Behavioral Development Bulletin
2015, Vol. 20, No. 2, 207–226

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1942-0722/15/$12.00 http://dx.doi.org/10.1037/h0101379

Using a Computer-Based Precision Teaching Program to Facilitate Learning of Complex Material: The Case of the Model of Hierarchical Complexity

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The model of hierarchical complexity (MHC) assesses a general, unidimensional behavioral developmental set of tasks that measure difficulty across different domains. Teaching the model is a challenge because of the abstract nature of the model. Using the traditional Precision Teaching method of SAFMEDS, those learning the model reported the approach to teaching to be rather boring. In the present work, computer-based instruction was integrated into the Precision Teaching of MHC. The results indicate that mastery was achieved in 8 of the 27 participants. Controlling relations developed that were not useful to scoring stage. This indicates that the program needs to analyze more closely the technology of process as derived from the basic and applied learning sciences. These considerations will be reviewed in detail.

Keywords: computer-based instruction, instructional design, precision teaching

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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 complexity of both the tasks ahead and the behavior of those who we prepare for the future. The problem, however, is 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, Barked, & Li, 2014), as well as broadly applied to constructing assessment tests in the fields of stages of social perspective-taking, general logic, problem solving, and other domains (Bernholt, Parchmann, & Commons, 2009; Commons et al., 2008; Commons et al., 2005; Dawson, 2002; Skoe, 2014).

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 focus on development within a particular domain, such as the moral, the social or the cognitive. The varying informational frameworks of different domains have often

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This research was supported by Dare Association.

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concealed the common underlying behavioral process of stage development. This makes standardization of research methods 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 et al., 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 use of computer-based instruction that simulates precision teaching of the MHC. Finally, we discuss problems in the initial methods of teaching the model and future directions.

The Model of Hierarchical Complexity

The MHC is both an enhancement and a simplification of Inhelder and Piaget's (1958) developmental model. Piaget and colleagues proposed that there is an invariant pathway along which stage development proceeds regardless of content area or culture (Piaget, 1976). In this theory, stages of development were described only for children and adolescents and were not applied across the life span There have been a number of other problems with this theory. For the purposes of this study, one of the most important ones is that in Piaget's research he did not systematically vary the difficulty tasks that that were administered to participants, but instead gave the same task to all participants. As a result of this method, he did not have an independent variable that he created and manipulated, and he had no way to definitely explain why different results were obtained with different participants. A related issue was that his explanations for why development took place were entirely mentalistic. According to Piaget, development occurred due to the development of internal mental schemas.

The MHC is a theory of task difficulty. This model is used to explain why stage-like behavior exists. More specifically, the MHC is a mathematical and logically derived formal system of measurement of tasks (Krantz, Luce, Suppes, & Tversky, 1971). The tasks are measured in terms of how hierarchically complex they are. This is called the Order of Hierarchical Complexity (OHC). When an individual successfully completes a task at a particular order they are said to have performed at that stage on that task (Commons & Miller, 1998; Commons & Pekker, 2008; Commons & Richards, 1984a, 1984b; Commons et al., 1998; Commons et al., 2014). The higher the order of hierarchical complexity the more difficult the task. In previous research (e.g., Commons et al., 2014), 17 orders of hierarchical complexity with examples have been classified and defined, as shown in Table 1. The MHC includes the four stages originally described in Piaget's work, but, in agreement with Pascual-Leone (1970) and others, splits each of those stages into two. It also includes adult stages beyond formal operations. As a result, it proposes that 17 stages can be observed.

To determine whether a task is one order more complex than another, the task's content must be shown to satisfy three axioms. These axioms are: the higher order task must be defined in terms of at least two tasks at the immediately prior, lower order of complexity (Axiom 1); the higher order task must organize the lower order task actions (i.e., the more complex action specifies the way in which the less hierarchically complex actions combine; Axiom 2); this organization or coordination of the lower order tasks has to be carried out nonarbitrarily (Axiom 3). 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, multiplying and adding (Axiom 1). To complete the task, that act nonarbitrarily (Axiom 3) orders or coordinates adding and multiplying (Axiom 2). 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. Higher levels of complexity are, therefore, found when components are combined to perform as required.

The Importance of Teaching MHC

One of the many domains to which the MHC can be applied to is the production of task analyses (Commons et al., 2014). A task analysis is a process that makes explicit the context, sequence of stimuli, and sequence of actions

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Table 1
Orders of Hierarchical Complexity With Definitions 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; various kinesthetic movements	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 and other words as successful commands	A word such as "cup" names the concept of a container of liquid.
6	Sentential	Imitate 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

(*table continues*)

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Table 1 (*continued*)

Orders	Performance	Definition	Corresponding verbal behavior	Example
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	Crossparadigmatic	Fit paradigms together to form new fields	Form new fields by crossing paradigms; put together relativity with quantum mechanics to form string theory	

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Table 1 (*continued*)

Orders	Performance	Definition	Corresponding verbal behavior	Example
16	Metacrossparadigmatic	Metacrossparadigmatic actions reflect on various properties of crossparadigmatic 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	

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that occur in a given task. The MHC can be used to analyze task properties and the performances that result from those tasks. One thus examines behavior accounting for the known complexity of the task. It is this examination that drives focus to the important building blocks which leaning is based on. Fluency in using the MHC permits administrators and clinicians to rapidly develop effective teaching strategies and to allow for the creation of sequences of training, rather than just isolated training tasks. It also allows researchers to classify the order of hierarchical complexity of a task they are studying, relative to other tasks.

