# Acquisition of New-Stage Behavior

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*Acquisition of new stage behavior (stage transition) was an important aspect of Piaget's (1954) theory. If there are steps during acquisition, why might there be and what might they be? Is change gradual or quantal? Although these questions raise important issues about the nature of development, little research has been undertaken, at least among American psychologists. The reason for this seems to be the controversy surrounding Piaget's notions of stage and stage change. Here Hierarchical Complexity's Treatment of Stage Transition is presented which addresses all the above. Examples of ways of inducing stage change are reviewed.*

To overcome the huge gap between lower-stage behavior and higher-stage behavior, Piaget suggested two processes: assimilation of new behaviors and new performances to the present stage; and accommodation of new behaviors to the higher-stage performance. The ***stage of performance*** is the highest-order-of-complexity task performed correctly (Commons & Miller, 2001; Commons & Pekker, submitted; Commons, Trudeau, et. al. 1998). The model of hierarchical complexity (MHC) shows that at each higher order of complexity there is a new, more abstract "layer" of actions added that organizes the previous component actions in a nonarbitrary way. Note that stage of performance on any given task will correspond to the order of hierarchical complexity of the task itself. In both the case of assimilation and of accommodation, we argue that the laws of learning apply. Different forms of instruction produce different combinations of assimilation and accommodation. Assimilation is the acquisition of more skill at the current stage. Accommodation is the acquisition of a skill at the next stage. The general finding (Binder, 2000; Rosales-Ruiz, 2000) is that the more solid the performance at lower stage behaviors, the more easily new-stage behavior may be acquired.

We very briefly describe five general ways of advancing stage change:

(1) The didactic method of teaching about higher-stage behaviors.

(2) The Piagetian notion of immersion, the use of contradictions and use of reflective abstraction (Campbell, 1993). There are a wide range of programs and variation on this theme. (See Brendel, Kolbert, & Foster, 2002; Lovell, 2002; McAuliffe, 2002).

(3) The use of reinforcement for correct answers and outcomes.

(4) The use of support or demand (Arlin,1975; Commons & Richards, 1995; Fischer et al., 1984; Gewirtz, 1969; and Vygotsky 1962; 1966.

(5) The use of direct instruction and charted performance as feedback (Binder & Watkins, 1990).

Didactic teaching has many variants. The most common is show-and-tell. At the high-school level and above, this is referred to as lecture. Preaching goes back to the time of Moses and before. Historically, in many Western colleges and universities, a major purpose of lectures was to train clergy. Thus, lectures seem to have been derived in form from sermons. Information is imparted by speaking to the multitude. Other forms of this technique include the viewing of films, videotapes, DVDs, or the use of other electronic one-way media, such as listening to audio tapes. Sometimes a lecture may be followed by a discussion section, which may include a more detailed lecture with some possibility for students to pose questions and comments.

A second form of didactic teaching related to lectures is the use of reading material. Not surprisingly, it is more effective. It allows a student to self-pace, review and highlight. Also, reading is a much more active process for the student than listening. In the order of activity, show and tell is the least active, followed by listening, and reading, which is the most active of the means so far reviewed. Reading can be easily modified to allow the student to be much more engaged in the material, as exemplified by problem sets and programmed instruction. This includes the use of flash cards in paper or computer form.

In the Piagetian notion of immersion, people work in environments in which materials for learning and development, and problems are present. They may construct and solve problems with the materials. There is interaction among the actions of the person and the outcomes produced by changes in the environment (including the social environment). Such immersion works well for children and adults who already care about contradictions in academic-like settings. Contradiction arises when ones own actions and reasons do not match what is being said in what one is reading. In everyday settings, it arises when one's actions fail to produce the predicted results. In dialectical theories of stage change of which Piaget's theory is one of the first, contradiction leads people to adopt an opposite same stage behavior or a complementary same stage behavior. But when people find out that these behaviors produces contradictions as well, they will, in most cases, alternate back and forth between the positive and alternative same stage behavior. Finally, after they realize that alternating between behaviors still produces contradictions, they attempt to organize the behaviors together in arbitrary ways. The process of reinforcement will eventually select those organizations of behavior that work and do not produce contradictions.

