where the "discriminated operant" is never acquired or "established by reinforcement." The reasons for such failures to acquire the behavior are forever hidden, in principle, by the Skinnerian dictum that "shaping is an art." Relegating the acquisition or "shaping" (i.e., learning) of behavior to an "art" and ignoring instances of failures has undesirable consequences both for science and for applications of psychology. The Skinnerian definition of psychology is the prediction and control of behavior. But prediction is undermined if we cannot tell in advance whether a certain rat (perhaps combined with a certain shaper) will acquire the behavior, *and at what rate.* Control is also lessened if one cannot provide scientific principles (and not those of "art") to guide the practitioner in how to administer maximally effective training.

Still, some may object that the above fact about bar-press-for-food Skinnerian conditioning concerns only a few animals. That objection does not apply to a second set of brute facts that emerges when one changes the reinforcer or the to-be-learned target behavior (the discriminated operant). An instance of a change in reinforcer is when one replaces food with shock avoidance. In that case, as is common laboratory knowledge, about 50% of the rats fail to ever acquire the discriminated operant.

An instance of changing the target behavior also illustrates problems for applications – that is, the "control" of behavior rather than its prediction. The example I use is relevant to Skinnerian conditioning's most enthusiastically touted application: "biofeedback" or the instrumental conditioning of autonomic functions.

The central concept behind biofeedback is that supplying "information" about the relations between changes in such autonomically controlled functions as heart rate and blood pressure, on the one hand, and feedback or contingent reinforcement, on the other, will result in an increase of "self-control" over these functions. There was considerable excitement and enthusiasm for such instrumental autonomic conditioning following the report of Miller (1969). But when it comes to such difficult and medically relevant behaviors as heart rate deceleration and blood pressure decrease, there is practically no evidence, not only in the clinic (e.g., Furedy & Shulhan 1987) but even in the laboratory (e.g., Furedy 1987), that the contingency between the reinforcer (feedback) and the target behavior (e.g., blood pressure decrease) has *any* specific beneficial effect on control.

A similar set of lacunae exist for current contingency accounts of the phenomenon of Pavlovian conditioning. For N&G, Pavlovian conditioning is the "contingency space" or the "informativeness of the stimulus with respect to the reinforcement" (p. 79). Essentially, this is the original Rescorla (1967; 1969) formulation, which itself is a resurrection of the Tolmanian idea of sign-significance (S-S) learning (for details of the nature of this sort of cognitive, propositional, current account of Pavlovian conditioning, see Furedy & Riley 1987). No doubt the formulation is "intuitively reasonable," but whether it is also "empirically useful" (p. 79) is open to question, if one includes under the rubric of empirical usefulness the ability of the approach to be sensitive to relevant factual evidence regarding actual Pavlovian conditioning phenomena.

To begin with, it follows from any "contingency-space" account of Pavlovian conditioning that in Pavlovian preparations such as those of eyelid conditioning and human electrodermal conditioning, a stimulus that predicts the absence of the reinforcer (a so-called explicitly-unpaired conditional stimulus [CS]) should produce lower levels of performance than one that is merely uncorrelated with the reinforcer (a so-called truly-random CS). This consequence of the contingency position (first formulated by Prokasy [1965], and then by Rescorla [1967]) has been consistently disconfirmed in the experiments that compared acquisition functions to the "explicitly unpaired" and "truly random" CSs, although more complex post-acquisition assessments (e.g., transfer of training) have yielded some confirmations (see, e.g., Furedy & Riley 1987).

Still, one might object that the above set of facts pertain to relatively esoteric methodological issues about which Pavlovian conditioners still disagree (see, e.g., Furedy et al. 1975 vs. Prokasy 1975). A more obvious and gross violation of the facts by contingency-space accounts is that in eyelid conditioning preparations, the CS-US interval (between CS onset and US or unconditional-stimulus onset) is so crucial that CS-US intervals as short as 2 seconds produce no acquisition conditioning, even though it is patently obvious that the "informativeness" of the stimulus with respect to the reinforcement" (i.e., awareness of the CS/US relation) has been established.

Similarly, with heart-rate deceleration as the target response, when the CS-US interval is extended from 1 to 5 seconds, even repeated sessions fail to produce any acquisition in human subjects who are clearly aware of the contiguity relation between the tone CS and the negative-tilt US (Furedy 1992). This deficiency of the contingency position for predicting behavior is paralleled by a weakness for its control. As with Skinnerian conditioning, the most relevant applied situation for Pavlovian conditioning is that of teaching target behaviors that are beneficial and that are difficult to learn.

