Origins of the Molar-Molecular Debate

"Nature, Nature, why art thou so dishonest, as ever to send men with these false recommendations into the World!" (Henry Fielding, 1751, *Amelia*, Book IX, Ch. 5)

John W. Donahoe
University of Massachusetts/Amherst

The following is necessarily a brief account of what led some in the behavior-analytic community to become enamored of the molar approach to theory, an approach that is decried in Catania's prescient chapter.

Until the 1960s, the only generally agreed-upon requirement for conditioning was contiguity of a reinforcer with a stimulus in the Pavlovian procedure or with a response in the Thorndikian procedure (or with both in the discriminated operant procedure). As but one example, "To say that a reinforcement is contingent upon a response may mean nothing more than that it follows the response. ... conditioning takes place presumably because of the temporal relation only, expressed in terms of the order and proximity of response and reinforcement" (Skinner, 1948, p. 168). Several supplemental requirements were proposed from time-to-time—such as drive reduction (Hull, 1943)—but these are not considered here. Beginning in the 1960s, findings emerged that challenged the contiguity requirement. Using the Pavlovian procedure, Leon Kamin (1968, 1969) demonstrated that a stimulus presented in a contiguous relation with a known reinforcer would not acquire control over the response if that stimulus was accompanied by another stimulus that already controlled responding as the result of prior conditioning with the same reinforcer. Prior conditioning to one stimulus *blocked* conditioning to the new stimulus. This finding was soon confirmed with an appropriate operant procedure (vom Saal & Jenkins, 1970). Something beyond contiguity seemed to be required.

The initial explanation of the apparent failure of contiguity was provided by Robert Rescorla (1967). He proposed "a new conception of Pavlovian conditioning postulating that the contingency between CS and US, rather than the pairing of CS and US, is the important event in conditioning" (p. 71). Kamin's new stimulus did not change the pre-existing contingency of the prior stimulus with the reinforcer. Note that Rescorla's view of contingency distinguished it from contiguity. Contiguity denoted a purely temporal relation of a stimulus (or a response) with a reinforcer, a relation that could be satisfied on a single co-occurrence of the relevant events. Contingency, however, required multiple observations to determine the relative frequency of one event in the presence and absence of another. A close reading of Skinner indicates that he invariably used the term contingency to denote simply a co-occurrence of events, not an "if-then" relation (Donahoe, 2006). "Events which follow behavior but are not necessarily produced by it may have a selective effect" (Skinner, 1966, p. 1207). Skinner used the terms "contiguity" and "contingency" interchangeably. During roughly the same time period as Rescorla's proposal, a conceptually related proposal was being developed—apparently independently—within behavior analysis. Richard Herrnstein (1958, 1961), continuing his earlier work with Skinner (1950, p. 210), discovered that the relative frequency of responding to an alternative was proportional to the relative frequency of reinforcers for that alternative when there were two concurrently available alternatives. This outcome became known as as the *matching principle* (Herrnstein, 1970). The matching principle and Rescorla's correlational account are alike in that both involve relations between events observed over substantial intervals of time. In this sense, both are *molar* accounts. Neither approach appeals to the conjunction of individual stimuli or responses with a reinforcer, the hallmark of the contiguity, or *molecular*, approach.

In the Pavlovian procedure, some investigators were reluctant to discard the historical role accorded contiguity. They soon demonstrated experimentally that results thought to require a molar interpretation could, in fact, be accommodated by a molecular view. As examples, Pavlovian conditioning studies from John Ayres' laboratory demonstrated that conditioning would occur despite an overall random relation between stimuli and reinforcers if the random sequence of CS and US contained—by

chance—a few early contiguous co-occurrences of the events (Ayres, Benedict, & Witcher, 1975; Benedict & Ayres, 1972; see also Quinsey, 1971; Kremer, 1971). According to a molar view, conditioning should not occur because there was no overall correlation between the occurrences of CS and US. According to the molecular view, however, a few early CS-US contiguities would begin the conditioning process. In the face of such results and augmented by his own experimental work and that of Allan Wagner, Rescorla abandoned the molar view of Pavlovian conditioning. In its place Rescorla and Wagner (1972) developed a contiguity theory that accounted for the blocking effect, but in a way that preserved the essential role of contiguity. They proposed that conditioning depended on contiguity of a CS, not with the US, but with a *discrepancy* between the current "association value" of the CS and the maximum association value supportable by the US. This particular characterization of the nature of the discrepancy has conceptual difficulties (Donahoe, 1984), but it can be redefined as a discrepancy between the ongoing behavior during the CS and the behavior elicited by the US—that is, as a CR-UR discrepancy (Donahoe, Burgos, & Palmer, 1993; Donahoe, Crowley, Millard, & Stickney, 1982; Donahoe & Vegas, 2004; Stickney & Donahoe, 1983). With the changed definition of discrepancy as the critical event paired with the CS, the blocking effect is consistent with the contiguity position. In the Pavlovian procedure, a stimulus becomes conditioned when it is contiguous with a CR-UR discrepancy. The discrepancy account is a landmark in our understanding of the conditioning process (Siegel & Allan, 1996) because it identified the previously unappreciated nature of the contiguous events. There is now general agreement in the Pavlovian procedure that contiguity is sufficient for conditioning, but contiguity with a *change* in the behavioral (and neural) processes evoked by the US and not with the US/UR itself (cf. Schultz, 2006).

