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Using SAFMEDS and direct instruction to teach the model of hierarchical complexity

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ABSTRACT

The model of hierarchical complexity (MHC) assesses a general, unidimensional behavioral developmental set of tasks and stages that measures difficulty across different domains. Teaching the model is a challenge because of the abstract nature of the model. Using traditional methods of lecturing to teach the model often failed because there was no active responding required on the part of the learners. In the present work, precision teaching was employed as a method of teaching the model and to assess whether this could improve students' learning of the model. Two components of Precision Teaching were used: *(a)* the systematic method of evaluating instructional tactics and curricula (West & Young, 1992) using Standard Celeration Charting; and *(b)* recording students' directly observable behavior to provide feedback on their success using SAFMED (Say-All-Fast-Minute-Each-Day-Shuffled) (Graf, 1994). The results indicate that 24 participants from four workshops all met criteria for acquisition. This indicates that precision teaching provides an effective way to teach difficult conceptual material, such as the MHC.

KEYWORDS: precision teaching, the model of hierarchical complexity, learning behavior, adult learning

Complex thinking is increasingly required in our evolving society. As various cultures move toward producing, servicing, and providing information, the systems supporting the cultures are becoming more complex. To effectively prepare citizens for this shift, our educational, vocational, and business education all need to consider how best to evaluate, communicate, and assess the complex of both the tasks ahead and the behavior of those who we prepare for the future. The problem, however, if that there are few models of critical, or complex, thinking that are reliable or valid (Williams, 1999).

A relatively recent innovation is the model of hierarchical complexity (MHC). The MHC is a useful general model of behavioral development that has been shown to be applicable to many domains including, for example, physics problems (balance beam and pendulum) and information science (Commons & Miller, 1998; Commons & Pekker, 2008; Commons & Richards, 1984A, 1984B; Commons, Trudeau, Stein, Richards, & Krause, 1998; Commons, Gane-McCalla, Barker, Li, 2014), as well as broadly applied to constructing assessment tests in the fields of stages of social perspective-taking, general logic, problem solving, etc. (Bernholt, Parchmann, & Commons, 2009; Commons, Goodheart, Pekker, Dawson, Draney, & Adams, 2008; Commons, Goodheart, Pekker, Dawson-Tunik, Cyr, E., Rodriguez, et al., 2005; Dawson, 2002; Skoe, 2014).

A major basis for the MHC's developmental theory is task analysis. Tasks are defined as sequences of contingencies, in which in each part of the sequence stimuli are presented, in the presence of which a behavior or a sequence of behaviors 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 later in this manuscript. One thus examines, or assesses, behavior with respect to the analytically known complexity of the task.

Even though the MHC has been shown to be useful, teaching it has been a challenge. One might wonder how the MHC is different from other developmental models that already exist and why it is important to teach the model. Other models (Colby, & Kohlberg, 1987A, 1987B; Inhelder & Piaget, 1958) that conceptualize development only focus on development within a particular domain. The varying informational frameworks of different domains have often concealed the common underlying behavioral process of stage development. This makes standardization of research methods

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Table 1. orders of hierarchical complexity, its description and examples

orders	performance	definition	corresponding verbal behavior	example
0	calculatory	exact—no generalization [of any kind]	human made programs manipulate 0, 1 or any other objects	
1	automatic	organism engages in a single action at a time and the action is "hard wired" into the organism; no respondent conditioning	single celled organisms respond to a single environmental stimulus	
2	sensory & motor	discriminate in a rote fashion; stimuli generalization; move	move limbs, lips, eyes, head; view objects and movement	
3	circular sensory-motor	form open-ended classes of stimuli	reach, touch, grab, shake objects; babble	
4	sensory-motor	form concepts	respond to stimuli in a class successfully	
5	nominal	find relations among concepts; use names for objects	use names and other words as successful commands	A word such as "cup" names the concept of a container of liquid.
6	sentential	limitate and acquire sequences; follow short sequential acts; following the command "Find representation objects."	generalize match-dependent task actions; chain words; two or more nominal order 4 words are coordinated to form short sentences and phrases	"I want water," or "cup of water"
7	preoperational	make simple deductions of propositions; follows lists of sequential acts; tell stories	count roughly events and objects; two or more sentential order 5 sentences are organized into long paragraph utterances	"Jane was studying history. She answered her cell phone. Later she ate dinner and watched TV." This example uses sentences to tell sequential acts.
8	primary	simple logical deduction and empirical rules involving time sequence.	counts, adds, subtracts, multiplies, divides, proves, does series of tasks on own; preoperational order 6 long paragraph utterances are organized into stories that may be matched to reality	"There was a blizzard. School was cancelled." This example makes simple (inferable) logical deductions by stating sequential acts in a logical way.
9	concrete	carry out full arithmetic; form cliques; plan deals	does long multiplication, division; follows complex social rules; takes and coordinates perspective of other and self	stories about things, incidents, events, actors, actions, places in the context of the interaction between self and other
10	abstract	discriminate variables such as stereotypes; logical quantification (none, some, all)	form variables out of finite classes; make quantify propositions; labels are given to a group of order 8 concrete classes of things; as a result of using label words (e.g. bests/worst, good/bad), stereotypes are formed	The label "furniture" is used rather than listing the concrete objects "desks, chairs, tables."; quantification words like "everyone in my group" or "What would others think?"
11	formal	argue using empirical or logical evidence; logic is linear, 1 dimensional; relational statements are built from abstract order 9 variables	solve problems with one unknown using algebra, logic, and empiricism; statements are supported by empirical findings and are verifiable with facts	phrases "if…then…," "in every case it turned out the same," or "the reason is"
12	systematic	construct multivariate systems and matrices; Multiple formal order 10 relations are put into relation with each other, this must produce a sensible system of relations.	coordinates more than one variable as input; considers relationships in contexts; words like "system" may be used to indicate multivariate relations	"Relationships are built on trust and though we cannot always keep them, making promises is one way we build trust, so it is generally better to make promises than not to make them."
13	metasystematic	construct multi-systems and metasystems out of disparate systems [results from combining or comparing systems of relations	create metasystems out of systems; compares systems and perspectives; name properties of systems: e.g. homomorphic, isomorphic, complete, consistent, commensurable	"Contracts and promises are articulations of the unique human quality that is mutual trust, which coordinates human relations."
14	paradigmatic	fit metasystems together to form new paradigms; show properties of all metasystems such as "incomplete" or "inconsistent"	synthesize metasystems	
15	cross-paradigmatic	fit paradigms together to form new fields	form new fields by crossing paradigms; put together relativity with quantum mechanics to form string theory	
16	meta-cross-paradigmatic	metacrossparadigmatic actions reflect on various properties of crossparadimatic actions seeing with the crossparadigms are consistent, possibly true and determining other properties of crossparadigms	seeing the limitations of string theory; models of stage and action	

extremely difficult to achieve. Thus, there is a need for a broadly applicable behavioral model of developmental assessment. A model is necessary not only to better conceptualize the patterns and themes of development, but also to conduct comparable studies. The MHC is one such model that assesses a general, unidimensional developmental measure of difficulty across different domains (Commons, Gane-McCalla, Barker, Li, 2014). It offers a standard method of examining the universal pattern of development. In this paper, we first briefly introduce the MHC, and then discuss the importance of teaching the model. Finally, we discuss problems in the initial methods of teaching the model and propose a new and more effective way of teaching the model.

The model of hierarchical complexity

The MHC is an enhancement and simplification of Inhelder and Piaget's (1958) developmental model. Although Inhelder and Piaget were pioneers in the field of developmental psychology, they only defined the stages of childhood development. However, they established that there is an invariant pathway along which stage development proceeds regardless of content area or culture (Piaget, 1976). The MHC adopts some of the developmental stages and behavioral characteristics of Inhelder and Piaget's model; however, it does not incorporate the mentalistic theorizing or inferences used in cognitive models.

More specifically, the MHC is an instantiation of axiomatic theory, or a logically derived formal system, of measurement (Krantz, Luce, Suppes, & Tversky, 1971). The different levels in a hierarchical sequence of task complexity are "orders" and the successful completion of a task (i.e., the behavioral performance) of a given order is a "stage." Each order in the model is represented by the *orders of hierarchical complexity* (OHC; Commons & Miller, 1998; Commons & Pekker, 2008; Commons & Richards, 1984A, 1984B; Commons, Trudeau, Stein, Richards, & Krause, 1998; Commons, Gane-Mcalla, Barker, Li, 2014), the higher the OHC, the more difficult the task. In previous research (Commons, Gane-McCalla, Barker & Li, 2014) 17 orders of hierarchical complexity with examples have been classified and defined, as shown in Table 1.

