A BEHAVIORALLY-BASED THEORY OF DEVELOPMENT

A Quantitative Behavior-Analytic Theory of Development

Michael Lamport Commons, Ph.D. and Patrice Marie Miller, Ed.D.
Harvard Medical School Harvard Medical School and Salem State College

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Abstract

This paper describes a quantitative analytic theory of development. Two of the major contributions that such a developmental theory can make are: a) an explanation of why certain tasks have to be acquired earlier than others (developmental sequences) and b) an account, based on selectionist principles, of the biological, cultural, organizational and individual psychology of performance. The behaviorism that can encompass these two goals incorporates quantitative analysis, where the assumptions are explicit and mathematically describable, and the measures of performance are quantitative. The two largest differences in this theory from others occur in the deliberate separation of task and performance, and the simplification of the basic unit of analysis, which in this theory is the event rather than the behavior or the stimulus and response. The definition of events is explicit and simple, containing very few assumptions.

A theory of development must be able to account for two aspects of behavior: a) what behaviors develop and in what order and b) why development takes place. It must be able to account for simple as well as complex behaviors. Behavior analytic theories of development have concentrated on explaining why development takes place (e.g. Bijou & Baer, 1961; Baer & Rosales, 1997). Development has been explained primarily in terms of contingencies of reinforcement. Such accounts have argued that the sequences in which behaviors develop are environmentally determined. Any particular behavior is viewed as being "shapeable" given the proper contingencies. As a result, sequences have been largely seen as arbitrary and easily changed. Behavior analytic theories have been better at explaining relatively simple behavior (the behavior of nonhuman species, of infants, and of individuals who are mentally retarded or autistic) rather than complex behavior. For these reasons, such theories have tended to become marginalized as far as developmental psychology as a whole is concerned.

Developmental psychology as a whole has been concerned with what develops and in what sequence. The major theory that dealt with the possible sequences in which behavior is acquired has been the mentalistic theory of Jean Piaget (e.g. Piaget, 1954; 1976).

We propose here a quantitative behavior-analytic theory of development that deals both with the sequences of development and with why development takes place. The theory presented here is behavioral because it makes only behavioral assumptions and avoids mentalistic explanations. The theory also uses principles derived from quantitative analysis of behavior (e.g. Commons & Nevin, 1981) in that the assumptions are explicit and the measures of performance are quantitatively describable; neither are limited by the earlier forays into quantification such as those of Hull (1943; 1952) or Piaget (Inhelder & Piaget, 1958; Piaget, 1954; Piaget, 1976; Piaget & Inhelder, with Sinclair-de Zwart, 1973).

Events

Scientific accounts of behavior are built out of both empirical and analytical analyses of ***events***. Events are perturbations or changes in the universe that can be detected by two independent means. In the case of a verbal report, an observer may hear it. A microphone and meter will show it. Stating that all other behavioral constructs (such as stimuli, behaviors, or consequences) have to be shown to be events eliminates mentalistic explanations and referents to revelations, hallucinations, and illusions. Examples of potential events can include stimuli, behaviors and consequences of behaviors.

Tasks

One major basis for this developmental theory is task analysis. The study of ideal tasks, including their instantiation in the real world, has been the basis of the branch of stimulus control called Psychophysics. Tasks are defined as sequences of contingencies, each presenting stimuli and requiring a behavior or a sequence of behaviors that must occur in some non-arbitrary fashion. Properties of tasks (usually the stimuli) are varied and responses to them measured and analyzed. In the present use of task analysis, the complexity of behaviors necessary to complete a task can be specified using the complexity definitions described next. One examines behavior with respect to the analytically known complexity of the task.

The Sequence of Development

Dimensions of Tasks

In this theory, how well an individual performs a task is postulated to be controlled by seven dimensions of tasks, as well as aspects of the situations in which tasks are presented, and the reinforcement history of the individual. As Table 1 shows, we characterize tasks in terms of five stimulus and response dimensions, and two performance dimensions. The first part of the discussion focuses on the dimensions of tasks because it is these dimensions, and particularly the first one (hierarchical complexity) that determine the sequence in which development takes place. These sequences occur in this order no matter how the reinforcement contingencies may favor out-of-sequence acquisition. Due to considerations of space, only the first three dimensions, which are also the most important, will be discussed here.

Hierarchical Complexity

Beginning in the 1980s, Commons and his colleagues presented an argument for an analytic (logical and mathematical) notion of what, in traditional developmental psychology, has been called "stage", but what we call developmental complexity (Commons & Richards, 1984a, 1984b: Commons, Trudeau, Stein, Richards, & Krause, in press). This model was originally called The General Stage Model, but in its newest transformation is called the General Model of Hierarchical Complexity (GMHC).

As suggested above, analyzing tasks for their hierarchical complexity and then sequentially ordering the tasks forms a task sequence. Such a task sequence presents an analytic, rather than an empirical or a mentalistic notion with which to explain development.

First we define what makes one behavior or set of behaviors more hierarchically complex relative to another. Using the first definition, we then define the overall rather than relative order of hierarchical complexity; this overall order goes from 0, 1, 2,..., on. Third, we present the quantitative form of the order of hierarchical complexity.

Actions are said to be at a higher order of hierarchical complexity then another set of actions when they:
(a.) are defined in terms of the other actions,
(b) organize and transform the other actions;
(c) produce organizations of the other actions that are new and not arbitrary, and cannot be accomplished by those other actions alone.

For example, if an action organizes two or more actions from an order before it, that organizing action is by definition one order higher and therefore more hierarchically complex.

The *Order of Hierarchical Complexity* refers to the number of recursions that the organizing actions must perform on a set of primary elemental operants. Mathematically, there are at least two possible ways ($n = 2^1$) of organizing of the lower order actions. In the simplest case, action a comes before action b or action b comes before action a. Each additional more hierarchically-complex action adds another order ($n = 2^1$) to the previous order action. Using combinatorial algebra, if the previous order action was of hierarchical complexity $n = 2^m$ then the next higher order actions is of order $n = 2^{m+1}$. The overall number of orders, n, then equals 2^n alternatives. The amount of this type of information required by a task is the *hierarchical (vertical)* complexity.

