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A CENTURY OF EFFECT: LEGACIES OF E. L. THORNDIKE'S ANIMAL INTELLIGENCE *MONOGRAPH*

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Edward L. Thorndike's monograph, *Animal Intelligence: An Experimental Study of the Associative Processes in Animals,* is reviewed with respect to three contemporary issues: the relation between human behavior and that of other animals, the law of effect, and research methods for studying behavior. Thorndike employed an experimental analysis, rather than relying on either anecdote or naturalistic observation, to study problem solving and other behavioral processes of cats, dogs, and chicks. His analysis focused on whether the similarities between humans and other animals were homologous, that is, functionally equivalent, or whether they were merely analogous in form. Concluding the latter, he used the law of effect, not stated as such until long after the monograph was published, to account for the behavioral processes he studied, without appeal to reason or other cognitive mechanisms. His combination of applying experimental methods to the study of animal behavior and his insistence on objectivity in behavioral description were prescient of such later behaviorists as Watson and Skinner.

Key words: E. L. Thorndike, intelligence, human–animal comparisons, homologues, analogues, law of effect, research methods

The year 1998 marks the centennial of the publication of E. L. Thorndike's *Animal Intelligence: An Experimental Study of the Associative Processes in Animals.* Given the historical significance of this monograph, its centennial seems a fitting time to revisit some of its enduring effects on psychology and its relevance to contemporary behavior analysis. As may be expected with any scientific treatise entering its second century, many of the concepts and issues, as well as the language, seem arcane and obsolete. Nonetheless, there remains in the monograph a freshness and relevance to core values in the experimental investigation of nonhuman animal (hereafter, animal) and human animal (hereafter, human) behavior. This review considers three major themes of *Animal Intelligence* that are among its legacies to behavior analysis: the relation between animal and human behavior, the law of effect, and research methods for studying behavior.

Background

The roots of *Animal Intelligence* are in Thorndike's earliest contact with psychology. He originally planned a career in medicine after completing his studies at Wesleyan University in 1895. His plans began to change that same year when he took a psychology course taught by William James at Harvard University (Clifford, 1984). During a subsequent course taught by James, the eminent British comparative psychologist C. Lloyd Morgan lectured on animal intelligence. Those lectures, according to Boakes (1984), piqued Thorndike's interest in the topic. Morgan's impact, in combination with the fact that his planned investigations of ''responsiveness of young children (3–6) to facial expressions or movements made unconsciously'' (Thorndike, 1936/1961, p. 264) were thwarted by institutional authorities, led Thorndike to conduct a series of experiments on ''instinctive and intelligent behavior'' (Thorndike, 1936/1961, p. 264) of chickens. He thereafter left Harvard for a graduate fellowship at Columbia, with his ''two most educated chickens'' (Thorndike, 1936/1961, p. 264) in tow. The chickens resided in his flat for several months when the promised animal space in the Psychology Department at Columbia failed to materialize. When that space did materialize, he added dogs and cats to the chickens to complete the menagerie used to study the ''mental life of animals'' (Thorndike, 1936/1961, p. 264) in his doctoral dissertation, the basis for the 109-page *Animal Intelligence* monograph.

Psychology as a discipline was less than 20 years old when Thorndike embarked on his

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dissertation under the direction of James B. Cattell. The experimental method was only barely in use in the study of human behavior, let alone in that of animals. C. Lloyd Morgan's skepticism about, and scathing critiques of, Romanes' anecdotal interpretations did not go far enough for Thorndike (Boakes, 1984, p. 69), because Morgan's approach was largely devoid of systematic data collected through experimentation. The emerging experimental *zeitgeist* in psychology, the historical concern of moral philosophers and early psychologists with the association of ideas, the pragmatic empiricism of the American Functionalist psychologists and their predecessors, and the strong influence of Darwin all converge in Thorndike's monumental monograph, to which we now turn.

The Purpose of Animal Intelligence

During the period in which Thorndike was educated as a psychologist, there were two coexisting extremes in the interpretation of animal behavior. On the one side, Jacques Loeb interpreted much of animal behavior in terms of tropisms, or involuntary movements, giving animals a mechanical, reflexive character. On the other, Darwin's great admirer Romanes offered a baroque portrayal of the mental life of animals in such work as his influential volume on *Animal Intelligence* (1882), interpreting isolated anecdotal accounts of animal behavior as evidence of higher reasoning and inference. It probably is not accidental that Thorndike's title shares that of Romanes' earlier work; more likely it was chosen to emphasize the differences in their points of view on the subject. Thorndike's monograph expresses skepticism of and displeasure with both of the aforementioned approaches, but particularly with Romanes' anecdotal approach, and brings the analysis of animal behavior into the controlled environment emphasized by experimental psychology.