Children who do not find contradiction in academic realms punishing or feel that their actions lack reinforcement (less motivated) do not necessarily change stage of performance very readily under these conditions (Commons & Miller, 1998). As described by Commons and Miller (1998), in one experiment, children earned points by performing the following task correctly. In this task, they had to figure out which of four possible ingredients would clean a stained piece of cloth. They were given six episodes in which the cloth came out clean three of the times, and dirty three of the times. The children's points from the ten test episodes were then pooled for each of their different teams. Each team competed with each other to earn the highest number of points. These competitions for points led 75% of fifth- and sixth-grade students tested (who mostly scored concrete stage) to acquire formal operations on a number of Piagetian tasks. A concrete performance consisted of using combinations of variables or matching a few variables from one or two episodes to predict how the cloth would come out. A formal operational performance consisted of finding which variable consistently predicted whether the cloth would come out clean or dirty using all the episodes. Note that they were given no instruction or support, so this is an example of immersion, but with extrinsic reinforcement. Extrinsic contingent reinforcement may be needed in some settings to ensure that immersion will generally succeed.

Fischer (personal communication) reported that various forms of support lead to acceleration of the acquisition of new-stage behavior. Support might consist of providing examples or prompts for the correct response. This acceleration is probably due to the fact that such supports reduce the required task demands by exactly one order of hierarchical complexity. By definition, support assists performance.

The question is, could support assist performance in increments less than multiples of one stage? The proof that difficulty (but not the order of the task) is reduced by a multiple of one stage is not complicated, and is the following. There cannot be intermediate stage performances between stages because there are no intermediate order tasks nor intermediate behaviors. No matter how hard people look, they have never found any. One of the easiest ways to see why this is so is to try to find a behavior that is in-between solving addition and multiplication problems on the one hand and long multiplication on the other hand. Try to find some intermediate stage action between those two actions and long multiplication. Of course one can do chains of addition and chains of multiplication, which is more difficult than adding or multiplying a single pair of numbers. But those chains are still at the same stage. Solving simple addition problems (e.g. $2 + 3 = ?$) and solving simple multiplication problems (e.g. $2 \times 4 = ?$) are same stage behaviors. Solving problems that require distribution such as long multiplication problems (e.g. $2 \times (3 + 4) = ?$) is a behavior of the next higher stage. When a person combines the behaviors of solving simple addition and simple multiplication problems to solve a long multiplication problem, s/he reaches the higher stage. Yet in a transition from the lower stage to the higher stage, people do perform behaviors that are between the stages because there are no intermediates between solving simple addition and multiplication problems and solving long multiplication problems requiring distribution. Perhaps they would first attempt to solve a long multiplication problem by solving chains of addition, but this behavior is in the same stage as solving simple addition problems.

Some behaviors at the same stage do have intermediates. For example, crawling and walking are at the same stage. This is because they both require a similar stage of the coordination of perception and motor control. So there are intermediate behaviors such as walking while holding on to a supporting object. The stage of performance by definition is the highest order task performed correctly (Commons, et. al. 1998; Commons & Miller 2001) This makes it possible to perform the higher-stage tasks. Repeated performances at the higher stage are reinforced and therefore acquired.

