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Introducing a new stage for the model of hierarchical complexity: A new stage for reflex conditioning

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ABSTRACT

The model of hierarchical complexity (MHC) is known to have 16 orders so far. However, applying the model to explain the development of operant conditioning (*original order 2*) from respondent conditioning (*original order 1*) in non-human animals has led to the recent discovery of a new stage.

Actions that make up respondent conditioning are more hierarchically complex than habituation, sensitization, and other simple actions or behavioral tendencies that were also included in *original order 1*. Thus, the *original order 1* has now been separated into the new *automatic order 1* and the new *sensory or motor order 2*. All the orders above the *original order 1* also had their numbers incremented by one. Thus, there are now 17 orders of hierarchical complexity. This paper describes this new sequence of orders at the lowest end of the model.

KEYWORDS: revised, orders, model of hierarchical complexity, stages

The addition of a New Order 2 between the Revised Order 1 and the Original Order 2 has a curious history. Kurt Fischer (personal communication, June, 1984) suggested that there has always been a possibility that there are more stages in infancy than the ones foreseen in the Model of Hierarchical Complexity. There would actually be a couple of reasons for this. One is that Piaget had originally proposed six stages during the first 18 months of life. The other is that original stage schemes were not conceived of with non-human animals in mind. In our work, we have been applying the Model of Hierarchical Complexity to explain the development of operant conditioning (Original Order 2) from respondent conditioning (Original Order 1) in non-human animals. This led to the discovery that actions making up respondent conditioning were more hierarchically complex than habituation, sensitization, and other simple actions or behavioral tendencies also included in Original Order 1. This realization led to the insertion of a New Sensory or Motor Order 2 that follows the renamed and revised Automatic Order 1 to account for the evolution and development of respondent conditioning. The revised Automatic Order 1 goes between Original Calculatory Order 0 and the new Sensory or Motor Order 2. The Original Order 1 then became Sensory or Motor Order 2, and all the orders above that also had their numbers incremented by one. This paper is about this new sequence of orders at the lowest end of the Model.

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The model of hierarchical complexity and its axioms

The Model of Hierarchical Complexity (MHC) is a mathematical model that sets forth a measurement system by which actions are put into a hierarchical order. The model assesses a general, unidimensional developmental measure of difficulty across domains. The Model of Hierarchical Complexity suggests that one of the major ways in which sequences of tasks are arranged is in terms of their complexity (or difficulty). The complexity of a task is operationalized in terms of its Order of Hierarchical Complexity (OHC). The measurement system of the model is composed of axioms. Axioms are rules that are followed to determine how the model orders actions to form a hierarchy. There are five axioms:

Axiom 1 (Well-ordered). If one action is less complex than another action, then the assignment function, which gives a numerical order of hierarchical complexity to an action, must preserve the action's order in the hierarchy. In non-mathematical terms: That is, simpler actions are lower in the order than more complex actions.

Axiom 2 (Transitivity). If action a is more hierarchically complex than action b, and action b is more hierarchically complex than action c, then action a is more hierarchically complex than action c.

Axiom 3 (Chain rule). When actions a and b are chained together in some order, and the order in which they are executed is not influential to accomplishing a task, the order of hierarchical complexity of $(a \circ b)$ equals that of the highest subaction. In non-mathematical terms: That is, when two actions, a and b, are organized in some way, but the actions can be completed in any order, then the overall hierarchical complexity of the two chained actions is only as high as the most hierarchically complex action in the chain.

Axiom 4 (Coordination rule). The organization of the ordering of action rules is non-arbitrary. In non-mathematical terms: When two actions, a and b, are organized, that organization has to be non-arbitrary.

Axiom 5 (Equal spacing[1]). The a priori difficulty of a task action changes by 1 for each change in the Order of Hierarchical Complexity, irrespective of what adjacent Orders of Hierarchical Complexities one is comparing. In other words, there is equal spacing between each order

Original order 1 violates axiom 1

Originally, Sensory or Motor Order 1 was defined as an order in which organisms coordinate one action or operation with one stimulus. They engage in a single action at a time and the action is not coordinated with other actions, but with a stimulus. Both the detection of stimuli and the production of responses are somewhat flexible, but the relationship between them is not. This order was described as including actions such as reflexes, sensitization, habituation, tropisms and last but more troubling, respondent conditioning.

