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Account of Operant Conditioning Based on Coordinating Three Procedural Steps of Respondent Conditioning Processes

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A new conceptual account of operant conditioning based on coordinating 3 procedural steps of respondent conditioning processes is introduced. In this account, stimuli, actions and conditioning are only used procedurally and conceptually. Convergence of 2 theories is used to support this account: (1) the model of hierarchical complexity and (2) ordering of evolutionary development and the corresponding changes in neural structure and biochemistry of organisms. Three very different cases of procedural respondent conditioning are used. The only commonality among the 3 respondent conditioning steps is the basic procedure. Those procedural steps are the "what to do" (Step 1), "when to do" (Step 2), and "why to do" (Step 3). In Step 1 of the respondent conditioning the representation of behavior takes on the elective properties of the S^{R+} making the representation of behavior salient. We leave the representation of behavior undefined. One might use common notions of it instead. In Step 2, the now salient representation of behavior (*rb*) is paired with an environmental *S*. This makes the *S* elicit the representation of a behavior which requires the saliency of the representation of a behavior. In Step 3, the environmental *S* is paired with the S^{R+} making the *S* more salient and valuable. When the environmental stimulus is more salient, the representation of a behavior rate relative to other representation of a behavior's not associated with reinforcement increases.

Keywords: operant and respondent conditioning, reinforcement, representation of behavior, two-factor theory, reduction

Ever since operant and respondent conditioning were introduced by Skinner (1938) and Konorski and Miller (1937), there has been controversy regarding the relationship between them. There are many levels of analysis of this relationship: functional, procedural, physiological—including neurological—and biochemical. This particular analysis of the relationship between operant and respondent conditioning uses procedural and functional comparisons. This article seeks to describe the procedures used in conditioning, the coordination of the procedures, and briefly give an evaluation of what organisms' behavior is affected by these procedures. A procedure sets the order that events occur. A functional change occurs from the application of a procedure when the events' functions change. For example, after conditioning occurs, a stimulus becomes elicitative. That stimulus has undergone a functional change. This article does not take a position on whether conditioning is purely associate or purely nonassociative nor does this article build a simulation.

A respondent conditioning procedure is understood as a form of learning where the Neutral Stimulus (*NS*), is procedurally followed by an Unconditioned Stimulus (*UCS*) that has characteristically elicited an unconditioned response (*UCR*). Note that this pairing of a neutral stimulus (*NS*) with an unconditioned stimulus (*UCS*) follows a particular ordering of events. After conditioning, the neutral stimulus be-

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comes the conditioned stimulus (conditional stimulus [*CS*]). The neutral stimulus has been paired with the unconditioned stimulus, $NS-UCS$, which means that the events have been paired. The conditioned stimulus now elicits the conditioned response (*CR*), $CS \rightarrow CR$. For example, food (*UCS*) causes dogs to salivate (*UCR*). A bell (*NS*) was procedurally paired with the UCS. After the pairing occurred, ringing of the bell (now a *CS*), resulted in salivation (*CR*; Ferster & Perrott, 1968).

Here, we take the notion of pairing as conceptual rather than some reified versions as to what constitutes the details of the pairing. We ignore any underlying mechanisms other than the ordering of the events in the pairing. The physiological processes of pairing are left undefined as this analysis relies solely on the procedural definition of respondent conditioning. That is, only the order of the events that occur in respondent conditioning is important to the analysis. Pairing is a nonsymmetrical predicate. That is, "*x* is paired with *y*" does not entail that "*y* is paired with *x*".

That is why the term procedural respondent conditioning is used. An operant conditioning procedure is defined as a form of learning where an environmental stimulus (*S*) is followed by a response (*R*). The response is followed by an operant reinforcer (S^{R+}). For example, in an experiment using a maze, the maze serves as the environmental stimulus (*S*). The rat completes a run through the maze (*R*). The run through the maze is reinforced with a food pellet, the operant reinforcer (S^{R+}). In respondent conditioning, the response is automatic. It is not dependent upon or contingent upon the operant reinforcer (Skinner, 1938).

This article is organized as follows. In the first section, we present our account of how operant conditioning may be explained by three procedural steps of respondent conditioning. The three procedural steps are as follows: Step 1 "what to do"; Step 2 "when to do it"; Step 3 "why to do it". Each of the three procedural steps is explained. Support for this account is shown through two legs of convergent support; that is, Leg 1: Model of hierarchical complexity (MHC) and Leg 2: Evolution. Each leg of support is explained.

In this article, we suggest an alternative, more integrative model to account for operant conditioning procedure. This proposal is more versatile than existing proposals. It suggests that operant conditioning may be explained by three procedural steps of respondent conditioning procedures. The relationship that explains operant conditioning sets forth the coordination of three procedural steps of respondent conditioning.

The first respondent conditioning step ("what to do step") procedurally is the reinforcement of a response, R–S^{R+}. It assumes that an operant response is elicited by certain representation of behavior (*rb*) that is made salient by the R–S^{R+} pairing. The specification of the antecedent events may also be thought of as being a neural event that comes before a response.

The second respondent conditioning step ("when to do step") pairs a prior environmental stimulus, *S*, with the representation of behavior to elicit the operant behavior, *R*.

The third respondent conditioning step ("why to do step") pairs the environmental *S* with the S^{R+} making the *S* more salient and more valuable than other environmental stimuli: the value and salience resulting from the higher relative rate of reinforcement.

Previous Accounts of the Relationships Between Operant and Respondent Conditioning

The relationship between operant (instrumental) and respondent (classical) conditioning procedures has been a concern in the field of learning and conditioning since the 1930s. Sutton and Barto (1998) argued that modern reinforcement learning (RL) encompassed two types of learning procedures. One type of learning is similar to operant conditioning procedure: $S-R$ habit formation suggested by Thorndike (1932, 1932) and Guthrie (1935, 1942). RL refers to this type of learning as "model free." The second type is similar to respondent conditioning procedure: $S-S$ learning as envisaged by Pavlov (1927) and Tolman (1932).

Two types of theories have tried to explain whether or not there might be a relationship between operant (instrumental) and respondent (classical) conditioning. Single-factor theorists (Hull, 1943, 1952; Pavlov, 1927) presuppose that all conditioning requires the reinforcement of stimulus–response associations (Pavlov, 1955). Some of these theorists (Hull, 1952) did not distinguish between reinforcing stimuli that follow neutral stimuli (*NS*), as in respondent or classical conditioning, and reinforcing stimuli (S^{R+}) that follow responses or as in operant or instrumental conditioning. Because single factor theories do not make this distinction, they may not adequately account for differences found between the two conditioning processes. Two factor theories, on the other hand, have focused on the differences between the two conditioning processes or have tried to reduce one to the other.

The earliest two factor theories included Konorski and Miller's (1937) and Skinner's (1938). They argued that respondent and operant conditioning, despite quite similar properties, are two separate forms of conditioning. They made no effort to relate the two forms of conditioning. The major problem with the most popular two factor theory (Skinner, 1938), is there is no clear procedural account as to how reinforcement changes the future rate or probability of behavior.

