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A Basic Evaluation of Distraction

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in Psychology

by

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Abstract

The author developed and applied a laboratory preparation to evaluate the effects of distraction on performance under varying conditions. "Distraction" occurs when there is suppression in the frequency of a response. There are often contextual stimuli in the environment that prompt responding despite having no prior or specific stimulus control over that response. There are also stimuli that prompt observing responses but not directly competing responses. The current study specifically investigates types of distracting stimuli which exert stimulus control and prompt directly competing responses that interrupt responding, as well as those which prompt observing responses but do not necessarily prompt a competing response. Training approaches are typically validated when successful under conditions present in the natural environment; previous research on distraction demonstrates difficulty controlling and isolating the relevant variables in that context. This laboratory preparation uses sensitive measurement systems such as the Standard Celeration Chart and the cumulative record to observe moment to moment responding as distractions are introduced. It also allows for quantitative evaluations across and within different modalities of distractors. Although further analyses are warranted, prediction of behavior under "distracting" conditions has been accomplished here in a way that has not been accomplished previously. Data indicate that distractors which directly compete for stimulus control with response requirements for a task at hand result in the greatest response suppression. Stimuli that did not prompt a response that directly competed for stimulus control had less suppressive effects on responding.

Keywords: distractors, analog preparation, cumulative record

Dedication

I dedicate my dissertation work to my family, friends, and many colleagues who have been a part of the history that has shaped my interests and dedication to behavioral science. A special thanks to my loving parents, Michael and Rosemary Nosik whose words of encouragement and support over the many years provided the additional push to accomplish this milestone. My sisters Veronica and Jennifer have never left my side and are very special to me.

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A Basic Evaluation of Distraction

Before pursuing a Ph.D. at the University of Nevada, Reno, I spent five years as a behavior analyst practitioner. Entering graduate school gave me an opportunity to address problems that I witnessed in the clinical world. Managing staff performance is difficult given limited control of organizational management entities. The amount of time and funding typically provided to teach and train staff is minimal. Additionally, research in training direct support therapists tasks such as discrete trial instruction has become very important due to the successes of early intensive behavior intervention (EIBI) (Lovass, 1981; Lovass 1987; Smith, 2001; Tarbox and Najdowski, 2008) for treating children with autism.

Tom Gilbert's (1978) behavioral engineering model ideally should be used to improve staff performance outcomes because of its focus on distinguishing between performance (employee production, outcomes), individual (knowledge, capacity, and motives), and environmental factors (data, instruments, and incentives). Binder's (1998) Six Boxes® approach expands upon this model and provides a non-technical way to train managers to align variables to improve performance, analyze problem areas, plan effective implementation, communicate organizational change, and support management practices. When using this model with a dimensional measurement system some informative data could be gathered, unlike empirical studies that have previously addressed training in mainstream journals. Dimensional measurement and the Six Boxes® model provided the starting point for this exploration into environmental variables that affect responding. Ultimately, use of inductive methods in the development of an appropriate laboratory preparation was the guide to a more primary focus on distraction.

The initial purpose of the current research was to create a laboratory analog preparation of a commonly used applied teaching procedure such as discrete trial instruction. In establishing a laboratory preparation, procedures and measurement systems take time to be developed and tested. We created software with the assistance of a programmer that allowed us to present sequences of paired associates to university student participants. We started to see orderly data and evaluated variations to the length and discriminations in sequences at different levels of performance accuracy. This laboratory preparation yielded learning and error patterns that have already been demonstrated in the precision teaching literature. Tasks with conditional discriminations were more difficult to learn and resulted in more errors. Performers that demonstrated perfect accuracy plus practice on tasks showed better stability and retention than those with less-than-perfect accuracy. We then investigated the suppressive effects on sequential performance of visual distractors that prompt an observing response, which were analyzed using cumulative records, allowing for observation of the effects of those stimuli in real time. After some software modification of the output data, we were able to then use the cumulative records of all responses, following which the data gathered show a definite, orderly impact on the cumulative records of responding, worthy of further research in this area. The current investigation includes many of the experimental preparations followed as we progressed through refinements to the software and methods.

Given the amount of extant research that may be overlooking the potential significance of distraction, it is an ideal candidate for investigation. Research in this area is especially significant for application to precision teaching and training. In training, approaches are determined effective when there is evidence that the participants receiving training are able to perform well in a "natural environment"; however, further description of the range or type of distractors in that environment is lacking. Similarly, precision teachers evaluate performance stability and endurance by measurement in the face of distraction, also without any definition or standard regarding what is used as a "distractor."

Distraction is a term generally used to describe ambient "noise" (visual, auditory, tactile). Characteristics of "distractors" can be classified in terms of stimulus control that might help to better identify the stimulus properties most likely to affect responding. The use of a laboratory preparation to investigate the role of distraction in acquisition provides an environment of isolation and control as different types of distractors are introduced. This preparation, when paired with the use of direct measurement tools (standard celeration chart and cumulative records), provides a real time view of responding in the presence of distractors. This approach differs from other research on distraction, which often use indirect measurement systems such as latency based trials and percent correct of task accuracy (Demeter, Sarter & Lustig, 2008; Cohen, Ivry, & Keele, 1990; Singer, Cauraugh, Murphey, Chen, & Lidor, 1991). This change results in more sensitive data collection that affords enough detailed data to allow for the use of a suppression ratio to quantify observed suppression of responding as distractions are introduced. Describing the data in this way allows for an analysis of the stimulus control that such distractors exert over desired behaviors, and serves as a step in the direction of better prediction and control of these effects.

Attention and Distraction

Stimulus control is a key feature of a behavior analytic account of attention and distraction. Stimulus control is defined as the frequency, latency, duration, or amplitude of a response being altered by the presence or absence of an antecedent stimulus (Cooper, Heron, & Heward, 2007). Throughout this paper, the word 'attention' will be used to refer to the situation where stimulus control is present and the organism is consistently responding only in the presence of some discriminative stimulus in the environment. Similarly, distraction occurs when environmental stimuli prompt directly competing responses, have no prior specific stimulus control and are just "noise," or prompt an observing response. These distracting stimuli differentially impact the stimulus control exerted by the discriminative stimulus; sometimes observing the impact of these stimuli requires very sensitive measurement.

I have been known to become so immersed in computer tasks at times that friends and co-workers have to make loud sounds to get any response (luckily these people are generally forgiving). At times, the consequences for not attending can be much less pleasant. Stimuli in our environment are constantly competing for our attention and, most often, consequences determine which will win. Schneider (2012) articulates this well:

> You are on the Internet when a pop-up suddenly chimes and animates, grabbing your gaze and your attention. This unlearned orienting reflex follows Pavlovian principles. More often, though, what wins our attention follows the consequences that matter to us. We learn to ignore those time-wasting computer pop-ups to focus on what we should be doing (most of the time, anyway). (p. 127)

What we attend to and the events that “distract” us may at times be reflexive, but most of the time this is operant behavior, and responses emitted depend on an individual history of reinforcement.

When multi-tasking, or attending to multiple things at one time, there are many environmental events presented simultaneously. Schneider (2012) suggests that we often ignore things that are not historically linked to salient consequences. Some people are able to attend to only one conversation at once; others may participate in two interesting interactions at the same time. Hearing your name is a stimulus that may grab your attention depending on how valuable the competing event is at a given time. It is also possible that a person could become so immersed in something that they could fail to notice events in their environment that have serious consequences, such as the sound of sirens or the stop sign on the corner.

Environmental contingencies play an important role in what we attend to and what we do not. For example, I had an interaction with a parent whose son has autism and is particularly skilled at object and facial recognition and labeling. She spent 15 years taking him with her everywhere she went. When he moved into a community group home and she began working without him by her side, she reported struggling to remember the names of people that she recently met. Her son would say everyone’s name before she even could think to do it and now she had to remind herself to attend to those things. Similarly, after years of relying upon the appointment calendar in my phone, it is rare that I can recall my daily meeting schedule without assistance. There also seem to be some similarities and patterns to what a person attends to across cultures that have similar social contingencies, such as the tendency of drivers who have a history with sirens and emergency vehicles to pull aside to allow passage upon hearing an ambulance.

Under some circumstances, we can observe and measure external environmental stimuli that affect performance. However, some of these stimuli are unobservable and/or are more difficult to measure and control. Watson (1924) defines behavior by its form, describing it as simply muscle movements and glandular secretions. His methodological perspective reduces all activities of an organism to those events. Watson's behaviorism relies on public agreement within the scientific study of human behavior: from this perspective, without public agreement occurrence is impossible. In contrast, Skinner's radical behaviorism adopts a selection by consequences approach, which includes all behavior, even thoughts and feelings. These stimuli are important to consider in a science of behavior because they influence how an organism behaves in each instance of responding. A fluent therapist delivering discrete trial instruction may continue to perform speedily and without error even while thinking about other things. An observer would not even recognize the therapist was actually making a list of groceries, for example. On another occasion, while observing the same therapist in a new environment, she makes multiple errors. Was it just the unfamiliar setting? Was it the combination of the unfamiliar setting and the grocery list? When investigating the role of distractions on performance, these variables both affect behavior and are difficult to control. In the current study, we attempt to account for these variables by using a direct measurement system to establish functional relationships between contrived distractors and performance.