In the MHC, there are three axioms for an order to meet in order for the higher order task to *coordinate* the previous, lower order tasks. Axioms are logically derived rules that are followed to determine how the MHC orders actions to form a hierarchy. These axioms are: ***(a)*** defined in terms of tasks at the *immediately prior, lower* OHC task action; ***(b)*** defined as the higher order task action that organizes two or more less complex actions (i.e., the more complex action specifies the way in which the less complex actions combine); ***(c)*** defined as the lower order task actions have to be carried out *non-arbitrarily.* To illustrate how lower actions become organized into more hierarchically complex actions, consider a simple example. Completing the entire operation $3 \times (4 + 1)$ constitutes a task requiring the distributive act. That act is defined in terms of two primary order tasks (axiom 1), multiplying and adding. That act non-arbitrarily (axiom 3) orders (axiom 2) adding and multiplying to coordinate the axioms. The distributive act is therefore one order more hierarchically complex than the acts of adding and multiplying alone; it indicates the singular proper sequence of the simpler actions.

The importance of teaching the MHC

One of the many domains to which the MHC can be applied to is verbal behavior. There has been an attempt in behavior analysis to understand verbal behavior, including critical thinking. Among all other works, we assert that the MHC can better explain changes in verbal behavior and complexity than Bloom's Taxonomy of Learning (Bloom, 1956). Researchers have more recently used Bloom's Taxonomy as a scheme to classify tasks and verbal behavior as a way to understand critical thinking. These attempts included modifying the definitions of the categories in Bloom's Taxonomy, which yielded higher reliability than Bloom's original taxonomy on both undergraduate-level test questions and answers in the assessment (Crone-Todd, Pear & Read, 2000; Pear, Crone-Todd, Wirth & Simister, 2001). However, there is still low reliability on the highest levels of Bloom's taxonomy, and it is unclear why this is the case. Recently Crone-Todd (2007) suggested that a possible reason for the low reliability at the higher levels is that the behaviors engaged in each level in the taxonomy are recapitulated as the stimuli and behavioral repertoire required for thinking increases in complexity. If this is the case, using the MHC and scoring hierarchical complexity of the tasks (Commons, Gane-McCalla, Barker, Li, 2014) and the corresponding behaviors involved should produce higher reliability in scoring. It should also produce higher reliability in the application of methods to increase higher-order thinking by adults. Also, the MHC allows for the construction of tasks to measure stage of development in a behavioral manner devoid of Piagetian (Inhelder & Piaget, 1958) mentalism. In order to reap these benefits of the application of MHC, there is a great need to teach the model and its scoring system to interested individuals.

Initial attempts to teach the model of hierarchical complexity

Teaching the MHC was found to be challenging during the first few attempts when a traditional manner of lecturing was conducted in workshops. The workshops were conducted to teach the concepts of the MHC during professional conferences, including the Society for Research in Adult Development (SRAD) and the Association for Moral Education. There were several problems with these traditional lecture workshops. First, there was little activity, or engagement, on the part of the audience that could lead to reinforced practice with using the model. Second, there was never any sort of test or performance data to assess whether participants had actually learned the concept of the MHC with the lecturing, and if so, to what degree. The only "measure of success" in teaching the material was through participant self-report evaluations. From informal observations and interviews, only about 20% of the participants reported that they understood the model.

In order to understand the MHC, it is essential to know the terms, definitions, and how to assess the large number of higher order adult behaviors, including verbal behavior. This may involve learning how to identify both the hierarchical complexity of the underlying task and the success of the individual emitting behavior in relationship to that task. Successfully teaching the MHC should depend on three requirements: ***a)*** the value and application of immediate consequences; ***b)*** the number of timed repetitions of the target behavior (i.e., fluency); and ***c)*** the success rate on the repetitions of learning the target behavior, which are achievable through individualized instruction. These three concepts determine the total amount of "engagement" a person has with the concepts. The more the person is engaged with the concepts, the easier it is to understand and apply the concepts. As we see it, the problem with the traditional lecturing strategy is that it failed to fulfill the three requirements in teaching the model successfully.

Using precision teaching to teach the model of hierarchical complexity

Starting from the SRAD meeting in New York in 2008, *Precision Teaching* was employed as the new method to teach the MHC. *Precision teaching* is a systematic method that utilizes the standard celeration chart to evaluate learning progress in terms of fluency. The standard celeration chart is a measurement technology within behavior analysis (Potts, Eshleman, & Cooper, 1993) in which quantitative analyses of behavior is used in applied behavior analysis. It is derived from a quantitative scientific tradition pioneered by Ogden Lindsley in the 1960s (see Lindsley, 1991). It is based largely on some of Skinner's (1938) notions of operant conditioning. Precision teaching is really not a way of teaching, as would be suggested by the label. Rather, it is a general approach to training and assessment of learning that involves repeated practice, error-correction procedures, timed drills to meet predetermined fluency aims, and the use of the standard celeration chart (Pennypacker, Koenig, & Lindsley, 1972).

The goal of precision teaching is to maximize learning based on the learner's fluency measurements. Behavioral fluency is defined as the combination of speed plus accuracy (Binder, 1996), or the number of correct responses over a given unit of time. By focusing on fluency, the teaching program or teacher can adjust where the tasks should be presented in the task sequence. Fluency has been shown to correlate with an increase in both retention of knowledge and the likelihood of application of that knowledge (Binder, 1996; Kelly, 1996; Péladeau, Forget, & Gagné, 2003; Singer-Dudek & Greer, 2005). According to Owen White (1986), precision teaching has been used successfully to teach the progress of learners ranging from the severely handicapped to university graduate students, from the very young to the very old (p. 8).

Precision teaching has been shown to help with the acquisition of fluent performance of the elements which, when combined and ordered, produce the next stage of complex behavior, or behavioral *compounds* (Commons & Richards, 2002). It is the combining and ordering of elements into compounds that defines the order of the task, or stage of performance on that task. Elements must be fluent (i.e., relatively high rate of responding) before they can be organized into compounds of elements (Binder, 1996). The basis of precision teaching is making individuals fluent in the elements they learn or, in other words, making the elements or skills "automatic" to them. This is the critical part of teaching the MHC. *Precision Teaching* was employed as the new method to teach the MHC, as per the three requirements of teaching the model identified in the preceding section.

In teaching MHC using precision teaching methods, the subject matter that was taught was how to assess or score verbal behavior (Skinner, 1957) in the form of textual responses (i.e., narratives) using the MHC. We reasoned that given the past research in which precision teaching was used to teach precision teaching methods (Eaton & Fox, 1983), and since developmental researchers recognized training as an effective method for producing stage change (e.g. Inhelder, Sinclair, & Bovet, 1974), that precision teaching would be and effective method to teach both the basic concepts of the MHC and the application of those concepts. This rationale, then, formed the basis for the present study.

» METHOD

Participants

Data were collected from 24 attendees at four different workshops for learning and scoring the MHC. Within the four workshops, two were preconference events for the Society for Research in Adult Development (SRAD) in 2008 (eight participants) and 2009 (four participants), one was a preconference event for the Association for Moral Education (AME) in 2009 (seven participants), and the fourth took place at the University of Minho in Portugal in 2009 (five participants). Participants' prior experience in scoring task complexities vary based on the MHC. The educational backgrounds of the participants ranged from college students enrolled in undergraduate programs to individuals who had completed doctoral degrees. One of the participants at the SRAD 2008 conference self-identified as legally blind.

Materials

Cards

The materials used in the workshops consisted of seventy four 8.5" by 11" sheets of paper with different information about tasks on both sides. The cards were divided into seven sections of different tasks. The first card of each section had the instructions printed on it. For example, the instruction in section 2 was:

> *"The next group has the definition of an order of hierarchical complexity on the front side; the name and number of the order of hierarchical complexity are on the back side. Each presentation lasts just one minute, so work as fast as you can. Do not read everything if you do not need to."*

Even though the content of the tasks within one section included materials on order 5 to order 13, the complexity level or the order of the difficulty level of each task in a section remained the same. In other words, within one section, orders 5 to 13 were described as being at the same difficulty level. However, as participants progressed from one section to the next, the order of hierarchical complexity for sections increased from order 8 to order 13. This means that the description of the materials in each section became progressively more difficult.

