Title
Evocation of Behavioral Change by the Reinforcer is the Critical Event in both the Classical and Operant Procedures

Journal
International Journal of Comparative Psychology, 27(4)

ISSN
0889-3675

Author
Donahoe, John W.

Publication Date
2014

DOI
10.46867/ijcp.2014.27.04.05

INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2014, 27(4), 537-543
Stanley J. Weiss, Editor
Special Issue
Peer-reviewed

Evocation of Behavioral Change by the Reinforcer is the Critical Event in Both the Classical and Operant Procedures

John W. Donahoe
University of Massachusetts, USA

By definition, in a Pavlovian (classical) procedure a stimulus is presented prior to an eliciting stimulus whereas in an operant procedure a response occurs prior to the eliciting stimulus. In spite of the different contingencies implemented by the two procedures, some behavior necessarily precedes the eliciting stimulus in the Pavlovian procedure and some stimulus necessarily precedes the eliciting stimulus in the operant procedure. If conditioning depends on the momentary relation of environmental and behavioral events to an eliciting stimulus, then the two procedures must engage a common conditioning process. The cumulative effects of that common process may be different, however, because of differences in the frequency with which specific environmental and behavioral events are contiguous with the eliciting stimulus (and its elicited response). The view that the critical reinforcing event is the evocation of a change in ongoing behavior evoked by the eliciting stimulus provides the basis for an interpretation of the conditioning process that encompasses the effects of both procedures.

Within 10 years of the publication in English of Pavlov's Conditioned Reflexes (1927) American psychologists began to differentiate between Pavlovian, or classical, conditioning and operant, or instrumental, conditioning. Others had recognized the distinction (e.g., Schlosberg, 1937), but the difference was most fully appreciated by B. F. Skinner (1935, 1937). Two primary differences were emphasized. First, the nature of the contingency that defined the operant and Pavlovian procedures differed: "There are two fundamental cases: in one the reinforcing stimulus is correlated temporally with a response and in the other with a stimulus" (Skinner, 1937, p. 272). Second, whereas the Pavlovian procedure primarily changed only the stimulus that controlled a response already evoked by another stimulus, the operant procedure potentially brought a wide range of behavior under the control of the stimulus. As a Pavlovian example, the ticking sound of a metronome acquired control of salivation after the sound had been followed by food, a stimulus that already elicited salivation. As an operant example, an auditory stimulus presented to a rat would acquire control of lever-pressing, chain-pulling, or running depending on which response preceded food. The response that preceded the food was designated an operant to indicate that it operated on the environment to produce food.

A close reading of Skinner's early writings (e.g., Skinner, 1938) on the classical-operant distinction indicates that he viewed the difference as primarily one of procedure, not process. To wit, Skinner acknowledged without dissent that "…'reinforcement' is essentially the same process in both [procedures]" (citing Hilgard, p. 111) and that conditioning "...may eventually be reduced to a single formula" (citing Mowrer, p. 111). In spite of Skinner's early willingness to consider the possibility that the two procedures engaged the same conditioning process, different conceptions of the conditioning process increasingly arose.

Please send correspondence to Dr. John Donahoe, Department of Psychological and Brain Sciences, Tobin Hall, University of Massachusetts, Amherst, MA 01003 (Email: jdonahoe@psych.umass.edu).

The differing conceptions were fostered, in part, by the use of different technical terms to designate analogous events manipulated and monitored in the procedures. The technical terms employed in the classical procedure followed Pavlov's usage. The environmental event that preceded the elicited response was termed the conditioned stimulus, the eliciting stimulus the unconditioned stimulus, and the elicited response the unconditioned response. The monitored response that ultimately came under control of the conditioned stimulus was termed the conditioned response. *Conditioned* was used to indicate that the control exerted by the conditioned stimulus was not innate, but conditional upon – that is, dependent upon – its presentation within the Pavlovian procedure.