Within the behavior analytic literature, the most notable of investigations on this content area comes from an unpublished manuscript written by Carl Binder (1979c). During the early 1960s, B.H. Barrett applied functional behavior analysis in her Behavior Prosthesis laboratory. Barrett was a student of Lindsley and Skinner and relied upon cumulative response records of behavior frequencies as the basic measurement and analysis technology. The work in Lindsley's lab resulted in a technology called precision teaching, where students and teachers used standard frequency measures and the Standard Celeration Chart (Pennypacker, Koenig, & Lindsley, 1972). In Barrett's lab, Binder created a free-operant analog of automaticity experiments (distraction) conducted by cognitive psychologist LaBerge and Samuels (1974). Laberge and Samuels used latency-based trials in their evaluations of this phenomenon. Binder evaluated reading numbers, saying answers to simple addition problems (sums to 18), reading printed Anglicized names of Hebrew characters, saying numbers in response to the names of Hebrew characters (learned through a previous paired associate task), and adding Hebrew characters by using the previously learned paired associate to assign number to the characters (a stimulus equivalence task). He had the participants perform the task by reading from practice sheets out loud into a microphone. The microphone was attached to a voice-operated relay with electromechanical equipment for counting and recording responses on a cumulative recorder. After completing the tasks multiple times, experimenters introduced a set of headphones through which the subject would hear random numbers while completing the task. In this arrangement Binder used ongoing or "narrative" stimuli versus discrete stimuli. A suppression ratio was calculated by using the average frequency before the distraction and dividing it by the average frequency after the distraction in order to quantify observed effects (Estes & Sinner, 1941). The suppression ratios and dips in the cumulative records reflect suppression in responding associated with the distracting stimulus. This initial data set, though in need of replication, may indicate that lower performance frequencies may be associated with great distractibility, measured as relative suppression of responding during presentation of an external stimulus. Most importantly this design applies free-operant laboratory methods to measure distractibility as an alternative to the less sensitive latency-based trials procedures used by cognitive researchers and by some behavior analysts (Binder, 1996). The current research provides some support of the idea that an organism that can maintain response frequencies over time in the face of distraction is demonstrating well-measured endurance.

Stimulus Control

In a technical definition by Dinsmoor (1995a, b), he describes stimulus control as occurring when multiple aspects (the rate, latency, duration, or amplitude) of a response are altered in the presence of an antecedent stimulus (an environmental event). For example, when I am driving and approach a red traffic light, I am more likely to press the brake when the red light is present versus when it is absent. This might be described as the red light (environmental event) having stimulus control over my brake pressing response. Environmental events acquire this type of control when responses occurring in the presence of those stimuli produce certain consequences more often than they do in the absence of those stimuli (Cooper et al., 2007). The stimuli in the environment that acquire control over certain responses have been further categorized as discriminative stimuli and are characterized by the specific type of effect they exert on responding (increasing, decreasing, or no response at all).

With respect to distraction, stimulus control is relevant because it is what occurs when stimulus control is exerted by more than one stimulus at the same time and disrupts responding in a particular way. In other words, more than one environmental event (stimulus) can exert control over behavior; sometimes the stimulus prompts a competing response, sometimes an observing response, and at other times stimuli that have no prior history of stimulus control can, under certain circumstances, acquire control, all of which can cause disruptions or reductions in response patterns.

Motor Performance Tasks and Distraction

Distraction is difficult to operationally define because what is distracting varies between individuals and across different responses and/or situations, which includes environmental and historical variables. As mentioned earlier, in behavioral terms, distraction is defined with respect to stimulus control. Hirsh and Burk (2013), define distracting stimuli as those that disrupt the ability to focus on cues (discriminative stimuli) that indicate important outcomes for an organism. In a conversation a person might participate in different ways: listen closely, hear, but not completely, or look and nod, but be attending partially to something else. Distraction occurs when we are “attending partially”; when we are unable to respond fluently and effectively with respect to certain stimuli because of the presence of other stimuli in the environment. When these other stimuli exert stimulus control covertly, it presents a challenge for researchers attempting to evaluate their role in the observed behavior of the organism.

When environmental stimuli exert joint control under conditions where an organism is responding to one primary stimulus, they are more likely to make errors in responding to those events. Hemond, Brown, and Robertson (2010) conducted a study on distraction and whether it impairs or enhances motor performance. The authors suggest that there is potential for certain distractors to enhance performance if the characteristics of the two tasks are similar. They manipulated the tasks they requested participants to complete while engaging in a driving simulation. As a measure of how well participants performed across three tasks, authors used the difference in response time between sequential and subsequent random position trials. For example, it took an average of 25 seconds to respond during the sequential condition versus 36 seconds on average to respond during the random position trials. This arrangement provides a widely used, sensitive, and specific measure of motor sequence performance. Adding a distractor element - in this case asking participants to count the number of stimuli - impaired motor sequence performance. In contrast, when participants learned a color sequence and identified them during their performance, outcomes were greater than under conditions where they were counting or determining position of a visual stimulus. Learning the color sequence (similar characteristics) enhanced performance of the independent motor sequence task.

Nissen and Bullemer (1987) used sequencing tasks in their evaluations of distractors and their effects on motor performance in individuals with memory disorders. The study evaluated how motor performance was impacted by participants' attention to the sequences. Subjects in this study performed a serial reaction time task comprised of a repeating 10-trial stimulus sequence. A few characteristics of their task should be noted.

First, learning of the sequence may be categorized as associative learning involving the acquisition of associations between stimuli and responses or *response sequences*. Second, their sequence did not require remembering an already existing sequence, but rather the production of new associations. Third, in their task each stimulus consistently specified a particular response and, more importantly, it employed a fixed stimulus sequence and a fixed response sequence. This study was focused on outcomes related to memory disorders and ability to learn new sequences. In their work, Nissen and Bullemer were able to establish sequences of paired associates presented on a variable schedule, which serves as a foundational preparation for investigations of distraction.

Similarly, Cohen, Ivry, and Keele (1990) investigated the role of attention, sequence structure, and effector specificity in learning a structured sequence of actions. Four experiments addressed different parts of these questions. These studies demonstrated that simple structured sequences could be learned in the presence of distraction, and only structures with some unique associations can be learned under attentional distraction. Additionally, they found using varying presentations of the structure important because it requires attention to stimuli.

In applied behavior analysis, teaching people to use behavior change tasks is important. The effects of distraction on motor performance should provide information about how to best teach these skills (Banbury, Macken, Tremblay & Jones, 2001; Sarter, Gehring & Kozak, 2006; Zhang, Smith, & Witt, 2006). In a laboratory preparation using rats, Hirsh and Burk (2013) evaluated the role of distraction in learning new motor tasks. As previously stated, the authors define distracting stimuli as those that disrupt the ability to focus on cues that indicate important outcomes for an organism. They used the term 'attentional effort' described by Sarter et al. (2006) for the process to restore task performance following a variety of demands, such as distracting stimuli. In applied research "attentional performance" might be considered adherence to a treatment protocol (treatment integrity) under demanding conditions and is recognized as critically important (Banbury et. al., 2001; Zhang et.al, 2006). Initial distractor exposure decreased overall accuracy of task performance in this study. However, participants exposed to the distractor exhibited higher accuracy of performance and reached above-chance performance more quickly in a new light-location discrimination task compared to those that were not exposed to the distractors. Multiple factors, such as the modality, severity and duration of the distractor as well as the nature of the information to be learned, are important factors to study to further understand the effects of distraction on learning.

Modality of Distraction

Research has focused on evaluating the types of distractors and how they differentially affect performance based on the sensory modality. Singer, Cauraugh, Murphey, Chen, and Lidor (1991) investigated the influence of auditory and visual distractors on two different motor tasks. In this particular study, they used an attentional-focus training program to overcome external and unpredictable distractor occurrences. The authors acknowledged that covert distractions (private events) may affect performance but are not observable. Additionally, Singer et al. point out that a limited literature describes self-paced, repeated-performance motor skills, attentional processes, distractors, and attentional-training programs. The authors hypothesized that an attentional-training program would serve as an effective strategy in aiding performers to successfully execute two motor tasks in the presence of auditory and visual distractors.

There were eight treatment conditions crossing two levels of attentional training and four levels of distractors (noise, light, noise and light, and no distractor). Ten subjects were randomly assigned to each treatment condition. Subjects either threw paddleballs at a target underhand with their non-dominant arm or threw overhand with their non-dominant arm. In between sessions, a divisionary task was used to occupy the subjects and keep them from thinking of tasks performed by other individuals. Overall, data indicated that the attentional-focus training group was more accurate and consistent than the no-attentional training group early and later in learning. Better performance was found under the separate noise and light distractor conditions in comparison to the combined distractor condition.

However, Hockey (1970) argued that performance disruption is only partially determined by the physical properties of the distractor. The perception of a nonthreatening external noise and/or light stimuli may minimize their overall effect as a distractor. The focus on attentional-training resulted in subjects that were more adaptable to the distractor conditions. Hockey noted that in most cases, when training is occurring, the objective is to be cost efficient (provide the most training in the least amount of time). Favorable learning conditions under which tasks can be performed predictably and in a stable manner seem relatively easy; the challenge is generating adaptable and consistent performers.

Kim, Carr, and Templeton (2001) conducted a study where they trained three participants to say the English translation when presented with a Hindi character on a flash card. After the experimental participants could accurately and consistently respond at a certain criteria during a one-minute long timing, the researchers conducted an endurance probe during which participants engaged in the targeted task for 20 consecutive minutes. Next, a distractibility probe was administered. During this probe, the participants were required to respond to the targeted stimuli in the face of “distractions” during a 20-minute long timing. The programmed distraction consisted of the participant and another person engaging in the same task simultaneously. The results of this study showed that the participants were able to respond to the stimuli at the same rate for an extended period of time, regardless of the present distraction, which allowed for the identification of a suitable range of responding for that task. In precision teaching, this range is often called an “aim” and will be referenced as such throughout the paper. Similar to Ivarie (1986), neither the amount of programmed reinforcement nor the number of practice opportunities were controlled during the Kim, Carr, and Templeton study. They also failed to assess stability, making it unclear whether or not reaching the aim was necessary and/or sufficient in producing stable responding. Most relevant is that the results of the distractibility probe were not conclusive. The distractors were chosen to represent the types of distractions in a classroom; however, it was not determined whether the stimuli chosen would actually compete for stimulus control and affect performance for each individual.