Thorndike proposed that an animal's mental life (his term) consisted of sensory capacity, instinctive behavior, and ''reactions which are built up by experience'' (Thorndike, 1898, p. 1). Of the three, reactions resulting from experience most commanded his attention. In suggesting that ''these reactions [built up by experience] can all be explained by the ordinary associative processes without aid from abstract, conceptual, inferential thinking'' (Thorndike, 1898, p. 1), Thorndike placed association somewhere in the middle of a continuum anchored by instinctive behavior on one end and by what he called ''reasoning'' on the other. One of his purposes in writing the monograph was to provide experimental evidence in support of an account of animal behavior based on a combination of instinctive behavior and ordinary associative processes, without invoking reasoning into the explanation of such behavior, as Romanes had done. In this vein, Thorndike asserted that ''the cat does not look over the situation, much less *think* it over, and then decide what to do. It bursts out at once into the activities which instinct and experience have settled on as suitable reactions to the situation '*confinement when hungry with food outside*' '' (1898, p. 45). The second, and more important, reason for the research leading to the monograph was to better understand the ''development of mental life down through the phylum'' (Thorndike, 1898, p. 2), in particular, to ''trace human intellection back through the phylum to its origin'' (Thorndike, 1898, p. 38). Thorndike sought to learn about the evolution of mind, which he defined later as ''the sum of connections between situations which life offers and the responses which man makes'' (cited from Joncich, 1962, p. 11, by O'Donnell, 1985, p. 227). Most generally, he sought to determine whether human and animal minds differed only quantitatively, or whether they differed qualitatively as well. If there were merely quantitative differences, then the study of animals could offer valuable insights into questions about human faculties. If, on the other hand, the differences were more qualitative, then the enterprise of comparative psychology as it related to understanding human mentation and intelligence would require reconsideration. Thorndike's means to understanding animal intelligence was an experimental and conceptual analysis of learning, which is the feature for which the work is best known.

Thorndike's Experimental Analysis of Animal Intelligence

The monograph is divided into several sections, each addressing through experiments a specific aspect of animal intelligence; taken together, these aspects implicitly define the

topic. The first series of experiments, involving cats and dogs escaping from either puzzle boxes or, in the case of the chicks, mazes, led Thorndike to dismiss reason as the basis for the animals learning to exit the experimental apparatus. Despite the evidence against reasoning in those experiments, he then questioned whether complex behavior might be established through imitation.

Imitation learning by animals was accepted among early comparative psychologists (specifically, C. Lloyd Morgan), and it could be used to account for complex learning in the absence of reasoning. In a second series of experiments, Thorndike therefore arranged for naive animals to observe experienced animals escape from some of the puzzle boxes or mazes that had been used in the earlier research. He then tested the animals to determine whether they had learned the escape response through observation. The evidence was overwhelmingly negative: Few if any naive animals imitated the responses modeled for them by other animals. These two sets of experiments led him to conclude that ''till the primates we get practically nothing but instincts and individual aquirement [of new responses] through trial and error'' (Thorndike, 1898, pp. 62–63).

Subsequent experiments allowed Thorndike to refine his conclusions and provided further evidence of the central role of trial-and-error learning in animals at the expense of more complex processes. In a third set of experiments, he showed that animals must emit the response and not be manipulated through the movements in a passive, mechanical manner if learning is to occur. Other experiments showed the ''savings effect''; that is, once animals learned to escape from one chamber their subsequent learning to escape from a different one was facilitated. He argued that these latter experiments did not show that the animals had learned a concept but rather only a series of movements. Still other experiments addressed what he called the delicacy of associations, dealing with issues of what today would be called stimulus control, and, in addition, with the number of associations that can be learned by animals and humans. In the final experiments, he examined task retention by retesting animals on tasks that they had learned earlier. He concluded, however, that the effects were not due to memory as it functions in humans. Thorndike's experimental analysis of what he identified as animal intelligence is a benchmark in the understanding of learning by animals. The significance of Thorndike's monograph, however, extends beyond these empirical findings to conceptual and methodological issues that, in the words of Boakes, ''changed his thesis from a solid, original, but somewhat unexciting, demonstration of the use of experimental method in studying animals into a highly provocative piece of work'' (1984, p. 71).