The technical terms used to designate the corresponding events in the operant procedures did not follow Pavlov's usage. The environmental events prior to the operant were simply described in general physical terms (the characteristics of the conditioning chamber) or in terms of their specific properties (the wavelength of light, the frequency of sound, and so on). One of Skinner's major contributions was to demonstrate that behavior could display orderly properties without identifying the environmental events if the precise relation of behavior to its consequences was specified (Ferster & Skinner, 1957; cf., Donahoe, Palmer, & Burgos, 1997). Skinner did not deny that operants were under environmental control but asserted that their specification was often unnecessary. Indeed, under appropriate experimental arrangements the precise stimuli that controlled the operant could be identified and, in such cases, these stimuli were termed discriminative stimuli. In fact, Skinner maintained that "…it is the nature of [operant] behavior that ... discriminative stimuli are practically inevitable" (Skinner, 1937, p. 273). Note, however, that in the operant procedure the temporal relation of a discriminative stimulus to an eliciting stimulus (e.g., food) could be comparable to the temporal relation of the conditioned stimulus to the unconditioned stimulus in the classical procedure. Thus, stimuli bearing similar temporal relations to the eliciting stimulus were designated by different technical terms. Next, consider the terms used to designate the eliciting stimulus. As previously noted, the eliciting stimulus is called an unconditioned stimulus in the classical procedure. In an operant procedure, the eliciting stimulus is called a reinforcer if the operant increases in frequency but a punisher if it decreases. Once again, different technical terms are applied to the same physical event when it appears in the two procedures. Finally, the behavior monitored in the procedures clearly differs. In the classical procedure, a response similar to that evoked by the eliciting stimulus is typically measured (e.g., salivation occasioned by the conditioned stimulus). In the operant procedure, the operant is monitored but the response corresponding to the conditioned response in the classical procedure almost always goes unmeasured even though it may be occurring. (There are a few notable exceptions in which both the operant and the conditioned response are measured, e.g., Shapiro, 1962.)

The fact that analogous events are designated by different technical terms in the two procedures and that the behavior monitored also differs has encouraged the conclusion that different conditioning processes are engaged by the two procedures. This conclusion is revisited in the next section.

Two Conditioning Procedures, but One Conditioning Process?

Let us examine afresh the events that occur in the classical and operant procedures. In both procedures the organism is immersed in a succession of environmental stimuli in which a stream of responses is occurring (cf., Schoenfeld, 1972). Also, in both procedures an eliciting stimulus (or elicitor) is introduced into that environment (see Figure 1). What differs between the procedures, as Skinner observed, is whether the elicitor follows an environmental stimulus, in which case it is a classical procedure, or follows a behavior, in which case it is an operant procedure. Note, however, that at the moment the reinforcer occurs, there is no detectable difference between the two procedures (Donahoe, Burgos, & Palmer, 1993). In the classical procedure, some behavior has inevitably occurred prior to the reinforcer, although that behavior may change from moment-to-moment. Similarly, in the operant procedure, some stimulus must have been detected immediately prior to the reinforcer, although that stimulus may also vary from moment-to-moment. If conditioning involves processes

that are engaged on a moment-to-moment basis, then at the moment when the reinforcer occurs there can be no difference in the processes engaged by the two procedures. The undeniable difference in the behavioral effects of the procedures emerges over time – the conditioned response in the classical case and the operant as well as the conditioned response in the operant case. In the classical procedure, the behavior occurring during the moment prior to the reinforcer varies, whereas in the operant procedure it is the stimulus occurring during that moment that varies. The stimulus-reinforcer relation is constant in the classic procedure; the response-reinforcer relation is constant in the operant procedure. This difference in the event temporally correlated with the reinforcer has encouraged different conceptions of the conditioning process in the two procedures.

