ability to participate in the social rhythm of life, the symbolic nature of organized human contact with one another. Without this essential symbolism, the point of using linguistic symbols is difficult, if not impossible, to grasp.

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References

Curtiss, S. (1977). *Genie: A psycholinguistic study of a modern-day "wild child."* New York: Academic Press.

Goldin-Meadow, S. (1984). Gestural communication in deaf children: The effects and noneffects of parental input on early language development. *Monographs of the Society for Research in Child Development, 49*(3–4).

Lane, H. (1975). *The wild boy of Aveyron.* Cambridge, MA: Harvard University Press.

Anatomy of a Controversy: The Question of a "Language" Among Bees

By Adrian M. Wenner and Patrick H. Wells. New York: Columbia University Press, 1990. 399 pp. Cloth, $55.00.

As an esteemed colleague of mine once remarked, "Don't you just love it when you stumble onto something like this?" The *this* refers to a forced rethinking and reconsideration of an accepted fact. The earth and people shaking news, in this case, comes in the form of an important book that should be read by all members of the scientific community and establishment. The authors received the short end of the stick in an important controversy in biology—the question of a honey bee "dance language." Many psychologists accept the notion of this dance language as uncontroversial (e.g., Johnson-Laird, 1988), and many of us have even taught it as fact. The "facts" are (a) when honey bees return to the hive after finding a food source, they perform a dance of waggles on the vertical surface of the honeycomb, (b) the number of waggles is correlated with the distance of the food source, (c) the angle of the waggling dance relative to gravity is correlated with the angle of the food source relative to the sun, and (d) other bees observe the dance and are able to make a beeline directly to the food source.

Psychologists are in good company in the dissemination of these facts because they are part of the lore of evolutionary biology (Gould & Gould, 1988). As noted in their lovely book, *The Honey Bee,* dance language is one of the most impressive feats of animal behavior and plays a prominent part in most introductory biology texts. Even one of the best textbooks in animal behavior accepts without question the notion of a dance language for bees (Alcock, 1989). Although Alcock acknowledges the possible roles of taste and scent in communicating about the location of the food, he completely accepts the dance language hypothesis. As Wenner and Wells emphasize, dance language for honey bees quickly evolved from a hypothesis to fact, with the dissemination of the classical work of Karl von Frisch (1950), which earned him a Nobel prize in 1973.

Adrian Wenner and Patrick Wells initiated their studies as firm believers in dance language. Only slowly over many years did their studies lead them to question the facts. Their peers and discipline, however, in the form of scientific exchanges, conferences, invited lectures, publication outlets for their work, and grant support, frowned on this heresy. The authors withdrew from the debate and spent two decades "studying the elements of scientific controversy" (p. vii). There is much to be gleaned from this book, particularly with respect to hypothesis testing, experimental design, and inference in scientific investigation.

The seminal experiments of dance language in bees by von Frisch putatively established the facts of dance language. His experiments were flawed, however, as was most of the research that followed. The flaw, according to Wenner and Wells has to do with a commitment to a verification strategy of scientific inquiry. First, it is uncontroversial that the honey bee provides veridical information about the location of food during its dance upon return to the hive after foraging. (The amount of weight that should be given to observations of this type is discussed later in this review.) The question von Frisch and others have asked is whether naive bees are able to interpret this "message" and be recruited to fly to the same source of food. The prototypical experiment carried out by von Frisch and the many scientists who replicated his results involved the following procedure: A feeding station and a number of control stations were set up. A honey bee was fed at the feeding station, and it returned to the nest. The number of new recruits arriving at the feeding station relative to the control stations was taken to indicate the degree to which the fed bee was successful in communicating the location and distance of the feeding station. When the recruited bees flew out, they putatively followed the directions given by the experienced bee's dance, and flew directly to the indicated station. In these experiments, the recruited bees traveled to the indicated station and ignored stations set closer or farther away. It appeared that the recruits had used the direction and distance information contained in the dance maneuver.