The order of the sections was carefully designed. Each subsequent section was more complex, or difficult, than the previous section because the subsequent one combined the elements from the previous one. The sections followed the order of hierarchical complexity, in which higher order elements are the combination of lower order elements. In this way, understanding on the part of participants is inferred based on their demonstration of fluency on the prior section of tasks in order to initiate learning the next section of tasks. For example, section 1 presented the name and number of the order of hierarchical complexity, which were

Table 2. examples of card sections

sections	one side	the other side
section 1	"Systematic"	order 12
section 2	the order name "nominal" and the order number "5"	the definition of a nominal order: "two or more concepts being coordinated to form single representations (words)."
section 3	"Jane had a dog. The sun came out."	"This passes sentential order 6 because it contains short sequential acts and chains words. It fails preoperational order 6 and violates axiom 1 because there are sentences but not a story. The story action is not defined because there is no relationship between the sentences (axiom 1)."
section 4	"Bowers offers a treatment that has been studied and is shown to work well."	"Formal"
section 5	a vignette describing a metasystematic order 13	"Metasystematic 13" and listed the variables, relations, systems, and relations among systems contained in the vignette that made it metasystematic.

considered the simplest elements in the workshop. In section 2, definitions of orders were presented in which the names and numbers previously learned in the first section were used.

The topics of the five sections were as follows (examples of each section and representative cards are shown in Table 2).

Section 1. the names and corresponding numbers of the OHC
Section 2. the definitions of the MHC in each order
Section 3. the three axioms of MHC
Section 4. sentence examples from counselor patient vignettes
Section 5. counselor patient vignettes instrument

The descriptions of the contents of each section are provided below.

Section 1. Each of the cards contains the name of an order of the MHC on one side, and its corresponding number on the other side. These cards depict orders from Nominal (5) through Metasystematic (13).

Section 2. Each of the cards contains the name and number of an order of the MHC on one side, and the corresponding definition of the order on the other side. These cards describe orders from Nominal (5) through Systematic (13).

Section 3. Each of the cards contains materials about axiom rules of the MHC. The cards contain sentence examples illustrating the axiom rules on one side and the explanations of how the axioms relate to the example sentences on the other side, including ***(a)*** the order of the MHC of the example sentences, and ***(b)*** which axioms are violated by the example sentence that precluded the example sentence from reaching a higher order of the MHC. These cards also covered stage Nominal (5) through Systematic (13).

Section 4. Each of the cards contains sentence examples from the Counselor-Patient Interaction Instrument (Commons, 2013). This instrument has been used to assess the level of complex reasoning present in informed-consent process vignettes about counselors and patients. These vignettes are similar in content and outcome, but vary in terms of complexity of reasoning. In this section, sentence examples from the vignettes were put on one side of each card, and the corresponding order of the MHC of the sentence example and a brief explanation were put on the other side. This section of cards covered stages from Concrete (9) to Metasystematic (13).

Section 5. Each of the cards contains the entire Counselor-Patient Interaction instrument on one side and the stage and elements of the vignette on the other. The vignettes in this section ranged from the Concrete (9) to the Metasystematic (13) stage.

Standard Celeration Chart

The Standard Celeration Chart (SCC) (Lindsley, 1992) is used in precision teaching, and is based on a student's own self-paced evaluative performance of learning. It is a tool to measure and display performance and learning in terms of fluency. Students' performance is timed, counted, and recorded on his or her individual standard celeration chart. It shows a number of features of student performance, including logarithmic growth of learning in which the frequency of behaviors is charted is charted over time. The results show whether or not celeration, or change, in learning fluency occurs over time (Calkin, 2005). Celeration charts indicate acceleration, decelerating, and steady states of response rate, or fluency.

The semi-logarithmic SCC was used to record data, which consists of a linear *x*-axis, representing day sessions or timings. Since the workshops in this study provided a relatively small time frame for both training and collecting data, the unit of time per trial was one minute. Therefore, the *x*-axis on the graphs represents one-minute trials instead of one day. The *x*-axis is divided into increments of 10 trials, which in the present study represent sections of flash cards. Therefore, 0–10 is the first group of cards, 11–20 is the second group of cards, and 21–30 is the third group of cards. Dashed lines indicate at which trial a participant shuffled cards or shifted within the third section of cards. The logarithmic *y*-axis presents the count of behaviors per minute. Fluency, then, is measured by the number of items completed correctly and incorrectly per minute, and the celeration of performance is determined by the trend evident on the graphs. Participants' data about the tasks they were on, the trials they were on, the number of cards they turned over, and the number of correct guesses, were all recorded in a four column table and on the SCC.

Displaying growth in the rate of responding on the *y*-axis logarithmically is advantageous because it allows for both large and small gains of growth to be displayed on the same scale. This is advantageous because one can see both large and small gains over time. For example, a growth of 10 to 20 trials in frequency of targeted behaviors is viewed as greater on the SCC than a growth of 40 to 50 trials. During the first few trials of a section, when participants were learning the material for the first time, the fluency of the targeted behavior increased rapidly as they practiced the material. Using a normal scaled chart, it would be harder to detect changes in fluency over many trials because the relative change in fluency is smaller. Although fluency increases involve increments of 10, moving from 10 to 20 trials is a 100% increase in performance. In comparison, moving from 40 to 50 trials is only a 25% increase. This difference in rates of fluency is visually represented on the SCC.

While the fluency of behaviors on the SCC clearly illustrates student performance at a given point in time, Precision Teaching emphasizes the importance of celeration of the performance (i.e., acceleration, steady state, or deceleration). A change in fluency over time provides more information about individual learning rates than performance in a single time period alone. The SCC provides these data, which form the basis for decisions related to students' individual instruction. It is recommended that a new condition is only introduced once a steady state is demonstrated in the data (Cooper, Heron, & Heward, 2007), and this is the case with the SAFEMEDS and Precision Teaching methods used in the current study.

All of the charts and participant-generated written examples of stages were collected at the meetings mentioned earlier. The data from the charts were entered individually into a SCC template developed for Microsoft's Excel application (Harder, White, & Born, 2008). The template was used to process the data to create a unique SCC for each participant.

Procedure

The total time length of the workshops was three to five hours. The procedure of the workshop is called SAFMEDS (Say-All-Fast-Minute-Each-Day-Shuffled (Graf, 1994)).

Step 1: getting familiar within order. All participants received a stack of cards and the traditional blue Standard Celeration chart paper, which participants used to record their data. Participants read the instruction card from the first section in order to become familiar with the concepts in section 1. Next, they were instructed to go through the cards as quickly as they could. Although participants were asked to try to memorize what they saw on the cards, they were told not to be overly concerned with remembering the content on the flip side of the card correctly. At this step, speed was more important than correct memorization. The cards had to be read in order, and participants were instructed not to shuffle the cards after they finished the memorizing them. Then, participants were instructed to complete the first self-check for one minute with the material they learned from the card. They were told to guess as many cards as they could and they were not allowed to flip the card over for answers until after the one minute period, during which they were instructed to state their guesses privately to themselves. This method was chosen because stating the answer out loud could disturb other participants. After finishing the first minute, they were given an additional minute to turn over the cards, check the correct answers and record the total number of guesses and corrections they made. Participant recorded both of these data points in the traditional blue chart paper and then plotted them on their Standard Celeration chart. After recording the data, participants repeated the card memorization task with the instruction to try to increase fluency performance.

Rules for moving on to the next step

There was a three-part set of fluency mastery criteria used for progressing to the next task:

a) A fluency criterion (based on both frequency and accuracy), whereby if the participants had a reasonably high rate of turning cards over and that rate as shown on the chart was reasonably flat (topped out), they should move on. Coupled with the high rate of card turning was the rule that accuracy of answering questions must be 80 to 85% correct. When a participant fulfilled both of these fluency criteria, the participant was deemed qualified as having mastered the task and thus ready for the next task;

b) if the participant's fluency measures were improving from their beginning performance, but still lower than criterion, they stayed on the present task until a stead state was observed; and

c) a three-part rule for participants who struggled with fluency on a task and would be given this set of three reasons to move back to an earlier task if they:

i) did not turn over and guess any or very few cards correctly,

ii) were not improving in speed, or

iii) were not close to the frequency aim.