On Comparisons Between Behavior of Humans and That of Other Animals

The most central and provocative conclusion in the monograph, that animal and human intelligence were qualitatively different from one another, was counter to prevailing theory in psychology and evolutionary biology. Such a startling conclusion required the construction of logical, rigorous, and well-developed comparisons between humans and animals. These comparisons distilled down to questions of how animal and human adaptive behavior were modified as a function of experience, which are in turn questions of continuing importance to behavior analysts (cf. Davey, 1983). Thorndike's conceptual and experimental framework for comparing animal and human behavior has had a lasting impact on how such comparisons continue to be made.

Nonexperimental human–animal behavior comparisons. At the time of Thorndike's monograph, as now, many such comparisons between the behavior of humans and other animals were made informally, based on casual observation of apparent or superficial similarity. Such comparisons frequently are either anthropomorphic or metaphorical. In the first type, an instance of animal behavior is equated to a similar instance of human behavior, for example, the observation that ''the dog *is* intelligent.'' When similes or metaphors are the basis of the comparison (considered together here as instances of metaphorical comparisons), animal behavior is seen as being like that of the human in certain ways, but not necessarily isomorphic with the human case. The dog behaves *as if* it were intelligent: The dog's and the human's intel-

ligence may share certain (frequently unspecified) features. One issue with either anthropomorphic or metaphorical comparisons is that the words used to describe the behavior presumed to be shared between the two, for example, a jealous dog or a shy cat, often are themselves poorly understood as concepts regardless of whether they are applied to animal or human behavior. Another is that they are not supported by systematic experimental analysis.

Thorndike rejected both of these approaches as being inappropriate for the science of psychology. His harshest criticism was directed towards Romanes, for his anecdotally based, anthropomorphic approach. Although in strong agreement with C. Lloyd Morgan's call for parsimony in accounting for behavior, Thorndike disagreed with many of Morgan's interpretations of animal behavior. One source of this disagreement centered on Morgan drawing metaphorical comparisons between animal and human behavior. For example, with respect to the formation of associations, Thorndike noted that Morgan's interpretation of impulse took ''for granted that the performance of a cat who gets out of a box is mentally *like* [italics added] that of a man who thinks of going down the street or of writing a letter and then does it'' (1898, p. 66) without providing any systematic evidence for the suggested similarity.

An experimental alternative: Behavioral homologues and extrapolations. Thorndike's analysis of the relation between animal and human behavior was more systematic, and experiment based, than that of any of his predecessors. As such, it subsequently has been a valuable model for such comparisons. Unlike the anthropomorphic and metaphorical approaches he criticized, Thorndike conceptualized his central question as one of whether ''animal association is homologous with the association of human psychology'' (1898, p. 108), and he proceeded to investigate the question through experimentation. The term *homologous* was drawn from evolutionary biology, where homologous structures are those with similar phylogenetic origin (e.g., the wing of a bird and the foreleg of a horse) despite different function (e.g., walking and flying). These may be contrasted to structures labeled analogous, which have, despite different phylogenetic origins, similar functions (e.g., the wings of a bee and those of a hummingbird) and are the result of parallel evolution (Lorenz, 1974). Thus, the distinction between homologues and analogues is that between shared structural origin and shared function despite different origins.

In psychology, homologues describe different response classes controlled by the same process despite physical differences in the response classes, and analogues describe response classes that appear to be similar despite their different controlling mechanisms. For example, lever presses maintained by either positive or negative reinforcement may be similar in appearance but have different controlling mechanisms; hence, the two classes of lever pressing are analogous to one another. A behavioral homologue is illustrated by Ferster's (1966) suggestion that the extinction of key pecking by a pigeon and the loss of behavior by a person following the death of a close friend both result from the removal of their controlling stimuli. Extinction of key pecking and grief reactions may be said to be, at least in Ferster's functional sense, homologous. Thorndike was among the first to ask the question of whether different-appearing behavior patterns such as the ones in the preceding examples had common origins. His questions about the homology of animal and human intelligence operationally were questions of *behavioral* homologues: Are similar behavioral processes involved in the control of problem solving in humans and animals?