Using Precision Teaching to Teach the Model of Hierarchical Complexity

Starting from 2008, Precision Teaching was employed as the new method to teach the MHC. Based on some of Skinner's notions of operant conditioning, it is derived from a quantitative scientific tradition pioneered by Ogden Lindsley in the 1960s (see Lindsley, 1992).

Precision teaching is a general approach to teaching, 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 to evaluate learning in terms of fluency (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 White (1986), precision teaching has been used successfully to teach 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. Utilizing Precision Teaching to teach the MHC, as per the three requirements of teaching the model, brought a framework that not only gave learners immediate feedback on their rate of acquisition, but also ensured all learners met the mastery criterion (Commons et al., 2014).

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 accuracy and frequency of behaviors 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 semilogarithmic SCC was used to record data for this study. The linear *x* axis represents day sessions or timings. Because 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 1-min trials instead of one day. The *x* axis is divided into increments of 10 trials, which in the present study represent one of the five sections into which the material was divided for presentation. Therefore, 0−10 is the first 10 trials completed, 11–20 is the second group of trials, and 21–30 is the third group of trials. Dashed lines indicate at which trial a participant opted to change section to either a simpler or more difficult module. The logarithmic *y* axis resents the count of behaviors per minute. Fluency, then, is measured by dividing the total number of accurate responses by the total number of opportunities by the time responses were counted, 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, were all recorded in a four-column table and on the SCC.

Displaying growth in the rate of responding logarithmically on the *y* axis 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. Using a normally 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.

Whereas the fluency of behaviors on the SCC clearly illustrates student performance at a given point in time, Precision Teaching emphasizes the importance of accuracy and fluency of the performance (Johnson & Layng, 1992). 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 Precision Teaching methods used in the current study.

Problems in Teaching MHC

After attempting to teach the MHC using traditional lecture and practice methods, researchers began instead to use Say All Fast, a Minute Each Day, Shuffled (SAFMEDS) to present the material. All participants that attended workshops teaching MHC with Precision Teaching reached the mastery criterion of 90% (Commons et al., 2014). Yet, in a follow-up questionnaire, earlier conference attendees reported that SAFMEDS was rather monotonous, boring, and sometimes difficult with all the cards.

Because instructional designers should arrange the technology of tool in a way motivates, energizes, and sustains change efforts, the purpose of this research was to use computer-based instruction, instead of SAFMEDS, to teach the MHC with Precision Teaching. Creating a computer-based teaching model required changing SAFMEDS based delivery of a see-say learning channel into a see-do method of responding. Learners instead of seeing an example of a task on a card and saying the stage number would now instead see the example and select the stage number among a list of possibilities. Test examples could would now be novel thus extending beyond memory and the recall level. We were now testing participants on their true understanding of the concepts being taught (Tiemann, & Markle, 1991). A scientific approach to development of a computer-based program requires a process of formative evaluation consisting of the single organism approach and careful monitoring and assessment of program effectiveness (Layng, Stikeleather, &

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Twyman, 2006). And recording learner progress on the Standard Celeration Chart not only provides immediate feedback to learners showing where they are in the program indicating how to proceed, but also to instructional designers showing effectiveness of program indicating changes that might be made to better facilitate learning (Binder, 1988).

Method

Participants

Data were collected from 68 attendees that attended a workshop teaching MHC, 10 of which attended a workshop that was given at the *Society for Research in Adult Development* (SRAD) in 2015, and the other 58 attended a workshop on MHC given at *Shandong University, China*. The participants in the U.S. attended a workshop in which their work within the teaching program was discussed and reinforced by experienced users of the MHC. In China, because of Internet difficulties, many of the participants were either not able to get into the program until the workshop was almost over, or alternatively, may have at a later time accessed it on their own away from the University. As a result, these participants did not have the same degree of support as those in the U.S. The often only completed just one module. The educational backgrounds of the participants ranged from college students enrolled in undergraduate programs to individuals particularly in China who were either in teacher training programs or were working as teachers in schools in their country.

Materials

The materials used in the workshop consisted of a computer based program that provided content to review, instructional modules, and following completion of items within a module, produced digital standard celeration charts (SCC's) for learners to monitor their progress. This computer-based instructional method taught MHC through 6 different modules, 5 learning modules and a final test module with novel examples. (a) The first section required participants to match stage name with stage number; (b) the second section required participants to match stage characteristics with stage name; (c) the third section required participants to score a variety of tasks at different stages and select a rationale for their answer; (d) the fourth section required learners to score more tasks embedded in a short story and select a rationale; (e) the fifth section required learners to score more complex stories and select a rationale; (f) the sixth section required learners to score novel tasks presented in a variety of contexts. Participants could practice on a sequential set of problems before testing their knowledge on a randomized set.

Even though the content of the tasks within one section included materials to be learned about Orders 5 through 13, the order of hierarchical complexity and the difficulty level of the task within a section remained the same. For example, during the first section, participants were required to match stage names to stage numbers for each of the stages being learned about (that is, 5 through 13). The task of matching stage names to stage numbers was at the same order of difficulty irrespective of the specific stage they were learning about.

At the same time, each subsequent section was more complex, or difficult, than the previous section because the subsequent one combined the elements from the previous one. The first section's task was at Order 8, the second section's task was at Order 9, and so on, increasing to Order 13 for the fifth section's task. That is, the sections followed the order of hierarchical complexity, in which higher order elements are the combination of lower order elements. Because of this structure, correct performance on the part of participants is inferred based on their demonstration of fluency on the current task they are working on and serves as a cue for them to initiate learning the task in the next section. For example, section 1 presented the name and number of the order of hierarchical complexity, which are paired-associate repertoires necessary for successful completion of successive repertoires. In section 2, definitions of orders were presented in which the names and numbers previously learned in the first section were used.