The orders of complexity obtained through these task analyses are not arbitrary; rather, they are grounded in the hierarchical complexity criteria of mathematical models (Coombs, Dawes, & Tversky, 1970) and information science (Commons & Richards, 1984a, 1984b; Commons & Rodriguez, 1990, 1993; Lindsay & Norman, 1977).

An Example of Different Orders of Hierarchical Complexity: In order to illustrate what a difference in the order of hierarchical complexity would look like, we will describe two specific tasks at different orders of hierarchical complexity. These tasks represent two different orders because the second one takes the actions of the first one and organizes them in such a way that it is not reducible to the first one.

In the second grade, a child may add together two numbers. Some second graders may also multiply two numbers. We label such actions simple arithmetic operations (see line 8 of Table 2 for an example). A somewhat older child may combine addition and multiplication by carrying out a distribution action:

$5 \times (1 + 3) = (5 \times 1) + (5 \times 3) = 5 + 15 = 20.$

This hierarchically more complex action coordinates the less complex actions of adding and multiplying by uniquely organizing their sequence. The distributive action is therefore one order more complex than the acts of adding and multiplying alone. This action is required in both long multiplication and long division. Table 2 in its entirety shows the analytic sequence of the development of distributivity. For this sequence there are 12 orders of hierarchical complexity; in some sequences an additional two, even more complex, orders are added on at the end. Each order of hierarchical complexity is labeled in terms of a number (1-12 in this case) and an order name.

The lowest orders are characteristic of infancy (or of nonhuman species). The highest orders describe the complexity of tasks that can generally only be solved well into adulthood; this differs from the theory, for example, of Jean Piaget who postulated that the highest order of reasoning was reached in adolescence. In some respects, the orders here resemble the levels proposed by Fischer (1980; Fischer, Hand & Russell, 1984), as well as others (e.g., Case, 1985; Pascual-Leone, 1986). The major difference is that their sequences are primarily empirically based and only secondarily rely on task analyses whereas the current sequence can be derived solely through analyzing tasks.

The notion of hierarchical complexity is to replace current accounts of development that rely on mentalistic notions (e.g., cognitive stages or schemas). The suggested task analyses can be carried out for any content area for which task analyses can be constructed. Thus far, we and various colleagues have carried them out in the areas of: political development (Sonnert & Commons, 1994), workplace culture (Commons, Krause, Fayer, & Meaney, 1993), workplace organization (Bowman, 1996), relationships between more and less powerful persons such as doctors and patients; (Commons & Rodriguez, 1990, 1993; Rodriguez, 1989), decisions by therapists to report a patient's prior crimes (Commons, Lee, Gutheil, Goldman, Rubin, & Appelbaum, 1995), Kohlberg's moral interviews (Dawson, 1996), views of the "good life" (Danaher, 1993; Dawson, 1997; Lam, 1994), Commons's (1991), attachment sequence, extensions and adaptations of traditional Inhelder and Piaget balance beam and pendulum tasks (Commons, Goodheart, & Bresette, 1995; Inhelder & Piaget, 1958), and Loevinger's Sentence Completion task (Cook-Greuter, 1990).

Measuring Hierarchical Complexity In our quantitative behavioral analysis of development, one would like to empirically verify three things. First, the General Model of Hierarchical Complexity (GMHC) predicts that the empirically-scaled task order should match the analytically-predicted sequence. Second, the GMHC suggests that scaled values of the difficulty of the tasks of the same type and content should be some simple unidimensional transformation of linear. Third, the GMHC predicts that the ordinal nature of hierarchical complexity should produce gaps in task difficulty. The most powerful quantitative analytic techniques that we have found for testing these predications are Rasch Analysis (1980) and the related Saltus analysis (Draney, 1996; Mislevy & Wilson, 1996; Wilson, 1989).

Rasch Analysis Once a hierarchical order of tasks has been analytically determined, each participant is asked to solve all the tasks including the "easiest" and the "hardest." Participant responses are classified as either "right" (that is, fulfilling that task's contingencies) or "wrong" (failing to fulfill that task's contingencies). A Rasch (1980) analysis determines the probability of each participant performing a given task in terms of **task item difficulty** (delta or d) and **participant proclivity to respond correctly** (beta or b). See Appendix 1 for the specific model.

A Rasch and a Saltus Analysis of Two Different Tasks We tested the three predictions by constructing two task sequences (Inhelder & Piaget, 1958) adapted by Commons (in press; Commons, Goodheart & Bresette, 1995). One is the balance beam task and the other is the laundry task (based on an isolation of variables problem called the pendulum problem). Here, both were pen and pencil instruments, consisting of a series of multiple choice problems of increasing hierarchical complexity. The tasks form a series because every higher order task has the lower order task embedded within it (see Siegler, 1986 for a review of various pre-formal and formal-balance beam tasks). Both tasks contained, at a minimum, items at the concrete, abstract, formal and systematic orders (or, as seen in Table 2, order #'s 8, 9, 10, and 11). Both adults and 5th and 6th grade children were participants.

For both the balance beam and the laundry problems, Quest software (Adams & Khoo, 1993) generated a separate Rasch model. The results support our prediction from GMHC that the Balance Beam Task Series and the Laundry Task Series each measure a single dimension of performance with tasks that were posited to be less complex being easier for subjects (see Commons, in press, for more details). The tight linear relationship between difficulty and hierarchical complexity as predicted by GMHC (predictions 1 and 2 above) is shown in Figure 1. Scaled item difficulty (called Threshold) is plotted in log coordinates on the y axis and Order of Hierarchical Complexity is plotted on the x-axis. Hierarchical complexity is also a log scale because order n is taken from the coordination of 2^n actions. Hence one would expect a straight line, which is pretty much what is obtained. In other words, as the order of hierarchical complexity increases, so does the difficulty of the item. The regression equation for difficulty (threshold) versus hierarchical complexity for the balance beam data is $r(16) = .92439$, $F(1,16) = 93.96473$, $r^2 = .85450$, $p < .0000$. Findings from the analysis of the laundry data are very similar (figure not shown here). The regression equation for laundry difficulty (threshold) verus order of hierarchical complexity is $r(22) = .918$, $F(1,22) = 118.417$, $r^2 = .843$, $p < .0000$.