When the experimental design is described in these terms, it becomes obvious that much more than communication could be influencing the results. What is obvious in retrospect, however, was not so apparent at the time. Our students of experimental psychology could point to a number of potential confoundings. The feeding station tended to be nearest to the geometric center of all of the stations. For this reason, von Frisch had not controlled for the equal attractiveness of control stations relative to the experimental station. He also failed to control for the potential influence of the experienced bees on the new recruits. As an example, the sight, sound, and scent of experienced feeders at the feeding station could have influenced new recruits to approach that station, as opposed to the control stations. In addition, one suspicious surprise in the original results was that the recruits actually did better than what would be expected from the information contained in the dance movements. It turns out that the dance is very sloppy for longer distances out to a kilometer, which is the range for most foraging. For foraging at shorter distances, bee species without language are about as efficient as honey bees.

These limitations were gradually understood as Wenner and Wells slowly matured in their studies from confirmatory research to exploratory research to multiple hypothesis testing. Their observations indicated that the bees were flying much more downwind than what would be expected if they were flying directly to the signaled search area. Also the recruits were more reluctant to enter a control station once they came fairly close to it. For whatever reason, the control stations were not as attractive as the experimental one. To compensate for this difference, the investigators installed both visual and odor markers that might permit the bees to land more readily at the control stations. When this experiment was carried out, the bees no longer preferred the experimental station relative to the controls. Their landings were distributed in a manner predicted by an odor hypothesis—bees use odor to guide their passage to a food source. It is also possible that bees use sight and sound along with odor, because these cues were confounded with the odor cues placed on the control stations.

A leap forward occurred when the authors measured not only the number of arrivals but the time it took a bee to travel from the hive to the feeding station. Von Frisch has stated that the recruited bee flies directly to the location of the communicated food source. In actual fact, however, it took much longer for the new recruit to find the food than that required by the experienced bee. This result was consistent, on the other hand, with an odor search hypothesis. After some apparently random flying, the bee is captured by an odor plume and then systematically flies in the direction of the wind, making a zigzag pattern and eventually reaching the feeding station. This prolonged travel is highly damaging to the dance language hypothesis, but is consistent with the odor explanation.

Von Frisch also was impressed with the rapid rerecruitment of experienced foragers. In this case, bees were rerecruited to the same sites at which they had earlier obtained food. These results were easily understood once Wenner and Wells had "seen" that bees, like most other living organisms, learn by classical conditioning and association. Although it had long been demonstrated that honey bees could be conditioned to visit a particular feeding station, this result had not been evaluated in the context of dance language. With respect to everyday life, a bee discovers a food source and learns its location and the corresponding odor of its food. The bee will make repeated trips to this source until the food source dries up, the work day ends, or some other good reason crops up. At some future time, a nestmate returns with a full load of honey with that same odor. The first bee is conditioned to make a beeline to the location of the associated food source.

We might believe that it is also important to ask, "If bees do not use direction and location information in the dance, why is this information contained in the dance?" Without an answer to this question, scientists could be expected to stick to the belief of a dance language of the bees. However, Wenner and Wells, like several authors before them, highlight the weaknesses in a teleological argument of this nature. Why do geese fly south in the winter? "To keep warm"—a surprisingly reasonable answer. Why do bees dance? It seems every bit as reasonable to answer "to communicate this information to their nest mates."

There are two good arguments against this type of reasoning, however: one already in the literature, and another familiar to psychologists who make a living from teasing out influences on behavior. The first counterargument is that many behaviors have no purpose or no obvious purpose. The flash rate of fireflies (family Lampyridae) contains ambient temperature information. Even so, we would not want to conclude from this fact that the fireflies are communicating this information to one another. Similarly, the rate of cricket chirps is correlated with temperature. More to the point of honey bee dances, a ladybird beetle walks at a given angle to the sun. If one turns the surface to vertical, the direction of the walk now deviates left or right of vertical by the exact angle the beetle had been walking with respect to the sun. Similarly, some moths tremble after flying, and the duration of the trembling correlates with the distance flown. However, in the latter two instances, no one has proposed communication as the purpose for these behaviors.