The problem is that respondent conditioning cannot belong to Original Sensory of Motor Order 1 or Original Circular Sensory-motor Order 2. Although respondent conditioning was previously categorized as Original Order 1, it is more hierarchically complex than the Original Order 1. Respondent conditioning requires that a neutral stimulus NS be changed into a conditioned stimulus CS. This involves the procedural pairing of a presently neutral stimulus NS that only elicits attention with an unconditioned stimulus UCS that elicits an unconditioned response UR. According to Axiom 1 of the MHC, actions at the next higher Order of Hierarchical Complexity are defined in terms of two or more actions from the adjacent next lower order. In this case, actions from the adjacent next lower orders include: 1) attentional response to the neutral stimulus NS and 2) unconditioned response UR to unconditioned stimuli UCS. Once the neutral stimuli NS and unconditioned stimuli UCS are procedurally paired (ordered), the neutral stimulus becomes the conditioned stimulus CS that elicits a conditioned response CR. Thus, the conditioned response CR is more hierarchically complex than either the attentional response to a neutral stimulus or the unconditioned response UR. Hence, it is vital to separate Original Order 1 into two different orders, in which, the lower order includes actions such as unconditionable reflexes, sensitization, habituation and tropisms and the higher order includes respondent conditioning.

Likewise, it will be argued that operant conditioning belongs to new Order 3. This is because operant conditioning in our account is built out of three instances of respondent conditioning

1. Optional

Table 1. The updated orders of hierarchical complexity

Order number	Order name
0	Calculatory
1	Automatic
2	Sensory or motor
3	Circular sensory-motor
4	Sensory-motor
5	Nominal
6	Sentential
7	Preoperational
8	Primary
9	Concrete
10	Abstract
11	Formal
12	Systematic
13	Metasystematic
14	Paradigmatic
15	Crossparadigmatic
16	Meta crossparadigmatic

» THE NEW ORDERS

The Original Sensory or Motor Order 1 has now been divided into the new Automatic Order 1 and the new Sensory or Motor Order 2. Originally, there were 16 Orders of Hierarchical Complexity. With the insertion of the new Order 2, there are now 17 Orders of Hierarchical Complexity as shown in Table 1.

The need for a new Order 2 was discovered while reviewing observational and experimental literature on animal behavior in order to determine the behavioral developmental stages at which those animals performed. It was found that single celled organisms did not classically condition. When the literature on classical conditioning on single celled organisms was reviewed, it was found that the behaviors exhibited were habituation and sensitization. No neutral stimulus (NS) was conditioned. This suggested that habituation and sensitization could not be in the same order as classical conditioning.

This section presents the updated first four orders of hierarchical complexity. They are illustrated in Table 2 using examples drawn from observational and experimental literature on animal behavior. The table is followed by elaborate descriptions of each order.

Calculatory order 0

Order 0 includes pre-programmed behaviors that are very specifically elicited by exact computations. The forms of responses do not show variation and the responses to a "stimulus" show no generalization. There is no gradated response. The behavior is not elicited by any form of intelligent acting organism or thing. For example, a computer program behaves at stage 0. In a computer program, codes are initially provided by human programmers. Programmers perform at a stage that is incredibly higher than the computer programs do. What the program does is fixed and cannot be changed without a programmer. Of course there is programmed machine learning, but even small random changes in the stimulus or response are not possible. Similarly, in biology, the behavior of deoxyribonucleic acid (DNA) is at Order 0 because it performs a biological "calculation or programming" that happens almost the same way every time. In other words, for nucleotides, C always "bonds" with G and A always bonds with T, similarly to binary coding. We are not concerned with the biochemistry, but just the genetic code and the behavior of the nucleotide bases.