A related Saltus analysis successfully tested for gaps in item difficulty that should be produced by the ordinal nature of hierarchical complexity, a third prediction of the General Model of Hierarchical Complexity. In addition to the tasks being properly ordered, the analysis showed that individuals who perform at lower orders of complexity never or rarely perform at higher orders of complexity, although the opposite is not true (Dawson, Goodheart, Draney, Wilson & Commons, in press). This provides further confirmation for the hierarchical ordering of tasks.

Horizontal Complexity

Whereas Dimension 1 (Hierarchical Complexity) is postulated to be the most important dimension, as far as explaining performance, and many of the other dimensions are to some extent dependent on it, other dimensions are important as well. Horizontal complexity is the classical kind often found in information- processing theory. If one has a yes-no question, the answer contains 1 bit of information by definition. There are two alternatives, so the number of bits, n equals 2^n alternatives. Each additional yes-no question adds another bit. The amount of this type of information required by a problem is the *horizontal* complexity. All computer programs can be reduced to a flat organization that can be represented by such yes-no questions (Campbell & Bickhard, 1986). How many bits a person can handle (somewhere between 5 and 9) seems to define the size of what is called short term memory. If the choices can be organized into larger classes (chunking) the amount of information that can be handled can increase.

A good deal of variability in performance on tasks is due to variations in horizontal complexity. For example, one task may be $1 + 3 = ?$. A more horizontally complex task might be $5 + 1 + 3 + 2 + 7 + 18 + 56 = ?$. However, differences in horizontal complexity are not responsible for changes in hierarchical complexity. The two types of complexity are incommensurate and independent.

Level of Support

Dimension 3, or level of support, represents the degree of independence of the performing person's behavior from control by stimuli provided by others in the situation. There are 5 levels, and each level changes the relative difficulty of a task.. These levels are derived from Arlin (1975, 1984), Fischer, Hand and Russell (1984), Gewirtz (1969), and Vygotsky (1981a; 1981b). Table 3 lists the name, type of support at each level, and how each level of support changes the measured complexity relative to unaided problem solving.

Then the action with respect to the subject is stated and some further description is provided.

These differing levels of support generate a partial model of how individuals' performances change as they begin to move from solving problems at a lower order of hierarchical complexity to solving problems at a higher order of hierarchical complexity. Specifically, when an individual is beginning to acquire behaviors that are appropriate for solving a problem at a higher order of hierarchical complexity, they may first require one or more levels of support. For example, it may be useful to see a worked example (1 level of support) for doing distribution as above before tackling $6 \times (2 + 4) = ?$ the answer being,

$(6 \times 2) + (6 \times 4) = 12 + 24 = 36$.

Likewise, on a test, a problem may appear without support, examples or extra demands, $7 \times (3 + 5) = ?$

Last, for an extra credit project one might present $a \times (b + c) = ?$ This is one less level of support because they have to generalize numbers to variables as in algebra..

Adjacent orders of hierarchical complexity cannot be split further, although if the actions organized were from two rather than one order lower, there would be intermediate organizing actions. What does occur is steps in transition between adjacent orders.

Transition From one Order of Hierarchical Complexity to the Next

Describing the behaviors that occur during transition from one order of hierarchical complexity to the next (which can be called complexity transition) is important for behavioral developmentalists (Fischer, 1980; Fischer, Hand, & Russell, 1984; Fischer et al., 1990; Piaget, as cited in Flavell, 1963; Riegel, 1973). Recently, Basseches and colleagues (Basseches, 1984 ; Benack & Basseches, 1989) have applied dialectical notions to complexity transition. We elaborate and systematize these dialectical strategies using Piaget's "four-step probabilistic transition model" (Flavell, 1971), choice theory, and signal detection (Richards & Commons, 1990; Sonnert & Commons, 1994) .

The transition steps in Tables 4A and 4B are not orders of hierarchical complexity in the sense of the General Hierarchical Complexity Model. That is, they are not analytical constructs having the necessary properties of orders and hierarchical complexity. Instead, the steps belong to the realm of empirical science. They describe the many possible steps of acquiring behaviors that will solve problems of a higher order of complexity in an empirically testable manner. When individuals are in transition from one order of hierarchical complexity to another, they spend some of their time in what we call **deconstruction** and some in **construction**. During deconstruction, when change is beginning to occur, behavior from the last order of complexity is not being reinforced at what the participants detect as the highest rate or highest probability. Hence, that behavior is decreasing and alternative behaviors are increasing in relative frequency or probability. In adulthood, steps in deconstruction may be stable. During construction, newly constructed organizations of behavior are increasingly reinforced, leading to relatively rapid movement through the substeps. On a single task deconstruction always precedes construction but substeps may be missed.

Why Development Takes Place the Way it Does

While operant developmental theories have been largely silent on the issue of why development takes place in the order that it does, they have much more effectively discussed why behavior change takes place at all. Major difficulties with such accounts are that (a) often only local and immediate contingencies are discussed; (b) there is no account why contingencies may effectively contact behavior only after prerequisite (and not just precursor) behaviors have been acquired–any particular behavior has been viewed as being "shapeable" given the proper contingencies; (c) there is no account for the unvarying sequence of those prerequisites. In our view, this gives too limited a picture.