Up to this point we have reviewed past literature that looked at a possible relationship between operant and respondent conditioning. Although it is clear that accounts of how the two types of learning might be related are not new, this short review allows this article to indicate ways in which previous accounts did not fully explain existing data. First, whether one is discussing respondent or operant learning, from one-factor or two-factor accounts, the explanations for the mechanisms underlying each type of learning procedure are not equally well worked out. Especially the operant accounts do not have a clear mechanism for strengthening operant behaviors. Whereas one factor theorists such as Pavlov (1927) argued that conditioning requires the reinforcement of stimulus–response associations, two factor theorists such as Skinner (1938) argued that associations between *R* and S^{R+} gets strengthened. But he did not provide a mechanistic basis for this argument. Explanations of operant conditioning have mostly focused only on the behavior-consequence relationship. The major unexplained part of the mechanism is why the behavior occurs in the first place. From traditional operant accounts (Herrnstein, 1970), possible roles for both external and internal events that occur before the behavior have been largely neglected. This means that nonneural network and other current accounts of operant conditioning are incomplete and may focus on the wrong events as being the apparent causes of behavior.

To solve this problem of incomplete mechanistic accounts of operant conditioning, we propose a procedural model to account for operant conditioning. Operant conditioning is based on three procedural steps of respondent conditioning procedures. In this model, the immediate cause of behavior is not ignored as in many response strength accounts (Herrnstein, 1970), but is elicited by the representation of a behavior (*rb*) that is made salient by the R–S^{R+} pairing. It is assumed that all exteroceptive responses are caused by events. Some of these events are external stimuli; some may be interoceptive brain events. To be consistent with our account, one might say that the brain events has the function of a stimulus. That does not mean that it is not also a response, but that it may act as a stimulus. With the evolution from single neural cells to neural networks, what originally was an external behavior in a conditioned reflex could have become a second neural cell firing (*rb*, or representational behavior) that ends up eliciting the operant response, *R*. The difference is that the formally external behavior has now become an increase in firing by another cell.

Speculatively, think of a representation of behavior that used to elicit a behavior such as engulfing a "food particle' (consumption) that did not serve as a reinforcer but served to increase the likelihood of survival. At one point in evolution, that engulfing behavior may be elicited by an internal event rather than an external event. This requires a minimum of two cells. We need to choose an operant behavior that used to be respondent. The interoceptive brain events may occur relatively long after some exteroceptive stimulus that comes to control the response after operant conditioning. The proposed mechanism is the paring of the stimulus at each of the three procedural instances or steps. Pairing increases the salience and value of the first stimulus that is paired at each step. It does so separately for each for each case of the respondent conditioning procedure in each step (see Figure 1).

A second reason why a new account is needed is that one factor and two factor accounts do not build upon what we know about conditioning. These accounts do not account for evolutionary explanation of why operant conditioning evolved after respondent conditioning

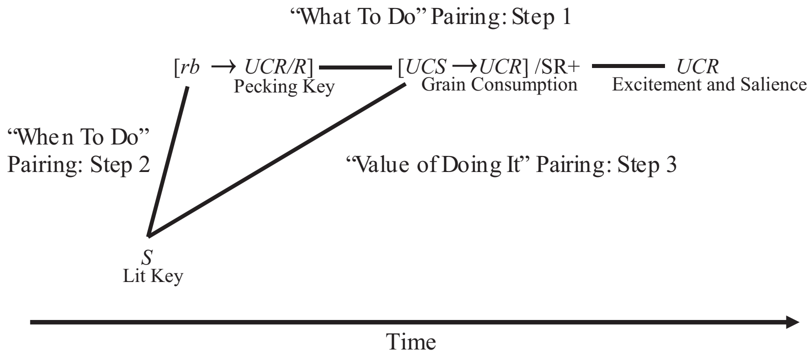

Figure 1. The proposed account of operant conditioning by three procedural cases of respondent conditioning. The first pairing step in operant conditioning occurs between the normally unobserved stimulus (*rb*) that elicits the operant behavior, and the operant reinforcer *UCS/S*$^{R+}$ The second pairing step occurs between the now salient internal *rb* and the external CS. The third pairing step occurs when the environmental stimulus (S) is paired with the operant reinforcer UCS/SR + making the S more salient and more valuable. Uppercase italicized letters represent presently observable events. Lowercase italicized letters represent internal events that are nonsalient but potentially observable. *S* = sight of the lit key. *rb* → *UCR/R* Brain event, nr-us, eliciting an operant response (key peck). *UR* = respondent notation for the unconditioned response. *R* = operant notation for the operant response. The two forms connected by a/denote the same event of pecking the key. [UCS_3 → *UCR*]/*S*$^{R+}$ Taste and ingestion of the grain (the operant reinforcer) elicits digestive activity.[*S* – [*rb* → *UCR/R*] The stimulus is paired with the brain event which elicits the *UCR/R*]. "—— "Indicates that two sets of events are paired.

evolved. This lack of evolutionary explanation also makes the relationship between the two learning mechanisms more blurred and less definitive. Our account of operant conditioning as consisting of three procedural steps of respondent conditioning solves the lack of evolutionary explanation in one and two factor theories. The proposed evolutionary sequence is also supported by the MHC. MHC is a mathematical measurement theory (Krantz, Luce, Suppes, & Tversky, 1971; Luce & Tukey, 1964) that analyzes the developmental difficulty of tasks represented by the orders of hierarchical complexity (OHC). A task action is defined as more hierarchically complex when the higher order action is defined in terms of the actions at the next lower order; higher order tasks organize the lower order actions; and the lower order tasks are coordinated nonarbitrarily, not just put together as an arbitrary chain. In our model of reduction, we put forth the possibility that operants organize and nonarbitrarily order three cases of respondent conditioning. We propose that this is consistent with what is known about evolution: newer adaptations may reuse, incorporate or transform previous adaptations.

Our account shows that there are similarities between properties of operant and respondent conditioning because operant conditioning is based on three procedural steps of respondent conditioning. We also assert that operant conditioning retains most of the properties of respondent conditioning including the effects of time delay, salience, and other variations of the situations.

Fourth, in one-factor and two-factor accounts, causation in operant conditioning is backward. How can something that follows behavior cause that behavior to change in frequency or probability? How are responses themselves affected without the stimuli that lead to them being changed? A response is an outcome and not a cause. This is an old criticism of operant conditioning. Gallistel (2002) made a similar criticism. The way people try to get around this is to say that in the future the frequency or probability of behavior is greater after reinforcement. But there is no explanation of what the mechanism is that makes this possible. The way we conceive of it is that the S^{R+} affects the representation of behavior by the mechanism of simple pairing.

It should be noted that each of the three steps in the account are derived from three present theories of what happens during operant conditioning. The first step is to account for response strength theory (Herrnstein, 1970), which describes that reinforcement establishes the operant response. The second step is to account for the acquisition of stimulus control theory (Reynolds, 1961). It does so by explaining how stimulus controls of the strengthened operant behavior. This is accomplished by pairing the environmental stimulus with the representation of behavior. The third step uses Killeen's (1984) Incentive theory to explain why the pairing of the environment stimulus with reinforcement provides incentives and additionally salience to the environment stimulus. Our model suggests that these three theories are essentially our set of three interconnected steps of our theory.

We suggest that operant conditioning and respondent conditioning cannot be immediately reconciled for their important differences. But, they can be united by conceptualizing the operant conditioning process as an ordered coordination of three respondent pairing procedures. This account seems feasible because, as some two factor theorists, including Konorski and Miller (1937); Skinner (1938), Kimble (1961), and Schwarz (1978) have argued, the properties of respondent and operant conditioning are nearly identical.

An Account of Operant Conditioning by Three Procedural Steps of Respondent Conditioning

Our account of operant conditioning by three procedural steps of respondent conditioning is only a conceptual proposal. As such, it is not directly the result of just a few new experiments or data, although there are considerable data that backs each of the legs of support for this account. As such, this article is a new integration, and consistent explanation of what is already known. This proposal is different from previous one and two-factor theories because a specific how the procedural mechanism by which operant conditioning may be accounted for by three procedural steps of respondent conditioning. The model to be introduced here proposes that operant conditioning should be considered as a hierarchically more complex action that results from coordinating three cases or steps of respondent conditioning. The entire process is shown in Figure 1. Each step is described in turn after Figure 1.

