1976) is well remembered for showing that precise measurement of the position *and* momentum of atomic particles cannot be done. This became known as the uncertainty or indeterminacy principle. Later, Heisenberg (2007) was clear in his *Physics and Philosophy: The Revolution in Modern Science* that the uncertainty/indeterminacy principle was not limited to quantum physics; see, especially, chapter "▶ The Relation of Quantum Theory to Other Parts of Natural Science." He mentioned psychology but was less clear how his principle applied to "psychological phenomena" except with reference to the brain. However, 13 years before Heisenberg (2007), London (1945, p. 162) had written:

> It is the purpose of this paper to demonstrate that the principle of indeterminacy as formulated for quantum theory is grossly inapplicable for psychology and that, in consequence, no matter what may be the arguments in defense of the statistical approach to psychological problems, Heisenberg's principle of indeterminacy may *not* be one of them.[2]

In part of footnote 2, London (p. 162) quoted Russell (1943, p. 249) who noted Max Born's preference for the concept of a "principle of limited measurability" over the concept of the uncertainty principle. Max Born was a Nobel Laureate in quantum physics.

Here, the "principle of limited measurability" is also deemed more useful, although its roots in the uncertainty/indeterminacy principle remain relevant. Applying Heisenberg's principle to behavioral science, one cannot know completely how the acts of observing and measuring influence the behavior or physiology of the human or nonhuman animals who are being observed and measured. Particularly applicable to animal cognition and behavior is the "Rosenthal effect."

The Rosenthal Effect

Based on previous research conducted by Rosenthal and colleagues, Rosenthal (1963) provided a general account in *American Scientist* of what came to be known as the *Rosenthal effect*. The following quotation summarizes the essence of the *Rosenthal effect*:

> For many of the sciences there seems to be little danger that the act of observation itself may change the object of study. . .. [Rosenthal did not cite and may have been unaware of Heisenberg (2007).] For the behavioral sciences, however, where humans or animals may be the object of study, the act of observation may very well change the object of study. (Rosenthal 1963, p. 268)

Further, Rosenthal and colleagues had shown that *observer expectations* may affect the behavior of the observed; it is this aspect of observer effects that most think of when they refer to the *Rosenthal effect*.

The Rosenthal effect in animal cognition research. The classic example of the *Rosenthal effect* in animal cognition research is that of Clever Hans. Interestingly, Rosenthal wrote the Introduction to the 1965 republication of the classic, *Clever Hans (The Horse of Mr. von Osten)* by Oskar Pfungst (1911); Pfungst was an early German psychologist. Rosenthal's Introduction should be required reading for anyone who studies animal cognition and, especially, those who work in the presence of the animals being studied. It will be instructive to recall some of the more relevant details about Clever Hans. All

Reductionism, Fig. 2 Clever Hans and Mr. von Osten

information here about Clever Hans comes from Rosenthal's Introduction, except for the comment below about marginal cue detection.

Clever Hans was best known for foot tapping (see below) the answer required in response to "questions" usually in the form of visual cues (see photo of Clever Hans and Mr. von Osten, (Fig. 2)). Presumably, Hans could add, subtract, read, spell, and identify musical tones as long as the question could be answered with foot tapping. Mr. von Osten sincerely believed that Hans's performances were genuine, and he invited critics to observe as Hans performed.

According to Rosenthal in Pfungst (1965, p. x):

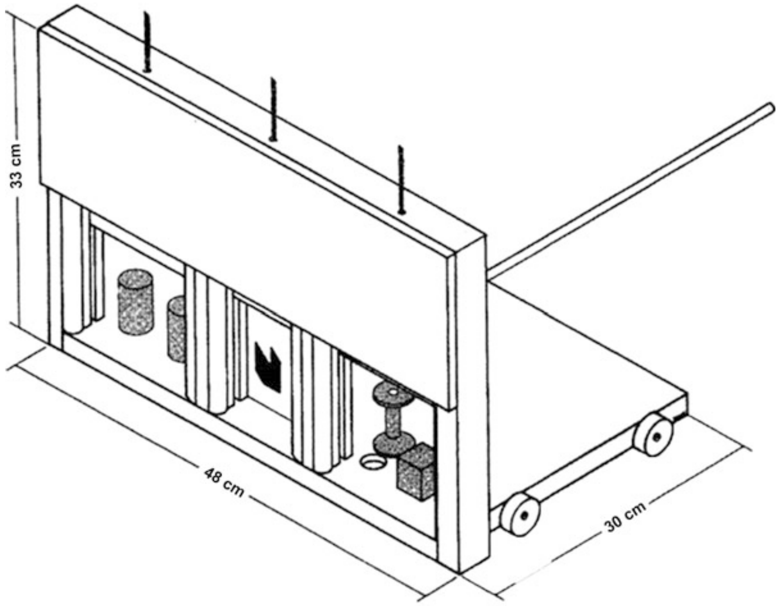
> . . .on September 4, 1904, thirteen men risked their professional reputations by certifying that Hans was receiving no intentional cues from his owner of any other questioner. . .these men, included in their number, a psychologist, a physiologist, a veterinarian, the Director of the Berlin Zoo, and a circus manager. . ..