If going back did not work to increase fluency, the researchers would check with the participants to try to find out why they were not progressing. Interventions included providing modeling, verbal prompts with fading, and shaping frequency.

This process was repeated until a participant reached fluency mastery criteria for one minute timings. Specifically, participants repeated the process until they turned over and guessed at least 8 out of 9 cards correctly in one minute and their Celeration chart for frequency was flat. When these mastery criteria were met, these participants shuffled the section of cards. For step 1, they shuffled the section of cards so the order of the cards was sequenced randomly on the next trial. Participants placed a mark on their graphs to indicate at which trial they had shuffled their cards.

Step 2: shuffled section 1 cards. During this step, participants followed the same procedure as the one in step 1, except that the order of the cards was shuffled and randomized. Participants had to meet the same fluency mastery criteria as above (i.e., at least 8 out of 9 correct in 1 minute timings with frequency flat) in order to move forward to step 3. Within each trial, the cards were required to be reshuffled.

Step 3: repeat steps 1 and 2 with section 2 definition cards. In this step, participants followed the same procedure as in step 1 except that they used cards for section 2 instead of section 1. In section 2, participants read the definition side of cards and guessed the

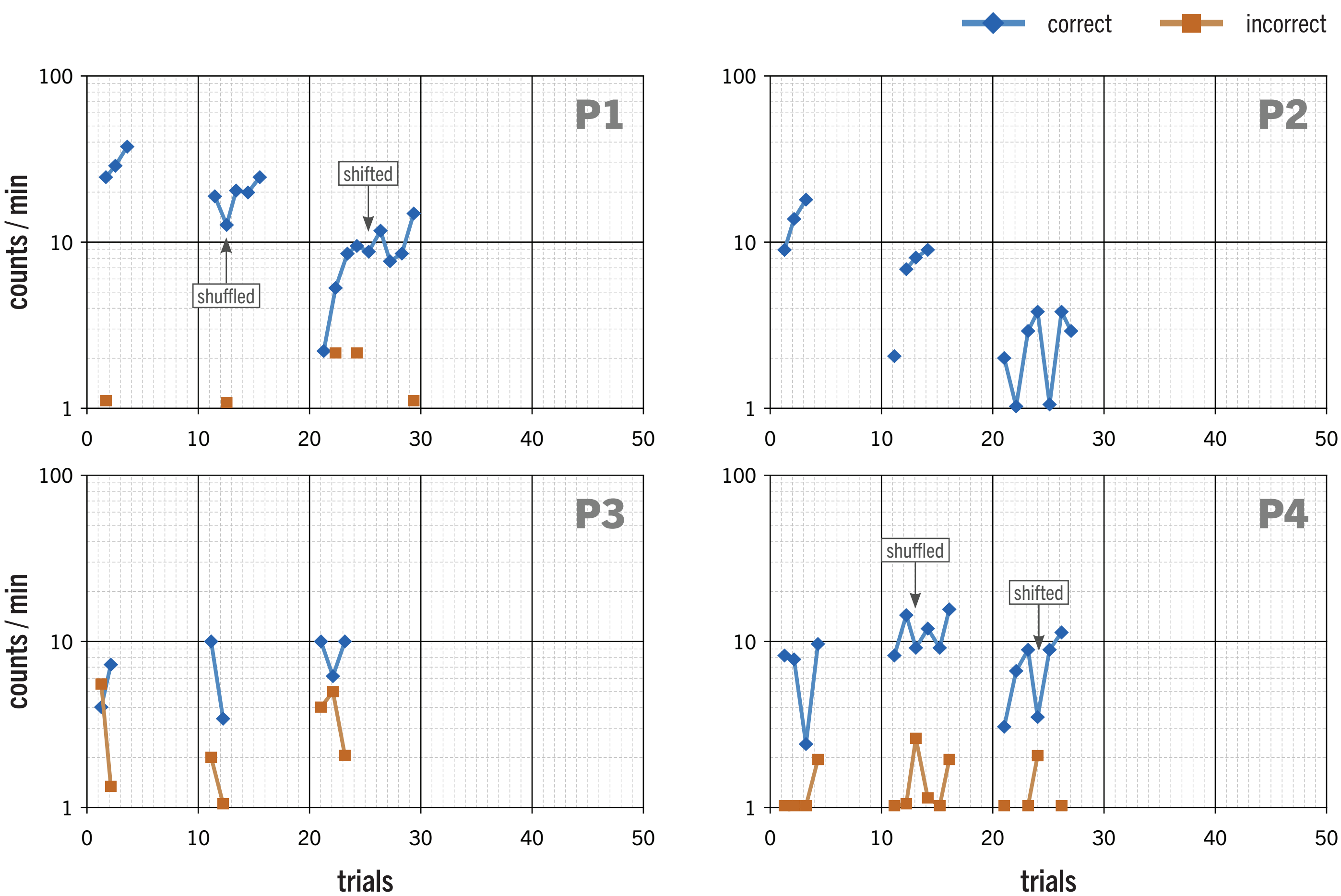

Figure 1. Individual celeration charts for participants 1 through 4 from the SRAD 2008 workshop. Each dot represents a one-minute trail. The *x*-axis is divided into increments of 10, which represent sections of flashcards. Smaller diamonds represent number of correct responses in a trial. Larger squares represent number of errors in a trial. Dashed lines indicate where a participant shuffled cards or shifted within a section of cards.

corresponding stage name and number of hierarchical complexity within one minute, just as what they did on step 1. For example, on one side of the card, participants would read "Sentences are organized into paragraph long utterances. Tell stories that are not matched against external reality." After they read the definitions, participants would either answer or guess the order corresponding to the definition shown above (in this case Preoperational Order 7). In every case before shuffling, participants had to guess on the first trial. They started to learn the material while they were guessing. When participants met fluency criterion 1from step 1, participants shuffled their cards. This process was repeated with the cards shuffled until they met fluency criterion 1 again.

Step 4: unshuffled shifting in section 3 axiom card section. When participants mastered the earlier cards of the axiom card group, they shifted, meaning they started on the last card they left on, instead of going back to the beginning. The set of fluency criteria for mastery was the same as that in steps 1 through 3. Participants marked on their graph when they shifted within the axiom card section. After shifting, when a participant turned over cards with 90 percent accuracy, they would shift again. Each shift was marked on the graph. This was repeated until the entire section was completed. After each shift, the section of completed cards was kept in separate groups.

Step 5: shuffling section 3 axiom cards within shifted groups. After completing the axiom card section, participants went back through each group of shifted axiom cards and shuffled the cards within the group. Participants turned over and guessed cards in each group of shifted cards, and also marked the data on the chart.

Step 6: shuffling all section 3 axiom cards. Upon meeting mastery criteria on each separate group of shuffled cards, participants then shuffled the groups (i.e., the previous separate groups of cards) all together and repeated the process of turning over and guessing cards. This step was marked on the chart by participants as well.

Step 7: section 4 sentence example from counselor-patient interaction vignette instruments cards. Participants repeated steps 1 and 2 with the section 4 cards that presented sentence examples from the Counselor-Patient Interaction Instrument. An example of the question is: "Burne asks the Patient to support the treat-