First Respondent Conditioning Step: "What to Do" and Salience

In our account of operant conditioning, the first proposed respondent conditioning step (what to do step) procedurally is the reinforcement of a response, $rb - R - UCS/S^{R+}$. Note that the representation of behavior (*rb*) is paired with the *UCS*.

The first respondent conditioning pairing occurs between the normally unobserved stimulus that we are calling *representation of behavior* that elicits the operant behavior and the operant reinforcer UCS/S^{R+}. A reinforcer also elicits some behavior and thus serves as a *UCS*. Both the representation of behavior that becomes the *CS* for the "operant response" and the S^{R+} have to be salient. Here is the proposed process by which the representation of behavior becomes salient: for the representation of behavior to become salient, it must be paired with a salient stimulus, UCS/S^{R+} (unconditioned stimulus/operant reinforcing stimulus) that reliably elicits some other response as all reinforcers do. This effectively strengthens the salience of the *rb-R*.

The normally unobserved stimulus representation of behavior that elicits the operant behavior initially has two properties. The representation of behavior is not salient before this operant conditioning. In the first step of operant conditioning, the first stimulus is the representation of behavior and the second stimulus is the reinforcer. A reinforcer also acts as a salient *UCS* that elicits a *UCR* (unconditioned response). This step is often referred to as free operant conditioning (Skinner, 1938). It is characterized by response strength (Herrnstein, 1970).

Second Procedural Respondent Conditioning Step: "When to Do It"

For respondent conditioning to occur in the second conditioning step, the first conditioning step must occur. The second respondent conditioning step (when to do step) pairs a prior environmental stimulus, *S*, with the increasingly salient representation of behavior to elicit the operant behavior, *R*. This establishes stimulus control of the elicited operant behavior. The *S*, which starts out being a weakly salient neutral stimulus, *ns,* becomes a conditioned stimulus, *CS,* by being paired with the salient representation of behavior. Remember, the operant reinforcer UCS/S^{R+}, already has already been paired with the representation of behavior in the first procedural respondent conditioning step, making the representation of behavior salient and the second step of conditioning possible. This second step is often referred to as stimulus control (Nevin, 1965).

Third Respondent Conditioning Step: "Why to Do It"

The "why to do it" step was elucidated at length by Killeen (1982a, 1982b, 1984, 1985) in a series of articles and studies on incentive theory. In the "Why to do step" the environmental stimulus (*S*) is paired with the operant reinforcer UCS/S^{R+} making the *S* more salient and more valuable. This pairing may also produce an incentive.

In the "why to do it step," relative rate of reinforcement for a particular stimulus is always in competition with rates of reinforcement for other environmental stimuli (*S*). When relative rate of reinforcement for the particular stimulus increases, the environmental stimulus is attended to more because of its increased salience. When the environmental stimulus is more salient and attended to, to the rate of eliciting, the representation of behavior goes up in rate relative to other representations of behavior that are not associated with reinforcement.

The next sections explain the "three legs" that support the above conception. Each leg is a separate theory or based on a separate theory. To fully support the proposal that the different legs must be integrated together. The need for these theories outside of the field of learning to explain the relationship between operant and respondent conditioning also explains why previous attempts to relate the two types of learning have not been adequate.

Convergence of Multiple Sources of Evidence

We propose convergent support as a methodological approach similar in form to Darwin's to support our claim that an instance of operant conditioning may be accounted for by the coordination of three procedural steps of respondent conditioning. We show convergent support from two sources:

Leg 1: The MHC

Leg 2: Evolution

The two legs are connected to one another. Leg 1 (The MHC between Order 2 procedural respondent conditioning and Order 3 operant conditioning (Commons & Pekker, 2008).

Leg 2 shows how evolution went from single cells, to organisms with simple nervous systems that could only respondently condition, to those with nervous systems that could operantly condition. However, there are still single-celled animals that can only solve respondent tasks and cannot address operant tasks. This may show that operant tasks are inherently more difficult.

Leg 1: MHC

The MHC is a mathematical measurement theory (Krantz, Luce, Suppes, & Tversky, 1971; Luce & Tukey, 1964). It provides an analytic a priori measurement of the difficulty of task actions. The difficulty is represented by the OHC (Commons & Pekker, 2008). Hierarchical complexity describes a form of information that is different from traditional information theory (Shannon & Weaver, 1949) in which information is coded as bits that increase quantitatively with the amount of information. Theorem 4 of the model (Commons et al., 1998) shows that every task action has an OHC associated with it. The ideal correct task actions may be classified as to their order of hierarchical complexity. The tasks actions may address every experimental task, every clinical test item that has a difficulty associated with it, every behavior, developmental task, survey item, and statement made by people regardless of the content or context. Each task action will have a difficulty of performance associated with it.

A task action is defined as more hierarchically complex when a higher order task is defined in terms of two or more tasks at the next lower OCH, the lower order actions, and the lower order tasks are coordinated nonarbitrarily, not just put together as an arbitrary chain. This is illustrated schematically in Figure 2.

The MHC can be illustrated by the examples drawn from evolutionary task sequence shown in Table 1. These represent the first four OHCs.

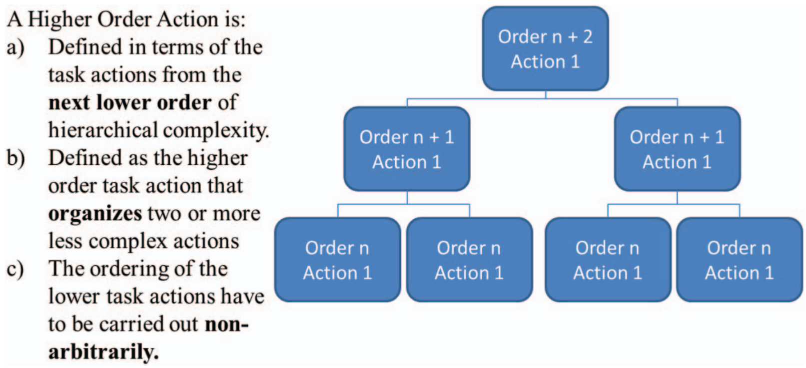

Figure 2. The three axioms of the model of hierarchical complexity (MHC).

They range from Calculatory Order 0 to Sensory Motor Order 4. To determine the behavioral developmental stage, observational and experimental literature was used to asses which of these tasks were correctly addressed. A person or organism is said to be a particular stage when they successfully complete the task actions of the OHC of the problem within the sequence. Below is the table showing the tasks at the particular OHC. These introduce a very short account of the OHCs first four orders.

MHC Is Applicable to All Task Actions

The MHC applies to all task actions. One aspect of the MHC that is important for the current account is that the model asserts that all task actions irrespective of the content belong to a single-task sequence regardless of the subdomain, context, or animal (Theorem 4, Commons et al., 1998). Therefore, one developmental task sequence from a given domain may be mapped into another developmental task sequence of another domain without implying synchronous development. This means that the OHC or difficulty of a task action is the same even if the task action may be part of a different sequence with different content. The OHC is the same regardless of how a person feels about the tasks or how a person performs in those task actions in different domains. Similarly, the task requirements to complete the task actions are also constant irrespective of the content and form. For example, the order of hierarchical complexity of the items necessary to complete an algebraic equation irrespective if they come from chemistry, physics, mathematics or a behavior science including psychology.