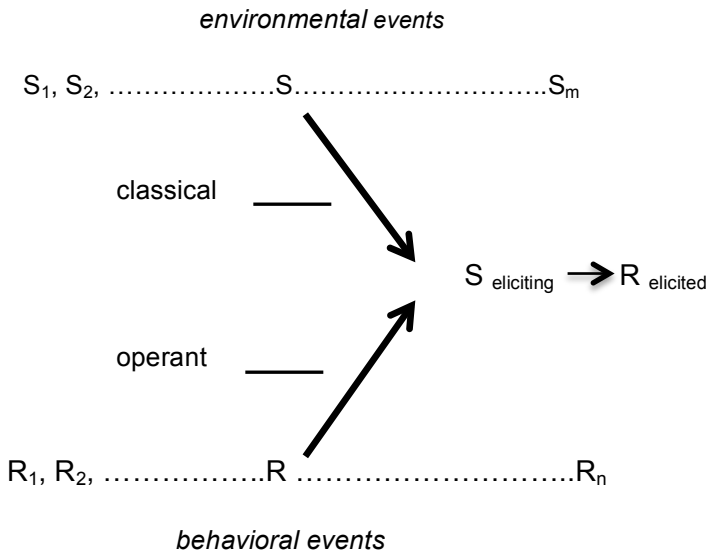

Figure 1. *A stream of environmental events (S) and accompanying behavioral events (R) into which a reinforcing eliciting stimulus ($S_{eliciting}$) and its elicited response are introduced.* A Pavlovian procedure is implemented when the eliciting stimulus is introduced after a stimulus (S), but note that some response (R) must also be occurring. An operant procedure is implemented when the eliciting stimulus is introduced after a response (R), but note that some stimulus (S) must also be occurring.

Moment-to-Moment Versus Molar Conceptions of the Conditioning Process

For Skinner, conditioning was consistently viewed as a moment-to-moment process. Contingency was defined by the temporal relation between an individual stimulus or response and an individual elicitor, not by the correlation between these events over extended periods of time. Perhaps the clearest examples of a moment-to-moment conception come from experimental demonstrations of what Skinner called "superstitious" behavior. When a stimulus is presented at varying times independent of on-going behavior, that stimulus can nevertheless acquire control of behavior when some response in its presence was – by chance – followed by a reinforcer such as food. This control persisted until – again, by chance – another stimulus happened to occur when the response was followed by the reinforcer (Morse & Skinner, 1957). Similarly, in an environment in which no stimulus was presented by the experimenter, if a reinforcer occurred independent of on-going behavior but – by chance – appeared immediately after some response, then that response increased in frequency, particularly when it was compatible with the behavior evoked by the elicitor (Skinner, 1948, cf., Staddon & Simmelhag, 1971). Based on such experiments, Skinner concluded: "To say that a reinforcement is contingent upon a response may mean nothing more than that it follows the response" (Skinner, 1948, p. 168). Causation was reduced to temporal coincidence, a very Humian (Hume, 1748) conception.

The conclusion that contiguity of a stimulus, in the classical case, or a response, in the operant case, with a reinforcer is sufficient to produce conditioning was directly challenged by findings in the 1960s and 70s. Experiments with both the classical procedure (Kamin, 1968, 1969) and the operant procedure (Vom Saal & Jenkins, 1970) demonstrated that an eliciting stimulus did not function as a reinforcer when it was presented in an environment in which conditioning with that same elicitor had already taken place. The ability of the elicitor to function as a reinforcer was said to be *blocked*. Given these findings, some theorists proposed that conditioning was not the result of moment-to-moment contiguities of an elicitor with a stimulus and/or a response, but of the overall correlation of these events with the elicitor. Such proposals are known as molar theories because contingency is defined, not by the moment-to-moment relation between events, but by the correlation between events over extended periods of time, such as the duration of an experimental session. As an example of a molar view with a classical procedure, if elicitors are more common during periods of time when putative conditioned stimuli are frequent than when they are uncommon, then conditioning occurs (Rescorla, 1967), supposedly independent of individual stimulus-reinforcer contiguities. Given such findings, molar theories were developed for both the classical (Rescorla, 1967) and operant (Baum, 1973) procedures. However, subsequent experimental and theoretical research has found that the molar relations observed in these studies could arise as the cumulative product of individual stimulus-reinforcer and response-reinforcer contiguities. This was found for both the classical procedure (e.g., Ayres, Benedict, & Witcher, 1975; Rescorla & Wagner, 1972) and the operant procedure (e.g., Crowley & Donahoe, 2004; MacDonall, 2009, McDowell, 2004; and see Donahoe, 2012 for a brief review of the molar-molecular issue).