The topics and descriptions of the representative content of the six sections are shown in Table 2.

Table 2
Section Exercise, Content, and Instruction

Section	Exercise	Material and content presented	Instruction
1	Identify corresponding numbers of the MHC order presented	Materials and content presented MHC order name and corresponding number	Each presentation lasts one minute, so work as fast as you can. Do not read everything if you do not need to.
2	Enter order of MHC when presented with definitions	Materials and content included descriptions and examples of orders of the MHC	Each presentation lasts one minute, so work as fast as you can. Do not read everything if you do not need to.
3	Score order of presented task and provide rationale	Materials included axiom rules; example tasks that explained which axioms are violated. Content was experimenter-generated tasks.	Each presentation lasts one minute, so work as fast as you can. Do not read everything if you do not need to.
4	Score order of presented task and provide rationale	Example tasks were drawn from Counselor-Patient vignette	In the following short groups of sentences, please determine the stage. After you correctly identify the stage, you will be directed to two questions. The first question will ask you to identify the reasons why that sentence or statement was at that particular stage. The second question will ask you why that sentence or statement was not at a higher stage. Each presentation lasts two minutes minute, so work as fast as you can. Do not read everything if you do not need to.
5	Score order of presented task and provide rationale	Example tasks were taken from Counselor-Patient interaction vignette	Read all five vignettes in the Counselor-Patient Interaction carefully. Score the stage of each vignette. Identify components of each vignette: Variables, Relations, Systems, Relations among systems. Each presentation lasts one minute, so work as fast as you can. Do not read everything if you do not need to.
6	Score novel tasks and provide rationale	Example tasks included experimenter-generated tasks that included a variety of domain in tasks	Each presentation lasts two minutes minute, so work as fast as you can. Do not read everything if you do not need to.

Note. Content covers the MHC orders from Nominal (5) through Metasystematic (13). Content was presented before exercises.

Procedure

U.S. participants sat in a chair facing a computer screen. In China they worked on portables or cell phones. In both the U.S. and China, they were instructed to create an account and sign in. Once participants were signed in, they were provided with general introductory information

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regarding MHC, Precision Teaching, and rules for progressing through the program. Rules of advancement read, "If the rate of response is stagnant then we move on to random order of questions. The User should move on to the next test if they can answer the question quickly. If one is missing a lot of items, please go to an earlier test, practice, and then move forward. This will help in terms of getting answers automatically."

Each module began with a start screen that provided brief instructions and content relevant to the module. Each module was timed. Participants were allowed to answer questions until they answered each question or their time was up. Each module lasted one minute except for modules 4 and 6, which lasted 2 min, because they had twice the amount of possible questions as the other modules. At the end of each module, participants saw the total number they got correct out of the total possible points permitted by that specific module. Participants were also encouraged to look at a program generated Standard Celeration Chart that recorded participants progress. They could then choose to go on to the next module, or to go through that module again.

The total time length of the workshops was three to five hours.

Results

Results are shown on the included Standard Celeration Charts. The computer-based program generated charts participants could view upon the completion of each trial. The data from the charts were entered individually into an 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. Six SCC charts for the participants from the U.S. are shown. The remainder of the participants did not complete enough of the workshop to be included in the analysis. For the Chinese participants, only those who completed more than the second module are shown. This resulted in charts for nine Chinese participants. In all charts, the circles depict correct answers and the "X" depicts incorrect answers. Dotted vertical lines indicate when participants change sections. The sequence of sections completed for each participant is indicated in the captions under each chart. While analyzing the results, experimenters quickly discovered a programming error that was not accounted for prior to testing. The program scored questions unanswered in a given trial as incorrect. So if there were 22 questions in a trial, and the participant only got through 5, and answered them all correct, the data would show 5 corrects and 17 errors. This deflates the use of the SCC as an analytic tool informing program changes and will have to be corrected in future workshops.

The frequency of correct responding accelerated and frequency of incorrect responding decelerated for participants who followed program instructions and worked on each section until they were answering each question presented correctly. The frequency jumped down at each module change. And each module had a lower frequency overall than the former because of its increased difficulty and the amount that has to be read. Even those who did not proceed as instructed showed an increase in frequency of correct responding. Yet all included participants showed persistent errors, or at the least, very low correct answer rates. Transfer trials reflect chance level across all participants. Average percent correct for transfer trial for participants who completed the transfer task is 14%; scores ranged from 5% to 20% correct. The 20% correct came from a participant who attempted to discover relevant variables while scoring. Others who made prior decisions by irrelevant factors fell to much lower levels of responding. One would expect that with only one transfer task, there would be very low degree of transfer. It takes training on at least three transfer tasks to get generalization (Baer, Sherman, 1964).

Participants reported responding to features irrelevant to the identification of stage. These biases varied across participants, although some reported patterns included responding to proper nouns used in examples and responding to the sequence of question presentation. Participants also reported wanting more time to complete each exercise.

Discussion

No participants reported the workshop to be boring or tedious. Participants were observed working through announced breaks. They kept working on the program. This is an advancement over our last workshop, where participants more quickly bored. Gone are the days where students should work tediously; instructional designers should strive to ensure the programmed instruction ignites interest and engages learners resulting in greater tendency to approach the subject matter (Mager, 1997). Showing participants how well they performed at the end of each trial, along with showing them the best score in the workshop, for that section, generated participants who were eager and devoted to learning the MHC.