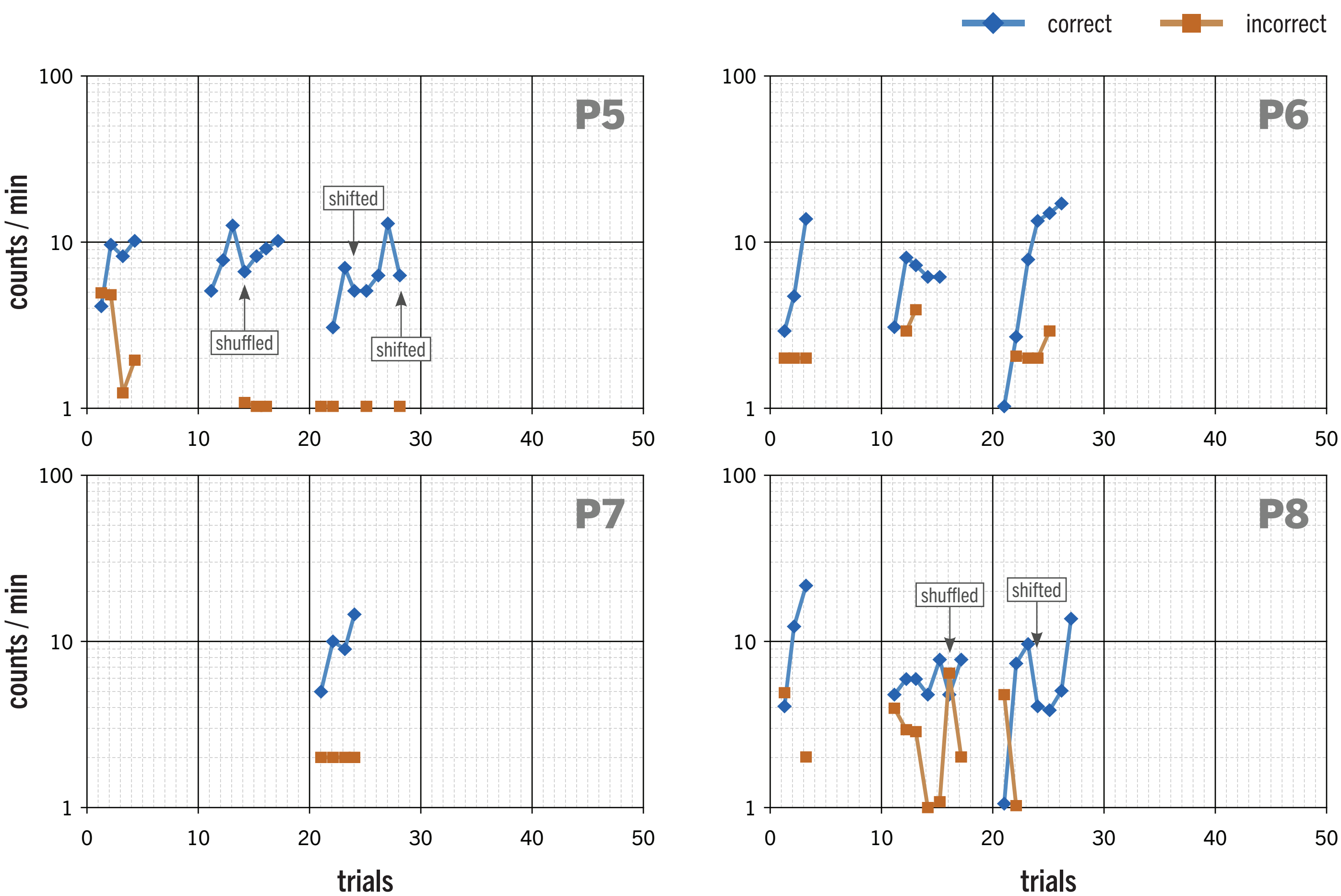

Figure 2. individual celeration charts for participants 5 through 8 from the SRAD 2008 workshop

ment. Burne says how much fun doing the treatment is." (Upon seeing this example, participants would have to correctly answer Preoperational Order 7.) There were sentence examples for each of the orders of complexity covered in the workshop.

Step 8: section 5 whole story from counselor-patient interaction vignette cards. Participants next shuffled the section of cards so the order of the cards was arbitrary. Participants guessed shuffled cards, and recorded their performance on their charts.

Due to the time constraints of the workshops at the various conferences, the actual time allotted varied as to which sections of cards could be completed. The third section axiom cards were the last card section completed at the SRAD 2008 workshops, the 2009 AME workshop, and at the 2009 University of Minho workshop. The fifth section of cards presenting vignettes from the Counselor-Patient Interaction Instrument were the last cards completed at the SRAD 2009 workshop. At the end of each workshop, a discussion took place following the final exercise of participants forming their own stage examples. Participants also filled out evaluation forms about the workshop. The procedure up to this point took two hours. To finish the rest of the deck of flash cards would have taken another hour.

» RESULTS

Figures 1 through 6 showed individual Celeration charts for all 24 participants. The number of trials performed varied due to time constraints of different workshops and individuals. Based on participants Standard Celeration charts, the eight participants from SRAD 2008 workshop performed 17, 14, 8, 16, 18, 14, 4 and 17 trials respectively; the four participants from SRAD 2009 workshop performed 16, 16, 14 and 14 trials respectively; the five participants from the University of Minho workshop performed 14, 13, 12, 12 and 14 trials respectively; and the seven participants from the AME 2009 workshop performed 12, 11, 10, 13, 13, 13 and 12 trials respectively. However, most participants did not plot all of their trials on their chart.

As shown in the figures, there was a great deal of individual variability in learning rates among participants. These individual differences were observed in both participant terminal fluencies and celeration values. However, all of the Standard Celeration charts show a general pattern of acceleration of learning (i.e., an upward trend in the data). Whenever the participants either shuffled or shifted the cards, their fluency rates decreased, but as trials continued their fluency increased. Similarly, when participants moved onto new sections of cards, the overall frequency of

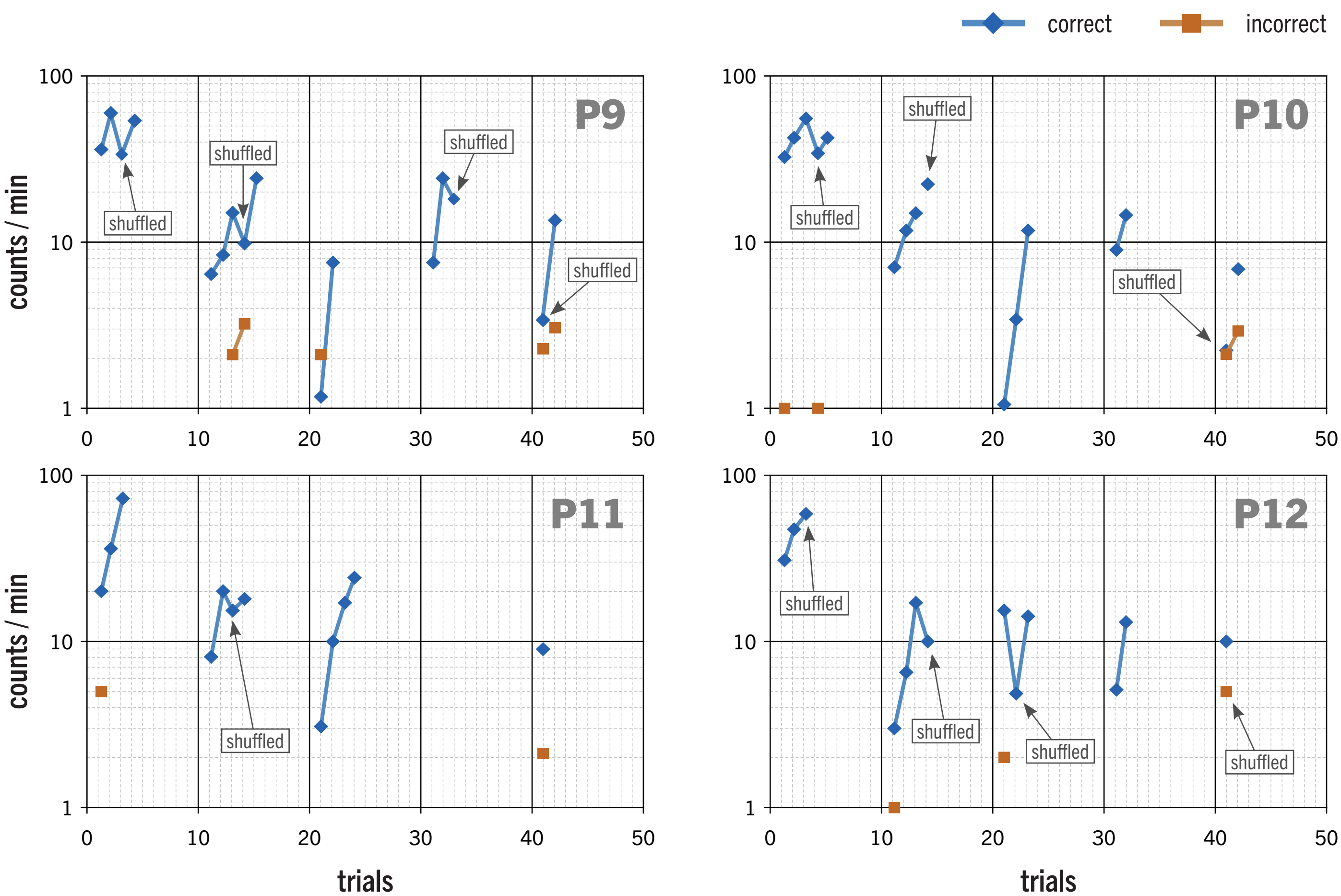

Figure 3. individual celeration charts for participants 9 through 12 from the SRAD 2009 workshop

responding dropped due to increased difficulty and length of the card material. Both of these findings show that changing tasks initially decreased fluency, but that performance increased again with repeated practice. This would also suggest that since the rate increases with performance, that using SAFMEDS through Precision Teaching provides reinforcement the behaviors in which the participants are engaging.