An Alternative Momentary Conception of Conditioning

Although a molar conception of the reinforcement process appears not to be required, the question remained as to what produced the blocking phenomenon. Blocking demonstrated that contiguity of either a stimulus or a response with a putative reinforcing stimulus would not produce conditioning if some other stimulus were simultaneously present that was previously contiguous with that reinforcer. Something beyond contiguity with a reinforcing stimulus was required for conditioning.

A candidate for the critical factor arises from the realization that when an eliciting stimulus is presented an elicited response also occurs: Contiguity of a stimulus or response with a reinforcing stimulus also produces contiguity with a reinforcer-elicited *response*. (Apparent exceptions in conditioned drug responses are resolved when the unconditioned response is properly identified as the immediate neural response to the elicitor and not the more delayed behavioral response; Eickelboom & Stewart, 1982.) From an evolutionary perspective it seems plausible that natural selection would be more sensitive to the behavior of an organism in response to a stimulus than to the perception of the stimulus alone. A very few theorists using the classical procedure explicitly recognized the potential importance of contiguity of the conditioned stimulus with the reinforcer-elicited response instead of the eliciting stimulus (Gormezano & Kehoe, 1981; Guthrie, 1935). The elicited response was generally ignored altogether in the operant procedure because the elicited response was rarely monitored. (Stimulus sampling theory developed by Estes (1950), a former student of Skinner, is an exception.) More recently, an experimental preparation was developed that allowed the question of whether contiguity with the reinforcing stimulus or with the reinforcer-elicited response was crucial for conditioning (Donahoe & Vegas, 2004). Using a liquid-elicited swallowing response that has a latency of several hundred milliseconds and duration of several seconds, the temporal relation of the conditioned stimulus to the elicited response was varied independently of its relation to the eliciting stimulus. With this preparation, conditioning occurred whenever the conditioned stimulus preceded or overlapped the reinforcer-elicited *response* independent of its temporal relation to the eliciting stimulus. The neural mechanisms of conditioning naturally selected by the environment appear more attuned to the occurrence of the elicited response than to the

perception of the eliciting stimulus. Thomas Huxley's maxim (1887) endures: "The great end of life is not knowledge but action."

The current proposal is that the critical reinforcing event in both the classical and operant procedures is more closely correlated with the evocation of a change in behavior induced by the reinforcing stimulus than with the presentation of that stimulus itself. In experimental analyses conducted at the behavioral level, the change in behavior induced by the reinforcer is apparent and may be directly measured, as with salivation induced by food in the mouth. However, once the neural mechanisms correlated with changes in behavior have been naturally selected, those same mechanisms could become exploited by other stimuli, such as conditioned reinforcers whose direct behavioral effects are less apparent. As an example, liquid introduced into the mouth of a monkey evokes activity in dopaminergic neurons of the ventral tegmental area and very similar neural activity is produced by a formerly neutral stimulus after it had reliably preceded the liquid (Schultz, 1997). As noted elsewhere (Donahoe & Vegas, 2004),

> It has long been recognized that the behavioral expression of the UR [the reinforcer-elicited response] is not necessary for conditioning as demonstrated by cases in which the behavioral UR is prevented (as when transmission at the neuromuscular junction is blocked; e.g., Solomon & Turner, 1962) or by cases in which the CS does not support expression of the UR (as when an auditory CS is paired with food for the pecking response of the pigeon; e.g., Leyland & Mackintosh, 1978). However, if the behavioral expression of conditioning were not highly correlated with the neural mechanisms that mediate conditioning, then those mechanisms could never have been naturally selected. As E. O. Wilson has observed, "Learning is the pacemaker of evolution" (Wilson, 1975, p. 156). Nevertheless, once these mechanisms have been naturally selected, their behavioral expression is not necessary for the environment to engage them. (p. 31)

From the perspective that the evocation of the reinforcer-elicited response is the critical event in conditioning, blocking may be interpreted as follows: Blocking occurs when the environment present when the reinforcing stimulus occurs already evokes the conditioned response previously established with that reinforcer. When these circumstances obtain, the reinforcer no longer evokes a change in behavior because the conditioned response is already occurring. Without a change in behavior evoked by the reinforcer, conditioning does not occur. Research using computer-simulations with biologically informed neural networks demonstrates that only an elicitor that evokes a behavioral change functions as a reinforcer and that this conception of reinforcement applies equally to conditioning with the classical and operant procedures (Donahoe et al., 1993). A unified conception of selection by reinforcement appears viable. Note that a unified conception of conditioning is not simply a claim that classical conditioning affects operant conditioning but that the different outcomes of both procedures are expressions of a common conditioning process.