Questions of whether behavioral processes are homologous can be restated as questions about extrapolation. For example, can grieving be conceptualized as an extrapolation of the principle of extinction? Extrapolation of behavioral processes does not imply a direction, only that there are common behavioral processes at work across organisms or circumstances. Although the usual method of extrapolation is from controlled laboratory settings, often involving animals, to human situations involving less environmental control, the opposite also can occur. The work in Thorndike's monograph exemplifies the latter. Beginning with rather intuitive or introspective ideas of the important processes in human intelligence, Thorndike searched for homologous ones in animals. If he found them, he could conclude that differences in

intelligence were more differences in degree than differences in kind.

Evaluating comparisons between animal and human behavior. Thorndike's experimental analysis of whether human and animal intelligence are homologous gives rise to several general considerations in evaluating the validity of asserted similarities between human and animal behavior: the selection of animal species for comparison to humans, the dimensions across which comparisons are made, the need for clear definition and understanding of the controlling variables of the phenomenon in humans, the role of language in human–animal behavior differences, and a focus on functional rather than topographical similarity of behavior.

The selection of a species for comparison to human behavior can be affected by many factors. Extrapolation of findings with some species of ''representative'' animals to human behavior may be limited by phylogenetic factors (cf. Harrison, 1994) and by technical constraints on the study of some types of behavior of some species (e.g., many invertebrate species). Furthermore, the species often is dictated by such practical demands as availability of the appropriate apparatus, of funding, and of housing for a given species. Such practical constraints must be balanced against the potential theoretical and logical advantages of using a particular nonhuman species for comparison to human behavior. For example, Mineka (1987) effectively used monkeys that exhibit marked reactions to snakes to investigate both the etiology and treatment of snake phobias in animals. The ecological or face validity of having an animal that displays a fear response resembling that of a human may be critical in persuading both skeptical nonscientists and granting agencies of the value of using animals in investigating human behavior pathology. Thorndike studied cats and dogs in response to the fact that many of Romanes' (1882) anecdotal analyses involved these two species, with the implicit assumption that his alternative interpretations of the behavior exhibited by Romanes' animals were more likely to be accepted because he used members of the same species as Romanes had described.

Systematic replication adds generality to an observation (Sidman, 1960). In comparisons of human and animal behavior, such replications are a necessary part of establishing the validity of an assertion of similarity between the two. Thorndike's analysis of animal intelligence was exemplary with respect to systematic replication. Each experiment was a variation on the general theme of the relation between animal and human associative learning. His consistent findings in favor of trial-and-error learning over reasoning and imitation lend credence to the assertion of essential differences between animal and human behavior.

The greatest weakness in Thorndike's comparisons of animal and human behavior was his offering only intuitive or introspective evidence of the processes responsible for the human behavior against which the controlling variables of the animal behavior were so carefully analyzed and compared. The assumption that reasoning and related processes were necessary in accounting for human behavior was not subjected by Thorndike to the same meticulous scrutiny as were the processes whereby animal behavior was assessed. Instead, he simply assumed that these processes were integral to human learning and intelligence. Toward the end of the monograph, however, he did suggest that the extrapolation of the principles of trial-and-error learning might prove useful in understanding human behavior. On employing ''this animal-like method of learning'' (Thorndike, 1898, p. 105), he proposed ''that in many cases where at present its use is never dreamed of, it may be a good method. As the fundamental form of intellection every student of *theoretical* pedagogy ought to take it into account'' (Thorndike, 1898, p. 105). He also speculated about the acquisition of knowledge by primitive man, suggesting that ''progress was not by seeing through things, but by accidentally hitting upon them'' (1898, p. 106).

The presence of language in humans is an obvious difference that requires consideration in evaluating comparisons between human and animal behavior. Many behavioral processes have been established as functionally similar in humans and animals. Nonetheless, behavioral differences in such phenomena as fixed-interval schedule performance and the controversy over demonstrations of stimulus equivalence in animals (e.g., Hayes, 1989; McIntire, Cleary, & Thompson, 1989; Saunders, 1989; Vaughan, 1989) have led

many to assert qualitative differences between animal and human behavior in some domains. Thorndike's analyses were consistent with this latter assertion, but he also concluded that language was not the only variable in determining behavioral differences between humans and other animals. He noted that if an observer says ''language has been the cause of the change from brute to man, when one talks as if *nothing but it* were needed to turn animal consciousness into human, he is speaking as foolishly as one who should say that a proboscis added to a cow would make it an elephant'' (1898, p. 83).