Whether the aim is to achieve conditioned heart-rate or blood-pressure decrease or autoimmune increase, any practitioner who is guided by a "contingency-space" account of Pavlovian conditioning will fail because this metaphorical concept ignores the non-propositional stimulus-response (S-R) processes, which, *in addition to propositional sign-significate* (S-S) processes, actually influence the phenomenon of Pavlovian conditioning (see, e.g., Furedy & Riley 1987).

Accordingly, although the "momentum metaphor" may "encompass" the Skinnerian explanatory concepts N&G advance in their target article, and although their analysis may be useful in such fields as economics where the psychology of human preference is a legitimate area of study, in my view the metaphorical explanatory physics-aping emperor has no scientific or applied psychological clothes.

Behavioral momentum in Pavlovian conditioning and the learning/performance distinction

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Abstract: Behavioral momentum theory has evolved within the realm of operant conditioning. The thought-provoking momentum metaphor equates the strength of an operant response with its resistance to change and preference (i.e., choice) for that response over other available responses. Whereas baseline response rate (velocity in the metaphor) is assumed to be largely influenced by the response-reinforcer contingency, resistance to change and preference are assumed to reflect an intervening variable called *behavioral mass*, which is determined primarily by the stimulus-reinforcer relationship. This invites the question of how well the momentum metaphor applies to the stimulus-reinforcer relationships of traditional Pavlovian paradigms. Presumably, a correspondence exists between behavioral mass and the notion of associative strength in the associative learning literature. Although response rate has little meaning in the trialwise structure of classical (i.e., Pavlovian) conditioning, response probability or magnitude might be regarded metaphorically as velocity. Momentum theory suggests that resistance to change (e.g., extinction) is a better indicator of associative strength than is response probability or magnitude. Therefore, variables that strengthen Pavlovian learning should influence resistance to extinction of conditioned responding in a similar manner. Moreover, it is important to assess momentum theory outside of strictly operant paradigms, particularly because in clinical settings many common disorders (e.g., phobias) and their therapies (e.g., cue exposure) are thought to be classically conditioned.

Behavioral momentum theory can be contrasted with the traditional theories of associative learning, which are exemplified by the Rescorla and Wagner (1972) model. Models of associative learning are considered dynamic theories because they have been con-

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cerned primarily with the rate at which associative learning takes place. In contrast, momentum theory is typically considered a steady-state model in that it deals with asymptotic levels of responding. Whether the variables that determine behavioral mass also affect the rate at which that asymptote is reached is not explicitly stated by Nevin & Grace (N&G 2000) in their target article. Yet, resistance to change is by definition a dynamic measure and presumably reflects a dynamic process. The analogy to physical mechanics implies that the mechanisms of associative acquisition and extinction should oppose one another. In other words, variables that facilitate acquisition should impede extinction and vice versa. Moreover, the variables that enhance asymptotic behavioral mass should both decelerate extinction and accelerate acquisition. It would be interesting to see whether such a correlation exists. Research in this vein would encourage the development of behavioral momentum theory as a dynamic model of behavior.

Among the variables known to influence associative learning in Pavlovian situations are conditioned stimulus (CS) intensity, reinforcer magnitude, and CS rate within the context. (It is a separate question whether these specific attributes of experience or just their effects on learning are ultimately retained by the organism.) As predicted by the Rescorla-Wagner (1972) model, CS intensity appears to directly affect the rate but not the asymptote of learning, whereas reinforcer magnitude directly influences both rate and asymptote in the expected manner. In the Rescorla-Wagner model, CS intensity is captured by the learning rate parameter α, and reinforcer magnitude modulates λ, the total amount of learning that can occur, and β, a learning rate parameter for the unconditioned stimulus (US).

Although behavioral momentum theory is silent concerning the effect of CS intensity, reinforcer magnitude and rate are the two main variables the theory has used to establish different baselines of behavioral mass. It is with respect to reinforcer magnitude that the two theories contrast most sharply. Although both theories anticipate that greater reinforcer magnitude will increase the asymptotic strength of learning (mass or associative strength), they make different predictions regarding resistance to extinction following training with reinforcers of different magnitude. The Rescorla-Wagner model implies that during extinction β will be larger for a larger (now-omitted) reinforcer. Therefore, extinction (just like acquisition) of associative strength should proceed faster with the cessation of larger reinforcers than smaller reinforcers, even when baselines are normalized. This rather counterintuitive prediction is, of course, opposite to that of a Pavlovian extension of momentum theory, which anticipates that subjects trained with larger reinforcers will exhibit greater resistance to extinction.