In this case, we would argue that the low correct response rates seen did not reflect a lack of involvement in continuing within the program. The fact that participants were observed to move into the next section, and in several cases up to 5 sections, provides further support for the idea of high engagement.

At the same time, response bias developed for nearly all participants. Each individual bias competes with the development of correct conceptual responding. A critical component to the production of effective instructional design is the formative evaluation process, which makes use of performance data during developmental testing to revise the design (Hendrix & Tiemann, 1971; Twyman, Layng, Stikeleather, & Hobbins, 2004). Most participants failed to transfer scoring skill to the only novel instances successfully. But with only one transfer task, this would be expected. Experimenters need to draw more upon the "technology of process" to enhance the effectiveness of the computer-based instruction (Layng & Twyman, 2013). Revisions to the program, to preempt error formation, are often done through one-to-one discussions with participants (Layng, 2014). It is important that "technology of process" be considered when integrating "technology of tools" for instructional purposes (Layng & Twyman, 2013).

Design Modifications

Nearly all participants reported answering questions by features not relevant to scoring. The question to instructional designers becomes, how do we potentiate responding to features relevant to scoring stage? There have been many approaches to correcting or transferring controlling relations include adding counterweight measures into the procedures. If learners are "incorrectly" attending to sample sequence of problems, sequence is then randomized. If learners are "incorrectly" attending to irrelevant features, these features are then rotated. These attempts often increase responding to 90% on training material, yet when probed further the bias tends to reappear (Iversen, 1993).

SCC charts identify the moment guessing or bias formation occurs. Teaching MHC with Precision Teaching allows instructional designers to avoid development of bias by not providing occasions to respond where appropriate responses have not yet been established in the future or providing information to guide correct responding. One possible solution for this would be to provide a rejection response so as to avoid guessing and the development of unwanted stimulus-response topographies; another is to design a system that establishes responding to criterion-related cues (Ray & Sidman, 1970). Guessing, as indicated by errors, for each participant, began in the second section until indicators of correct responses were abstracted through several attempts. The next revision to the program will attempt to avoid the incorrect responding that occurs during each phase change.

Another confound that needs to be addressed is the amount of reading necessary to answer the questions on Section 5, as indicated by the low frequency of correct responding relative to other sections. The extra reading constrains the accurate number of responses that can occur. Future revisions to the program will look to develop an equation, based on reading rate and amount of reading necessary to answer the problem accurately, and amount of irrelevant material in the problem, and it will adjust how the data is reported back to program designers.

Conclusion

As discussed above, the material provided increased in complexity as participants progressed. Repertoires being taught consisted of multiple categorical relations. Participants had to first get the categories of the MHC, and then they had to apply these categories to different examples (Layng, 2014). The prompted, or sequenced test, had stages in sequential order, and maximum performance reflected reading; however, when order was randomized, there was a

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dramatic decrease in frequency. As sections progressed, so did difficulty; thus, terminal frequency was always lower. Overall, most of the people who took the workshop in the US were scoring correctly after just one other session with feedback.

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Appendix

Charts From the Society for Research in Adult Development (SRAD) Workshop Participants

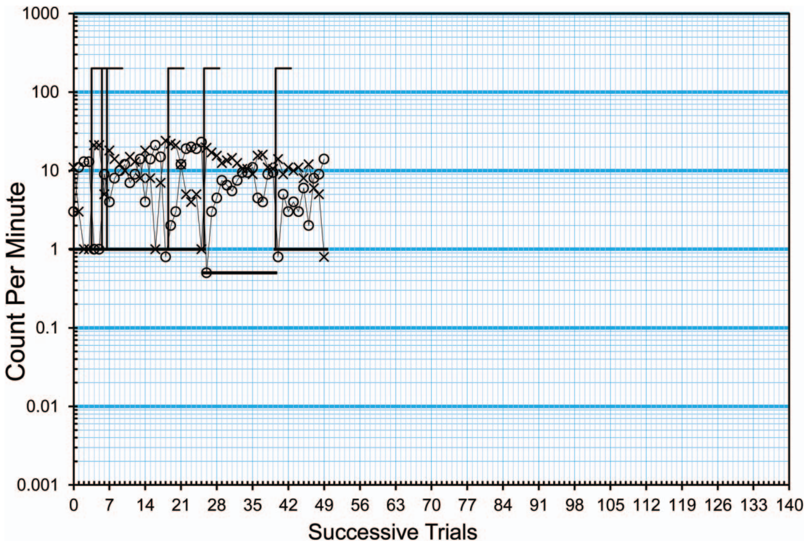

Figure A1. SRAD1 performance reached 100% correct ("o") and 0% incorrect ("x") upon completing sections 1, 2, and 3. Dotted vertical lines indicate when participants change sections. The sequence of sections completed for each participant is indicated in the captions under each chart. Sections 4 and 5 show an increase in frequency of correct responding, but also reflect below chance level responding. Order followed was 1,2,1,2,3,4,5.