Understanding Our Account of Operant Conditioning Using the MHC

The MHC forms a basis for an understanding of how operant conditioning is accounted for by three procedural steps of respondent conditioning. It does so primarily because a central feature of this model is the proposal that more complex actions are necessarily formed from the coordination of less hierarchically complex actions. We assert that coordination of three respondent actions to produce operant conditioning follows the same procedure as any coordination of lower order task actions into higher order task actions as seen in the MHC. In this implementation of the model, the three procedural respondent conditioning steps are classified as being at Sensory or Motor Order 2 of hierarchical complexity in MHC. Here, it should be noted that, we are not suggesting that all respondent conditioning steps are limited to the Sensory or Motor Order 2 of hierarchical complexity. Respondent conditioning steps first occur at the sensory or motor Order 2 of hierarchical complexity.

Additionally it is noted that the steps in the process, both within a single organism or over evolutionary time, are not necessarily independent of one another. Although both the conditioning and evolutionary processes are both cumulative, preexisting components are potentially modifiable by the consequences encountered by later occurring components.

Table 1
Task Sequence From the First Five Orders of Hierarchical Complexity (OHC)

Order name	Order	Task	How it is done	Who Does It
Calculatory	0	Follow computer program; DNA; calculate; store information	Manipulate 0, 1; four nucleotide bases	Human made program
Automatic	1	Reflexes, sensitization, habituation, tropisms	Engages in one action at a time. Cellular activities: Sensing, effecting	Single-celled organisms
Sensory or motor	2	Reflexes and respondent conditioning	Procedurally pair an unconditioned stimulus (*UCS*) that elicits an unconditioned response (*UR*) with a salient neutral stimulus (*NS*)	Animals with very simple nervous systems, slugs, leeches, some mollusks
Circular sensory motor	3	Operant conditioning	Coordinate three steps of respondent conditioning	Animals with a nervous system: some worms, Insects
Sensory−Motor	4	Learn concepts	Coordinate two or more operant	Mammals, birds, reptiles

Automatic Order 1

For most of evolutionary time, there were only single-celled organisms. From our review it makes sense to assume that single-celled organisms in the evolutionary past also only had "hardwired" responses including taxis, tropisms and phagocytosis and the like (Commons & White, 2006/2009).

The criterion for classifying something as Automatic Order 1 is that the organism engages in a single action at a time and the action is "hardwired" into the organism. Responses to naturalistic events occur because these hardwired actions are tuned to certain relatively specific stimuli. Simple learning such as habituation and sensitization has been shown to occur. This learning is distinct from later forms in that while changes in behavior do occur, they only occur in response to changes in those specific stimuli to which those behaviors generally respond. Single-celled organisms engage in actions at Order 1. There are no uncontroversial reports of such organisms engaging in actions above Order 1.

Sensory or Motor Order 2

Respondent conditioning becomes possible at Sensory or Motor Order 2. The criterion for classifying something as Sensory or Motor Order 2 is that the pairing of stimuli leads to conditioning (Commons, Miller, Commons-Miller, & Chen, 2012). Unlike at Order 1, the responses become to be more flexibly associated with stimuli with which they have been paired. Either the detection of stimuli or the production of responses is somewhat flexible.

Reflexes and Respondent Conditioning Sensory or Motor Order 2

For organisms performing at Sensory or Motor Order 2, the important forms of behavior for the account being presented here are reflexes and the most complex process is respondent conditioning.

A *reflex* procedurally links stimulus to response (Pavlov, 1927). Reflexes can be mediated by a reflex arc only a few neurons long (Palkovits & Záborszky, 1977). In a reflex, the stimulus and the response are coordinated, but the coordination is automatic. For example, when water moves, mollusks open their shells reflexively (Palkovits & Záborszky, 1977). If something touches their membrane, the shells close. There is very little variability in these responses.

The Transfer of Salience Is a Sensory or Motor Order 2 Task Action

For a respondent conditioning procedure, a Sensory or Motor Order 2 task action is the pairing of two eliciting stimuli: an environmental stimulus (*S*) and an unconditioned stimulus (*UCS*). A salient *US* and *S* already exist before the pairing and the endogenously salient *US* automatically elicits the unconditioned response (*UCR*). After a sufficient number of occurrences, such pairings transform the neutral stimulus (*S*) into a conditioned stimulus (*CS*). We will refer to the *CS* as just *S*. The *S* becomes more salient by having acquired most of its saliency from being paired with the endogenously salient *US* (Lawrence, Klein, & LoLordo, 2009). This *CS* then elicits the conditioned response (*CR*), which is a variation of the unconditioned response (*UR*) (Pavlov, 1927).

This kind of respondent conditioning is at Sensory or Motor Order 2 of hierarchical complexity because two stimuli are arbitrarily paired either by accident or by an experimenter, the organism's behavior does not directly cause the reinforcing stimuli in this situation as it does in operant conditioning, and the organism does not temporally or in some other way organize or coordinate more than one action to more adequately accomplish this task. Therefore, this pairing of the *S* and *US* does not constitute an increase in the hierarchical complexity of the task that must be solved. Using the preceding example, each of the arbitrary pairings of two salient stimuli that make up the three procedural steps meets the criteria for Sensory or Motor Order 2 in the MHC.

Circular Sensory-Motor Order 3: Operant Conditioning May Be Built Out of Three Procedural Steps of Respondent Conditioning

Our account of operant conditioning is also based upon the application of the axioms MHC (see Figure 2). The MHC analytically and empirically requires higher order task actions to be built out of lower order task actions that the higher order task action orders in a nonarbitrary way. Three steps of respondent conditioning, Sensory or Motor Order 2 tasks, are nonarbitrarily coordinated to produce operant conditioning. Again, these steps are "what to do," "when to do it," and "why to do it." Coordination of the three steps means that operant conditioning is an Order 3 task action. By definition, this nonarbitrary coordination cannot be done at Sensory or Motor Order 2 of hierarchical complexity.

One example is provided next. The rest of the examples are in a following section. In the example of the blowfly, the coordination of three steps of respondent conditioning is illustrated when a blowfly (*Protophormia terrae novae*) operantly conditions (Sokolowski et al., 2010). Individual flies were trained to enter and reenter a hole as the operant response. Moving in and out of the hole was detected with two infrared emitter and detector pairs. On each side of the hole, seven lines of light-emitting diodes (LED) were arranged in alternations of green and yellow. LEDs were turned on when a session started and were turned off when the fly entered the hole. The reinforcer was sucrose solution delivered at the bottom of the hole by the needle of a glass syringe.

In Step 1, there is an assumed representation of behavior that elicits entering the hole. That representation of behavior becomes salient by being paired with the sucrose reinforcement, UCS/S^{R+}.

In Step 2, we understand that Sokolowski et al. (2010) indirectly showed that the now salient representation of behavior, which elicits the operant behavior, *R*, is paired with the environmental stimulus, *S* (the turning on of the LED lights around the hole). Here the operant behavior *R*, is entering the hole to get to the reinforcement.

In Step 3, the environmental *S* (the visible hole with LED lights around it) is paired with the sucrose reinforcement, UCS/S^{R+} making the *S* more salient and valuable. This pairing acts to produce an incentive. The environmental *S* takes on the elective properties of UCS/S^{R+} This illustrated in Figure 3.