Finally, fields such as Precision Teaching offer training of new stage actions. Two basic notions in Precision Teaching are those of elements (components) and compounds (combinations of elements). Here we apply the acquisition of compounds to address the problem of stage transition. Higher-stage behaviors are the compounds that combine their components--the lower-stage behaviors. But not all compounds are higher stage, only those that organized lower stage actions in a non-arbitrary fashion. Precision teachers train individuals on the elements or components to fluency, and only later train individuals to combine these elements (Graf & Lindsley, 2002). Fluency training on the elemental behaviors consists of repetition until an individual is able to perform at an extremely rapid rate. In this type of training, the rate at which a student completes a task is charted. The teacher then makes decisions about the effectiveness of current instructional interactions based on the charted performances. The teacher compares the obtained rates to performance on the same task by experts or people of equivalent standing. Graphical cusps may be observed during acquisition (Rosales-Ruiz & Baer, 1997).

When the rate of behavior reaches a maximum, most closely matching the rate of an expert, the behavior is deemed to be *fluent*. Even moderate numbers of errors in performance may have long disappeared when rates of behavior increase greatly. If the behavior is over-learned to the extent that very little effort or special attention is required, then the performance is deemed *automatic*. Fluency training on the components seems to increase the speed at which compounds are acquired from components. The implication of this work is that Precision Teaching in behavior analysis helps provide an empirical account of development.

The example of developing the use of the distributive property is expanded to illustrate the effectiveness of fluency training in Precision Teaching. The example shows how one could move rapidly from the primary stage behavior of using simple single operation arithmetic to using distributive properties. A student is trained with flash cards to predict the correct answer to such primary stage problems such as $2 + 3 = ?$ The problems are written on one side of the card. On the other side is the answer 5. For a one minute session, students do as many of these problems as possible with the instruction to go as fast as possible. The number of problems completed is then charted on log-linear paper. Each session, the number of problems completed increases. On log-linear paper, the increase looks like a straight line. Finally the asymptotic performance is reached. In a similar fashion, the students learn from speeded practice simple multiplication problems such as $4 \times 5 = ?$ These two elemental or component actions are then integrated into a distributive problem. The student learns to calculate the answer to $4(2 + 3)$ as $4(2) + 4(3) = 8 + 12 = 20$. The students generally learn distributive problems more quickly because they are fluent in simple addition and multiplication problems.

During the relatively rapid acquisition of the compound, concrete-stage behavior of using distributive methods, one might observe the following steps. At step 1, either addition or multiplication is tried. At step 2, whether addition or multiplication is tried changes with each example. At Step 3, substep 0, both multiplication and addition are tried in a disorganized fashion, for example 4 is multiplied by 3 but not by 2. At substep 1, multiplication of at least the first term is tried and then the results added, for example 4(2) + 3 = 11. There can be variations on this but basically, multiplication is carried out first, addition second but not necessarily on the right terms and variables. At substep 2, the order and variables are correctly chosen but there may be a failure to add or to simplify, for example 4(2) = 8, 4(3) = 12. Finally at step 4, the multiplicand is distributed across the terms connected by the addition sign, +, 4(2) + 4(3) = 8 + 12. Then the resulting products are added, 8 + 12 = 20. Because the multiplication and the addition are almost automatic, the concrete stage distributive ordering may be rapidly acquired.

## Speed and Limits of Stage Transition

If we start with the assumption that the sequential increase in hierarchical complexity of tasks is linear, then there are at least four questions regarding the speed and limits of acquisition. The first question is, why does the speed of acquisition decrease over the life span as the order of complexity of required actions increase? Second, if acquisition were linear, as it might be for machines, what might be an equation for an overall first approximation of that acquisition? Third, are the acquisition curves for animals (including humans) and machines similar? And last, do the acquisition times explain the limits as to the highest stage attained?

Assume that the difficulty is equal for all transitions between task performances on task differing by one order of hierarchical complexity (or as some might say, to increase the stage of performance by one). This is the simplest assumption. If it is wrong, it could be rejected by data showing otherwise. This does not imply that there are not increasing times between acquisitions of next stage behavior, and in fact, there are. The underlying causes of developmental stage transition and its limits is not to be decided here. It could be some combination of neural development and environmental history (e.g. Elman, 1993). There are a number of models that have been proposed (e.g. Hartelman, van der Maas & Molenaar, 1998; Molenaar & van der Maas, 2000; Saskia, Olthof & Boom, 2000; van Geert, 1998). In gross form, it could be related to age and education. Because stage change at any stage may be equally difficult, the variable of stage of development may not be predictive of difficulty.