Due to the length of the set of cards that came after these initial trials, the cards based on learning the axioms and applying them are incomplete. None of the participants were able to complete the whole set in a minute. Thus, the figures typically show only one or two data points where participants started this section after their previous set.

» DISCUSSION

Behavior analysts' view learning as a situation in which as fluency increases, the hierarchical complexity of the verbal repertoire may either be being reinforced or increasing. As fluency increases, early rule-governed verbal behavior becomes more and more "automatic." Such behavioral change may be a form approximating contingency-shaped behavior. Another account would simply describe how many elements one can discriminate is directly related to how fast reaction time is to each one of the elements. So the more fluent the performance, the easier those actions are to form in to a more hierarchically complex compound. Note, also, that every time the cards are shuffled that fluency decreases. One possible explanation for this finding is that the particular sequence of the cards provides some sort of stimulus control over a sequence of responding when presented with the cards in that order. Shuffling, at least temporarily, disrupts the sequence of discriminative stimuli over each of the responses. With practice, shuffling, and repeated practice participants learn the concepts *despite* the order. When this occurs, deeper learning occurs as well. This is because the controlling stimuli are not order-dependent; rather, the verbal repertoire is more likely a function of the task itself rather than of the order in which it appears.

Another important aspect of increasing, decreasing, and flat fluency rates is that these can represent dynamic versus steady-state behavior. Steady-state behavior is important in terms of experimental control over responding, and the rules used in this study indicated that one should move onto the next step once steady-state responding was observed. However, if dynamic states are present, then the rule is slightly different. If rates are decreasing, then one should try the current step again; however, if there is no change in the trend (either no longer decreasing, or starting to increase), then one should move back one step until fluency increases again. In this way, then, the fluency of the behavior is a data-based measure that is used to determine when to move up or down in the learning task.

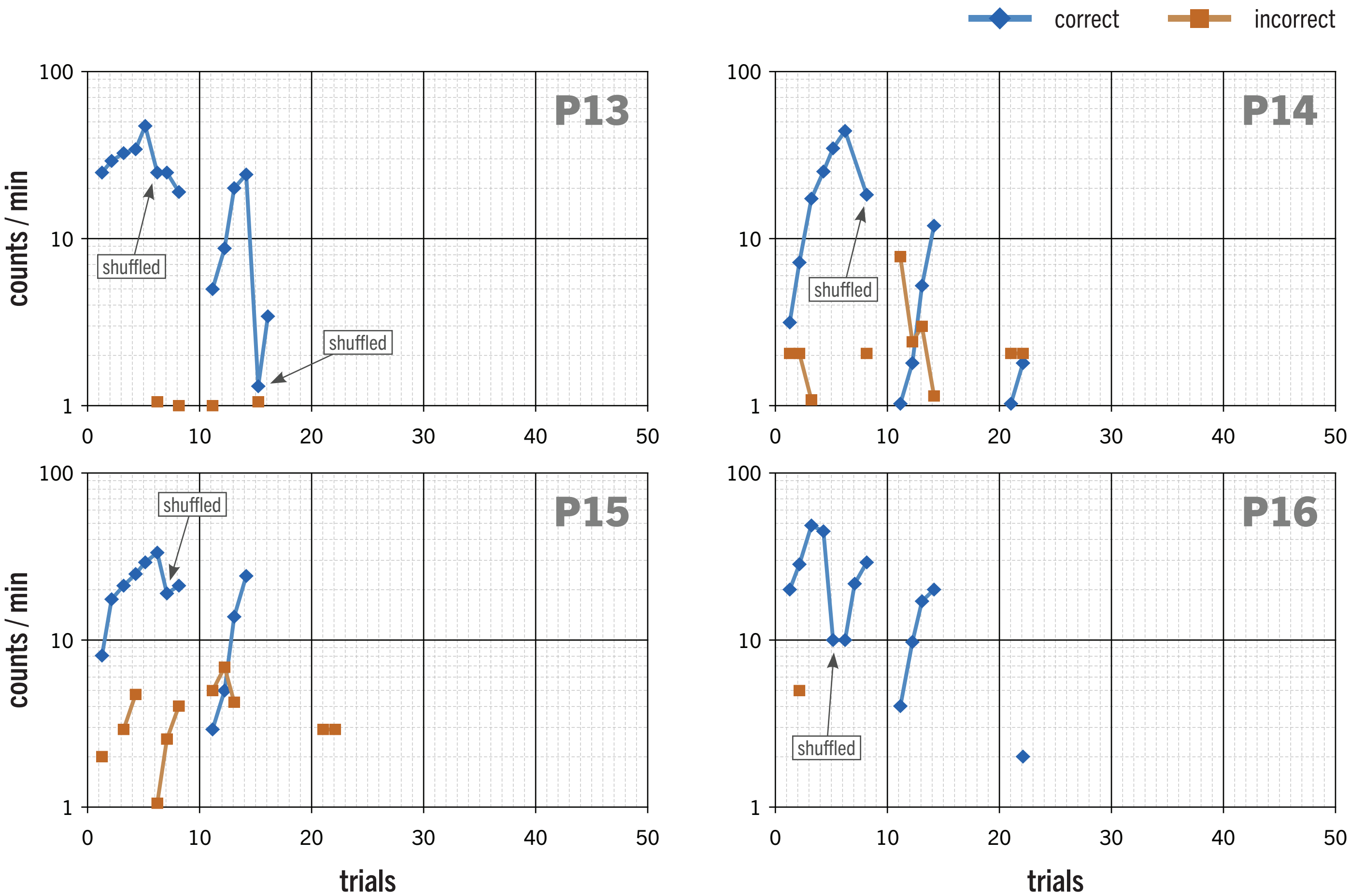

Figure 4. Individual celeration charts for participants 13 through 16 from the University of Minho 2009 workshop

The most compelling finding is that SAFMEDS coupled with precision teaching successfully taught all of the workshop attendees the concepts of the MHC. Although traditional lecturing methods did help previous participants remember what was presented in the workshop, this earlier method of teaching involved passive learning and failed to result in people understanding and being able to apply the model. In contrast, with the use of the SAFMEDS plus precision teaching procedures, these procedures successfully resulted in the involvement of all attendees and were effective in helping their progress in learning the subject material. Also, the gains in fluent performance likely serve to reinforce later guessing behavior (i.e., performance on this task). Reporting the gains also serves to further reinforce (as evidenced by increases) performance, and provides information that although there is variability within the group, that the gains demonstrated by individual are lawful.

Prior to the workshop, there was some concern over the number and length of the cards. There is a possibility that learning might be hindered due to participants' statements indicating frustration with longer cards provided near the end of the workshops, specifically in the section 3 teaching axiom rules. The material covered in these cards is considered challenging, even for people who were familiar with the MHC. However, according to the figures, the data clearly demonstrate that participants' learning rates accelerated as the workshop progressed, regardless of the difficulty of the task. Also, of the 16 participants who completed more than two trials in axiom section 3, 13 participants reached the criteria for speed and accuracy in their performance on the axiom section. Although some participants had difficulty dealing with cards containing the concepts of the metasystematic order (order 13), which was considered as the most difficult material, they were still able to learn it. This indicates that precision teaching is effective in teaching fluency related to highly complex concepts. According to the figures, the participants' charts showed acceleration of learning for basic knowledge of orders in the MHC and being able to score using the MHC.