To jump ahead in the Clever Hans story, psychologist Oskar Pfungst conducted extensive studies that failed to reveal the basis of Hans's performance. Only when he put a visual barrier between Mr. von Osten and Hans did Hans's performances fail. Mr. von Osten was emitting inadvertent cues that informed Hans when to begin tapping his foot and when to stop tapping. Cues might be such as a slight forward lean of the head or body or other inadvertent slight movements, cues that were undetected by the 13 motivated human observers. There was never any basis to believe that Mr. von Osten was aware that he was cueing Hans. Furthermore, Pfungst found that 23 of 25 questioners in the place of Mr. von Osten also engaged in inadvertent cueing of which they were unaware.

Somewhat lost in this story is the amazing ability of Hans to detect such marginal cues that went undetected by human observers who were deliberately looking for them. Whether other horses or other animals possess such marginal cue detection skill is a question worthy of further investigation.

Given that the questioners were unaware that they were emitting inadvertent cues, one should question whether this applies to contemporary investigators whose research occurs in the presence of their animal subjects. Perhaps all who study animal cognition today are aware of the lessons of Clever Hans, but it is doubtful whether any investigator who works in the presence of the animals can avoid inadvertent cues. Beran (2012) provided a commendable commentary intended to remind contemporary researches in animal cognition of the hazards of inadvertent cues.

An effort to avoid Clever Hans cues in animal research. Harry Harlow invented the Wisconsin General Testing Apparatus (WGTA; see separate entry about the "▶ Wisconsin General Testing Apparatus" in this encyclopedia) as a way to avoid Clever Hans cues. The WGTA is essentially an enclosed box, illuminated inside, and with guillotine doors at the front and back. With the front door closed to prevent the animal



Reductionism, Fig. 3 Apparatus and representative discriminada. Here a heptagon in the center door is the cue to choose the member of the difference-pair of objects nearest the center door where a food reinforcer is in the exposed food well. Had the center door revealed a triangle, the triangle would be the cue to choose the member of the sameness-pair nearest the center door. Unique, sameness-difference pairs of objects were used on each trial, and their left-right positions were determined quasi-randomly. Other options were tested; see Thomas (1993)

seeing the experimenter set up a problem involving discriminanda and food reinforcers, the experimenter sits behind the WGTA and raises the back door to set up the problem. After setting up the problem, the experimenter closes her/his door and raises the front door so the animal can see the discriminanda and make its response. Correct responses typically are reinforced with a bit of food that is typically located in a food well beneath the discriminanda, and responses are observed by the experimenter usually through a one-way mirror and, historically at least, recorded by hand. With nonhuman primates who are micronosmic, it seems unlikely they would smell the food and make their responses on that basis, but with macronosmic animals, such as rats, it is best to have food beneath all discriminanda while also using some means to prevent access to the food beneath incorrect discriminanda (see Bailey and Thomas 1998; Thomas and Noble 1988).

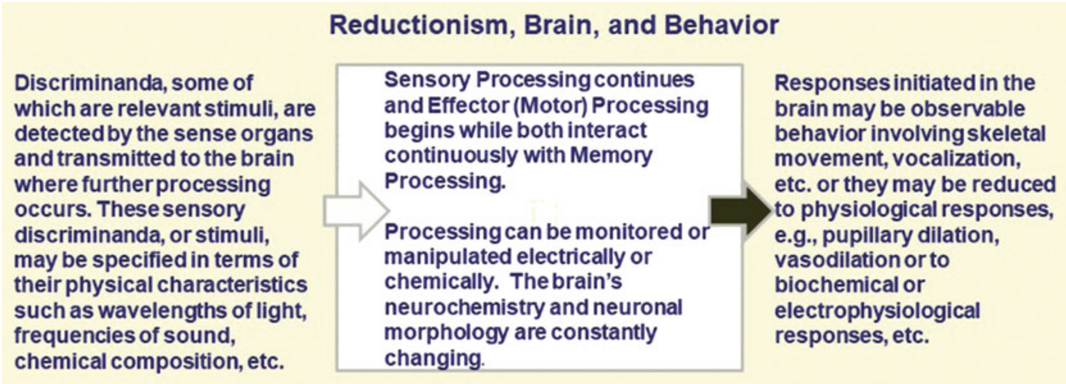
Often the WGTAs will have a tray or cart on wheels on which discriminanda are presented that can be pushed toward the animal in order to place the tray with the discriminanda within reach of the animal. Consider the apparatus below (from Thomas 1993) where the cart was designed with three guillotine doors (Fig. 3).