In a translational research paper, Demeter, Sarter, and Lustig (2008) identify some difficulties in the integration of rodent-based research and human studies that validly assess attention in both species on comparable tasks. The primary question in this research was whether the distraction manipulation would lead to qualitatively similar performance changes across the two species. A sustained operant attention task that has been used in research with rats was re-designed and validated for use in humans. The basic paradigm is that of signal detection, which in most studies uses a short, centrally-presented visual signal. Signaled and non-signaled events are presented in a randomized order. The subject's task on each trial is to indicate whether or not a signal appeared by pressing the correct lever (one for hits, another for correct rejections) during the response period, which is indicated by a separated event (extension of the lever for rat studies; a distinct auditory tone for the human experiments reported here). Researchers used a flashing computer screen as a distraction tool as opposed to the flashing house-light typically used in rat studies. As a control to ensure participants were not responding by chance, there were varied inter-trial intervals as well as length of distractor presentation which required participants to sustain high levels of attention in order to maintain successful performance (Bushnell, Benignus, & Case, 2003; McGaughy & Sarter, 1995; Parasuraman & Mouloua, 1987). This is consistent with findings that suggest that distraction further challenges attention and performance (Gill, Sarter, & Givens, 2000; Sarter et al., 2006). The human version of the rat preparation varied in that they did not require extensive pre-training and are completed within a single session. However, the task preserves critical features of standard and distractor-condition testing, including varying signal durations, inter-trial intervals and feedback for correct performance. This task provides a useful tool for integrative cross-species research, and may help to determine how specific neurotransmitter systems contribute to the hemodynamic changes observed in human functional neuroimaging experiments. Although humans showed better performance overall, the two species showed similar effects of several attention-related variables, including the introduction of distractor-related challenge. The results of this study generally support the view that tasks developed for animal research can be effectively re-designed for research in humans. Both species maintained performance over time in the standard condition, showed reduced performance at shorter durations compared to longer durations, and also showed reduced performance under distracting conditions.

Training Skills and Knowledge: Approaches and their Measurement

In combination with a focus on distraction, performance variables are seemingly relevant since it has been suggested that the more practiced a response is, the more easily it is emitted at the same rate in the face of distractors. Evaluation of this in a basic preparation is something that has not been done under controlled conditions with very sensitive measurement systems.

Accuracy and Rate

Within the behavior analytic training literature, a commonly used competency criteria in staff training is the accuracy measure of percent correct. Behavior skills training (BST) packages consist of different procedures that are combined into one training program, and have received significant attention in the applied research literature. They have been used to teach a wide variety of behavioral and other skills (Reid & Parsons, 1995), such as implementing discrete-trial teaching (Catania, Almeida, Liu-Constant & DiGennaro-Reed, 2009; Sarokoff & Sturmey, 2004), functional analysis (Iwata, Wallace, Kahng, Lindberg, Roscoe, Conners, Hanley, Thompson, & Worsdell 2000; Moore & Fisher, 2007) and stimulus preference assessments (Lavie & Sturmey, 2002). A majority of the research evaluations that have been published in behavior analytic journals on BST have used an arbitrary training target, often 80% accuracy.

Additionally, a factor related to performance problems in educational systems is often related to the measurement system employed by educators. Students' performances in the classroom are measured using a dimensionless unit: that of percent correct. Teachers use percent correct as their primary measure in the classroom; the grading scale of A through F is rooted in a percentage system reliant upon accuracy. Countless individuals have learned extremely complex skills from teachers who measured the accuracy of the learners' performance alone. However, teachers often encounter learners that are not easy to teach; this can occur for many reasons, including skill deficits, biological constraints, environmental issues, or any combination of these. Barriers that teachers often encounter include students that can accurately complete the component skills of a task, but cannot use those skills to complete a more complex, composite skill (involving several component or sub skills); and learners who fail to perform well on previously mastered material. A percent correct measurement system does not provide teachers with the information necessary to identify why the learner has a difficult time acquiring or maintaining skills (Binder, 1996).

Dimensionless measurement systems often lead to inflation of academic achievement. This inflation occurs because a percent correct measurement system is not sensitive enough to identify when a student's performance is accurate, but not efficient. Specifically, teachers are unable to identify the duration of task completion, which is an indication of skill proficiency. When teachers use a percent correct measurement system, it is unlikely that skill deficits are detected immediately (Binder, 1996). For example, a learner may cram for a test and receive a grade of 100%. However, two months later that same learner may not be able to repeat that perfect performance. The instructional strategy in the previous example does not program for retention of skills. Achieving only accuracy on the skill may not be sufficient enough to ensure that the skill is retained.

In 1987, Skinner said that countless educational fads have been suggested and implemented in an attempt to remedy the failing educational system; in 2013 we could make the same statement. The underlying problem is that teachers are not learning and applying evidence-based methods which have been found to produce the greatest learning outcomes. Within the "Precision Teaching" (e.g., Johnson & Layng, 1994) literature, these outcomes are achieved when learners perform the targeted skill(s) quickly and accurately after significant periods without practice (retention), over an extended period of time (endurance), in the face of distraction (stability), and for the learning of more difficult composite tasks (application and adduction).

It has been demonstrated that rate and frequency measures of behavior are more sensitive to environmental changes and enable a more reliable detection of academic proficiency when compared with more traditional, accuracy-only measures (Binder 1996; Johnston & Pennypacker, 1993; Lindsley, 1991b, 1992a, 1992b, 1971, 1964; West, Young, & Spooner, 1990). Rate and frequency in behavior measurement are used synonymously and are in contrast with the non-dimensional measurement of percentage. Rate is considered a ratio of count per observation time; often expressed as count per standard unit of time (e.g., per minute, per hour, per day) and calculated by dividing the number of responses recorded by the number of standard units of time over which observations were conducted. The ratio is formed by combining the different dimensional quantities of count and time (i.e., count time). Ratios formed from different dimensional quantities retain their dimensional quantities (Cooper et al., 2007).

B.F. Skinner often said in his classes and laboratory that "rate is the universal datum" (Lindsley, 1992). All behavior occurs in time; therefore, all behavior has a temporal dimension, which is an essential part of a complete description of the behavior itself (Binder, 2003). Since all behaviors have a frequency count occurring within a given time period, then any number of different behaviors can be directly compared against one another using these rates. The primary measurement systems used in B. F. Skinner's basic experiments were response frequencies/rate and cumulative response recording (Binder, 2003; Lindsley, 1964, 1991a, 1992; Skinner, 1938). Though procedures have been introduced in an attempt to improve effectiveness when using accuracy-based measures, they remain flawed.

Over-learning. Over-learning is defined as "the deliberate overtraining of a task past a set criterion," (Driskell, Willis, & Cooper, 1992). Over-learning studies have attempted to identify teaching procedures that lead to retention of skills over a period of time. Due to a flawed measurement system, over-learning studies have been unable to provide consistent evidence regarding the specific aspect(s) of overtraining that lead(s) to retention. Two types of over-learning procedures have emerged as a result of this line of research: criterion-based and duration-based (Rohrer, Kelli, Pashler, Wixted, & Cepeda, 2005).

In the criterion-based procedure, the set criterion for mastery is 100% accuracy, or one errorless trial (Rohrer et al., 2005). One errorless trial is defined as the first time the learner engages in the response correctly without any prompts or feedback. Once the learner reaches 100% accuracy, they are then required to engage in additional practice of the same task. The number of trials required to reach 100% accuracy determines how many additional practice trials are afforded.

In the duration-based procedure, the number of learning trials is predetermined for each degree of learning (Rohrer et al, 2005). For example, the experimenter may select 15 learning trials to constitute the training condition and 30 learning trials for the over-learning condition. Under these conditions, all learners in the training condition have only 15 opportunities to engage in the task. If any learner in the training condition responds with 100% accuracy prior to engaging in 15 trials, they are required to continue to engage in the response under the training conditions until 15 trials are completed. If a learner in the training condition does not respond with 100% accuracy by the 15^{th} trial, the training condition is still concluded.

The over-learning literature relies heavily on a measurement approach that looks at the percentage of correct responses emitted by the learner. In using a percent correct measurement system, the performance of the learner is not precisely displayed, does not reveal differences in skill level, and makes it difficult to identify specific aspects of the teaching situation that may accelerate or hinder skill acquisition for individual learners (Binder, 2003). It is incredibly difficult to visually inspect data displayed as percent correct and get valuable results because it is on an arbitrary scale, allowing for inflation or deflation of the quantitative value of performance. Also, it does not identify the time for completion of a task; a learner that can complete a task in five minutes with perfect accuracy looks the same as the learner who takes an hour to achieve the same level of accuracy.

Fluency

Fluency has been described by Johnston and Layng (1996) as a metaphor for flowing, effortless, well-practiced, accurate performance. Binder, Haughton, and Bateman (2002) further distinguish fluency as a task that is completed "both accurately and quickly, *without hesitation."* When we hear someone speak a foreign language, as Binder et al. so eloquently describes, we know fluency. We observe smooth flow, clean transitions, and a pace that occurs without hesitation. Some would also describe professional athletes, musicians, and dancers' movements as occurring fluently, without hesitation. Anyone who trains people to do things might also admire this type of fluid and seemingly effortless performance as a valuable outcome.