Thus, "why" questions do not always ring true and the authors nicely convince the reader that disguising this type of "why" question as a "what for" question does not salvage the argument. All we can conclude is that the dances may or may not have an adaptive value—we cannot conclude that they *must* have one or else they would not exist. Many nonadaptive behaviors exist. For example, male oriental fruit flies overindulge on methyl eugenol to the point of death.

For psychologists, the limitations of a teleological argument are more apparent when the distinction between ecological and functional validity is known. Brunswik emphasized the importance of this distinction. The ecological validity of the information is used to represent the extent to which the information reflects the environmental property of interest. The honey bee dance provides some information about the distance and location of food. However, an independent question is to what extent this information has functional validity—that is, is it used by other honey bees to locate the source of food? This is a common, if only implicit distinction in psychological inquiry. Perceptual psychologists, for example, know that height in the visual field is informative about the distance of an object. An important question, however, is the extent to which perceivers use this information. Ecologically valid attributes might be nonfunctional and functionally valid attributes might be ecologically invalid. This question can be answered only by experimentation, and sophisticated experimentation at that. As an aside, James Gibson might have been susceptible to teleological arguments because he did not seem to appreciate the value of this distinction. Given an organism's long biological history, Gibson would have difficulty accepting the notion that an ecologically valid property would be nonfunctional or that a functionally valid property would be ecologically invalid. When viewed in the light of teleological arguments, however, we see that we simply cannot accept ecological validity as equivalent to functional validity.

Wenner and Wells organize their journey within the dominant metatheories of scientific inquiry. The overall framework is illustrated in Figure 3.1 of their book, (reprinted in this review, with its original caption, as Figure 1). Each stage of the journey is depicted as an adventure within one of the depicted dimensions of inquiry. Little of this will be new to experimental psychologists, but how it is used to organize the authors' thinking and research is refreshing. Perhaps similar exposés would be valuable within mainstream experimental psychology.

Obviously, the dance language controversy is not resolved. Gould and Gould (1988), two of the major advocates of the existence of a dance language, warn that "it is a truism of science that for every experiment supporting one side in a controversy, there is an equal and opposite experiment bolstering the other" (p. 77). However, Gould and Gould come down strongly on the side of dance language as fact. The *experiment crucis* that they present had been amply criticized (Ohtani, 1983; Rosin, 1980) before their book was published. What is important for us, however, is to keep in mind that dance language in honey bees is a hypothesis, not a fact. As emphasized by both sides of the controversy, research has shown that honey bees can be influenced by a variety of factors. These influences include the touch, sight, sound, and odor of other bees and the sources of nectar and pollen. In addition, if bees communicate distance information, reliable information can be obtained from the number of waggles in the dance, the number of sound bursts, and the duration of both of these.

Given these multiple sources of information, one hypothesis is that bees are influenced by different sources at different times. Another hypothesis is that bees, like humans, integrate multiple sources of information in perception and action (Massaro, 1987). The acknowledgment of multiple sources of potential information and the concomitant issues concerning how these sources of information are processed could offer a new paradigm for inquiry in the impressive behavior of honey bees. Finally, the role of learning in behavior probably has not received the attention it deserves. Learning can illuminate what the sources of information are and how these sources are processed. Real (1991), for example, found that bumble bees overestimate common events and underestimate infrequent events. This behavior not only agrees with human performance, but also can be understood in terms of adaptive evolution.