The existing data based on traditional Pavlovian paradigms seem to favor the view of behavioral momentum theory. There is a positive relationship between resistance to extinction and magnitude of reinforcement. For example, Wagner et al. (1964) found more rapid salivary conditioning and greater resistance to extinction when the US consisted of six food pellets rather than one. Annau and Kamin (1961) and Kamin and Brimer (1963), varying the intensity of shock used as a US in conditioned suppression, found that higher intensity shocks facilitated acquisition and retarded extinction. Smith (1968) found that conditioning of the nictitating membrane response of rabbits and its resistance to extinction were directly related to the intensity of a shock US.

However, all of these studies used what would be analogous to continuous reinforcement (CRF) schedules; that is, all trials were reinforced. It is well known that in operant situations a direct relationship between reinforcer magnitude and resistance to change only holds for partial reinforcement (PRF) schedules, in which not every response is reinforced. With CRF schedules, greater magnitude of reinforcer often leads to more rapid extinction. This is an example of the partial reinforcement extinction effect with which behavioral momentum theory has struggled over the years (e.g., Nevin 1988). This latest version of momentum theory borrows the concept of generalization decrement, a mechanism that has been used many times before to explain partial reinforcement effects (e.g., Sheffield 1949). In fact, N&G's "augmented model" for resistance to extinction (equation 17 in the target article) is basically a formal statement of Capaldi's (1967) account of the interaction between reinforcement schedule and reward magnitude: Effectively, the generalization decrement involved in the transition from continuous reinforcement to extinction outweighs the "reinforcing power" (mass) gained by using a larger reinforcer. With PRF schedules, the amount of generalization decrement is presumably less, allowing the pattern anticipated by behavioral momentum theory to emerge. But a discrepancy remains: Why was there a positive relationship between resistance and US magnitude when all trials were reinforced in the Pavlovian experiments cited above? There is a literature suggesting that the effect of generalization decrement is less pronounced in Pavlovian tasks (e.g., Gormezano 1966) because the short CS-US interval favors a broad stimulus generalization gradient. Therefore, the short intervals typically found between the CS and the US in Pavlovian conditioning mitigate against the partial reinforcement extinction effect, thereby leaving unopposed the effects of reinforcer magnitude on resistance to change.

Leaving these issues aside, N&G draw a strong distinction between learning and performance, a long-known (e.g., Tolman 1932) but often overlooked (e.g., Rescorla & Wagner 1972) dichotomy that we have examined in our laboratory over many years (e.g., Miller & Matzel 1988). Therefore, we welcome N&G drawing attention to this distinction. However, for them, response rate (metaphorical velocity) is influenced by the operant (response-reinforcer) contingency, whereas resistance to change and preference (metaphorical behavioral mass) are influenced primarily by the Pavlovian (stimulus-reinforcer) contingency. Thus, behavioral momentum (resistance to change) and velocity (response rate) appear differentially sensitive to two different contingencies. This is not necessarily the learning-performance distinction, but rather different measures reflecting two different memories. There is ample evidence that organisms learn about both stimulus-reinforcer and response-reinforcer relationships (e.g., Colwill & Rescorla 1985). Simply noting that resistance to change and response rate are sensitive to different variables may not warrant classifying one measure as an indicator of learning while relegating the other to the status of a performance variable, particularly because the authors acknowledge several exceptions to the assumption that resistance to change is determined solely by stimulus-reinforcer relations.

Authors' Response

Behavioral momentum and Pavlovian conditioning

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Abstract: The constructs of behavioral mass in research on the momentum of operant behavior and associative strength in Pavlovian conditioning have some interesting parallels, as suggested by **Savastano & Miller**. Some recent findings challenge the strict separation of operant and Pavlovian determiners of response rate and resistance to change in behavioral momentum, renewing the need for research on the interaction of processes that have traditionally been studied separately. Relatedly, **Furedy** notes that some autonomic responses may be refractory to conditioning, but a combination of operant contingencies and enriched Pavlovian stimulus-reinforcer relations may prove effective.

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