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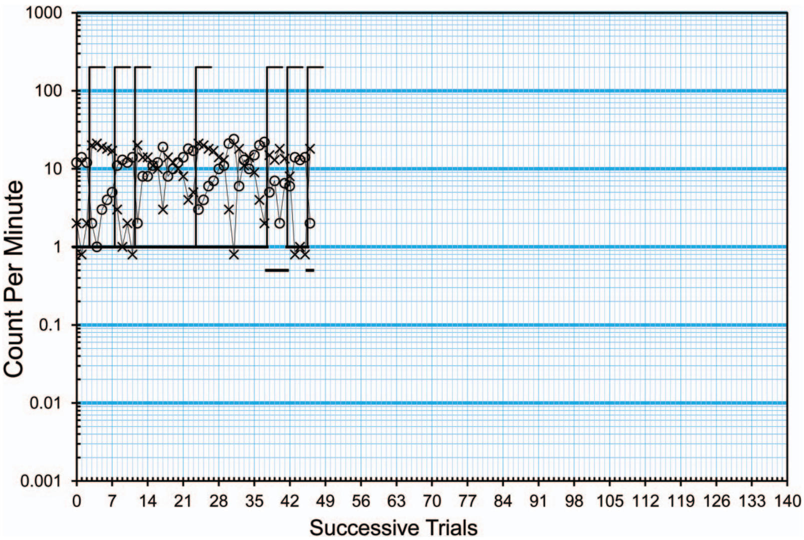

Figure A2. SRAD2 reached 100% correct and 0% incorrect in sections 1, 3, and 5. Responding in other sections reflects chance level. Percent correct in transfer task dropped to 10%. Order followed was 1,2,1,2,3,4,5,T.

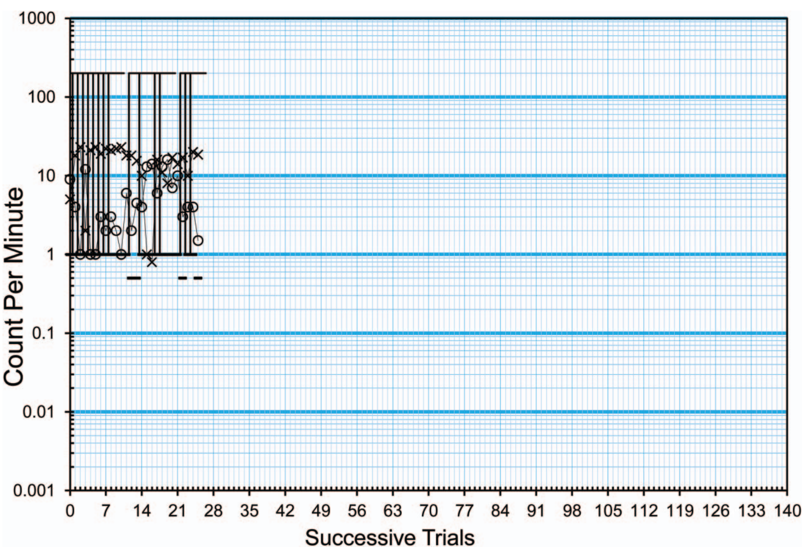

Figure A3. SRAD3 reached 100% correct and 0% incorrect in Section 2. Correct responses remained high and there were more correct responses than incorrect across all sections. Errors persisted into the transfer task where percent correct was 15%. Order followed was 1,2,3,1,2,3,2,3,4,5,2,3,T,5,3,4.

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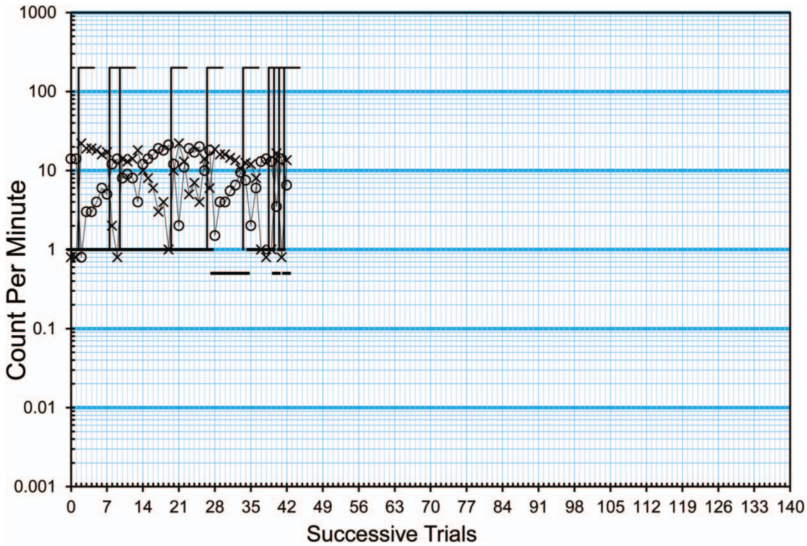

Figure A4. SRAD4 reached 100% accuracy upon completing sections 1, 2, 4, and 5. Section 3 had an observable increase in frequency of correct responses, yet there were also persistent errors. These errors persist into the transfer task where percent correct was 17.5%. Order of modules followed was 1,2,1,2,3,4,5,T,5,4.