In our account, operant conditioning is an Order 3 of hierarchical complexity action because it is built out of the nonarbitrary coordination of three lower order task actions, specifically the three steps of respondent conditioning from Order 2. We show that reflexes and respondent conditioning exist at Sensory or Motor Order 2. Additionally, operant conditioning results from the coordination or organization of three respondent conditioning steps; Step 1: $R-S$; Step 2: $rb-R-S^{R+}$ and $S-R$, and in our terms $S-rb–R$; Step 3: $S-S^{R+}$. Operant conditioning is a Circular Sensory Motor Order 3 task behavior.

Leg 2: The Evolution of Operant Behavior From Respondent Conditioning

In the case presented in the preceding text, we put forth the possibility that operant conditioning was built out of a coordination of three cases of respondent conditioning and that respondent conditioning was built out of a coordination of hardwired actions that tended to be automatically elicited by a stimulus, which then became paired with an arbitrary stimulus. Here we use evolutionary theory and findings to support this overall proposal, since the order in which animals evolved should be consistent with what has been described by the MHC. Living organisms started out as single cells, and gradually became more complex. It is also the case that in evolution, newer adaptations may reuse, incorporate or transform previous adaptations. These are both features of the MHC.

It is important to include evolutionary theory as the second leg to support this proposal, since the order in which animals evolved is consistent with what has been described by the MHC. An evolutionary account supports the idea that it takes a very simple nervous system to classically condition and then a more complex nervous system to operantly condition. Therefore, more complex animals, that could operantly condition, developed later than animals that could only respondently condition. If this can be shown, there would be convergent support from what is known about evolution. Examples of animals and types of learning at each of the orders are given. Although not a strong form of proof, as long as the simplest animals also show only the simplest forms of learning, and the more complex animals show more complex learning, this at least would show that this proposal is consistent with evolutionary theories.

Automatic Order 1

For most of evolutionary time, there were only single-celled organisms. In the Automatic Order 1, single-celled organisms respond to a single environmental stimulus. The environmental stimulus *S* that leads to the behavior is not paired with any other stimulus. The single action is an innate biological action to a specific environmental stimulus. Examples of the environmental stimulus *S* could be a chemical emitted by possible food, light, heat, or electricity. The actions are built into the organism. Examples of such built in or automatic actions include taxis, tropisms, phagocytosis and unconditionable reflexes (Commons & White, 2006/2009). Obviously, single-celled animals do not have nervous systems. The Automatic Order 1 is a very slightly modified version of Original Sensory or Motor Order 1. The only change was the removal of respondent conditioning.

Here, *conditionable* and *unconditionable* reflexes are distinguished. Uncontionable reflexes are an Order 1 behavior. Reflex, is nearly an instantaneous movement in response to a stimulus (Purves, 2004). In an unconditionable reflex, the stimulus and the response are coordinated, and the coordination is totally automatic. Reflexes that are not classically conditioned are Automatic Order 1 responses. They are referred to as unconditionable reflexes. Also, the term reflex is used here, as opposed to tropism or taxis because the term reflex is traditionally used for fast responses that do not have long durations. Reflexes that are classically conditioned are referred to as conditionable reflexes, which are Sensory or Motor Order 2 response.

Other Automatic Order 1 actions are habituation and sensitization. These are two forms of nonassociative learning. These are two behavioral processes that may have evolved to deal with stimuli that occur iteratively in the environment (Eisenstein, Eisenstein, & Smith, 2001). *Habituation* is a decrease in magnitude of a response to an iterative stimulus. On the other hand, sensitization is an increase in magnitude of a response to an iterative stimulus. These forms of learning are distinct from later forms of classical conditioning, sometimes called associative learning. Single-celled organisms at Order1 have limited sensors and effectors. There are no uncontroversial reports of such organisms responding in actions above Order 1.

Some examples of Order 1 animals. Order 1 actions are illustrated using examples from studies on paramecia, protozoan *Vorticella convallaria* and protozoan *Spirostomum*.

Example 1. This is an example of unconditionable reflex and habituation as an Automatic Order 1 behavior in protozoan, *Vorticella convallaria* by Patterson (1973).

Stimulus 1(S_1). Electric stimulation of different intensities administered every 10 seconds for 5 min.

Response 1 (R_1). Response to S_1, was contraction of the body and stalk.

S_1 eliciting R_1 is an example of unconditionable reflex which is an Automatic Order1 behavior.

Stimulus 2 (S_2). Mechanical stimulus administered by dropping different weights on the microscope stage every 10 seconds for 5 min.

Response 1(R_1). Response to S_2 was contraction of the body and stalk.

S_2 eliciting R_1 is also example of unconditionable reflex which is an Automatic Order1 behavior.

Stimulus 3 (S_3). Mechanical stimulus was administered by modifying the media of the organism.

Response 1(R_1). Response to S_3 was contraction of the body and stalk.

S_3 eliciting R_1 is also example of unconditionable reflex which is an Automatic Order1 behavior. Habituation occurred with administration of all the three stimuli. The longer the organisms were exposed to the stimuli, the longer became the periods in which the organism were nonresponsive.

Example 2. Paramecia are Automatic Order 1 animals. This is shown by their failure to classically (Mingee, 2013) and operantly condition (Mingee & Armus, 2009). They show behaviors of sensitization.

Stimulus 1(S_1). One of the stimuli used in the study by Mingee (2013) was level of illumination.

Response (R_1). Response to S_1, level of illumination, was moving away from light (in most paramecia with the exception of Paramecia *bursaria*).

S_1 eliciting R_1 is an example of taxis which is an Automatic Order1 behavior.

Stimulus 2 (S_2). The other stimulus used was shock in the cathode side of the trough.

Response (R_2). Response to S_2 was swimming to the noncathode side (i.e., moving away from the shock).

S_2 eliciting R_2 is also example of taxis which is an Automatic Order1 behavior.

When S_1 and S_2 were paired to investigate whether S_1 would elicit the same response as S_2 after the pairing (i.e., checking for presence of classical conditioning), it was found that S_1 no longer elicited R_2 after 1 min of the first testing trial. Thus, pairing of the two stimuli was unsuccessful and classical conditioning did not occur suggesting that paramecia behave at Automatic Order 1.

Example 3. This is an example of unconditionable reflex, habituation, and sensitization as an Automatic Order 1 behavior in protozoan *Spirostomum ambigum* in the study done by Hamilton, Thompson, and Eisenstein (1974).

Stimulus 1 (S_1). Vibratory stimulus was administered for 10 min repetitively (0.1 Hz).

Response 1 (R_1). Response to S_1, vibration stimulus, was contractions, rapid shortening of the organism to about one half of its resting length.

S_1 eliciting R_1 is an example of unconditionable reflex which is an Automatic Order 1 behavior.

The organisms that were initially less reactive (contracted less frequently) showed sensitization, whereas the organism that were initially more reactive habituated. These results were replicated by Eisenstein, Brunder, and Blair (1982).

Organisms behaving at Order 1 would be insensitive to outcomes except in an evolutionary sense. That is, consequences may be selected for in an evolutionary sense if the single response leads to survival and reproduction.

Sensory or Motor Order 2

At Sensory or Motor Order 2, organisms coordinate two stimulus response pairs from the lower Automatic Order 1. An example of this is respondent conditioning. In respondent conditioning, the first stimulus response pair is the unconditioned stimulus (*UCS*) and the unconditioned response (*UCR*). Procedurally, respondent conditioning is the pairing of the unconditioned stimulus (*UCS*) with a salient neutral stimulus (*NS*). This increases the salience of the previously neutral stimulus (Lawrence, Klein, & LoLordo, 2009). Over time this will lead to the neutral stimulus also automatically eliciting the unconditioned response. Such pairings transform the neutral stimulus into a conditioned stimulus (*CS*) and the unconditioned response into a conditioned response (*CR*). In respondent conditioning, there is the organization of stimulus elicited actions by organizing the stimuli. Reflexes that are conditioned, which are called conditionable reflexes in this article, are also Order 2 behaviors. At Sensory or Motor Order 2, organisms more flexibly respond and are more flexibly sensitive to stimuli of various intensity and kind.