Precision Teaching (PT). In the behavior analysis community we have used the term fluency to label the performances of tasks that occur quickly and accurately. Within the PT literature, there are multiple examples of fluency producing the greatest learning effects leading to mastery of material.

PT is a teaching methodology used in an applied branch of behavior analysis that utilizes dimensional and sensitive measurement systems. The teaching technique has been shown to produce skill retention, endurance, stability, application and adduction (RESAA) - the five characteristics of fluent performance (Johnson & Street, 2004). It has been shown both empirically and clinically that learners must engage in responses at optimal frequencies (aims) for the production of RESAA (Binder Haughton, & Van Eyk, 1990; Binder, 2003; Evans & Evans, 1985; Evans, Mercer & Evans, 1983; Haughton, 1972; Ivarie, 1986; Johnson & Layng, 1994; Kim et al, 2001; Shirley & Pennypacker, 1994).

Based on a behavior analytic history, PT employs teaching procedures that implement a precise measurement system, looking at response frequencies through measurement of behavior in real time. B. F. Skinner's basic experiments used response frequencies and cumulative response recording as the primary measurement system (Skinner, 1938; Lindsley, 1964; Lindsley, 1991; Binder, 2003). When behavior is examined as ongoing, it can be manipulated directly (Sidman, 1960). Precision teachers have very effective technologies for teaching because they employ these rules within their practice.

Behavior occurs in time and therefore has a temporal dimension, which is an essential part of a complete description of the behavior itself (Binder, 2003). Precision teachers use timed and charted measures of learners' performances on instructional and practice activities to support a curriculum-based decision-making process (Binder et al., 1990). This is a systematic and efficient way of measuring performance on many academic and nonacademic tasks, allowing teachers and learners to identify when an instructional approach is not leading to accurate responding at optimal rates (Binder et al., 1990).

Since ongoing behavior is examined, teachers and learners are allowed to evaluate and manipulate both the accuracy criteria and allotted time with which individuals respond to stimuli. Additionally, precision teachers and learners are able to quickly identify when an instructional approach is not working because of the use of a systematic measurement system. The instructional approach can systematically be modified quickly and on an ongoing basis until the learner's behavior indicates to the instructor that the approach is effective.

Free operant. In a free-operant teaching situation, the only restrictions placed upon the subject's recorded behavior are those inherent in the laws of behavior; the organism is free to respond (Sidman, 1960). The behavior is not constrained by antecedent or consequent stimuli for each response; rather, the response may occur repeatedly without restriction (Pear, 2001). Operant behavior is behavior that "acts on the environment to produce an immediate consequence and, in turn, is strengthened by that consequence" (Miltenberger, 2008). The term 'free operant' means that a learner responds as often as possible and is not restricted by the presentation of a discriminative stimulus for each response. However, there is still some stimulus that provides cueing for the behavior. For example, doing math problems on a work sheet is considered free operant in that the learner responds as quickly as they can to the problems on their work sheet. A rat pressing a lever is also free operant in that the rat can press as quickly as possible. The definition of the word fluency includes that the performance being measured must be free operant, rather than discrete trial (Ferster, 1953; Lindsley, 1964).

In contrast, a controlled operant is a response which is not going to occur without a discriminative signal serving as an antecedent to responding (Ferster, 1953; Lindsley, 1996). For example, doing math problems in a classroom is a restricted operant when the teacher presents the math problems for the student as they complete the previous one. In a discrete trial procedure, a discriminative stimulus is presented during which a response can occur only one time (Pear, 2001). The teacher controls the presentation of discriminative stimuli, the presentation of reinforcers, and the interval between trials (Johnson & Layng, 1996). These are typically methods used and/or investigated in education, child development and some areas of behavior analysis (Lindsley, 1992a).

Using a controlled operant to evaluate frequency restricts options to using a percent correct measure. Free-operant performance (rather than discrete-trial responding) is a critical feature of behavioral fluency and Precision Teaching (Johnson & Layng, 1992) and is optimal given the limitations of the restricted operant.

Frequency aims. When the use of the free-operant method was introduced to classrooms it was found that criteria needed to be set for ideal rates of responding to ensure fluency. Over the years, precision teachers found that some students failed to respond at optimal frequencies despite high levels of reinforcement (Haughton, 1972). Precision teachers were initially encouraged to use brief daily samples of correct and incorrect academic response rates to make decisions about students' progress (Haughton, 1972). The use of short, timed samples of performance allowed teachers to observe that learners had to achieve certain rates of correct responding on prerequisite skills in order to progress smoothly through subsequent applications of those skills (Binder, 1993; Haughton, 1972). The use of frequency aims was then adopted to establish fluency. . If a frequency aim has not yet been clinically demonstrated to produce fluency, the term frequency building is used (Johnson & Street, 2004). Frequency aims are determined in two ways: normative sampling and outcome measurement

Normative sampling involves testing the response frequency of expert performers on component tasks and is the most common method (Binder, 1996). These frequencies are then identified as the aim. Alternatively, outcome measurement determines frequency aims by testing for outcomes after specific frequencies have been achieved (Berens, Boyce, Berens, Doney, & Kenzer, 2003; Binder et al., 1990; Johnson & Layng, 1992). Determining frequency aims by testing for outcomes enables teachers to use aims that produce fluency for each individual.

Testing individuals for outcome measures is functional in that performance of the individual learner, not an arbitrarily assigned number, determines the frequency aim for each skill. Clinically, it has been demonstrated that certain learners responding at frequencies much lower than the normative sample aim are able to retain the skill and apply it to more difficult tasks. Valuable time is not wasted training component skills that the learner can already perform in ways that produce fluent responding. Additionally, when learners respond at frequencies at the predetermined aim, but fluency is not achieved, further training can occur. Under these conditions, testing for outcome performance enables teachers to identify aims that are functional rather than arbitrary.

Measurement Tools

Standard line graph. The standard line graph (see Appendix 1) is based on a Cartesian plane, a two-dimensional area formed by the intersection of two perpendicular lines. Any point within the plane represents a specific relation between the two dimensions described by the intersecting lines. It is the most common graphic format for displaying data in applied behavior analysis (Cooper et al, 2007) and is also the most common display used in publications in major behavior analytic journals like *Journal of Applied Behavior Analysis*. In applied behavior analysis, each point on a line graph shows the behavior in relation to a specified point in time and/or environmental condition (i.e., sessions, days, etc.). Comparison of points on the graphs reveals the presence and extent of changes in level, trend, and/or variability within and across conditions.

There are some advantages to using this method to display data. First, the use of the line graph for data display is familiar to consumers of behavior analytic services and they often prefer it. Without extensive training on other data display methods, it is not likely someone working in an applied position would adopt a new method without pressure to do so from consumers. An extension of the previous point, another advantage to the continued use of a standard line graph is the avoidance of response effort inherent in learning about new tools.

However, there are numerous disadvantages of this method, as well. Some disadvantages include the fact that the vertical axis does not represent a standard measurement scale and visual interpretation can be difficult across graphs. A well-trained clinician using this type of display will need to ensure the scales are the same across their line graphs, which allows accurate interpretation of data and informed clinical decision making. Additionally, continuing to use this type of display can lead to a consumer incorrectly tracking and/or interpreting data because of the changing scale and the lack of easy development of this type of data display. Behavior analysts tend to use this type of display when presenting their data to consumers because it is received with less hesitation than other displays. Any type of response can easily be graphed on this type of display and is generally acceptable to do so; when keeping the axis the same across all of these graphs one of the disadvantages is eliminated.

Standard celeration chart. Frequency measures of behavior are more sensitive to environmental changes and enable a more reliable detection of proficiency when compared with more traditional, accuracy-only measures (Binder 1996; Johnston & Pennypacker, 1993; Lindsley, 1991b, 1992, 1971, 1964; West et al., 1990). The Standard

Celeration Chart (SCC) is a standard chart allowing for a visual description of a standard, absolute, and universal account of behavior (see Appendix 2).

Many traditional graphing or charting methods use arbitrarily selected units of time such as sessions or trials (Johnston & Pennypacker, 1993). This labeling system leaves out an important component of data analysis: time. If the x-axis represents successive sessions, trends in responding displayed on this type of graph could be misleading. With session information alone, one is unable to determine whether the sessions occurred over the course of minutes, hours, days, weeks, or months. Any trends in the data could reflect influences on performance related to time that are not detectable on the graph (Johnston & Pennypacker, 1993; Lindsley, 1964).

The standard unit of measurement on the SCC is count/time/time or frequency recorded over real time (Pennypacker, Guiterrez, & Lindsley, 2003). With the chart, all frequencies of behavior ranging from 1 per day to 1000 per minute can be measured with the same tool. To avoid being imprecise, the SCC is organized on a logarithmic scale (equal-scales and equal-intervals), since traditional equal-interval scales can lead researchers and clinicians to falsely conclude that clinically significant amounts of behavior change have been produced (Berens, 2005).

When visually inspecting the chart, it is noted that multiplication and division are used to move up and down the y-axis, which preserves proportional behavior changes regardless of starting frequencies (Pennypacker et al., 2003). For example, a change in response frequency from 2 to 20 is proportionally the same as a change from 50 to 500. The x-axis is organized as an equal-interval scale that is labeled as successive calendar days/weeks/months/years. Using successive calendar time allows trends to be observed according to days, weeks, months or years. Therefore, any changes in frequency of behavior that are related to specific days, weeks, etc., can be identified as such. Additionally, the use of the standard unit of time allows for comparisons to be made across many different learners and/or skill areas (Berens, 2005). Comparing progress of multiple learners enables teachers to identify the effectiveness of particular components of the teaching sequence.