Asserting similarity based on the appearance, as in the added proboscis, rather than on function was described by Bachrach (1963) as the ''analogue error,'' whereby kinds of behavior that appear to be similar are equated even though the controlling variables of each may be different. Thorndike's study of homologues provides perhaps the first example of how such errors might be circumvented through the analysis of behavioral function. This focus on homologous processes in accounting for the behavior of animals and humans is illustrated by his analysis of ''just what is in an animal's mind when, having profited by numerous experiences, he has formed the association and does the proper act when put in a certain box'' (1898, p. 65). He rejected conventional wisdom that the animal associates the stimuli present during learning with the pleasure of consuming the reinforcer on completion of the act. He contended that such an analysis implied that whenever an animal thinks of an act it can supply the impulse to do that act. In keeping with his overall interest in the phylogenetic origins of intelligent behavior, he suggested that, unlike humans, animals cannot supply such an impulse; rather, the impulse must be included in the association. In the third set of experiments in the monograph, for example, he trained cats to enter a puzzle box and then escape, which was followed by access to food. Other cats were placed in the puzzle box via an opening in its top, allowed to escape, and this also was followed by access to food. Thus, only the first group engaged in what might be called active learning or practice in entering the box (the initial response of a chain of responses). When animals in the second group were allowed to enter the puzzle box via either a door or the opening in its top, none did so reliably. Thorndike reasoned that animals in both groups ''had the same opportunity of connecting the idea of being in the box with the subsequent pleasure'' (1898, p. 67) of the food. The difference from his vantage was that the animals in the first group had the impulse to crawl into the box whereas those in the second did not, suggesting that the impulse is part of the association rather than an independent a priori event triggering the association and hence the behavior of entering the box. Thorndike concluded that ''the groundwork of animal associations is not the association of ideas, but the association of idea or sense-impression with *impulse*'' (1898, p. 71). He then suggested that this process of association is different from that involved in human behavior, where the impulse leads to the action. Inferences about mental mechanisms in learning aside, the appeal of Thorndike's logic in comparing animal and human behavior is that despite superficial similarities in appearance between animal and human behavior, his experimental analysis led him to conclude that different behavioral processes are operative. There are many other instances described in the monograph in which animal and human behavior patterns that appear to be structurally similar are, on more careful functional analysis, shown to be controlled by different behavioral mechanisms. The sum conclusion from these collective experiments on animals was that ''man is not an animal plus reason'' (Thorndike, 1898, p. 87), because there are functional differences in behavioral processes that lead to structurally similar patterns of behavior.

On the Law of Effect

Thorndike's most familiar legacy to behavior analysis, and perhaps also to psychology as a whole, is his law of effect, an expression first used in his 1905 textbook, *The Elements of Psychology* (Wilcoxon, 1969). In the monograph Thorndike demonstrated that simple practice, or exercise, is not sufficient for the formation of an association by animals, thereby undermining one of the principles of earlier philosophical associationism. Rather, for the association to be formed, the juxtaposing of a stimulus and response must be followed by a consequence, an effect. His emphasis on

effect in the monograph was provocative because it supplanted reasoning and any other process than trial and error followed by effects as the basis of all learning by animals. Thirty-odd years thereafter, Skinner would embrace and extend the empirical law of effect, placing it at the foundation of not only animal learning but also that of humans. The provocative implications of Skinner's law-of-effect-based analysis of human behavior was equally provocative to Thorndike's applications of it.