To perform Sensory or Motor Order 2 task actions, organisms have to have networks of neurons to organize the conditioning of reflexes. As it is likely that the existence of neurons dates to slightly before the Cambrian period, we speculate that organisms, which at a minimum respondently conditioned, developed not much before or during the Cambrian explosion. This speculation is based on the fact that prior to the Cambrian explosion, most organisms were simple, composed of individual cells occasionally organized into colonies (Butterfield, 2001). Then, in the Cambrian explosion, there was the relatively rapid appearance of most major animal phyla. Among the animals that evolved during that period were the chordates, animals with a dorsal nerve cord; hard-bodied brachiopods, which resembled clams; and arthropods, ancestors of spiders, insects, and crustaceans.

Some examples of sensory or Motor Order 2 actions. Order two actions are illustrated using examples from three studies.

Finding current animals that respondently condition but do not operantly condition is a difficult one. That is partly because many people who have been studying invertebrates in particular, who are candidates for being this kind of animal, have been primarily interested in doing neuronal studies of these relatively simple animals as they are undergoing classical conditioning (Abramson, 1994). For most of the instances of classical conditioning that we have come across, we just do not know whether operant conditioning of that organism has even been attempted. In most cases, no published reports have been found. That does not of course mean that attempts have not been made.

Example 1. The first example comes from the study done by Henderson and Strong (1972) on *Macrobdella ditetra* (leech). In the study, they successfully classically conditioned leeches.

Neutral Stimulus (NS). The neutral stimulus *NS* used in this study was light from light bulb.

Neutral Response (NR). Neutral response to *NS*, light, was cephalic turning response. This is a natural response to light.

Unconditioned Stimulus (UCS). The unconditioned stimulus *UCS* used in this study was shock.

Unconditioned Response (UR). The unconditioned response *UR* was the anteroposterior contraction after the presentation of UCS. This is the natural response to shock.

Neutral Stimulus and Unconditioned Stimulus Pairing. The neutral stimulus (*NS*), light, was paired with the unconditioned stimulus (*UCS*), shock. The *NS* was presented for 3 seconds and then the *UCS* was presented for 0.1 second during the last 0.1 second of the *NS*.

Conditioned Stimulus (CS). After the *NS* and *UCS* pairing, light became the conditioned stimulus.

Conditioned Response (CR). After the light became a conditioned stimulus, it elicited the same response as the *UR* did which was anteroposterior contraction during *CS*, but before *UCS*. Thus, anteroposterior contraction became the *CR* and the light no longer elicited the *NR*.

In this example, light (NS) eliciting cephalic turning response (*NR*) in leeches is one automatic order 1 action. The second automatic order 1 action was the shock (*UCS*) eliciting anteroposterior contraction (*UR*). These two order 1 actions are coordinated (paired) to form the Sensory or Motor order 2 action which is light (*CS*) eliciting anteroposterior contraction (*CR*).

Example 2. The second example planarian, dugesia dorotocephalau, were classically conditioned by Thompson and McConnell (1955).

Neutral Stimulus (NS). The neutral stimulus *NS* used in this study was light from light bulb.

Neutral Response (NR). Neutral response *NR* to, light *NS*, in the control animals was low (10–30%) rate of turn responses, and a very low (<5%) contraction rate.

Unconditioned Stimulus (UCS). The unconditioned stimulus *UCS* used in this study was shock.

Unconditioned Response (UR). The unconditioned responses *UR* were a sharp turning of the cephalic region to one side or the other, and a longitudinal contraction of the entire body.

Neutral Stimulus and Unconditioned Stimulus Pairing. The neutral stimulus (*NS*), light, was paired with the unconditioned stimulus (*UCS*), shock. The *NS* of light was presented for 3 seconds and then the *UCS* of shock was presented for 1 second during the last 1 second of the NS.

Conditioned Response (CR). After the light became a conditioned stimulus *CS*, it elicited the same responses as the *UR* did which were a sharp turning of the cephalic region to one side or the other, and a longitudinal contraction of the entire body.

In this example, light (*NS*) rarely eliciting a turning or contracting response (*NR*) in planarian is one automatic order 1 action. The second automatic order 1 action was the shock (*UCS*) eliciting a higher probability turning or contracting response (*UR*). These two order 1 actions are coordinated (paired) to form the Sensory or Motor order 2 action which is light (*CS*) eliciting a higher probability turning or contracting response (*CR*).

Example 3. The third example comes from the study done by Mpitsos and Davis (1973) on marine gastropod Pleurobranchaea (sea slugs). In the study, they successfully classically conditioned sea slugs.

Neutral Stimulus (NS). The neutral stimulus *NS* used in this study was tactile stimulation of the oral veil using a sterile glass probe.

Neutral Response (NR). Neutral response to *NS*, tactile stimulation of the oral veil, was withdrawal and bite-strike response.

Unconditioned Stimulus (UCS). The unconditioned stimulus *UCS* used in this study was food chemicals (Homogenized squid).

Unconditioned Response (UR). The unconditioned response *UR* was feeding behavior after the presentation of *UCS*.

Neutral Stimulus and Unconditioned Stimulus Pairing. The neutral stimulus (*NS*) was paired with the unconditioned stimulus (*UCS*), food chemicals. The *NS* (sterile glass probe for tactile stimulation) was coated with the food chemicals, *UCS*, and the oral veil was stroked for 10 seconds.

Conditioned Stimulus (CS). After the *NS* and *UCS* pairing, tactile stimulation of the oral veil became the conditioned stimulus.

Conditioned Response (CR). After the tactile stimulation of the oral veil became a conditioned stimulus, it elicited the same response as the *UR* did which was feeding behavior during *CS*, but before *UCS*. Thus, tactile stimulation of the oral veil became the conditioned response and the tactile stimulation of the oral veil no longer elicited the *NR*.

Circular Sensory Motor Order 3

At Circular Sensory Motor Order 3, organisms coordinate two or more actions from Sensory or Motor Order 2. The most important case is that of Operant Conditioning. Operant Conditioning may be accounted for by the three steps of procedural respondent conditioning. Organisms that solve Circular Sensory Motor Order 3 tasks are multicelled with some sort of more complex nervous system that what is seen in Sensory or Motor Order 2 animals. This section will present an argument that operant conditioning is Circular Sensory Order 3 action. Operant conditioning is built out of the nonarbitrary coordination of three Sensory or Motor Order 2 task actions or steps. These steps are step 1, “What to do”; step 2, “When to do it”; and step 3,“Why to do it”. Specifically the three steps of respondent conditioning are from Order 2 as required by the axioms of the MHC. At Order 2, the pairing at each step of procedural respondent conditioning occurs independently of the other respondent conditioning steps. Those steps are not coordinated at that order.

Some examples of Circular Sensory Motor Order 3 actions. What follows, are some examples of operant conditioning in insects. Insects and some related animals were chosen to show how Order 3 Operant Conditioning may be accounted for by the three steps of procedural respondent conditioning. Order three actions are illustrated using examples from three studies. Order three actions are shown to coordinate three Sensory or Motor Order 2 actions.