By displaying frequency against a continuous real time line, the chart provides a graphic means of displaying celeration, a universal measure of frequency change over time (Pennypacker et al., 2003). Celeration is a term that refers to increases or decreases in frequencies of behavior over time (Pennypacker, Koenig, & Lindsley, 1972; Johnston & Pennypacker, 1993; Berens, 2005). Celeration is seen on the SCC as the slope of a line describing a set of behavior frequencies arranged in real time (Pennypacker et al., 2003).

Celeration on the SCC generate straight trend lines that can be extended over time for prediction to be made regarding future occurrences of behavior (Pennypacker et al., 2003). When behavior is increasing (i.e., accelerating), the trend line will have a positive slope and is referred to as a “times” celeration. A “5- times” celeration indicates that behavior is increasing exponentially by 5 times as opposed to additively (Pennypacker, et al., 2003). If the trend line has a negative slope, it is called a “divide” celeration (i.e., deceleration). Repeated analysis has shown that visually significant changes using the SCC correlate with both statistically and clinically significant amounts of behavior change (Berens, 2005; Haughton, 1971; Johnston & Pennypacker, 1980; Lindsley, 1971b; Lindsley, 1964).

Advantages to the use of the SCC include ease of data entry and analysis by the behavior analyst. With the standard line graph, data is generally collected in real time in a table of some sort and then entered into an excel program that graphs the data for analysis. This is not the case with the SCC, you immediately drop your data points on the chart and can see them in comparison to previous responses and make adjustments to procedure immediately within session when necessary. Another advantage to the SCC is that charts can be compared to one another because the axis never changes, it can be deceptive to look at two line graphs because their axis is often different across different responses. Some disadvantages to using the chart include the novelty of it to most consumers of behavior analytic consumers. This type of measurement system has been advantageous for different types of acquisition skills like math fact families, manding, tacting, etc.

Cumulative graph. The cumulative graph (see Appendix 3) was developed by Skinner as the primary means of data collection in the experimental analysis of behavior (Cooper et al., 2007). Skinner used a device called the cumulative recorder that actually drew its own graph; a pen moves up one step on the paper for each response as the paper feeds continuously in real time. If there is no response at all there is a horizontal line indicating that no response occurred. The faster the response rates on the cumulative recorder, the steeper the slope of the line. When we use a computer program to create a cumulative graph the number of responses recorded during the observation period is added to all previous observations. The use of this type of data display is very sensitive and allows a researcher to see a graphical display of each and every response.

The cumulative graph has the advantage of showing responding in real time over all other data displays. The SCC will show response decrements over the course of brief timings but does not show moment-to-moment responses in real time and changes when variables are introduced. The cumulative graph allows the scientist to see exactly what happens to response frequency the moment a variable is introduced. This type of a graph is only beneficial when you need to see behavior as it occurs in the moment. Some types of responses that this type of graph would be appropriate for would be responses where certain cadences or annunciation is necessary or you are looking at task performance and introducing variables during the task to see immediate changes.

Summary

In the current study, we used dimensional measurement systems in a laboratory preparation to view celeration and error patterns that occur during learning under varying conditions. The investigation led to the study of the effects that distractors have on performance and the suppressive effects of different modalities of distractors (an extension of Binder, 1979c). The results of many variations leading to continually better preparations have provided information that will allow for more precise prediction of future behavior of organisms in the presence of distractors. As better prediction and control of behavior is of primary concern to scientists, that goal has been achieved within this research.

Inductive Method

Lindsley (1992) highlights in *Skinner on Measurement* that one reason that single-subject research was so effective in the hands of B.F Skinner was due to his inductive research approach. Skinner gathered large quantities of data and manipulated variables rather than testing for them, and major discoveries resulted. Lindsley quantified how inductive Skinner's research was by looking at the 'induction ratio.' The induction ratio was calculated by dividing the number of charts collected by the number of charts published on a topic. Skinner's induction ratio for *Behavior of the Organisms* in 1938 was 40 to one and for *Schedules of Reinforcement* (1957) was 78 to one. Lindsley also discussed the approach of "learner knows best," which is related to induction in the sense that the data is never wrong. This was an important tactic that B.F. Skinner used in reviewing and collecting data – it was never the data that was wrong. Instead, Skinner would likely say, "The book's wrong! The rat knows best!" The application of this principle in research provides a source of creative research ideas and a greater chance for discovery. The data itself is a source of motivation and fuels interest in the researcher. In the current study, an inductive method was employed to reach a research question that emerged based on many charts of collected data. Several findings are reported from the initial studies that were not originally the intended research direction as a result of testing the software to develop usable procedures and methods.

Experiment 1- Method

Participants

Participants included five undergraduate students enrolled at the University of Nevada, Reno. The five students participated for up to 1 hour in one laboratory visit, in exchange for bonus course credit. The provision of course credit depended on the completion of the 1 hour session.

Analog Preparation

Participants learned in an analog preparation simulated tasks that varied in types of discriminations. The software program provides many options for manipulating variables such as discriminations within task, length of task, duration of practice timings, types of distractors, and schedule of distractors (Configuration Settings). Initially, this study was intended to replicate the teacher's task requirements typically required by a discrete trial teaching program (see Table 3). We used one- minute trials of four sequences of paired associates (two conditional and two simple discriminations) which varied between 6 and 10 steps (see Table 1, Table 2). The simple sequences were always presented in the same order and included only simple discriminations (ex. A = B). The conditional sequences had several steps that randomly alternated in the order in which they were presented and also included some conditional discriminations (e.g., if blue A = B, if red A = D). All participants completed 10, 1-minute length trials of each of the four sequences counterbalanced for order effects (see Table 4).

Materials and Setting

Each participant worked with the experimenter in a 4 x 3 M room containing a desk, a computer and keyboard. The computer program the participants worked on was programmed in Microsoft Visual Basic© 2010. The participants used the keyboard to complete all task requirements. The instruction screen guided the participants through each phase of the study while responses were recorded to an output folder that was accessed later by the researcher.

The software program consisted of three types of application screens:

- Introduction screen: The introduction screen consisted of textual instructions to the participants and a “start” button. When the participant pressed the “start” button, the trial would begin. The participants could not go backwards or restart the trial at any point (see Appendix 4).
- Trial completion screen: The trial completion screen consisted of an initial letter as a prompt for the participant to enter the correct paired associate for that particular sequence. As the participant entered responses a prompt would appear on the screen for the next response. The participant would continue responding to the tasks until the timing was over.
- Feedback screen: The feedback screen would appear automatically after the given trial was completed. The feedback screen had textual information in it that provided information to the participant on the number of times they completed a sequence as well as the number of errors they made during the trial (see Appendix 4).

Experimental Design

This study used a sequence multi-element design across participants to expose the participants to all possible sequences and to complete retention checks (See Figure 1 and Table 4). The design was the best fit for this phase of the research because it assisted the researchers in comparing the response patterns generated by sequences differing in type of discrimination and length. Additionally, this format allowed researchers to identify possible problems with task performance ceiling effects and to make adjustments to the discrimination types in sequences. The counterbalancing across participants also allowed us to probe for sequence effects (Kazdin, 2010).

Procedures

Each participant worked through the program separately. As soon as a participant entered the session, he/she was given an Institutional Review Board approved information sheet to review and was asked if he/she would like to participate in the study. Once the participant verbally consented, he/she started the study. The participant sat in front of the computer. The experimenter then completed a practice trial with the participant. The practice trial consisted of the experimenter standing next to the participant while they sat at the computer. The experimenter would read the following instructions from a script:

> *During this study, you are going to be asked to learn several different sequences of randomly paired letters and sometimes colors and letters. The goal is to do the best you can to learn the sequences. You see on the screen now the introduction screen; here you will enter your number, which is ____________. After you enter your number you will press the "start" button. Now, you see a letter appears on the screen, this letter is a clue for you to think of the paired associate. The first time you will have to guess, regardless of the letter you press, the correct answer will show up. It is important to try to remember the correct letter because after this sequence is complete you will be prompted to enter it again later. Go ahead and try this sequence for the next minute. (The experimenter would wait until the participant finishes). Now, you see the feedback window, this window will tell you how many times you completed the sequence and how many errors that you made. This window will be displayed for 3 seconds and the program will automatically take you to the next trial. Whatever you encounter during the*

training just do your best and continue to complete the sequences to the best of your ability.

After the experimenter completed one practice trial with the participant, he/she then sat in the room while the participant completed the study. The experimenter did not interact with the participant until after they completed the study. If the participant asked questions during the study, the experimenter would just tell them to do the best they can. After the participant completed the study, the experimenter had them complete a survey regarding their experience in the study.

Measures

The application software collected all of the data from each participant including each response given (i.e., each key pressed by the participant during each timing was recorded), the configuration settings, participant number, trial number and phase.

Social Validity Measure

Participants completed a survey at the end of the study. The survey asked for ratings of issues related to each participant's experience of the study on a Likert scale and some open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Interobserver Agreement

The software program was tested for accurate recording prior to implementation with participants. Having a calibrated and verified measurement throughout the study required no treatment integrity data collection.

Each participant's responses were automatically transferred to output files in a spreadsheet (see Appendix 4). Two observers independently scored 30% of the data across all participants. Observers were students who were trained to enter data on the standard celeration chart by the researcher. The observers were trained on 20 different example charts of data and were required to practice charting data in the presence of the researcher until they completed 3 consecutive sessions with no errors. The researcher used a key for each data set to determine accuracy. Interobserver agreement (IOA) was calculated using an agreement percentage of data entries on the standard celeration chart from the output data file. For the 30% of files used for IOA, there was 98.2% agreement between the observers.