By 1911, when Thorndike published *Animal Intelligence*, a volume that reprinted the monograph and other previously published and unpublished papers on the same topic, he defined the law of effect in its now-familiar form:

> Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections to that situation weakened, so that, when it recurs, they will be less likely to recur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond. (1911, p. 244)

The first half of the first sentence above often is labeled the positive law of effect and the second half of that sentence, the negative law of effect. The close relation between the law of effect and earlier associationist theories of learning, and particularly the Spencer-Bain principle and earlier statements of Morgan, has been noted many times (e.g., Boakes, 1984; Wilcoxon, 1969). Thorndike's unique contribution, beginning with the monograph on animal intelligence and continuing in other studies reported in the 1911 book and thereafter, was to provide experimental evidence under controlled conditions in support of his statement of the positive law of effect. Although never labeled as such in the monograph, the germ of the concept of the positive law of effect is scattered throughout his descriptions of the different experiments:

> Whether the impulse to struggle be due to an instinctive reaction to confinement or to an association, it is likely to succeed in letting the cat out of the box. The cat that is clawing all over the box in her impulsive struggle will probably claw the string or loop or button so as to open the door. And gradually all the other non-successful impulses will be stamped out and the particular impulse leading to the successful act will be stamped in by the resulting pleasure, until, after many trials, the cat will, when put in the box, immediately claw the button or loop in a definite way. (1898, p. 13)

> The chick, when confronted by loneliness and confining walls, responds by those acts which in similar conditions in nature would be likely to free him. Some one of these acts leads him to the successful act, and the resulting pleasure stamps it in. Absence of pleasure stamps all others out. The case is just the same as with dogs and cats. (1898, p. 36)

Nor was the response confined to movements of the appendages of the animals:

> A box was held in front of [the opening in the problem box in which the cat was confined] and drawn away when the cats happened to lick themselves. Thus escape and food followed always upon the impulse to lick themselves, and they soon would immediately start doing so as soon as pushed into the [problem] box. (1898, p. 12)

In each of these observations, the implications are clear: Responding is controlled by its consequences and, for Thorndike, these consequences connect the response to the situation.

The law of effect has been criticized on both logical and empirical grounds, and, as will be described later in this section, more recently on what might be labeled ethical grounds. Early criticisms of the law of effect included allegations of its backward action, circularity, and affective emphasis in defining satisfying and annoying states of affairs (Wilcoxon, 1969).

In addressing these criticisms, it also is useful to note the historical distinction between the theoretical and empirical laws of effect, the former involving a search for mechanisms, either conceptual or physiological, underlying the effect of reinforcers. Thorndike's connectionist theory was an attempt in part to identify theoretically a mechanism of reinforcer action. Later theories made the same effort but took different tacks than Thorndike's. For example, drive reduction theory (Hull, 1943) was first proposed as a

physiological account of effect and later as a theoretical and conceptual one.

Skinner's functional account of behavior contains the most developed analysis of the empirical law of effect. By defining reinforcers in terms of their behavioral effects, Skinner addressed the aforementioned criticisms of circularity and affect: ''A reinforcing stimulus is defined as such by its power to produce the resulting change. There is no circularity about this; some stimuli are found to produce the change, others not, and they are classified as reinforcing and non-reinforcing accordingly'' (1938, p. 62); ''If we then go on to say that a stimulus is reinforcing *because* it is pleasant, what purports to be an explanation in terms of two effects is in reality a redundant description of one'' (1953, p. 82).

Other notable rejoinders to the early logical criticisms include Meehl's (1950) analysis of the problem of circularity in the law of effect, concluding with a recommendation that reinforcers be shown to be transsituational. First Premack (1959) and later Herrnstein, in different ways, provided contextualist analyses of the law of effect, and in so doing each offered a different solution to the circularity issue. Premack proposed an independent, yet strictly empirical, definition of a reinforcer. Herrnstein's (1970) matching law and its theoretical variations (e.g., Baum, 1973; Herrnstein & Vaughan, 1980) provided a quantitative framework for the law of effect that has become perhaps the most important heuristic and theoretical development related to the law of effect since Skinner's early work.

In his monograph, Thorndike argued in favor of general laws of learning, like the law of effect, based on the analysis of such processes in a few representative species:

> The probability that the other mammals, barring the primates, offer no objections to the theories here advanced about dogs and cats, is a very strong probability, strong enough to force the burden of proof upon anyone who should, for instance, say that horse-goat psychology was not like cat-dog psychology in these general matters. . . . My statements should stand for the mammalian mind in general, barring the primates. (1898, p. 39)

Concurrently, Thorndike was among the earliest psychologists to acknowledge the possibility of species differences in learning, while also reflecting on possible sources of such differences:

> [Regarding] the question of differences in intelligence between the different animals, it is clear that such differences are hard to estimate accurately. The chicks are surely very much slower in forming associations and less able to tackle hard ones, but the biggest part of the difference between what they do and what dogs and cats do is not referable so much to any difference in intelligence as to a difference in their bodily organs and instinctive impulses. (1898, pp. 36–38)

Thorndike nonetheless also observed that associations, learned because of the action of consequences on behavior, are sufficiently potent that one of their effects may be the ''inhibition of instincts and previous associations. . . . [Associations are] . . . a tremendous factor in animal life, *and the strongest instincts may thus be annulled* [italics added]'' (1898, p. 99).