In our approach, notions of transition are generalized to capture and integrate not only why change in behavior takes place within individuals but also to discuss the organizational, cultural and evolutionary bases for change. This has been called *Selectionism* (Donahoe, Burgos & Palmer, 1993). Within behavior analysis, selectionism was discussed early on by Skinner (1938) and Herrnstein (1970). Both proposed that reinforcement was a selectionist mechanism. The generalization here is to organizational and cultural change as well as evolutionary change. More recently Ribes-Inesta (1996), Baum (1994, 1995), and Commons (1991) among others have all suggested that selectionism is an important determinant of change.

Selectionism

Selectionism addresses the process of transition or change. We argue that while evolution is not necessarily progressive, in the evolution of Homo Sapiens there have been increases in the orders of complexity at the individual, organizational, cultural, and biological level. Traditionally, changes in biological, cultural, organizational, and individual behavior have been studied separately, with very little overlap. The current theory integrates selectionism across realms, while noting that in each realm, selectionism operates through somewhat different mechanisms. Similar notions of biological embeddedness have been discussed by Novak (1996).

In all cases, it is behavior that is differentially selected. There is no necessity that certain things in the environment be a certain way. What gets selected depends on local chance conditions or context (e.g. Morris, 1988 for a review) rather than on some grand design. Biological, cultural, organizational, and individual development are all contextual, chaotic, and historical processes (Gell-Mann, 1994). The selective characteristics of the environment at any one time are in and of themselves underdetermined.

Selectionism at the biological level. All other notions of selectionism are ultimately based on the biological notion. The results of biological evolution are represented in individuals by their genotype, which is encoded in the DNA (Ridley, 1996). The genotype represents all the biological evolutionary material that will be passed on through successive generations. For this material to be passed on, an individual must survive and must reproduce. While existing traits are assumed to have facilitated propagation, there is a time lag between reduced functionality and disappearance of a gene. There are also traits which on the surface do not seem to be of survival value. The gene for sickle cell anemia protects against malaria, for example, as long as one inherits one but not two of the genes for this trait and thus does not develop the illness itself.

Selectionism at the cultural level. The results of cultural evolution are represented in individuals by their behavior in situations. Dawkins (1981) calls these behavior patterns *memes*. Like biology, culture partially determines who reproduces and whose offspring survive to reproduce. At any one time, both biological and cultural evolution are represented in the individual. Evolutionary processes may be indifferent as to whether the information is passed on through biological or cultural mechanisms (Trivers, 1985). The two types of information may interact with each other. Biological information in the form of DNA that determines genes may confer advantages within a particular cultural environment. From an evolutionary perspective, engaging in behaviors that best meet situational demands increases the likelihood that information contained in both the genes and memes will be passed on (Petrovich & Gewirtz, 1985) .

We assume that both biological and cultural evolutionary processes operate on behaviors and on the organism's susceptibility to the potentially eliciting and reinforcing properties of events, in similar ways that they do upon such biological characteristics as height, strength, and agility (Baum, 1995; Boyd & Richerson, 1985; Skinner, 1981). Biological evolution requires isolation whereas cultural evolution may benefit from a combination of isolation for a period and then contact (LeVine, 1973). However it is not likely to be the behaviors themselves that are genetically programmed, as much of human behavior may be too complex to be genetically coded. It is more likely that the elicitors of behavior and the reinforcers for behavior are what is genetically coded. Evidence that reinforcers can be genetically programmed in humans is the fact that at birth humans have a positive preference for some tastes, so that these tastes are positively reinforcing, and a negative preference for other tastes, so that the removal of these tastes are negatively reinforcing (Lipsitt, 1977). However behavior is selected for, we assume that if a behavior exists today, then it has facilitated reproduction or genetic propagation (Baum, 1994; Buss, 1995; Lumsden & Wilson, 1985). Behaviors that do not facilitate reproduction will become extinct (Skinner, 1981).

How more hierarchically complex behaviors might develop and spread within a culture: While more hierarchically complex behaviors may often be more adaptive (offer an advantage to an organism in terms of reproductive success), they come at the cost of a larger brain that requires more calories. Over time there is a tendency for more complex behaviors to develop in some groups of species and across some species. This tendency is not inevitable.

In the transition from apes to humans, more hierarchically complex behavior may have developed when a member of a community, through minor trial and error variations in behavior, developed a new, more complex behavior (or a meme). This either may have happened randomly or only in a certain individuals who may have been more likely to discriminate contingencies for more hierarchically complex behaviors. Such a tendency could arise because of an interaction between mutated genes and unusual circumstances and the contingencies within them.

These potential memes can only become actual memes if they spread to a large enough group of individuals in the culture. This process has been called *infection by memes* (Commons, Krause et al., 1993; Trivers, 1985). In order for an individual to become infected by the new meme, a particular (new) set of contingencies must first be discriminated. Then, in actually executing a behavior that is controlled by that set of contingencies, the individual is further infected. Thus, there are degrees of infection by memes.

Uninitiated individuals may require some degree of support (as in Table 3) in order to discriminate the set of contingencies associated with the new meme. With such increased support many individuals should "downward assimilate" discoveries. This means that, with varying levels of support, such individuals may acquire complex operants. Support makes it possible for them to perform the behaviors discovered by another individual even though they themselves may not have initially discriminated the relevant contingencies. For apes and young children, for example, imitation is one level of support that is effective during acquisition. The more unlikely the unaided behavior is, the greater the amount of support that may be useful in raising the probability that the behavior will occur appropriately.

Support may also be necessary for individuals to discriminate contingencies that are far more hierarchically complex (Chernoff & Miller, 1997). For humans, such support can include all the forms of educating and training that humans engage in, including informal and formal education (Cavalli-Sforza, Feldman, Chen, Kuang-Ho & Dornbusch, 1982). Commons and Richards (1995) have discussed this process of the spreading of memes in more detail.