These findings provide good ammunition against the common belief among critics of behavioral methods of teaching (e.g., mastery-based methods including PSI, Precision Teaching, SAFMEDS, etc) that its usefulness ends with rote memorization of simple answers (Halonen, 1992). As has been pointed out by others (Reboy & Semb, 1991) with respect to personalized systems of instruction, it is not the system itself, but the content and how it is presented, that determines the complexity involved. We conclude that participants acquire intraverbal behavioral repertoires ("concepts") of different orders or stages in the model of hierarchical complexity. How can we support this conclusion? In order to know whether we have succeeded at teaching a concept, we must first give a definition of what understanding the concepts of hierarchical complexity entails.

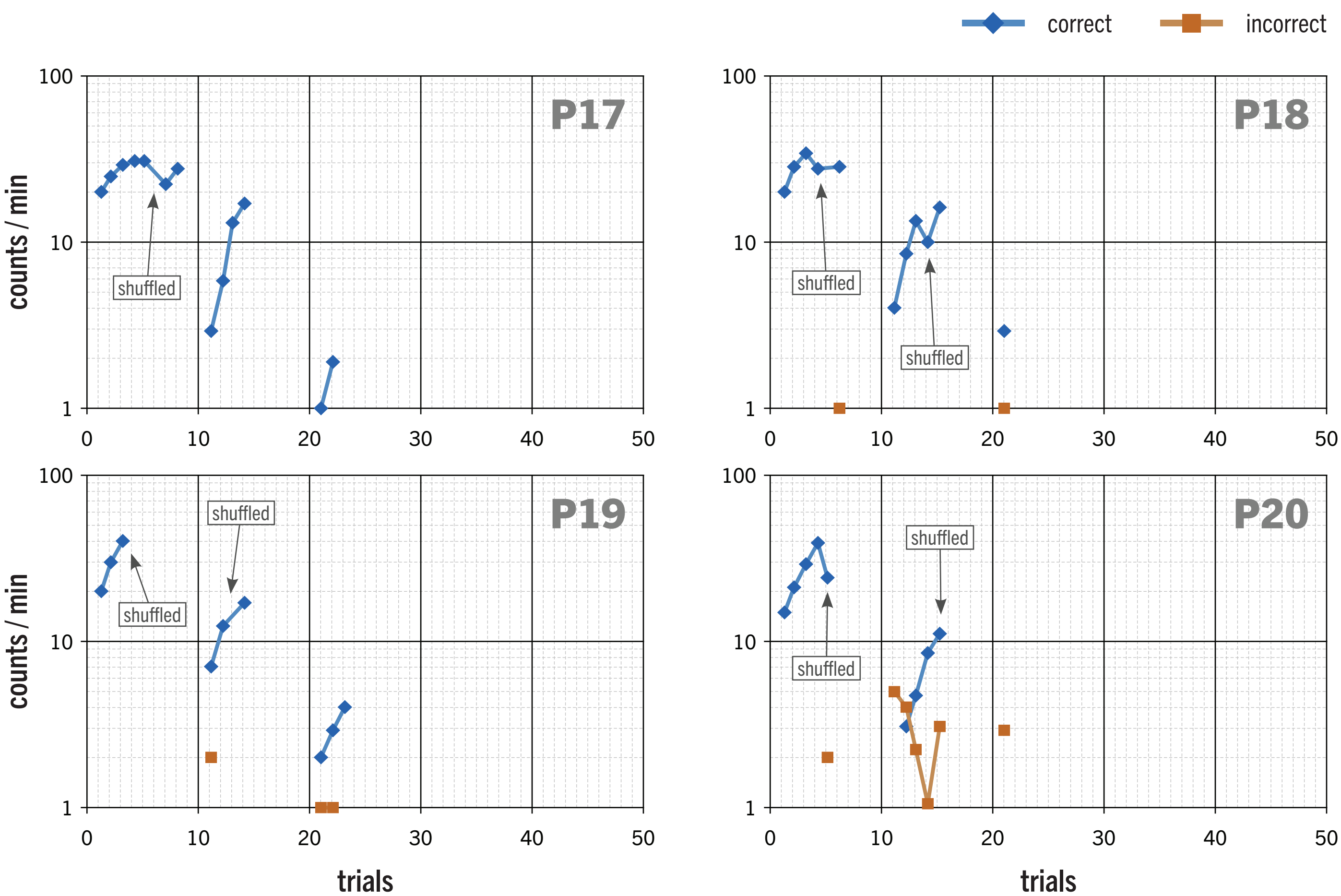

Figure 5. The individual celeration chart for participants 17 is from the University of Minho 2009 workshop, and participants 19, 18 and 20 from the AME 2009 workshop

The understanding of a concept might be defined in Hullian terms (Hull, 1920), namely that a single response correctly follows the presentation of any member in a class of stimuli connected by the relevant concept. This notion of a concept meets British Empiricist John Locke's theory that new and more complicated ideas are the combination of simpler ideas and concepts (Locke, 1689). One has to know what response goes with instances that represent the relevant concept and what response goes with instances that do not represent the relevant concept. Section 2 of the flash cards used in the workshop asks participants to guess the order/stage name of a definition presented on the front of the card. For example, when a participant is presented the definition of concrete stage (stage 9), this definition can be considered a member in a class of stimuli connected to the concept of concrete stage. Thus if the participant recognizes and categorizes (correctly identifies and names) the information presented as concrete, then they have provided a response that correctly goes with an instance of the concept of "concrete". We might conclude that correctly naming the definitions of the orders of hierarchical complexity on cards that have been shuffled meets Hull's definition of concept acquisition. Similarly, in sections 4 and section 5, correctly categorizing new sentence and vignette examples by their stage demonstrates participant learning of the concepts.

Another issue that must be addressed is why the results from the celeration charts and transfer tasks (i.e., generalization) show understanding. First, Piaget, and Inhelder (1973) suggested that one has to have the concept of something before one can imitate it or use it. To accurately predict what is on the other side of a card, one has to learn what is on each side of the card first. Learning what is on each side of the card means minimally having to read what is on each side, and then reciting what is on the opposite side of the card presented at a given point in time. This process could be considered cross-modal imitation. Using the visual modality, one reads the first side and then based on that reading determines what is on the other side. For example, when the participants begin learning the definitions of orders/stages, the participants are given time to read and to try to state the definitions on the cards. At first, participants' strategies for stating (a first step in understanding and remembering) definitions may involve attempts at memorizing whole sentences. However, our study does not provide us with results as to what exactly participants are memorizing or reading. All we can be sure of is that participants are stating the definitions and labels often enough to match the material on each side of the cards. Hence, they are at least providing intraverbal responses that are appropriate to the relevant symmetrical stimuli.