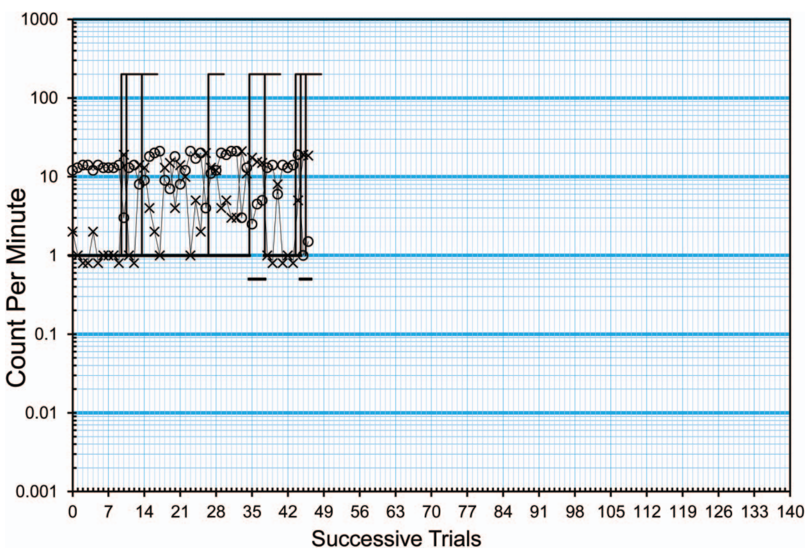

Figure A5. SRAD5 reached 100% accuracy in sections 1, 2, and 4. This performance did not maintain across consecutive trials in section 3. Errors continued to reappear after consecutive trials without errors. These errors returned during Transfer trial where percent correct responding was 5%. Order completed was 1,2,1,2,3,4,5,3,T,4.

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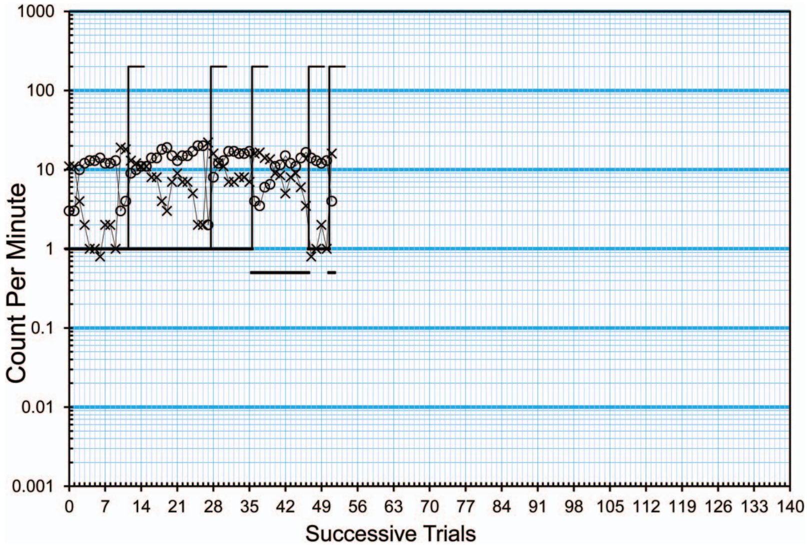

Figure A6. SRAD6 data showed acceleration of accuracy across all sections. This resulted in 20% correct response rate on transfer task. Order completed was 1,2,3,4,5,T.

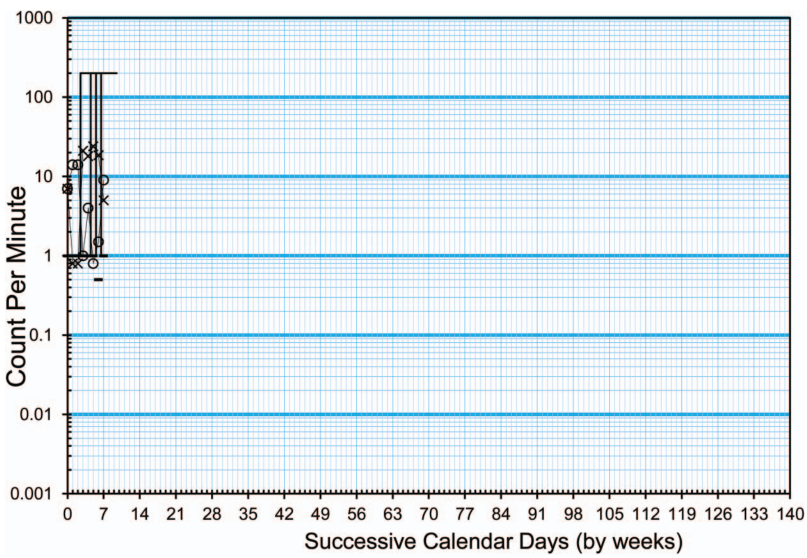

Figure A7. Shan1: Order followed was 1,2,3,4,5.

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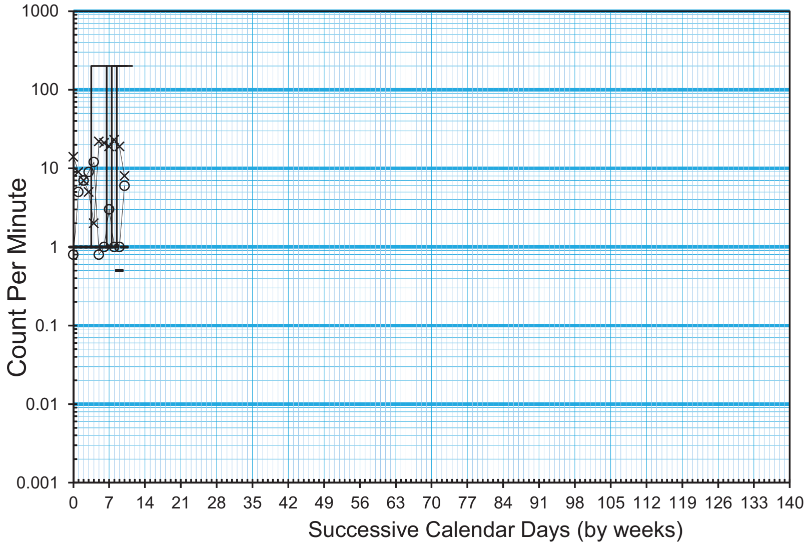

Figure A8. Shan2: Order followed was 1,2,3,4,5.