Results

Figures 2, 3, 4, 5 and 6 represent each of the five participants' data from this experiment across all sequences completed on a timings standard celeration chart. On the vertical axis each data point represents the number of keys pressed by the participant during a trial that lasted 1 minute. The horizontal axis represents trials lasting 1 minute in real time of actual task completion. The retention checks were completed after each participant had a several minute break (depicted by the empty space in the middle of the charts). The retention checks were completed in the same order as each of the training sequences. The upward slope of the trend line is indicative of the rate that each participant learned the relevant sequence. Each "x" on the chart indicates the number of errors in each trial.

Highest response rates for all participants occurred during the simple sequences (they were not randomized in presentation). The overall level of the simple sequences was higher than the level of the conditional sequences for all participants except participant 1. Participant 5's (see Figure 6) data were the most differentiated between conditional and simple sequences.

Retention checks were consistently higher across all participants for the simple versus the conditional sequences. Participants 3, 4 and 5 (see Figures 4, 5 and 6) show the most differentiation in the data between the conditional and simple sequences and had more errors overall on the conditional sequences.

Participant 1 (see Figure 2) had the most errors during the 6-step simple sequence and definitely shows patterns of sequence effects (i.e. by the last sequence the participant was performing at a personal best by trial 3). Participants 4 and 5 (see Figures 5 and 6) had the most errors across all participants across all four sequences.

Figures 7, 8, 9 and 10 depict each sequence across participants. This view of each of the sequences clearly shows the differences in performance between the conditional and simple sequences across all participants. Additionally, the sequences that the participants completed first have lower response rates.

Discussion

The sequences were developed for this analog task by breaking down two typical clinical training tasks (preference assessment and discrete trial instruction) into their component parts and determining the type of discrimination that was being utilized (see Table 3). The patterns and rates of response and errors for three of the participants on the non-random simple sequences indicate participants were not attending to the screen after learning the paired associates. Errors were not caught immediately by participants, resulting in multiple errors in a row. Sequences containing conditional discriminations presented some associates in a random order; they produced high response rates and did not result in the same error pattern. Randomized presentation order to control for attending to the stimuli is supported by research (Cohen et al., 1990). The 10-step sequences produced lower response rates across participants. At first sequence performance was variable, likely due to the short practice length prior to beginning the first sequence. To address these issues, the next experiment includes sequences containing 10 steps in a randomized presentation and additional practice opportunity at the beginning.

This evaluation has implications for the training community regarding task length and discrimination difficulty of training procedures and targets. The data collected in this experiment demonstrate benefits of more intensive training procedures for tasks that require multiple conditional discriminations in different orders versus repetitive tasks performed sequentially. Prior to this experiment we varied the presence of the feedback screen between timings for 2 participants (data not included). Sequences that did not have the feedback screen produced variable data compared to the orderly data produced when it was present. For this reason the feedback screen was used throughout all of the experiments.

Experiment 2 Method

Participants

Participants included four undergraduate students enrolled at the University of Nevada, Reno. The students participated for up to 2 hours in one laboratory visit, in exchange for extra course credit.

Analog Preparation

This analog preparation was identical to the previous except that the configuration settings were different. In this experiment we evaluated the effects of a training criterion of perfect accuracy plus practice versus just perfectly accurate (100% correct) performance and the durability of correct responding when distractors were added during the trained tasks. Participants would automatically move to a different phase based on their performance (either 100% correct responding one time versus 100% correct responding multiple times). The configuration was also slightly different for perfect accuracy plus practice versus perfect accuracy conditions. During the perfect accuracy plus practice conditions both sequences were completed until the participant reached 100% percent correct for at least 3 trials. After that condition had been completed, retention checks were conducted to ensure the participants were responding at the same or better rate on the sequence prior to introducing distractors.

Materials and Setting

The materials and setting were the same as experiment 1.

Experimental Design

This experiment used a multiple baseline across participants counterbalanced for conditions (see Figure 11 and Table 5). The design was the best fit for this phase of the research because it assisted the researchers in beginning to evaluate any changes needed as a result of adding the distractor component. The counterbalancing across participants also allowed us to probe for sequence effects (Kazdin, 2010).

Procedures

The procedures were the same as experiment 1.

Measures

The application software collected all of the data from each participant including each response given (i.e., each key pressed by the participant during each timing was recorded), the configuration settings, participant number, trial number and phase of the treatment.

Social Validity Measure

After completing all trials of this study participants completed a survey. The survey asks questions on a Likert scale related to each participant's experience of the study and open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Inter-observer Agreement

The software program was tested for accurate recording prior to implementation with participants. Due to the software having standardized measurement even during the practice trial, the experimenter did not provide any instruction or record dependent variables to require treatment integrity.

Each participant's responses were transferred automatically to output files in a spreadsheet (see Appendix 4). Two observers independently scored 38% of the data across all participants. The observers were trained on 20 different example charts of data and were required to practice charting data in the presence of the researcher until they completed 3 consecutive sessions with no errors. The researcher used a key for each data set to determine accuracy. Inter observer agreement (IOA) was calculated using an agreement percentage of data entries on the standard celeration chart from the output data file. For the 38% of responses used for IOA, there was 94.6% agreement between the observers.

Results

Figures 12, 13, 14 and 15 represent the each of the four participant's data from this experiment across all sequences completed on a timings standard celeration chart. On the vertical axis each data point represents the number of keys pressed by the participant during a trial that lasted 1 minute. The horizontal axis represents each trial lasting 1 minute in real time of actual completion. The upward slope of the trend line is indicative of the rate that each participant learned the correct relevant sequence. Each "x" on the chart indicates the number of errors in each trial.

Participants 1 and 2 (see Figures 12 and 13) received the perfect accuracy plus practice based training first for sequences A1 and A2 and then the simple accuracy based criteria for sequences B1 and B2. Both accuracy sequences were trained to 100% correct and then distractors were introduced. Data showed many more errors during the distractor phase of perfect accuracy alone than that of perfect accuracy plus practice. Participants 3 and 4 (see Figures 14 and 15) received the perfect accuracy training first with the distractor condition immediately following. For both participants during the distractor conditions, there were a high number of errors for the task acquired by perfect accuracy alone compared to the perfect accuracy plus practice training. For all four participants there were initial drops in correct responding when distractors were introduced, regardless of training condition. The level of correct responding for the simple sequences was differentiated across all participants from the conditional conditions.

Discussion

The current data indicate that there were no order effects; all four participants showed similar data patterns and response levels regardless of the order of training presentation. There was less retention of the sequences trained in the accuracy conditions across all four participants (more errors and lower levels during distractor conditions). The screen flash distractor may have disrupted performance because it momentarily removed visibility of the sequences. These data further demonstrate that the use of accuracy only as a training target (even at 100% criteria) should be reconsidered when training tasks involving conditional discriminations and that vary in presentation order. Task length was not investigated thoroughly enough to provide empirical evidence to support the spectrum of possibilities but should be considered in future study.

The findings in this experiment have implications for endurance of task performance. For the two participants where distractors were immediately introduced after they reached 100% correct, the temporal proximity to the training condition was minimally helpful in reducing errors when distractors were present. The difference in time between training and distractor presentation was approximately 10 minutes. However, the conditional discrimination task trained to accuracy alone produced the same level of errors as when evaluated later. It would be beneficial to compare the number of trials until performance reached perfect-accuracy plus practice rates if participants were required to continue until they had no errors during perfect-accuracy conditions. This will be further explored in the next experiment.

Based on these results additional changes were made: sequences all included conditional discriminations presented randomly, a pre-assessment was added as a correlate to task performance, the criteria for accuracy condition was lowered to 80% rather than 100%, and participants could max out during the accuracy condition until they reach perfect accuracy plus practice rates. The accuracy rate was lowered to 80% because that accuracy criteria is often used by trainers in applied settings and it was of interest to see what error rates and response patters were produced under those training criterion.

Experiment 3 Method

Participants

Participants included four undergraduate students enrolled at the University of Nevada, Reno. The four students participated for up to 2 hours in one laboratory visit, in exchange for bonus course credit.

Pre-Evaluation

A typing timing was completed as a pre-evaluation of keyboard skills when using sentences at a fourth grade reading level (see Appendix 6). Two timings were completed and each timing lasted 1 minute in length.

A free operant typing evaluation was also used to identify how quickly each participant could key press when no sequence was required of them.

Analog Preparation

This analog preparation was identical to the previous except that the configuration settings were different. In this experiment we evaluated the training criteria of perfect accuracy plus practice versus 80% accurate performance and durability with distractors. Participants automatically moved to a different phase based on their performance (80% correct one time versus 100% correct multiple times). The configuration was also slightly different for perfect accuracy plus practice versus 80% accuracy conditions. During the perfect accuracy plus practice conditions both sequences were completed until the participant reach 100% percent correct for at least 3 trials with no errors. After both conditions had been completed, retention checks were used to ensure the participants were performing at similar rates on the sequence prior to introducing distractors. During the 80% accuracy distractor conditions, participants continued until they met the criteria of zero errors. All sequences used were all conditional sequences, involving conditional discriminations that varied in length (i.e., 6 steps and 10 steps) and all sequences varied in order of presentation.

Materials and Setting

The materials and setting were the same as experiment 1 and 2 except that a pre-evaluation was added. During the pre-evaluation participants were required to complete a 1 minute typing timing of sentences at a fourth grade reading level. After completing the typing test participants were asked to press buttons as fast as possible on the keyboard for a one-minute timing. A computer was used to collect these data. The participant completed the typing test in a blank Microsoft Word© document.