There has been heated contemporary discussion about the role of phylogeny in learning (e.g., Herrnstein, 1977; Skinner, 1977), and particularly about the question of whether and how biological or phylogenetic considerations may limit the generality of the law of effect. The outcome of the debate has been that some theorists have rejected the law of effect outright in favor of more phylogenetically based or cognitive accounts of learning (e.g., Bolles, 1970), and others have emphasized restrictions on its range of applicability (e.g., Seligman, 1970).

Empirical support favoring constraints on the law of effect often has been in the form of apparent failures of certain responses to be learned despite putative reinforcing consequences following them (cf. Schwartz, 1974; see also Domjan & Galef, 1983, for a general review of the issues surrounding biological constraints on conditioning). Thorndike reported an early instance of what Breland and Breland (1961) later were to identify as *instinctive drift* in his experiments involving Puzzle Box Z, in which cats had to lick or scratch themselves to escape. A flurry of experiments on this topic between the late 1960s and late 1970s were interpreted as supporting phylogenetic constraints, but later studies revealed a more complicated picture than that portrayed in the earlier observations of such theorists as Bolles (1970) and Seligman (1970).

For example, the work of Iversen, Ragnarsdottir, and Randrup (1984) provided an especially illuminating analysis of the reinforcement of grooming by vervet monkeys in response to earlier conclusions that the generality of the law of effect is constrained by the difficulty of conditioning naturally occurring grooming (e.g., Shettleworth, 1975). There have been many productive effects of the ''biological constraints'' discussions related to the law of effect, such as the inclusion of ecological validity as a consideration in studies involving reinforcement (cf. Fantino, 1985) and the stimulation of many new lines of behavioral research.

Skepticism over the applicability of the law of effect has not been limited to phylogenetic considerations. Thorndike himself questioned the negative law of effect, a point that has given rise to different theoretical accounts of punishment (Azrin & Holz, 1966; Dinsmoor, 1980). Deci (e.g., 1971) and Lepper and his colleagues (e.g., Lepper & Greene, 1975) suggested what some have considered to be an ethical constraint on the applicability of the law of effect by proposing that its application may limit human initiative and creativity. Neuringer and his colleagues (e.g., Page & Neuringer, 1985), however, have found that behavioral inflexibility is not a question of effect (i.e., reinforcement) per se but rather a question of how one defines the response class on which the effect operates. Page and Neuringer showed that when variability in behavior is reinforced, such variability becomes likely and is maintained. In effect, their research suggests that creative behavior is operant behavior. Dickinson (1989) and Eisenberger and Cameron (1996) also have provided useful alternative accounts of the effects obtained by Deci and by Lepper and Greene.

Methodological Contribution and Innovation

Although they were perhaps not as controversial as his views on the relation between animal and human behavior and intelligence, the methods that Thorndike used to investigate animal intelligence certainly were novel and innovative in the context of his time. Critics such as Mills (1899) were sufficiently provoked by these methods as to reject the conclusions of the monograph (see also Thorndike, 1899, for a rejoinder to Mills' critique).

Thorndike's methods were those of an experimental psychologist, not those of a naturalist or an evolutionary biologist. As such, he was among the first to take naturalistic observations into the psychology laboratory and recreate under controlled conditions the essential features gleaned from those observations. His monograph reveals the following three characteristics of his methods, all of which subsequently have become standard ones in the experimental analysis of behavior (e.g., Hersen & Barlow, 1976; Johnston & Pennypacker, 1980; Sidman, 1960): Establish replicability of findings, establish generality of findings across situations and species, and control potentially confounding variables. In the monograph, direct replications occurred by repeated retests in the same environment until stable behavior, represented by the asymptotes of learning curves, was observed. Systematic replications involving different apparatuses, different subjects of a single species, and subjects of different species all contributed to establishing the generality of his findings.