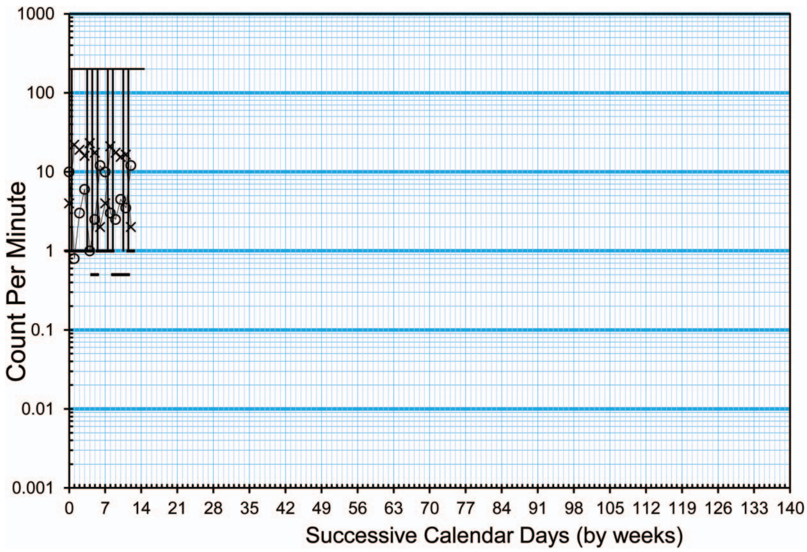

Figure A9. Shan3: Order followed was 1,2,3,4,1,3,4,T,5.

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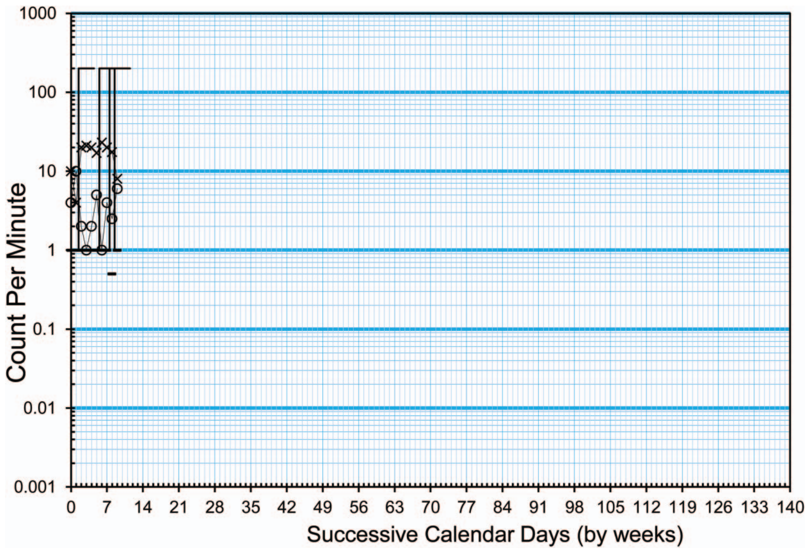

Figure A10. Shan4: 1,2,3,4,5.

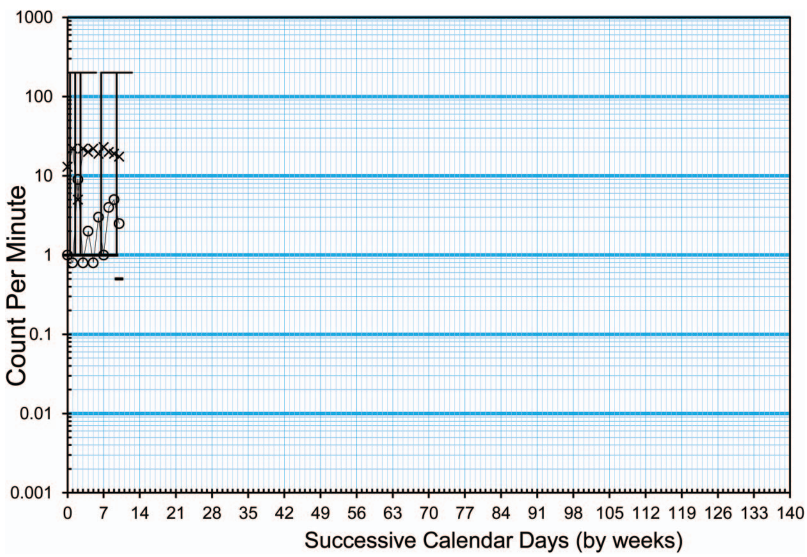

Figure A11. Shan5: 1,2,1,2,3,4.