Experimental Design

This experiment used a multi-element within participants design and counterbalanced across participants for conditions (see Figure 16 and Table 5).

Counterbalancing across participants also allowed us to ensure there were no sequence effects (Kazdin, 2010).

Procedures

Each participant experienced the program separately. As soon as the participants entered the session, he/she was given an Institutional Review Board approved information sheet and asked if he/she would like to participate in the study. Once the participant verbally consented, he/she started the study. The participant sat in front of the computer. The experimenter read the following instructions from a script:

> *We are going to begin today by doing a quick pre-evaluation of typing skills. On the screen in front of you there is a blank Microsoft Word© document on the right and one with a paragraph on the left. In the blank document on the right, when I say "start" you are going to type the paragraph on the left as quickly and accurately as you possibly can until I tell you to stop. When I say "stop" you need to pick your hands up off of the key board immediately. Let me know when you are ready.* [Experimenter uses a timer for 1 minute – the timing is then repeated a second time] *Next, I need you to in that same document just type anything as quickly as you can, they do not have to be words or anything that makes sense. I will time you doing this two times, for one minute each time. Let me know when you are ready.* [Experimenter uses a timer for 1 minute- the timing is then repeated a second time].

The experimenter next completed a practice trial with the participant. The practice trial consisted of the experimenter standing next to the participant while they sat at the computer. The experimenter then read the following instructions from a script:

> *During this study, you are going to be asked to learn several different sequences of randomly paired letters and sometimes colors and letters. The goal is to do the best you can to learn the sequences. You see on the screen now the introduction screen; here you will enter your number, which is ___________. After you enter your number you will press the "start" button. Now, you see a letter appears on the screen, this letter is a clue for you to think of the paired associate. The first time you will have to guess, regardless of the letter you press, the correct answer will show up. It is important to try to remember that letter because after this sequence is complete you will be prompted to enter it again later. Go ahead and try this sequence for the next minute. (The experimenter would wait until the participant finishes). Now, you see the feedback window, this window will tell you how many times you completed the sequence and how many errors that you made. This window will be displayed for 3 seconds and then the program will automatically take you to the next trial. Whatever you encounter during the training, just do your best and continue to complete the sequences to the best of your ability.*

After the experimenter completed one practice trial with the participant, he/she then sat in the room while the participant completed the study. The experimenter did not interact with the participant until after they completed the study. If the participant asked questions during the study, the experimenter would just tell them to do the best they can.

After the participant completed the study the experimenter had them complete a survey regarding their experience in the study.

Measures

The application software collected all of the data from each participant including each response given (i.e., each key pressed by the participant during each timing was recorded), the configuration settings, participant number, trial number, and phase. The pre-assessment data were collected in a Microsoft Word© document that has a function of character count when text is highlighted. This was the measure used for the pre-assessment numbers. Additionally, the number of errors was scored by independent experimenters for accuracy.

Social Validity Measure

After completing all trials of this study, participants completed a survey. The survey asked questions on a Likert scale related to each participant's experience of the study and open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Inter-observer Agreement

The software program was tested for accurate recording prior to implementation with participants. Due to the software having standardized measurement even during the practice trial, the experimenter did not provide any instruction or record dependent variables to require treatment integrity.

Each participant's responses had output files in a spreadsheet (see Appendix 4). Two observers independently scored 50% of the data across all participants. The observers were trained on 20 different example charts of data and were required to practice charting data in the presence of the researcher until they completed 3 consecutive sessions with no errors. The researcher used a key for each data set to determine accuracy. Interobserver agreement (IOA) was calculated using an agreement percentage of data entries on the standard celeration chart from the output data file. For the 50% IOA, there was 95.6% agreement between the observers.

For pre-assessment measures and further analysis of data which included number of trials with errors prior to perfect accuracy, two independent observers scored the data. For the typing timing, data were reviewed on total characters and total errors. For the number of trials with errors raw data were counted. The free operant test did not involve any error scores, but rather was used to provide a measure of a strictly free operant key press measure. This test did not require any IOA due to the standardized measurement used. For agreement on this measure the total number of agreements was divided by the total number of agreements plus disagreements and then multiplied by one-hundred. The IOA for 50% of participants on the pre-assessment measure was 97.6% agreement between observers.

Results

Figures 17, 18, 19 and 20 represent the four participants' data from this experiment across all sequences completed on timings standard celeration chart. On the vertical axis each data point represents the number of keys pressed by the participant during a trial that lasted 1 minute. The horizontal axis represents each trials lasting 1 minute in real time of actual completion. The upward slope of the trend line is indicative of the rate that each participant learned the relevant sequence. Each "x" on the chart indicates the number of errors in each trial.

When perfect accuracy plus practice was the training criteria, errors reduced by approximately a divide 12 when distractors were introduced versus a divide 2 when 80% accuracy was the training target (see Figure 21). There was one exception across all four participants where 1 participant had about a divide 10 in errors even when the target was 80% accuracy. Another way of saying this is that when perfect accuracy plus practice was the training target error reduction occurred 6 times faster (12/2).

The accuracy ratio is how many times there are correct responses as there are errors. So, and accuracy ratio of 2.7 means there are 2.7 times the number of corrects as there are errors. The accuracy ratio is calculated by taking the number of correct responses and dividing by the number of errors. The difference in accuracy, as calculated by the accuracy at the end of training and the first trial of distractors is a division of accuracy. The greater the number, the greater the divide in accuracy rate for that particular participant and sequence. The data show that there was a divide in accuracy across all participants when distractors were introduced. The data also indicate there were greater differences in accuracy on the first trial of distractors with the perfect accuracy plus practice group, one particular outlier with a divide of 44.5. The 80% accuracy group did have small divides (between 2 and 4; 1 outlier of 8).

Participants 1 and 4 (see Figure 17 and 20) received the perfect accuracy plus practice sequences first and the 80% accuracy sequences last. Participants 2 and 3 (see Figure 18 and 19) received the accuracy sequences first and the perfect accuracy sequences last. Across all participants it required a larger number of trials with errors to reach perfect accuracy when accuracy was the training target (see Table 7). All participants appear to be consistent in level across each of the sequences. There were clear differences in response levels for all participants between the conditional 6-step sequence and the conditional 10-step sequence. Distractor presentation consistently suppressed responding across all participants but the perfect accuracy sequences were the ones that recovered the quickest with the least amount of errors. Three out of the four participants during the accuracy sequences have fewer errors and required less trials to perfect accuracy during distractors on the 6-step conditional sequences than the 10-step conditional sequences.

Discussion

These data suggest that training targets of 80% correct may result in more errors in a natural environment setting than training to perfect accuracy plus practice prior to natural environment intervention. Typing scores and free operant key pressing scores varied across participants, but did not have any effect on level or errors during responding. It may be more effective to use shorter sequences that do not include conditional discriminations when training for accuracy. An improvement to methodology is the removal of retention checks during the perfect accuracy condition to maintain consistency with the accuracy condition. Perfect accuracy frequency ranges can be used as a response target. Additionally, the frequency ranges could then be used during the accuracy sequences when needed. This requires adding an initial phase to the proposed methodology strictly for the purpose of creating frequency windows for each sequence of paired associates. An additional refinement to the methodology is the addition of using the cumulative chart to see the effects of the distracting stimuli in real time.

Experiment 4, Phase 1

Participants

Four participants completed phase 1. Participants were recruited through the University online research system and psychology classes. They earned psychology research credits that can be utilized in University psychology courses, non-contingent upon performance.

Analog Preparation

A similar analog preparation was used as in the experiment 1. The difference in this study was that all four sequences included conditional discriminations and overlapping equivalence relations between associates (see Table 10), all sequences have 10 steps. This phase was used to establish perfect accuracy plus practice frequency rates for each sequence.

Materials and Setting

The materials and setting were the same as all other experiments except an additional pre-evaluation was added. During the new pre-evaluation participants were required to complete a 1 minute typing timing where they transcribe random words. A computer was used to collect this data. The participant completed the typing test in a blank Microsoft Word© document.

Experimental Design

This experiment had an ABCD design across participants to expose the participants to all types of sequences (see Table 9 and Figure 23). The design is the best fit for this phase of the research because it assists the researchers in comparing the response patters and identifies standard aims ranges for each of the sequences based on each participant's personal best.

Procedure

The procedure is the same as those used in experiment 3.

Measures

The measures are the same as those used in experiment 3.

Social Validity Measure

After completing all trials of this study participants complete a survey (see Appendix 5). The survey asks questions on a Likert scale related to each participant's experience of the study and open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Interobserver Agreement

The software program has been tested for accurate recording prior to implementation with participants. The software has a standardized measurement system and it is used throughout the study to collect data. It does not require treatment integrity measures.

Each participant's responses have output files in a spreadsheet (see Appendix 4) that are then entered to a graphical display. Two observers independently scored 30% of the data across all participants. The observers are trained on 20 different example charts of data and required to practice charting data in the presence of the researcher until they complete 3 consecutive sessions with no errors. The researcher used a key for each data set to determine less perfect accuracy. IOA index for the 30% of data reviewed was 93.2% across all participants.

Results

Each participant completed each of the sequences and performed them until they reached a point of stability in the data. The ranges for each of these sequences and cumulative record depictions of the data are presented in figures 24, 25, 26, and 27. Sequences 1, 2, 3, and 4 have ranges of: 58 to 64, 60 to 65, 55 to 59, and 50 to 58 respectively. Figure 28 represents the range of frequencies throughout all sequences within these studies. This depiction is used to show the changes in the frequency ranges across the different presentations, lengths, discrimination types within the different sequences.