The Sparseness of Profound Cultural Innovations: Profound cultural innovation is hierarchically complex behavior of order 13 (cross-paradigmatic). Examples include major scientific theories, such as the theories of evolution, general relativity, quark and strings. The extreme sparseness of such profound cultural innovation has been a major problem for the Behavior Analytic study of cultural change. Without a notion of hierarchical complexity, one might be hard pressed to see why profound innovation is so rare. One factor that contributes to their rarity is that they require such high orders of hierarchically complex behavior by single individuals (Commons & Richards, 1995), with little or no support. There is no direct history of reinforcement that would induce the subject to detect new phenomena. Even if the subject matter requires the 11th order of action, finding and identifying the underlying phenomenon requires an additional 2 orders.

Selectionism and Organizations

Organizations refer to groups that may be as small as families or as large as some countries. The reason organizations are discussed is because most modern cultures are made up of many organizations all of which have an effect on the behavior of individuals. In this behavioral developmental analysis of organizational behavior, we identify how contingencies at one level set contingencies at another. We also identify the reinforcement mechanisms (Skinner, 1938) through which these contingencies are enforced. We have used the term *institutional atmosphere* to refer to the dynamic relations between institutional behavior at various levels (Commons, Krause et al., 1993). Specifically, atmosphere includes: (a) the *ordered levels of contingencies* that affect individual behavior within an organization (the rules) and (b) the methods by which contingencies are set. The ordered levels of contingencies include: (i) contingencies that formed the organization (legal, political and economic systems); (ii) rules or by-laws governing policy setting; (iii) policy contingencies (laws), such as role definition and role rules, including how to make regulations; (iv) regulation contingencies (regulations), such as how various broad situations will be addressed procedurally and what behavior contingencies will be made; (v) target behavior contingencies, such as what behavior is reinforced and what is punished; and (vi) behavior.

Atmosphere's Contingencies and Effects on Behavior and Development : We suggest that the hierarchical complexity of the contingencies that constitute a particular workplace atmosphere affects the patterns of individual choice-making within that organization. The general order of complexity of the contingencies available to members of an organization will either allow for or not allow for more hierarchically complex behavior. If primarily lower-order decision making prevails, individuals' higher order decision-making will not be reinforced. Individuals decisions within such an institution will then most likely reflect the lower order contingencies available. For example, organizational decision making that excludes the perspectives of constituent groups may ultimately produce constituent decision makers who exclude the perspective (and interests) of the larger organization (see Meaney, 1990; Galaz-Fontes, Pacheco-Sanchez, & Commons, 1990). Other studies (Higgins & Gordon, 1985; Johnstone et al., 1991) have found similar effects of lower-order institutional atmospheres. As the order of complexity increases however, individuals increasingly evaluate and integrate competing perspectives and take the perspectives of others into account (Commons & Rodriguez, 1990; Rodriguez, 1989). The better one's perspective-taking skills, the better one's decision-making and managing skills (Weathersby, 1993).

An Example of Cultural and Organizational Effects: Biological, cultural, or organizational contingencies co-determine one another to produce effects at the individual level. Ultimately cultural and organizational contingencies work by affecting individual behavior. Two findings from a study in a Mexican border city illustrate this point (Galaz, Commons, Morse et al., 1994). First, unschooled, non-literate adult leaders solved more hierarchically complex problems than those who were not leaders. Second, students who either were identified as leaders, or had more cross-border experience, performed at higher orders of complexity. To be an effective leader one must take into account the perspectives of others and one must be empirical in obtaining results (as opposed to just doing what has traditionally been done). Individuals who have increased cross-border (and cross-cultural) experience learn that the social contingencies (norms) will differ from one culture to the next. In both cases, the use of more hierarchically complex perspectives is reinforced.

Selectionism and Individual Development

Selectionism at the individual level operates through the principles and laws of learning. These address reflexes and tropisms, fixed action patterns, sensitization, habituation, respondent conditioning, and operant conditioning. Operant conditioning principles useful in addressing complex human behavior include melioration, matching, maximizing (Herrnstein, 1997), and behavioral momentum (Nevin, 1988, 1992, 1993). We suggest at what orders of hierarchical complexity various contingencies may be effective.

Acquisition and Operant Conditioning: In an operant conditioning situation, behaviors occurring in certain stimulus situations come under the control of consequences in the environment. The main method of selection, therefore, is through these consequences. Contingencies may contact with behavior to varying degree. This contact may depend on the: (a) salience of events in the contingencies (Rescorla & Wagner, 1972); (b) time; (c) the responses and stimuli that might come to control the behavior (Fantino, 1981; Fantino, Abarca & Dunn (1987); (d) the amount of other reinforcement in the present and historical environment, and (e) the hierarchical complexity of the contingency, or in traditional terms, whether the contingency is discriminable.

Hierarchical Complexity and conditioning: The order of hierarchical complexity of a contingency determines its effect on the organism's behavior. First, if a contingency is too complex, it may have no effect at all. Second, there may be some very non-specific effect (e.g. heightening arousal). Third, if organisms only discriminate temporally local gains and losses in reinforcement, organisms generally match how much of the time they allocate responses to how much of the time they obtain reinforcers for what they are doing. Fourth, when organisms rapidly discriminate task contingencies of a given order of hierarchical complexity and it is possible to maximize the total amount of reinforcement, they tend to do so (Herrnstein, 1997). This may occur even more often if the rules in the contingencies are directly discriminated.

Reinforcement and increases in the complexity of performance: Reinforcement is necessary for changes in the hierarchical complexity of performance from order 1 (Table 2) on up. Commons, Grotzer & Davidson (in preparation) demonstrated this in a study of a large number of 5th and 6th students from mixed socioeconomic backgrounds. At the beginning of the study, most of the students reasoned at the concrete order (order 8) of complexity. All students were asked to solve a series of adult problems (order 10, formal) requiring them to detect causes. Problems were presented 16 times, over the course of one semester. Group 1 received no feedback about their performance. Group 2 received feedback alone, and Group 3 received both feedback and points toward a possible prize for correct answers. Each member of a Group 3 team that scored the most points received a prize (chosen by the children) at the end of the entire problem sequence. Only students in the reinforcement group (Group 3) group improved their proficiency in detecting causal relations from the pretest to the posttest–75% performing at the 10th order. This illustrates that even relatively complex behaviors can be acquired if reinforcement is available.