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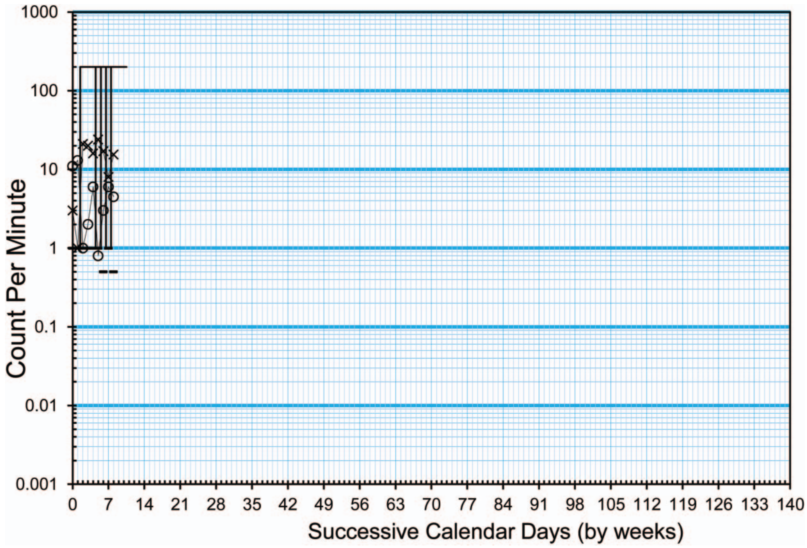

Figure A12. Shan6: 1,2,3,4,5,T.

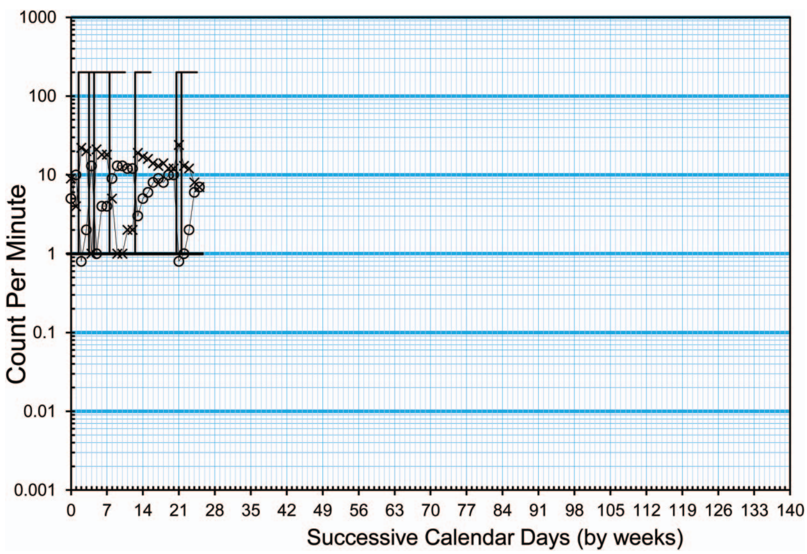

Figure A13. Shan7: 1,2,1,2,1,2,3,5.

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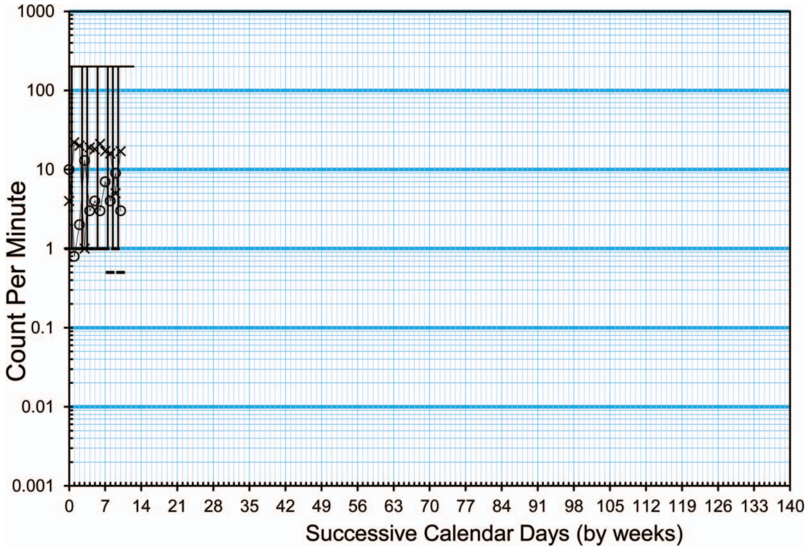

Figure A14. Shan8: 1,2,1,2,3,4,5,T.

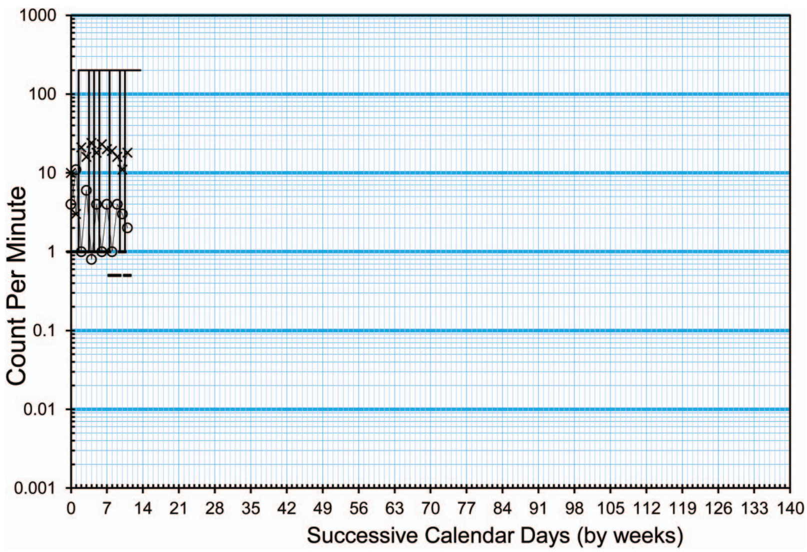

Figure A15. Shan9: 1,2,3,2,3,4,5,T.

Received August 15, 2015
Revision received September 28, 2015
Accepted October 8, 2015 ■

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