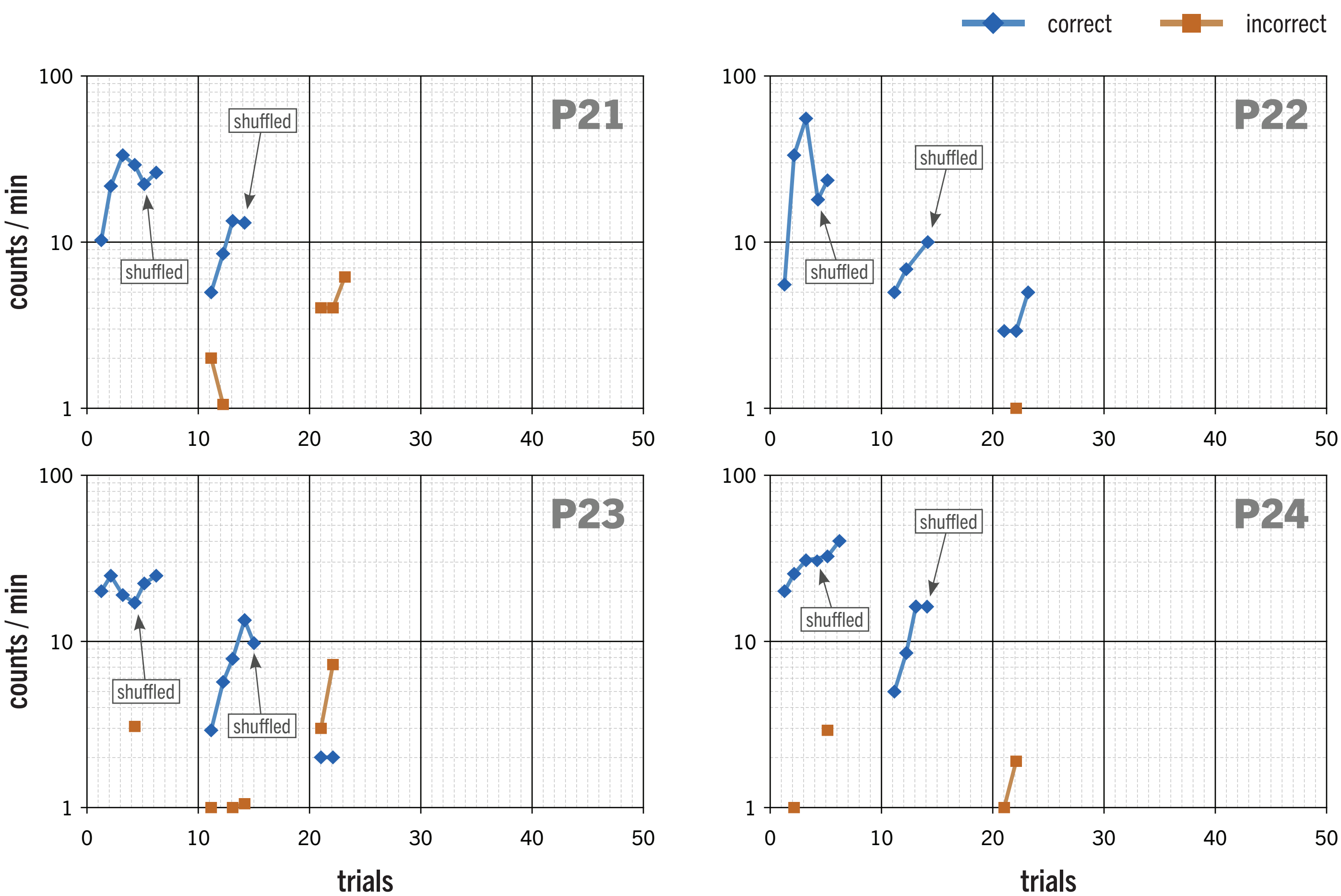

Figure 6. Individual celeration charts for participants 21 through 24 from the AME 2009 workshop

There are a number of methods for validating the degree to which one understands the concepts. The simplest way is to have a recognition task. In this task, one simply recognizes something as belonging to a conceptual stimulus class. For example, one would present the definition of the particular order of hierarchical complexity in different words on each occasion, and then ask the participant to name that order/stage of hierarchical complexity. In comparison, assessments that require recall are generally more difficult than recognition tasks. This has been demonstrated in memory research (Tulving & Psotka, 1971). For example, taking a different approach from our workshop, a cognitivist might like to have the participants see the name of the particular order of hierarchical complexity and give the definition in their own words. From a behavioral perspective, such a task would require more complex intraverbal behavior, as well as what Hayes (1994) calls a relational frame.

There is no easy way of distinguishing generalization (or transfer) of an old stage of behavior from the acquisition of new stage of behavior on a task. In our workshop, if participants learn the material on a particular section of the cards in only two trials, we cannot know the conditions under which they learned it that rapidly. One presumption, however, would be that the participant is transferring training from previous similar tasks. In another example, if a person is learning to use a new word processing program and has experience working with two other similar word processing programs, that person is likely to learn to use the new word processor quickly. This type of learning is due to response generalization from what was learned in using the older word processors. The same can be said of stage; learning new stage behavior is a developmental process that can take a long time, sometimes years. Consider, for example, that the way that one learns to perform mathematical distribution is to memorize the order of actions. After they are applied to at least two cases, the general concept of distribution may have formed. If one is asked to apply what he or she learned to a new concrete order task that requires the organization of two primary order actions, this would be a case of assimilation (transfer of training).

The point is that after looking at the definition on one side of a card and then guessing the name of the order correctly on the other side of the card, we might consider this as a test of learning of the concepts. Understanding the Model of Hierarchical Complexity does require "memory," as does any concept formation. In this instance, "memory" means that stimulus control of a concept has been established. That is, when instances of a concept are present, the participant produces the correct response.

Usefulness of the instruction methods

Training with the method used here may make it possible to learn the Metasystematic order of order-task notion. This is because a person who normally performs at the Systematic stage can perform at the Metasystematic stage with one level of support. A person receives various levels of support from the environment that decrease the difficulty of a task and raise the person's stage of performance on that task. The Social Constructivist literature suggests that levels of support represent the degree of independence that people have in their action and thinking from environmental influence (Vygotsky, 1962, 1966, 1978). From a behavioral perspective, the Social Constructivist approach is entirely consistent with the behavioral processes involved in the levels of support, which may include prompts, fading, shaping, chaining, or modeling (Pear & Crone-Todd, 2002). For example, in training as provided here, imitating and following examples all provide one level of support on a task. One level of support (Commons et al., 2008; Fischer, Hand, & Russell, 1984) lowers the task difficulty by one stage. To learn the name of the definition of the formal order concept would be a systematic order task. But because there is one level of support from being trained to name the concept, this requires just a formal stage action. Likewise, imitation also provides one level of support. Showing people how to complete a task reduces the required stage of the behavioral repertoire by one.

There are a number of potentially widely generalizable training and shaping rules that are necessary but not sufficient for teaching the concepts in the model of hierarchical complexity. The first rule is to teach everything in steps, starting with the easiest tasks and progressing towards the more difficult tasks. This rule is demonstrated in the sequencing of the sections of cards and in the sequencing of presenting material within each section of cards. Within each section, lower-order material is presented first and then the presentation of material progresses towards higher-order material as one moves through the section. The purpose of these progressions in difficulty is to allow participants to gain fluency in the simplest task first, out of which the more complex tasks are built. This process creates what Constructivists term "scaffolding in acquiring increasing complex concepts", which really involves cuing, shaping, chaining, and fading. The second rule is that participants' progress through the workshop at their own pace, as in any personalized system of instruction (Keller, 1968). The third rule is that participants chart their performance. The reason for the charting is multifold. The charting lets the participants know if they are not far enough along in a sequence, meaning the task or material is too difficult. This level of difficulty would show up on the chart as a lack of increase, or decrease, in the frequency of turning over and guessing cards correctly. Providing this information may also lead to reactivity on the part of the participant, which can have a positive effect on response rates (Cooper, Heron, & Heward, 2007).

In learning the MHC content, participants first learn the sequence of "order/stage" names. This performance is supported by the fact that they already know the numbers in order. The purpose of teaching the names in order is that it helps participants put the definitions in order. This ordering of the definitions is not only a necessary prerequisite for later learning, but it also serves to provide more immediate contact with the reinforcing contingencies associated with providing correct responses. Each step in the sequence of presenting material supports the learning of the following step. It serves as a prerequisite for the next step, and provides reinforcement for the increasing complexity of the behavioral repertoire. One only goes on to the next stage tasks after one correctly guesses or recalls the information from the present stage.

Other than learning the concepts of the MHC, participants acquire two sets of behavior. First, participants learn what to do with the flash cards: ***(a)*** look at the card; ***(b)*** guess what is on the other side. The first time they go through the cards their guesses will be pure guesses. Then they will ***(c)*** Turn the card over; ***(d)*** Check their guess. The participants learn to do this fluently, speeding up over one-minute trials no matter what material is being taught. Participants also learn to chart their performance.

» CONCLUSIONS

The results from the workshop provide a basis for two conclusions. First, as argued earlier, precision teaching can be very effective in teaching complex and difficult adult-level subject material. Although SAFMEDS procedures have been used to teach a taxonomy (Clorfene et al., 1998), as far as we can determine, Precision Teaching has never been demonstrated as an effective teaching tool with concepts as difficult as those contained in the MHC. The second conclusion is that precision teaching is effective in teaching higher order "thinking" skills, as suggested by others (Crone-Todd, 2007; Reboy & Semb, 1991). This effectiveness was demonstrated by participant success in tasks that required the application of knowledge learned at increasingly more complex orders of task difficulty.

Additionally, this method may provide a way to train assessors that will ultimately result in higher inter-scorer reliability among them. This improved training would increase reliability, which is the first step in demonstrating validity (Williams, 1999). In the future, we would like to look at the highest order at which a participant correctly provides a response. A test related to the order of items that participants start demonstrating errors in identifying orders/stages of hierarchical complexity would be a necessary next step in this research. Such research would require spending more time analyzing errors to see learn what sub-tasks and support might benefit further acquisition and fluency. ■

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