The relationship between operant and respondent conditioning: The current theory views development as a joint product of task characteristics (such as hierarchical complexity) and of selectionism at all the levels. Because the vast majority of the learning that takes place is due to operant contingencies, it is important to communicate our view of the underlying mechanism of operant conditioning (Commons & Hallinan, 1989; Commons, as cited in Pear & Eldridge, 1984).

We posit that operant conditioning begins when an initial, internal but potentially observable response produces an internal stimulus (us) that then elicits the operant behavior (R). For this stimulus, us, to be conditionable to the previous environmental stimulus or stimuli (potential S^D), it must be salient. That is, the organism must detect it. What makes the little us salient and detectable is that it is paired with the operant reinforcer. After the little us has become salient, it can be successfully paired with an environmental stimulus. That environmental stimulus will become the discriminative stimulus.

This view of operant conditioning allows us to more easily explain three phenomena because it suggests why: (a) humans increasingly see the internally mediated causes (rules) for their own behavior; (b) the freewill illusion persists throughout development, even for a behaviorist; (c) punishment strengthens alternative behavior. Each of these will be discussed in turn below.

In people, the response that produces the little us may be implicit or explicit verbalizations. There are three conditions when these rules may be implicit: during early acquisition--the sequence of behaviors they organize has not been verbalized; after overlearning; or when memetic performances are being imitated. As the required behaviors become more hierarchically complex, the rules still may be implicit as in the "presolution" period of problem solving. If the responses are explicit verbalizations, they may first be words and later rules (Gewirtz & Pelaez, 1991). As complexity of the effective contingencies increases, implicit rules, verbal behavior and rule-governed behavior become increasingly powerful in controlling behavior. Contingencies reinforce the greater hierarchical complexity of those rules.

If the us is salient enough, people may report they are "conscious of it." The fact that it precedes behavior leads to the illusion of free will. When discriminations are very difficult or not made, humans do not report a sense of free will. What we sense as consciousness is dramatically effected by increases in the discriminability of hierarchical complexity. As intraverbal rule-governed behavior increases in complexity, we increasingly report our "conscious thought" as directing out behavior.

We assert that operant learning, including punishment, works in all cases by strengthening behavior. This is true because the consequence that follows the response can only strengthen the us-response relationship. This makes it impossible for punishment to have its own mechanism. We would argue that punishment works by negatively reinforcing alternative behavior. This leads to a different understanding of the role of trauma in development. Traumatic events may reinforce various kinds of behaviors, including thinking about things unrelated to the traumatic event rather than facing them, viewing oneself in disembodied form (dissociation), breaking off relationships, thinking about how hapless, incompetent and bad one is, how hopeless life is.

The Nature of Reinforcement: The general operant literature refers to just a few reinforcers, from food stuff to sex. Most other reinforcers are thought to be acquired through the conditioning of secondary reinforcement. Perhaps as a result, reinforcers have become reified. There is a tendency to see just a few, very concrete reinforcers: pellets, M & M's, tokens, praise. There are two problems with this view of reinforcement. It ignores (a) developmental changes and (b) evolutionary changes in what is reinforcing. We briefly argue that what can serve as a reinforcer changes dramatically as order of complexity of reasoning changes (that is, from childhood to adulthood and from nonhuman species to humans).

One example comes from the study of attachment. Attachment refers to the nonsubstitutability of reinforcers from different sources. During infancy, both nonhuman and human species show strong evidence for preference for certain figures (usually mothers) over others. There may be calling or other vocal behavior, following behavior, and other kinds of proximity seeking behavior. In addition, cues and reinforcers delivered by those figures are more powerful (Commons, 1991). There are changes with age and order of complexity in attachment entities. Listed in order of increasing complexity, the attachment entities could be caretakers, things, places, pets, peers, groups, organizations, the culture at large, and the universal community. Clearly, because events emanating from attachment objects are reinforcing, this generates a large potential pool of reinforcers just from this one related source (attachment).

Conclusion

Behavioral approaches to development that go beyond Bijou and Baer (1961) are developing rather quickly. Some behavioral accounts have addressed development though adulthood for a broad range of people. We have based our account of development on five quantitative "laws" and referred to a number others. Before 1970, none of these laws had been formulated. Almost 30 years later, very few have been incorporated into behavioral accounts of development. The theory presented here has been expanded and deepened to account for much traditional developmental data while remaining entirely behavioral.

Appendix:

The Rasch analysis then fits the data to the following logistic model:

$$Pr\,(X_{ni} = 0,1/b_n,d_i) = \frac{\exp\,(X_{ni}\,(b_n - d_i))}{1 + \exp\,(b_n - d_i)}$$

That is, e is raised to the index function. That total quantity is divided by 1 + e to the difference between the values of b and d in the index function. The index function $X_{ni} = 0, 1$; X_{ni} is either 0 or 1 for a given value of b_n or d_i. X is the response (right or wrong) given by the subject to a task or item. The value d is the task or item difficulty. The value b is the subject proclivity.

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Table 1
Stimulus, response and performance dimensions of tasks.

Name of dimension	Type of dimension	Definition
Hierarchical complexity	Stimulus	The number of times task-related actions act upon the output of lower-complexity actions in a chain of actions
Horizontal complexity	Stimulus	Number of stimuli and corresponding actions
Level of support	Stimulus	Transfer of stimulus control (level of support).
Reflectivity	Response	Degree of reflectivity of actions (from no reflectivity to epistemic cognitions).
Form of control over the operant responses	Response	Implicit or explicit control.
Sensitivity to relationships in a task of given hierarchical complexity	Performance	
Tendency to assert relationship occurs	Performance	

Table 2. A sequence of behaviors placed into different orders of hierarchical complexity.