Conditioning and its Neural Mechanisms

A unified conception of conditioning is also not a claim that the neural mechanisms ultimately engaged by the two procedures are totally the same. Instead, it is a claim that the events sensed by the organism are identical at the moment of reinforcement and, for that reason, all the neural processes relevant to both procedures must be engaged at that moment. The cumulative effect of reinforcement on the conditioning process differs because the events that are most reliably contiguous with the reinforcing behavior differ, most prominently the response that precedes the reinforcer in the operant procedure.

An elaboration of the differences in the neural processes engaged by the two procedures is beyond the scope of this discussion but two obvious ones merit mention. First, in the operant procedure the entire behavioral repertoire of the organism is a potential candidate for selection. In mammals, this necessarily

involves cortical structures whereas many responses that are conditionable with the classical procedure can be mediated by subcortical structures alone (e.g., Oakley & Russell, 1972). Second, there is typically a greater delay between the occurrence of the operant and the reinforcer-elicited response in the operant procedure than between the conditioned stimulus and the reinforcer-elicited response in the classical procedure. For example, the time between bar pressing and the ingestion of food in Skinner's procedure is generally greater than between hearing a tone and injecting acid into the mouth in Pavlov's procedure. In Skinner's first studies with the operant procedure, he addressed this temporal asynchrony by first pairing the sound of the operation of the feeder with the ingestion of food and then later presented this sound immediately after a bar press had occurred. Computer simulations using neural networks have demonstrated that without additional neural systems to bridge the temporal gap between the operant and the reinforcer, conditioning fails to occur (Donahoe & Burgos, 2005).

References

Ayres, J. J. B., Benedict, J. O., & Witcher, E. S. (1975). Systematic manipulation of individual events in a truly random control in rats. *Journal of Comparative and Physiological Psychology*, *88*, 97–103

Baum, W. M. (1973). The correlation–based law of effect. *Journal of the Experimental Analysis of Behavior, 20*, 137–15.

Crowley, M. A., & Donahoe, J. W. (2004). Matching: Its acquisition and generalization. *Journal of the Experimental Analysis of Behavior*, *82*, 143–1593.

Donahoe, J. W. (2012). Origins of the molar-molecular divide. *European Journal of Behavior Analysis*, *19*, 196-200.

Donahoe, J. W., & Burgos, J. E. (2005). Selectionism: Complex outcomes from simple processes. *Behavioural and Brain Sciences*, *28*, 397-468.

Donahoe, J. W., Burgos, J. E., & Palmer, D. C. (1993). A selectionist approach to reinforcement. *Journal of the Experimental Analysis of Behavior*, *60*, 17-40.

Donahoe, J. W., Palmer, D. C., & Burgos, J. E. (1997) The S-R issue: Its status in behavior analysis and in Donahoe & Palmer's *Learning and Complex Behavior*. *Journal of the Experimental Analysis of Behavior*, *67*, 193-211.

Donahoe, J. W., & Vegas, R. (2004). Pavlovian conditioning: The CS-UR relation. *Journal of Experimental Psychology: Animal Behavior Processes*, *30*, 17-33.

Eickelboom, R., & Stewart, J. (1982). Conditioning of drug-induced physiological response. *Psychological Review*, *89*, 507-528.

Estes, W. K. (1950). Toward a statistical theory of learning. *Psychological Review*, *57*, 94-107.

Gormezano, I., & Kehoe, E. J. (1981). Classical conditioning and the law of contiguity. In P. Harzem & M. D. Zeiler (Eds.), *Predictability, correlation, and contiguity* (pp. 1-45). New York, NY: Wiley.