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 "hard wired" responses including taxis, tropisms and phagocytosis and the like (Commons & White, 2006/2009).

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. The criterion for Automatic Order 1 is that the organism engages in a single action at a time and the action is "hard wired" into the organism. Single celled organisms respond to a single environmental stimulus. Responses to naturalistic events occur because these hard wired actions are tuned to certain relatively specific stimuli. 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.

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 will be 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 will be referred to as conditionable reflexes, which are Sensory or Motor Order 2 response.

Simple learning such as habituation and sensitization are also Automatic Order 1 actions that have 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. These are two forms of non-associative learning. These are 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 Order 1 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 will be 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 minutes.

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 Order 1 behavior.

Stimulus 2 (s_2). Mechanical stimulus administered by dropping different weights on the microscope stage every 10 seconds for 5 minutes.

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 Order 1 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 Order 1 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 non-responsive.

Table 2. Revised description of the first five orders of hierarchical complexity

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

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 non-cathode 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 minute 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 minutes 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. 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 begin 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.

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.

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 *UCS* and *S* already exist before the pairing and the endogenously salient *UCS* automatically elicits the unconditioned response (*UCR*). After a sufficient number of occurrences, such pairings transform the neutral stimulus (*S*) into a conditioned stimulus (*CS*). The *CS* becomes more salient by having acquired most of its saliency from being paired with the endogenously salient *UCS* (Lawrence, Klein & LoLordo, 2009). This *CS* then elicits the conditioned response (*CR*), which is a variation of the unconditioned response (*UR*) (Pavlov, 1927). In respondent conditioning, there is the organization of stimulus elicited actions by organizing the stimuli.

The transfer of salience is at Sensory or Motor Order 2 of Hierarchical Complexity because: *a*) two stimuli are arbitrarily paired either by accident or by an experimenter, *b*) the organism's behavior does not directly cause the reinforcing stimuli in this situation as it does in operant conditioning, and *c*) the organism does not temporally or in some other way organize or coordinate more than one action in order 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 example above, 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

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 will be 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 multi-celled with some sort of more complex nervous system than what is seen in Sensory or Motor Order 2 animals. This section presents an argument that operant conditioning is Circular Sensory Order 3 action. Operant conditioning results from the coordination or organization of three respondent conditioning steps. These steps are: step 1, "What to do"; step 2, "When to do it"; and step 3,"Why to do it".

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 Disma and Abramson (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+}.

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.

Order 3 — Examples

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.

Some examples of order 3 actions. Order three actions will be illustrated using examples from three studies. Order three actions will be shown to coordinate three Sensory or Motor Order 2 actions.

Example 1. Sokolowski et. al (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 light-emitting diodes (LED) were arranged in alternations of green and yellow. LED's 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 *representation 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* → 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 towards 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* → 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 towards 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.

Relationship among order 1, order 2 and order 3

This differentiation between these three types of learning is actually an old one (see Rescorla, 1988). In that paper, Rescorla states that the three most studied forms of learning, are: *a*) learning that involves exposure to a single stimulus (New Automatic Order 1); *b*) learning that relies on the relation between two stimuli (New Sensory or Motor Order 2) ; and *c*) learning that examines the relation between an organism generated response (R) and a stimulus S (Step 2 of Circular Sensory Motor Order 3). All we are showing is that these differ in their hierarchical complexity.

The difference between Order 1 action and Order 2 action is that, for Order 1 action, the endogenously salient unconditioned stimulus automatically elicits the unconditioned response. Organisms behaving at Automaticity 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 action leads to survival and reproduction. Very primitive animals, such as single cell organisms, differentially respond to stimuli, for example, rejecting non-food items. However, such simple animals do not change their behavior because of its being paired with other stimuli or immediate environmental consequences, other than in terms of processes like habituation or sensitization.

» CONCLUSION

This is the first revision of the order and the corresponding stage sequence of the Model of Hierarchical Complexity since it was created in 1982. Although it may be difficult to remember the new numbers, the names have all stayed the same. What may be of interest is that the axioms and new information made it possible to do this revision. ■

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