Order of Hierarchical Complexity	Name	Example
0	Calculatory	Simple Machine Arithmetic on 0's and 1's
1	Sensory & Motor	Seeing circles, squares, etc. or touching them.
2	Circular Sensory-motor	Reaching and grasping a circle or square. * * * * * O O O O O ■ ■ ■ ■ ■ ■ / ○▣ □
3	Sensory-motor	A class of filled in squares may be made
4	Nominal	That class may be named, “Squares”
5	Sentential	The numbers, 1, 2, 3, 4, 5 may be said in order
6	Pre-operational	The objects in row 5 may be counted. The last count called 5, five, cinco, etc
7	Primary	There are behaviors that act on such classes that we call simple arithmetic operations $1 + 3 = 4$ $5 + 15 = 20$ $5(4) = 20$ $5(3) = 15$ $5(1) = 5$
8	Concrete	There are behaviors that order the simple arithmetic behaviors when multiplying a sum by a number. Such distributive behaviors **require** the simple arithmetic behavior as a prerequisite, not just a precursor $5(1 + 3) = 5(1) + 5(3) = 5 + 15 = 20$
9	Abstract	All the forms of five in the five rows in the example are equivalent in value, $x = 5$. Forming class based on abstract feature
10	Formal	The general left hand distributive relation is $x * (y + z) = (x * y) + (x * z)$
11	Systematic	The right hand distribution law is not true for numbers but is true for proportions and sets. $x + (y * z) = (x * y) + (x * z)$ $x \sqcup (y \sqcap z) = (x \sqcap y) \sqcup (x \sqcap z)$
12	Meta-systematic	The system of propositional logic and elementary set theory are isomorphic x & (y or z) = (x & y) or (x & z) Logic $\Leftrightarrow$ $x \sqcap (y \sqcup z) = (x \sqcap y) \sqcup (x \sqcap z)$ Sets T(False) $\Leftrightarrow \varphi$ Empty set T(True) $\Leftrightarrow \Omega$ Universal set

Table 3
Levels of Support

Support number and Name	Change in measured complexity	Form of support	Action	Description
0. Manipulation	-3	Being moved though each step.	Literally being moved through each step of how to solve a problem.	Part of the stimulus is the push that guides the movement.
1 Transfer of stimulus control	-2	Being told each step (direct instruction).	Do a task based on a set of verbal instructions or other direct stimuli telling one what to do.	Train a discrimination with one set of stimuli on one task. Use the same set of stimuli to control performance in another task. Slowly remove first set of stimuli. This is like an errorless learning procedure (Moore & Goldiamond, 1964; Terrace, 1963).
2. Pervasive imitation	-1	Being shown.	Includes delayed imitation or observational learning (Gewirtz, 1969). The imitated action may be written, depicted or otherwise reproduced.	Fischer and Lazerson (1984) call this form of control the optimal level.
3. Direct	0	No help or support is given.	Problem-solving or hacking (without support).	Fischer and Lazerson (1984) call this the functional level. Most of Piaget's work was done at this level.
4. Problem finding	+1	In addition, to not getting help, one must discover a task to answer a known question.	Persons are given an issue and they are asked to give a example of a problem that reflects that issue.	Arlin (1975, 1977, 1984) introduced postformal complexity (systematic order) by requiring the construction of a formal-operational problem without aid or definition.
5. Question finding	+2	In addition, to not getting help and having to discover, one must discover the question	With a known phenomenon, people find a problem and an instance in which to solve that problem.	One has to discriminate the phenomenon clearly enough to create and solve a problem based on that discrimination.

6. Phenomenon finding	+3	No direct stimulus control is possible without a description of phenomenon.	Discovering a new phenomenon.	No reinforcement history with phenomenon.

Table 4A
Deconstruction in the Transition Steps

Step	Sub-step	Relation	Name	Dialectical Form
0(4)		a = a' with b'	Temporary equilibrium point (thesis)	Previous complexity synthesis does not solve all tasks. (Deconstruction Begins) Extinction Process
1		b	Negation or complementation (antithesis)	Negation or complementation, Inversion, or alternate thesis. Subject forms a second synthesis of previous complexity actions). (antithesis)
2		a or b	Relativism (alternation of thesis and antithesis)	Relativism. Alternates among thesis and antithesis. The schemes coexist, but there no coordination of them). (alternation of thesis and antithesis)

Table 4B
Construction in the Transition Steps

3		a and b	Smash (attempts at synthesis)	The following substeps transitions in synthesis.
	1		Hits and Excess False Alarms and Misses	Elements from a and b are included in a non-systematic, non-coordinated manner. Incorporates various subsets of all the possible elements.
	2		Hit and Excess False Alarms.	Incorporates subsets producing hits at complexity n. Basis for exclusion not sharp. Overgeneralization
	3		Correct Rejections and Excess Misses	Incorporates subsets that produce correct rejections at complexity n. Produces misses. Basis for inclusion not sharp. Undergeneralization
4(0)	4	a with b	New temporary equilibrium (synthesis and new thesis)	New temporary equilibrium (synthesis and new thesis)