Thorndike also achieved both replicability of effects and control over potentially confounding variables with the ingenious and revolutionary apparatus that he designed for his studies of animal intelligence. With his apparatus he was among the first to standardize behavioral samples by restricting the environment to one that could be controlled more precisely than a natural setting could be controlled, an innovation that is repeated in Skinner's work in the early 1930s. As a result of such environmental control, it also became possible to easily obtain repeated instances of the behavior under study, another critical feature of Skinner's analysis as well.

The puzzle boxes are Thorndike's most famous apparatus. Lamentably long since discarded, only his descriptions of them and a good set of photographs (Burnham, 1972) record their existence. Like his use of cats and dogs noted earlier, the use of these puzzle boxes was a deliberate action by Thorndike to address some of Romanes' (1882) observations directly. Romanes had described many anecdotal reports of cats escaping from closed windows and other confined quarters by opening windows or otherwise operating

on their environments, an effect Romanes attributed to the cats' powers of rational observation. After careful study of the animals' escape behavior, Thorndike dismissed this latter conclusion: ''There was displayed no observation of the surroundings or deliberations upon them. It was just a mad scramble to get out'' (Thorndike, 1898, p. 43). The puzzle boxes, which differed in design within and across experiments, also were complemented by mazes of various designs. The maze itself had been introduced to experimental psychology by Small and Kline only 3 years before the publication of Thorndike's monograph (Boakes, 1984), placing Thorndike among the first users of that new apparatus as well.

The monograph also represents one of the earliest applications of methods involving precise measurement and quantification of psychological processes to the behavior of ''whole'' intact animals. Thorndike referred to the quantitative depiction of his data as time curves, and he used these data to support his contention that ''no power of inference was present in the subjects of the experiments'' (1898, p. 44). The evidence for this statement was the fact that the latencies decrease gradually rather than suddenly, suggesting to him that learning was a gradual rather than an insightful process. Thorndike's work identified but did not resolve this particular issue, and the controversy regarding continuity versus noncontinuity in learning remained a contentious one more than half a century after the publication of the monograph (see Kimble, 1961, pp. 128–134, for a review of the controversy).

Arguably the most significant methodological contribution in the monograph is Thorndike's relentless attack on anecdote as a valid basis for understanding behavior, whether animal or human. The nascent comparative psychology of his time was replete with anecdotal accounts of human-like behavior of animals. As already noted, Romanes, and even Morgan, were taken to task for drifting into such unsubstantiated anecdotal or intuitive comparisons of animal and human behavior. One hundred years after the publication of Thorndike's monograph, the objective scientific study of animal behavior is well established but also continues to be challenged by some contemporary points of view that have many parallels to the anecdotalism and anthropomorphism of Romanes. In the popular culture, the hidden lives of dogs are described in the most anthropomorphic of terms in best selling books (Thomas, 1993). Thoughtful, reputable scientists from other disciplines argue in favor of anthropomorphic and metaphorical description in the absence of systematic analysis of the functional similarities between animal behavior and the putatively similar human behavior under discussion (e.g., Griffin, 1984). The language of intention and cognition frequently appears in other approaches to learning, comparative psychology, and ethology (cf. Heyes, 1987). Many of the behavioral phenomena described in all of these arenas are interesting and important ones, and often are ones that have not yet received attention from behavior analysts. The centennial of *Animal Intelligence* should serve to remind us not only of Thorndike's legacies to the experimental analysis of behavior but also of the many challenges of nonbehavioral approaches that remain to be addressed.

Animal Intelligence *and New Beginnings*

Thorndike developed ingenious methodological and conceptual alternatives to the anecdotal, anthropomorphic, nonexperimental comparisons between animal and human behavior made by many of his contemporaries. Despite his reservations about the commonalities between the minds of animals and humans, the effect of the monograph was to stimulate research and theory concerning both animal and human behavior and the relations between the two. Thorndike was philosophically of the American Functionalist school, but his positivism and commitment to objectivity in interpretation reverberate through the early work of John B. Watson that led to the behavioral revolution. In the 1930s and thereafter, Skinner (e.g., 1938, 1953, 1969) further expanded Thorndike's legacies of objectivity and attention to method in the experimental analysis of behavior, effect, and the relations between animal and human behavior, creating a systematic approach to psychology and the foundation for the substance of the *Journal of the Experimental Analysis of Behavior.*

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