Example 1. Sokolowski, Disma and Abramson (2010) showed that blowfly (*Protophormia terrae novae*) behavior can be operantly conditioned. In this example, Steps 1, 2, and 3 are illustrated by what happens when blowfly behavior is operantly conditioned.

Individual flies were trained to enter and reenter a hole as the operant response. Moving in and out of the hole was detected with two infrared emitter and detector pairs. On each side of the hole, seven lines of LED were arranged in alternations of green and yellow. LEDs were turned on when a session started and were turned off when the fly entered the hole. The reinforcer was sucrose solution delivered at the bottom of the hole by the needle of a glass syringe.

In Step 1, there is an assumed representation of behavior (*rb*) which elicits entering the hole [(*rb* → *UCR*/*R*)]. That *representation of behavior* (*rb*) becomes salient by being paired with the sucrose reinforcement UCS/S^{R+}. This pairing, [*rb* → *UCR*/*R*] – UCS/S^{R+} is an Sensory or Motor Order 2 action.

In Step 2, the salient *representation of behavior* (*rb*) which elicits (→) the operant response (*UCR*/*R*) is paired with the environmental stimulus (*S*). Here the operant behavior (*UCR*/*R*) is entering the hole which gets to the reinforcement (UCS/S^{R+}). This pairing of salient *repre-*

sentation of behavior rb and environmental stimulus *S*, represented as *S* – [*rb* → *UCR/R*], is an Sensory or Motor Order 2 action.

In Step 3, the environmental stimulus (*S*) is paired with the sucrose reinforcement (UCS/S^{R+}) making the environmental stimulus (*S*) more salient and valuable. This pairing acts to produce an incentive (Killeen, 1982a, 1982b, 1984, 1985). The environmental stimulus (*S*) takes on the elicitive properties of sucrose reinforcement UCS/S^{R+}. This is represented as $S – UCS/S^{R+}$.

Each of these steps on its own is a Sensory or Motor Order 2 action. The coordination of the three steps, on the other hand, is a Circular Sensory-Motor Order 3 task action.

Example 2. In this example, the three steps are illustrated using Schiller's (1949) study on *Octopus vulgaris*.

In a second example, *Octopus vulgaris*, the three steps of respondent conditioning are illustrated when Octopus vulgaris operantly conditions during maze learning. Two inverted cans, one covering a baited, the other an unbaited container was used. A partition wall had to be circumvented to reach the baited can. *Octopus vulgaris* learned to make a turn toward the proper side if the bait was visible all the time.

In Step 1, there is an assumed *representation of behavior* (*rb*) that elicits taking the detour by circumventing the partition wall (*UCR*/*R*). That *representation of behavior* (*rb*) becomes salient by being paired with the crab bait (UCS/S^{R+}). This pairing, $[rb \rightarrow UCR/R] – UCS/S^{R+}$, is a Sensory or Motor Order 2 action.

In Step 2, Schiller (1949) indirectly shows that the now salient *representation of behavior* (*rb*) which elicit the operant behavior (UCR/*R*) is paired with prior environmental stimulus (*S*), the visible bait can. Here operant behavior *R* is turning to the proper side to avoid the opaque wall and get to the baited can. The pairing of salient *representation of behavior* (*rb*) and environmental stimulus (*S*) is an Order 2 action. This is represented as *S* – [*rb* → *UCR/R*].

In Step 3, the environmental *S*, the visible bait can, is paired with the crab bait (UCS/S^{R+}). This makes the *S* more salient and valuable. This pairing acts to produce an incentive (Killeen, 1982a, 1982b, 1984, 1985). The environmental *S* takes on the elective properties of UCS/S^{R+}. This is represented as $S – UCS/S^{R+}$.

Again, each of these steps on its own is an Sensory or Motor Order 2 action. Coordination of the three steps, on the other hand, is a Circular Sensory-Motor Order 3 task action.

Example 3. In this example, the three steps are illustrated using Andrew and Savage's (2000) study on *Lymnaea* (Pond Snail).

In a third example, *Lymnaea*, the three steps of respondent conditioning are illustrated when Octopus vulgaris operantly conditions during appetitive learning. *Lymnaea* was placed in a glass gutter. The gutter was placed within a white surround, 30 cm high. Halfway along the gutter, and visible through its sides, two panels, either black or white, were placed on either side of the gutter. *Lymnaea* were reinforced with sucrose when its head reached the level of the panels. *Lymnaea* learned to reach the level of panels, either black or white.

In Step 1, there is an assumed *representation of behavior* (*rb*) that elicits moving toward the level of the black and white panels (*UCR*/*R*). That *representation of behavior* (*rb*) becomes salient by being paired with the sucrose (UCS/S^{R+}). This pairing, $[rb \rightarrow UCR/R] – UCS/S^{R+}$, is an Sensory or Motor Order 2 action.

In Step 2, Andrew and Savage (2000) indirectly show that the now salient *representation of behavior* (*rb*) which elicits the operant behavior (*R*) is paired with prior environmental stimulus (*S*), the visible black and white panel. Here operant behavior (*R*) is moving toward the level of the black and white panels to get the sucrose. The pairing of salient *representation of behavior* (*rb*) and environmental stimulus (*S*) is an Sensory or Motor Order 2 action. This is represented as *S* – [*rb* → *UCR/R*].

In Step 3, the environmental (*S*), the visible black and white panel, is paired with the sucrose (UCS/S^{R+}). This makes the *S* more salient and valuable. This pairing acts to produce an incentive (Killeen, 1982a, 1982b, 1984, 1985). The environmental *S* takes on the elective properties of UCS/S^{R+}. This is represented as $S – UCS/S^{R+}$.

Each of these steps on its own is a Sensory or Motor Order 2 action. Coordination of the three steps, on the other hand, is a Circular Sensory Motor Order 3 task action.

Adaptive Advantages of Developing Operant Conditioning

Evolution occurs when there are adaptive advantages to the new or altered functions as mentioned in the insect examples. The insects live longer for the most part than single-celled animals. Because of sexual reproduction, the genetic material is more varied.

What we argue is that the biochemistry from Order 2 organisms evolved to Sensory-Motor Order 3 organisms and as a result operant conditioning became possible. That required new coordination machinery by actual neural networks to fit together the three steps of respondent conditioning.

There are a number of evolutionary advantages that come with the evolution of operant conditioning. First, with an Order 2 task-performing animal, operant conditioning is more flexible than respondent conditioning for many reasons. More than one operant behavior may be formed into a chain of behaviors, the chain acting as an operant. A common observation is that with a more complex nervous system, many more reflexes evolve. This is because they are part of operant conditioning. There are more parts to the organism and more of the parts lead to various actions being elicited. There is the possibility of lots of inhibition that allows for very selective action.

Second, there are a huge number of possible contingencies making animals that operantly condition more adaptive to a wider range of environments. The wide variety of possible pairings between potential $S-rb\text{-}R$ behavior and reinforcers, UCS/S^{R+} goes up by the power of two to the number, N, of stimuli and response elements in the pairs with equal number of stimuli and responses $= 2^N$. This exponential growth in the number of pairs makes behavior and behavioral control much more plastic. With reflexes there were just a few *S*s that when the followed the *UCS* would lead to conditioning of the "desirable" behavior. Now the number of environmental *S*s seems to be almost unlimited.

Discussion

In this article, an alternative integrative account by which respondent and operant conditioning are related has been presented. Convergent theories and evidence were used to support this new account. This account posits that three procedural steps of respondent conditioning form the basis for operant conditioning. These were found to adequately account for operant conditioning. This account was also shown to be consistent with the MHC and evolutionary data on the ordering of evolutionary development.