Molar interpretations of the Thorndikian procedure—such as matching—have also been shown to arise from more molecular relations of responses and reinforcers, but the molar approach continues to be embraced by a substantial number of behavior analysts. Herrnstein himself soon discovered that responding sometimes "deviated systematically from matching" (p. 143) and concluded "that matching requires an ongoing interaction with the conditions of reinforcement and that what is learned about indi-

vidual alternatives bears an as-yet-unspecified relationship to frequency or probability of reinforcement" (Herrnstein & Loveland, 1976, p. 153). Skinner rejected the relative number of responses during an extended period of time as a measure of "choice" because it overlooked that "we are no longer dealing with just two responses. In order to analyze 'choice' we must consider a single final response, striking [i.e., pecking one key or the other], without respect to the position or color of the key, and in addition the responses of changing from one key or color to the other" (Skinner, 1950, p. 211; see also Skinner, 1986, p. 232). In short, Skinner advocated a contiguity position in which concurrent performance was the net outcome of the reinforcement of four discriminated operants—key pecking either of two keys and switching from one key to the other. Skinner lamented the use of molar measures, such as rate of responding (Skinner. 1976). In early work on matching, Stanley Pliskoff (1971) pursued Skinner's interpretation of concurrent performance and concluded that when the delay of reinforcement for switching was manipulated, "One may ask whether changeover responding is a byproduct of response distribution … or whether the latter are byproducts of changeover responding. ... The changeover model more easily employs the language of response and consequence common to behavior analysis, and to that extent, it enjoys an advantage over response distribution models" (Pliskoff, 1971, p. 255). Herrnstein himself, prior to his untimely death, shortened the period of time over which the rate of reinforcers affected responding from the entire session to the temporal neighborhood of the response, a process known as melioration (Herrnstein, 1982). William Vaughan (1982), a co-author with Herrnstein on melioration, concluded that "it is possible to derive melioration from the more basic processes advocated by Skinner" (Vaughan, 1997, p. 253). Skinner's interpretation of concurrent performance has received support from work showing that matching does not occur unless switching is explicitly reinforced (Crowley & Donahoe, 2004) and that relative responding to an alternative can be manipulated by the differential reinforcement of responding to an alternative versus changing to the other alternative (MacDonall, 2009). For related findings, see Silberberg, Hamilton, & Casey, 1978 and Hinson & Staddon, 1983 among many others.

Despite much evidence that molar relations are not fundamental in the Thorndikian procedure but

are the cumulative product of more molecular processes, Herrnstein's former graduate student William Baum and those influenced by his theorizing have continued their commitment to molar theory. Baum (1973) argued that behavioral theory "require(s) a simple, but fundamental, change in the law of effect: from a law based on contiguity of events to a law based on correlation between events." (p. 137). The reasons that some influential contributors to our field have persisted in this effort are complex, but among them I would list the following. First, molar relations are more easily communicated to an audience not intimately familiar with the experimental analysis of moment-to-moment, stimulus-response-reinforcer relations (that is, molecular processes). The statement that responding is proportional to reinforcers is more readily understood than that responding results from a mixture of different operants such as staying on one alternative or switching to another. Of course, if one were to follow this same reasoning in physics, Newton's laws of motion would be preferred to Einstein's field equations because the former are more readily understood. Second, it is more difficult to experimentally analyze the effect of response-reinforcer contiguity in a free-operant instantiation of the Thorndikian procedure than stimulus-reinforcer contiguity in the Pavlovian procedure. This is because the occurrence of a response in the former procedure cannot be as tightly controlled as the presentation of a stimulus in the Pavlovian procedure. Third, Rescorla's presentation of the discrepancy principle to a general audience unfortunately obscured the rejection of his earlier molar view (Rescorla, 1988). Note, that this is the article cited by Baum as congenial to a molar theory of operant conditioning (Baum, 2012, p. 109). Baum drew the erroneous conclusion that "Rescorla (1967, 1968), in both experiment and arguments, clarified the explanatory insufficient of contiguity" (Baum, 2001, p. 239). To the contrary, the contiguity position was actually affirmed in the cited article (Papini & Bitterman, 1990). Fourth, and perhaps most fundamentally, the molar approach to operant conditioning reflects a pre-theoretical commitment to a holistic view of theory that rejects what is characterized as "19th-century atomism" (Baum, 2001, p. 339). "The molar and molecular views are not competing theories; they are different paradigms (Kuhn, 1970). … No experimental test can decide between them, because they are incommensurable—that is, they differ ontologically" (Baum, 2012, p. 101). This last reason allows us better to understand how the molar view can be maintained despite the common finding that molar relations are cumulative products of molecular processes. Not only are molecular *behavioral* processes viewed as irrelevant by molar theorists but also the *neural* processes that underlie them. "Neurophysiology may be omitted … because it reveals only mechanism" (Baum, 2011, p. 119). The willingness to dismiss all but molar accounts is especially unfortunate given that the general acceptance of natural selection in evolutionary biology was dependent on the discovery of its genetic mechanisms (Gayon, 1992): If history repeats itself, the acceptance of selection by reinforcement as a comparably fundamental principle in the emergence of complex behavior awaits the discovery of its neural mechanisms (Donahoe, 2012).

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