For the general case, let T = time to attain a given stage of action, $\Delta T$ is the change in time, $\Delta$stage is the change in stage. The *learning cycle time* is the amount of time it takes to acquire a new stage behavior:

Learning cycle time = $\Delta T$/stage

Then the amount of time it takes to train a machine is:

I = k

Time to Train = $\Sigma$ (learning cycle time for stage k)

I = 1

If acquisition were linear then,

Time to train = learning cycle time * number of such cycles to retain.

But we know that in humans as well as in most other animals, learning time increases with stage of the required performance (e.g. Armon, 1984; Armon & Dawson, 1997). This is part of what sets the limit for the highest stage that can be acquired.

Another process that also partially sets the limits of stage transition is that at some point in an organism's life, the rate of loss of skills, knowledge, understanding, judgment, problem solving and the like surpasses the rate of acquisition (Baltes & Graf, 1997). The newest work on adulthood and aging suggests the rate of loss only accelerates precipitously in the last year or so before death of very active and engaged people. Put more simply, time runs out. It is also suggested that the upper limit for a particular individual seems almost completely heritable. Evidence is provided by the lack of variation as adulthood progresses among identical twins reared apart who have been given training. Before training begins the twins may be performing at different levels. However, giving both twins training causes acceleration in the lower level performing twin but not in the other twin, which suggests the existence of a biologically determined learning ceiling. If there was no ceiling, both twins would have improved (Bouchard, 1995; 1997).

This discussion may make it sound as if, under ideal conditions, there is nothing in the stage transition theory we have presented that necessitates an upper limit on stage transition for a population. This may be true even if those who are slower or environmentally challenged learners may progress to their maximum because they have reached their upper limit within their life span. The current formulation includes 15 orders of complexity. This may allow us to determine the upper limit for human beings. There have been an increasing number of informal empirical reports in Precision Teaching, that posit that there is a limit to the number of times a series of elements can be turned into a combination (Binder, personal communication). These reports in the form of training studies have shown that at a given age, there are limits to how much training is effective in bringing about change. This can be seen anecdotally in graduate education. Whereas it is probably true that most graduate instruction does not even come close to optimal instructional methods, we also suspect that no matter how much training people have received, some never move beyond the systematic stage in their problem solving. According to the formulation of limits given here, they have reached their biological limit.

## Solving the Most Highly Hierarchically Complex Problems: A Matter of Biological Limits, Educational Experiences, or Both?

Theorizing in psychology has always had an inherent tension as to the achievable developmental ends of individuals as well as organizations and what is actually found. Whereas some individuals are observed to develop skill at the highest orders of hierarchical complexity, others do not appear to do so (Kegan, 1995). How skillful in a developmental sense someone is can influence how effective they are in a number of situations. Skinner (1948), in Walden II, expressed this tension most fully, going back and forth between the need for a philosopher king in a semi-fascist system, and a system of personal choice based on variable proclivities and preferences of individuals. In the end, the issue has not been resolved. Semi-fascist systems represent the dying gasps of the systematic stage. Unfettered choice such as direct voting on laws would also be systematic stage. Even if there are many possible integrations of systems that are high on leadership and direction on one hand and individual choice on the other, there are no unique solutions (Sonnert & Commons,

1994) Kegan and Lahey (2001), Morris (1993), Demick and Miller (1993) discuss some adult developmental alternatives to Skinner's formulations. Recent advances in the study of positive adult development provide a beginning look at this issue. Data shows individuals could potentially solve problems of one order more complex than the ones they currently do without any further training (e. g. Colby & Kohlberg, 1987). This is found to be true even for individuals who hold seemingly complex professional jobs. Even though contingencies exist that might reinforce more hierarchically complex behavior, the contingencies fail. What is it that might limit the proclivities of individuals? Why does just one more order of complexity seem possible? In addition to the biological limits, the lack of appropriate training or education is also a cause of lack of development.