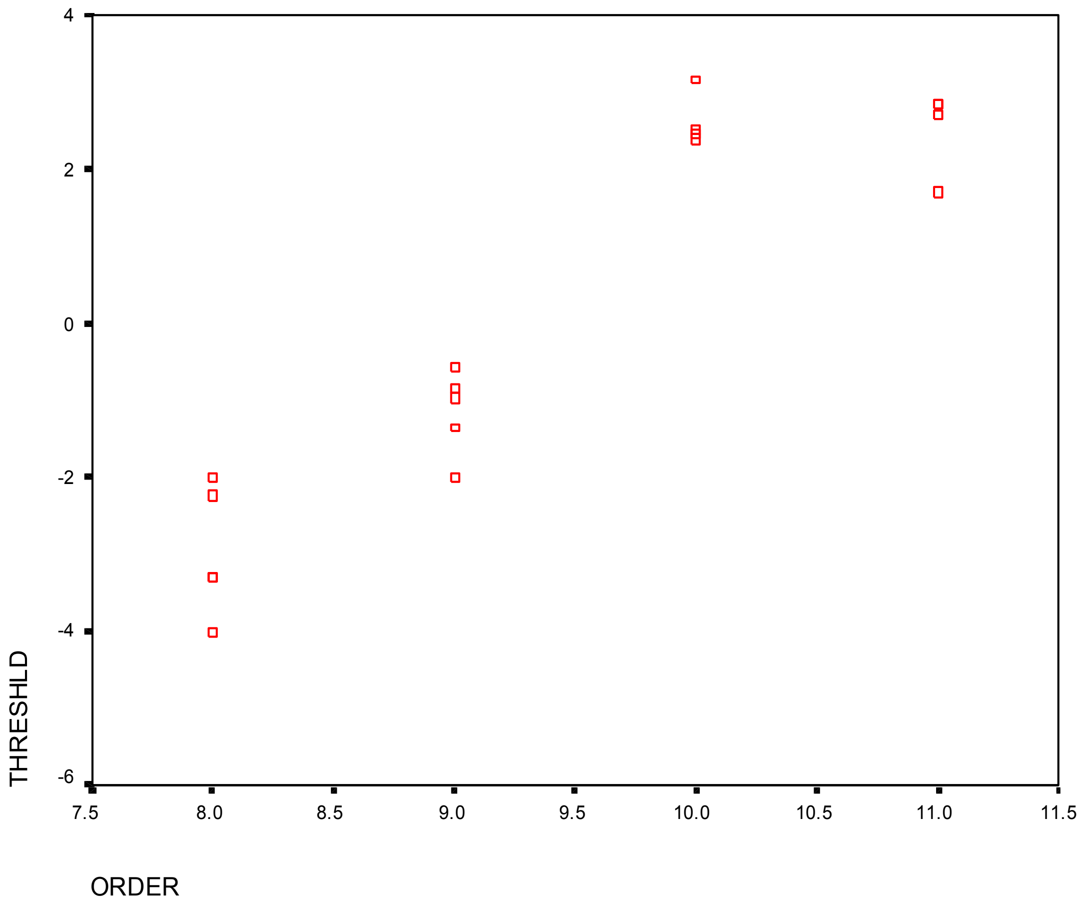

Figure 1 Threshold versus Orders of Hierarchical Complexity of Balance-Beam Tasks

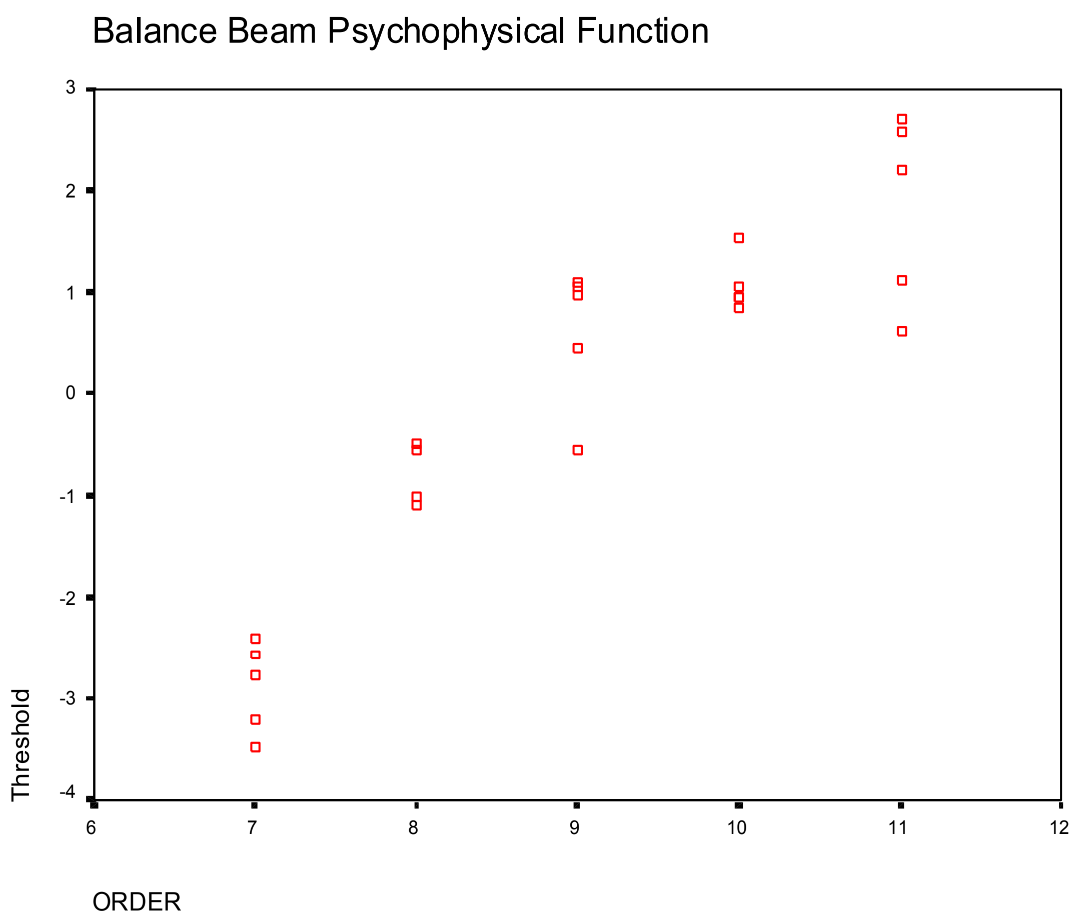

Figure 2 Threshold versus Orders of Hierarchical Complexity of Laundry Tasks