Guthrie, E. R. (1935). *The psychology of learning*. New York, NY: Harper & Row.

Hume, D. (1748/1955). *Philosophical essays concerning human understanding*. Indianapolis, IN: Bobbs-Merrill.

Huxley, T. H. (1877/1964). Technical education. In T. H. Huxley and J. Priestly (Eds.), *Science and education*. New York, NY: Philosophical Library.

Kamin, L. J. (1968). Attention-like processes in classical conditioning. In M. R. Jones (Ed.), *Miami symposium on the prediction of behavior: Aversive stimulation* (pp. 9-31). Coral Gables, FL: University of Miami Press.

Kamin, L. J. (1969). Selective association and conditioning. In N. J. Mackintosh & F. W. K. Honig (Eds.), *Fundamental issues in associative learning* (pp. 4-64), Halifax, Canada: Dalhousie University Press.

Leyland, C. M., & Mackintosh, N. J. (1978). Blocking of first- and second-order autoshaping in pigeons. *Animal Learning & Behavior*, *6*, 392-394.

MacDonall, J. S. (2009). The stay/switch model of concurrent choice. *Journal of the Experimental Analysis of Behavior*, *91*, 21–39.

McDowell, J. J. (2004). A computational model of selection by consequences. *Journal of the Experimental Analysis of Behavior, 81*, 297-317.
Morse, W. H., & Skinner, B. F. (1957). A second type of superstition in the pigeon. *American Journal of Psychology*, *70*, 308–311.
Oakley, D. A., & Russell, I. S. (1972). Neocortical lesions and Pavlovian conditioning. *Physiology & Behavior*, *8*, 915-926.
Pavlov, I. P. (1927). *Conditioned reflexes*. (Translated by G. V. Anrep). London, UK: Oxford University Press.
Rescorla, R. A. (1967). Pavlovian conditioning and its proper control procedures. *Psychological Review*, *74*, 71–80.
Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning: Current research and theory* (pp. 64-99). New York, NY: Appleton-Century-Crofts.
Schlosberg, H. (1937). The relationship between success and the laws of conditioning. *Psychological Review, 44*, 379-394.
Schoenfeld, W. N. (1972). *Stimulus schedules: The t-T systems*. Oxford, England: Harper & Row.
Schultz, W. (1997). Appetitive dopaminergic neurons report the appetitive value of environmental stimuli. In J. W. Donahoe & V. P. Dorsel (Eds.), *Neural-network models of cognition: Biobehavioral foundations* (pp. 317-335). New York, NY: Elsevier Science Press.
Shapiro, M. H. (1962). Temporal relationship between salivation and lever pressing with differential reinforcement of low rates. *Journal of Comparative and Physiological Psychology, 55*, 567-571.
Skinner, B. F. (1935). Two types of conditioned reflex and a pseudo type. *Journal of General Psychology*, *12*, 66-77.
Skinner, B. F. (1937). Two types of conditioned reflex: A reply to Konorski & Miller. *Journal of General Psychology*, *16*, 272-279.
Skinner, B. F. (1938). *The behavior of organisms*. New York, NY: Appleton-Century-Crofts.
Skinner, B. F. (1948). "Superstition" in the pigeon. *Journal of Experimental Psychology*, *38*, 168-172.
Solomon, R. L., & Turner, L. H. (1962). Discriminative classical conditioning in dogs paralyzed by curare can later control conditioned avoidance responses in the normal state. *Psychological Review, 69*, 202-219.
Staddon, J. E., & Simmelhag, V. L. (1971). The 'superstition' experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, *78*, 3-43.
Vom Saal, W., & Jenkins, H. M. (1970). Blocking the development of stimulus control. *Learning and Motivation*, *1*, 52-64.
Wilson, E. O. (1975). *Sociobiology*. Cambridge, MA: Harvard University Press.

Financial Support: This research was supported in part by a grant from the National Science Foundation, BNS-8409948

Conflict of Interest: The author of this paper declares no conflict of interest.

Submitted: *June 22nd, 2014*
Resubmitted: *October 15th, 2014*
Accepted: *October 22nd, 2014*