For example, as the cart moved forward toward the subject, strings and pulleys might raise all three doors as shown here; there were other possibilities (see Thomas 1993 for further details). In the trial shown here, when a heptagon appeared in the center door, the "difference" pair of objects was correct, and the subject needed to move the difference-object nearest the center door to reveal the food well and its food reinforcer. Had a triangle appeared in the center door, the correct response was to the sameness pair of trial-unique discriminanda.

The main point is that Thomas was concerned that one might hesitate in pushing the cart forward if the animal appeared to be moving toward the incorrect choice. This suggests that even the WGTA can be fallible to experimenter bias, and other examples, even inadvertent and unrecognized, might be cited to show how experimenter bias might occur using the WGTA. All that Thomas could do was to encourage his examiners to be consistent in how they advanced the cart on each trial.

Reductionism and Explanation

Reductionism does not mean that a person cannot be a good scientist and also limit her/his research to a given level. For example, B. F. Skinner forcefully



Reductionism, Fig. 4 Box representing and organism's brain. Not shown here, but responses at one moment in time likely become part of the discriminanda in the next moment in time. Therefore, (**a**) the bases for inferences from observing discriminanda and responses as indicated in the diagram are always changing, and (**b**) the exact meaning of behavioral concepts based on observations as indicated in the diagram also change, perhaps undetectably, from moment to moment

and effectively advocated throughout his career that behavioral science can be done meaningfully and well without reduction to, say, physiology, as long as it fulfills two of the defining goals of science, namely, prediction and control.

Most behavioral scientists conduct their research with little concern about what happens inside the organism. They are interested only in controlling the stimuli presented to the organism and measuring its responses with the goal of achieving the greatest degree of prediction and control that their research enables them to achieve.

A brief digression may be useful to distinguish between "stimuli" and "discriminanda." Those who use "discriminanda," such as objects or two-dimensional pictures or other representations, prefer "discriminanda" because a discriminandum may have several properties or features, and one may not always know to which feature a subject is responding. However, when one reduces the discriminanda to specific properties, such as, a 2,000 Hz versus a 5,000 Hz tone of equal loudness and duration, then it is appropriate to use the term "stimuli."

The reductionist approach may be represented with a diagram such as Fig. 4. In Fig. 4, the focus is on the brain, but it is realized that other parts of the body are involved in behavior.

Skinner's View of Explanation Compared to a Reductionist's Explanation

In Thomas's commentary on Skinner's article "Behaviorism at Fifty" (1963), Thomas (1988) quoted Skinner as follows:

> An explanation is the demonstration of a functional relationship between behavior [responses] and manipulable or controllable variables [stimuli]. [Paragraph break] A different kind of explanation will arise when a physiology of behavior becomes available. It will fill the gaps between terminal events.... It must be arrived at by independent observations and not by inference, or not by mentalistic constructions. (Thomas 1988, p. 650. Thomas's commentary and Skinner's response were reprinted in Catania & Harnad, 1988, with different page numbers, viz., 367–369)

Writing as a reductionist, the best explanation is equivalent to the best description together with conclusions related to prediction and control, and the more complete the description (e.g., via reductionism from behavior to physiology to neurochemistry, etc.), the better the explanation. The reductionist approach represented in Fig. 4 accomplishes the most complete description; therefore, the reductionist approach provides the best explanations. This author agrees with Skinner that, "It [explanation] must be arrived at by independent observations and not by inference, or not by mentalistic constructions."

Closing Remarks

Finally, Fig. 4, especially its Figure Legend, takes us back to earlier discussion here regarding limits on measurability as well as the involvement of uncertainty/indeterminacy. As indicated in the diagram and its legend, the neuronal morphology and the neurochemistry of the brain are continuously changing; therefore, what one observes, measures, and interprets at the behavioral level at one moment will change from moment to moment, even if unnoticeable or undetectable.

Such continuous changes in the organism and its behavior, together with the Rosenthal and Clever Hans effects, may appear to create a pessimistic perception of the future of behavioral science. However, all sciences are afflicted with uncertainties in observation and measurement, but most, including behavioral science, find sufficient constancy to obtain useful knowledge. This writer has sufficient confidence in the rabies vaccine that if he were to be bitten by a rabid animal, he would rely on the extremely high probability of the effectiveness of the rabies vaccine. This author is impressed by the high probabilities among the various sciences including behavioral science that enabled a human to walk on the moon, to place the Hubble telescope in outer space and enable it to send back observations and measurements that Galileo could only have dreamed, and to place to date (April 2019) the four rovers *Sojourner*, *Opportunity*, *Spirit*, and *Curiosity* on Mars and design them to send back a wealth of information about Mars as well as to position themselves for optimal recharging of their batteries by the sun.

Cross-References

- ► B. F. Skinner
- ► Causal Reasoning
- ► Cognitivism
- ► Equine Sensory Systems
- ► Hermann von Helmholtz
- ► Johannes Müller
- ► Morgan's Canon
- ► Stimulus Control
- ► Wisconsin General Testing Apparatus

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