## Conclusion

The acquisition of new stage behavior (stage transition) was an important aspect of Piaget's (1954) theory of stage and stage change. Our approach expanded upon Piaget's suggestion of steps during acquisition. Applying the Model of Hierarchical Complexity and the quantal nature of stages generates a description of stage change as the increasingly rapid alternation of last-stage behavior. It was suggested that alternation of alternative lower stage behaviors increased in rate until they were essentially smashed together and then organized into a new stage behavior. This alternation can be described by the steps and substeps. A variety of ways of inducing and measuring stage change were reviewed. Empirical field tests of the newer means of intervention are needed to establish what methods work best with which people and under what circumstances. Many methods of producing change work well in pilot studies, but do not replicate well. The problem is like with many interventions, one wants to mix methods. But to produce clean policy research, only the type of intervention may be varied. One might also notice the possibility that different interventions have different secondary effects. Direct instruction might not promote independence and reflection if it were the only method used for the entire program of education. But in the real world there are always mixtures. From present data, and relatively simple skills, Direct Instruction with Precision Teaching probably works the best. But discovery methods seem necessary to produce creativity in adults because there cannot be support by outsiders on key issues requiring creativity. Otherwise, the problems would have been previously solved and there would be no need for creativity.

*Table 1. Stage Transition Steps and Substeps*

*Table 1a. Deconstruction in the Transition Steps*

| Step | Sub-step | Relation | Name | Dialectical Form |
|---|---|---|---|---|
| 0 (4) | | a = a' with b' | Temporary equilibrium point (thesis) | Previous stage 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 stage 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 1b. 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 stage n. Basis for exclusion not sharp. Over generalization |
| | 3 | | Correct Rejections and Excess Misses | Incorporates subsets that produce correct rejections at stage n. Produces misses. Basis for inclusion not sharp. Under generalization |
| 4(0) | 4 | a with b | New temporary equilibrium (synthesis and new thesis) | New temporary equilibrium (synthesis and new thesis) |

*Table 2. Behaviors may form classes. Stimuli may be placed into classes both functionally and analytically.*

| Order of Hierarchical Complexity | Name | Example |
|---|---|---|
| 0 | Calculatory | Simple Machine Arithmetic on 0's and 1's |
| 1 | Sensory & Motor | Either seeing circles, squares, etc. or instead, touching them. O ■ |
| 2 | Circular Sensory-motor | Reaching and grasping a circle or square. O ■ |
| 3 | Sensory-motor | A class of filled in squares may be formed ■ ■ ■ ■ ■ |
| 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<br>* * * * * ■ ■ ■ ■ ■<br>O O O O O ■ / ○ □ □ |
| 7 | Primary | There are behaviors that act on such classes that we call simple arithmetic operations<br>1 + 3 = 4<br>5 + 15 = 20<br>5(4) = 20<br>5(3) = 15<br>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<br>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<br>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.<br>x + (y * z) = (x * y) + (x * z)<br>x □ (y □ z) = (x □ y) □ (x □ z) |
| 12 | Meta-systematic | The system of propositional logic and elementary set theory are isomorphic<br>x & (y or z) = (x & y) or (x & z) Logic<br>x □ (y □ z) = (x □ y) □ (x □ z) Sets<br>T(False) □ φ Empty set<br>T(True) □ Ω Universal set |

Symbols

& = and
] = is equivalent to
' = intersection (overlap, elements in common)
≤ = union (total elements)
T = Transformation of
N = Empty set (no elements)
Σ = Universal set (all the elements there can be)
(Ex) = There exists some element x
(x) = For all x
(Hx) = The action on element x

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