As part of our account, it was proposed that MHC requires the three procedural respondent conditioning steps individually to be Order 2 task actions. Operant conditioning was shown to be at Order 3 of hierarchical complexity because it is built out of the nonarbitrary coordination between three lower order task actions, specifically the three steps of respondent conditioning from Order 2.

Although it is not mentioned in the article, we predict that our account may allow for additional hierarchies in a neural network. For example, we predict that at Sensory-Motor Order 4, organisms may compare momentary changes in rate of reinforcement (Risk) (Commons & White, 2006/2009). This requires this order of the neural network to compare the outputs in rate of reinforcement from Order 3.

Our account also shows that data on the ordering of evolutionary development is consistent with what has been described by the MHC and neural networks. The same kind of conditioning procedures takes place in both respondent and operant conditioning. There is no need for completely separate procedure account.

The first precursors to animal organisms were single-celled organisms that operated at Automatic Order 1. Like the single-celled organisms of today, these organisms may have only had habituation and sensitization as forms of learning and tropisms. Organisms that only solve Order 1 tasks are single-celled or groups of cells without a nervous system (Commons & White, 2006/2009). Then Sensory or Motor Order 2 task solving organisms evolved. Organisms that solve Order 2 tasks are multi celled with some sort of simple nervous system. These animals could respondently condition. We argued that our account made evolutionary sense because more complex animals developed out of animals that could not respondently condition. It would follow that with a minimal nervous system, Order 2, could be solved; namely, respondent conditioning without operant conditioning.

Predictions Made by Our Account

Our account of how operant conditioning may consist of three procedural steps of respondent conditioning makes a number of predictions. First, it predicts the nature of the neural structure of animals as they evolve based on both the MHC and neural networks. This is not unique to this theory. Second, it predicts differences in structure and neural transmitters at different OHC. Many people have also said that these new structures and new neural transmitters had to evolve. Our contribution is to make operant conditioning out of the three cases of respondent conditioning. That means new structures (a nervous system) and new neural transmitters are needed to coordinate the three steps of respondent conditioning. This result can be seen in the differences in the structures and transmitters for single cell animals and multicellular animals with nervous systems. Third, it predicts, using a priori knowledge of the hierarchical complexity of task actions, the order in which evolution will take place. Because this prediction is supported, it makes our account of the relationship between operant and respondent conditioning more plausible. Fourth, our account predicts, from all that had to evolve as shown above, why there was a long evolutionary period between evolution of reflex and reflex conditioning and evolution of operant conditioning. Fifth, at each order, different aspects of value can be successfully dealt with. Value at the Automatic Order 1 is elicitive of tropistic and reflexive behavior. Value at Sensory or Motor Order 2 is despondently condiditionabee. The value may be partially transferred to a new stimulus paired with a previously valued stimulus. Value at Circular Motor Order 3 imputes the representation of behavior and the *S* with not only value but salience.

Finally, our account is consistent with what may have happened during the Cambrian explosion. Single cell animals evolved into the complex animals and into lower entropy animals with specialized organs such as nervous systems and new sensors. With the increase in OHC that an organism successfully addresses, there is a lowering of entropy. In achieving this lowering of entropy, there were huge increases in structure and the genetic information going into making and maintaining those more specialized structures. It might also show why low entropy animals took advantage of information acquisition through operant conditioning. By improving hunting and gathering, these adaptations made it possible to extract more energy more efficiently from higher entropic animals and plants. Predation was much more successful with operant conditioning than with tropisms and reflexes. As a result, larger animals could more efficiently eat more. They also grew in size. Our account may show why diversity of animals "smarts" evolved and how it evolved. This will lead to better studies of very simple organisms that operantly condition. It will lead to identifying structural and neural properties. For example, no one has looked for how operant coordination of three steps of respondent conditioning happens at the structural level in insects. One should be able to do fMRI studies of simple organisms to find such structures during the coordination.

Possible Criticisms

Our account of operant conditioning as being due to the coordination of three procedural steps of respondent conditioning could be seen as controversial. Comparative and behavioral analysts may deem it controversial because of its theoretical aspects.

Possible ways to reject our account. Our account of operant conditioning may be rejected on three grounds:

First, if there is no neural event preceding an operant behavioral response during operant conditioning for multicellular animals with nervous systems, then there is weak evidence to reject the reduction model. Also, if motor activity or even hormonal activity is not preceded by a neural event then there is sufficient reason to castoff the reduction model.

Second, if there is a failure to support the necessity of the salience of the neural event preceding some operant activities such as avoidance, punishment and withdrawal of aversive event then there is a possibility that it could harm the reduction model.

Third, even if explanations are given for operant activity such as avoidance, the explanations suggested are still controversial. Similarly, the point can also be made that there is an absence of total agreement on noncued avoidance.

Fourth the idea that synaptic connections are needed to classically or operantly condition may be violated if single-celled organisms were shown to exhibit respondent conditioning. A few researchers have maintained that such organisms can be classically conditioned (see Armus, Mongomery, & Gurney, 2006; Hennessey, Rucker, & McDiarmid, 1979), these claims have been met with a large degree of skepticism (see Hinkle & Wood, 1994; and Mingee, 2013) for some discussion). This is partly due to lack of replications, but also due to the fact that in many cases other mechanisms, such as habituation or sensitization, have been shown to account for the results. Mingee (2013) appeared to be able to replicate the Armus et al. (2006) findings, however the changes in the paramecium behavior did not persist even for a short period of time. This lack of persistence suggests that paramecia sensitive but cannot be respondently conditioned.

Fifth, there might be a possibility that there are no animals that just respondently conditions and not operantly condition. It is very difficult because one cannot check all animals. Also, there is no way to check on animals that are now extinct.

Other Benefits of Our Account

A benefit of the present account is it strongly argues that many properties of respondent conditioning should also appear in operant conditioning. For example, following Staddon and Cerutti (2003), respondent timing may help account for operant timing. Chaining might help account for the fact that operant conditioning occurs even with the temporal gaps found between the environmental stimuli and the response. Only somewhat complex animals can be conditioned operantly. Maybe some of the operant properties lie in the respondent properties because operant is built out of respondent. But with three pairings, there should be some new adaptive properties for some niches. We always find these when an organism moves up in the order of hierarchical complexity of their actions, they successfully address a wider range of problems.

Last, our account shows possible relationships between the hierarchical informational, biochemical, structural, behavioral and evolutionary levels of analysis. This leads to the possibility of some grand theories.

Conclusion

In this article, we suggest an alternative that may be more integrative and compact than many traditional accounts of both single factor or two factor theories of procedural respondent and operant conditioning processes. Convergent theories and evidence were used to support this new account. The account posited three steps of procedural respondent conditioning. These were found to adequately account for operant conditioning. The account also is consistent with the MHC, two-hidden-layer neural networks, and evolutionary development. The theory makes a number of predictions. It predicts differences in structure and neural transmitters. These new structure and new neural transmitters had to evolve to make the operant conditioning of the three cases of respondent conditioning work. That means new structures (a nervous system) and new neural transmitters are needed to coordinate the three steps of respondent conditioning. This results in the differences in the structures and transmitters.

The issue might come up, if operant conditioning evolved at Sensory or Motor Order 2: Is there further evolution that makes possible correctly addressing higher order tasks? Commons and Pekker (2008) present 16 orders of hierarchical complexity. Here we will mention only the on the next order after Sensory or Motor Order 2. At Stage and Circular Sensory-Motor Order 3, organisms may compare momentary changes in rate of reinforcement (Risk). Also, organisms may form concepts in the sense that Clark Hull (1952) described them.

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