This book offers valuable insight on a variety of issues in scientific inquiry and practice. Even though experts in the field of honey bee language will be familiar with the literature, it is important to understand how the results are woven into the thesis rejecting dance language. Professionals with an interest in the psychology and philosophy of science will also find this book necessary reading. Scientists in a variety of other domains will read a pro-

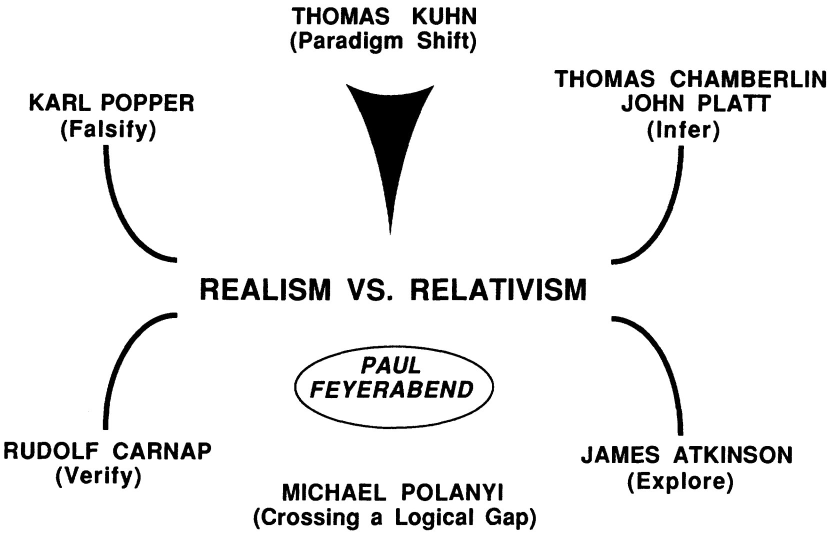

Figure 1. Diagram of our understanding of the relationship among different views of how science might operate. Whereas Popper and Carnap (the "Realism school") both indicated that "truth" exists and can be ascertained, they differed in their views about the means that "should" be employed in the search for that "truth." For Popper, repeated failures at sincere attempts to falsify an hypothesis can be recognized as reason to accept the probable truth of that hypothesis. Carnap accepted the presence of overwhelming supportive evidence as a sufficient basis for belief that truth has been "discovered" (i.e., proven to exist).

"Relativists" do not search for *ultimate* truth but still recognize the usefulness of acquired knowledge. Both Chamberlin and Platt insisted that acquisition of that knowledge can be accelerated by rapid testing and rejection of unsuitable explanations. Kuhn highlighted the problem; he recognized the hindrance posed by unwitting social commitment to explanations within accepted notions (paradigms). Progress would then be resultantly spasmodic, rather than steady (see figure 2.2).

Atkinson moved beyond the thinking of other relativists. He suggested that the process of science is a creative experience; we actually "create" phenomena ("truth") by generating support for our hypotheses and winning (i.e., "converting") others in the scientific community to our cause.

Note. Reprinted from *Anatomy of a Controversy: The Question of a "Language" Among Bees* (Figure 3.1, caption, p. 39) by A. M. Wenner and P. H. Wells, 1990, New York, Columbia University Press.

vocative and engaging story. Graduate students in behavioral sciences should know about this case history illustrating human inquiry and the sociology of scientific practice *in vivo.* I can even envision this book being used in a seminar with advanced undergraduates. As can be gleaned from my review and recommendations, many of you are encouraged to experience and enjoy the book.

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References

Alcock, J. (1989). *Animal behavior.* Sunderland, MA: Sinauer.

Gould, J. L., & Gould, C. G. (1988). *The honey bee.* New York: Freeman.

Johnson-Laird, P. N. (1988). *The computer and the mind: An introduction to cognitive science.* Cambridge, MA: Harvard University Press.

Massaro, D. W. (1987). *Speech perception by ear and eye: A paradigm for psychological inquiry.* Hillsdale, NJ: Erlbaum.

Ohtani, T. (1983). Is honeybee's "dance language" really fact? A criticism of Gould's work [In Japanese]. *Honeybee Science, 4,* 97–104.

Real, L. A. (1991). Animal choice behavior and the evolution of cognitive architecture. *Science, 253,* 980–986.

Rosin, R. (1980). Paradoxes of the honey-bee "dance language" hypothesis. *Journal of Theoretical Biology, 84,* 775–800.

von Frisch, K. (1950). *Bees: Their vision, chemical senses, and language.* Ithaca, NY: Cornell University Press.