Experiment 4, Phase 2

Participants

Four participants completed phase 2. Participants were recruited through the University online research system and psychology classes. They earned psychology research credits that can be utilized in University psychology courses, non-contingent upon performance.

Pre-Evaluation

A typing timing was completed as a pre-evaluation of keyboard skills using sentences at a fourth grade reading level (see Appendix 6). Two timings were completed and each lasted one-minute.

A typing timing was completed as a pre-evaluation of keyboards skills when using random words in no particular order (see Appendix 7). This pre-evaluation was most similar to the actual task participants complete because the arrangement does not make sense but the words are familiar to them. A free operant typing evaluation also was used to identify how quickly each participant could key press when no sequence was provided.

Analog Preparation

In this preparation we evaluated an immediate feedback component where participants would see errors show up in a red color. Immediate feedback could be a beneficial tool for building frequency quickly if it does not function as a distractor. In this preparation immediate feedback was used the entire time for two of the sequences and introduced after perfect accuracy plus practice for two of the sequences (see Table 11). No retention checks were completed and distractions were not introduced.

Materials and Setting

The materials and setting are the same as all previous experiments.

Experimental Design

This experiment used multi-element design within participants counterbalanced for conditions (see Table 11). Counterbalancing across participants allowed us to ensure there were no sequence effects (Kazdin, 2010).

Procedures

Procedures are the same as in phase 1.

Measures

The application software collected all of the data from each participant including each response given (i.e., each key pressed by the participant during each timing was recorded), the configuration settings, participant number, trial number, time-stamp and phase. The pre-assessment data were collected in a Microsoft Word© document that has a function of character count when text is highlighted. This was the measure used for the pre-assessment numbers. Additionally, the number of errors per participant, per sequence was scored by independent experimenters.

Social Validity Measure

After completing all trials of this study participants completed a survey (see Appendix 5). The survey asked questions on a Likert scale related to each participant's experience of the study and open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Interobserver Agreement

The software program has been tested for accurate recording prior to implementation with participants. The software has a standardized measurement used throughout the study that does not require treatment integrity measures.

Each participant's responses have output files in a spreadsheet (see Appendix 4) that are transferred to standard celeration charts and cumulative records in Microsoft Excel©. Two observers independently scored 30% of the data across all participants. The observers were trained on 20 different example charts of data and required to practice charting data in the presence of the researcher until they completed 3 consecutive sessions with no errors. The researchers used a key for each data set to determine accuracy. IOA was calculated using an agreement percentage of data entries on the standard celeration chart from the output data file and entries into the cumulative graph spreadsheet from the output file and were 95.2% across all participants. IOA collected on the number of trials with errors for this study was 94.8% across all participants.

Results

Each participant's data are displayed in figures 30, 31, 32, and 33. The primary finding in this data set was that immediate feedback did not result in suppression in responding. The evaluation presented immediate feedback after errors were reduced to zero at least 2 times consecutively; there is no suppression in responding and no increase in errors as a result.

Immediate feedback did not suppress responding when introduced after participants performed at perfect accuracy plus practice levels (see Figure 34).

However, immediate feedback resulted in quicker error reduction when used the entire time (see Figure 34).

Discussion

Determining whether immediate feedback would be useful in reducing errors quicker is important due to the fairly narrow window before fatigue is a factor during within session evaluations. Based on the data collected in this study, it appears that the immediate feedback component could be used in future preparations as a frequency building tool. The quicker participants achieve high rates of response with no errors the sooner environmental manipulations can be introduced. Another option if fatigue is an issue because sequences are too difficult to complete within session is to introduce across session methods.

Experiment 5

Participants

Participants included four undergraduate students enrolled at the University of Nevada, Reno. The students participated for up to 2 hours in one laboratory visit, in exchange for bonus course credit.

Pre-Evaluation

A typing timing was completed as a pre-evaluation of keyboard skills using sentences at a fourth grade reading level (see Appendix 6). Two timings were completed and each lasts one-minute.

A typing timing was completed as a pre-evaluation of keyboards skills when using random words in no particular order (see Appendix 7). This pre-evaluation was most similar to the actual task participants complete because the arrangement does not make sense but the words are familiar to them. A free operant typing evaluation was also used to identify how quickly each participant can key pressed when no sequence was provided.

Analog Preparation

A similar analog preparation was used as in experiment 3. The difference in the configuration settings included the addition of distractor conditions that included different audible and visual stimuli. Configuration settings reflected that all participants learned each sequence to perfect accuracy plus practice and then presented with distractions within each sensory modality (auditory and visual). Participants were required to hit the perfect accuracy aim 3 times without errors before moving to the distractor condition.

Distractors were presented on a fixed interval 10 second schedule for 3 seconds. The purpose of using a fixed interval schedule for this preparation was that it made it easier to identify where the "distraction" begins and ends. There were two different modalities of distraction (auditory and visual) and within modality three variations of type of distraction (see Table 12 and 13). These were presented in counterbalanced fashion to performers on 10-step conditional overlapping stimulus equivalent paired associate task sequences as was used in experiment 4. Volume levels for audible stimuli were controlled across participants.

Materials and Setting

The materials and setting were the same as all others.

Experimental Design

This experiment used a multi-element design between and within subjects counterbalanced for types of distractors (see Table 12 and Figure 35). Counterbalancing across participants allowed us to ensure there are no sequence effects (Kazdin, 2010).

Procedures

Procedures are the same as in experiment 4.

Measures

The application software collected all of the data from each participant including each response given (i.e., each key pressed by the participant during each timing was recorded and time-stamped), the configuration settings, participant number, trial number, time-stamp and phase. The pre-assessment data was collected in a Microsoft Word© document that has a function of character count when text is highlighted. This was the measure used for the pre-assessment numbers. Additionally, the number of errors per participant, per sequence was scored by independent experimenters for less perfect accuracy.

Social Validity Measure

After completing all trials of this study participants completed a survey (see Appendix 5). The survey asked questions on a Likert sc1ale related to each participant's experience of the study and open-ended questions related to the number of years they have taken college courses and specific comments about the computer program.

Treatment Integrity and Interobserver Agreement

The software program was tested and calibrated for accurate recording prior to implementation with participants. The software had a calibrated and tested measurement used throughout the study that does not require treatment integrity measures.

Each participant's responses were transferred automatically to output files in a spreadsheet (see Appendix 4) that are transferred to standard celeration charts and cumulative records in Microsoft Excel©. Two observers independently scored 30% of the data across all participants. The observers were trained on 20 different example charts of data and required to practice charting data in the presence of the researcher until they completed three consecutive sessions with no errors. The researchers use a key for each data set to determine accuracy. IOA for data entry on the standard celeration chart from the output data file was 92.5 across all participants.

Results

In this experiment we were able to identify a distractor that consistently suppressed responding and resulted in errors across all participants (see Figures 36, 37, 38, and 39). All participants performed each of the sequences until they had perfect accuracy plus practice. Distractors were introduced by modality alternating either audible or visual distractors. Suppression ratios were used to quantify the effects of the different types of distractors. The suppression ratio was calculated by dividing the average response rate during the 1 minute timing prior to distraction to the response rate during the 1 minute timing where the distractor was introduced. The auditory stimulus of hearing letters read aloud produced the greatest median suppression ratios across participants (see Table 14) 1, 2, 3, and 4 (.786, .775, 763, and .788 respectively). The auditory stimulus of an alarm sound had the second greatest median suppression ratios across participants 1, 2, 3, and 4 (.902, .823, .909, and .882 respectively. The auditory stimulus of unclear talking had the weakest suppressive effects of all stimuli across both modalities across participants 1, 2, 3, and 4 (.961, .989, .957, and.975 respectively). Of the visual stimuli, the stimulus of letters appearing on the screen produced the greatest suppressive effects of the visual stimuli across participants 1, 2, 3, and 4 (.8, .824, .797, and .861 respectively). The visual stimulus of a transparent screen flash with a random letter had the second greatest suppressive effects of the visual stimuli across participants 1, 2, 3, and 4 (.902, .918, .883, and .921 respectively).

Discussion

In this study, greater distractibility was found to be associated with lower frequencies of responding and there were different suppression ratios depending on the modality of the distraction. We defined distractors previously and categorized them into three main categories: stimuli that prompt a directly competing response with a task, stimuli that have no prior stimuli control and might be called “noise”, and stimuli which prompt an observing response. We attempted to ensure there were distractors presented that would prompt competing responses (letters showing up on screen and letters being read out loud), prompt observing responses (sound of an alarm and transparent screen flash with letter), and some that would just function as "noise" (talking that is not clear, screen animation). Based on the differentiated suppression ratios produced by each of the distractors it can be said that they all had different suppressive effects. It was expected that similar to Binder (1979), greater distractibility would be associated with lower frequencies of responding and there would be different suppression ratios depending on the modality of distraction. The cumulative charts showed us the effects of these stimuli in real time. Additionally, we were able to quantify the amount of suppression per type of distractor. This type of investigation with the type of measurement system we used has provided information that has improved the ability to predict and control future behavior. The questions this endeavor has generated are many and there are some specific recommended directions for future research discussed later.

General Discussion

All data supported that sequences that contain conditional discriminations and varied presentation resulted in lower response rates. Additionally, data support that the participants were attending to the stimulus on the screen. This is consistent with research supporting this arrangement (Cohen et al., 1990). For this reason all sequences included conditional discriminations that vary in presentation order.

In Experiments 1 and 2, the data from the simple sequences resulted in high and somewhat variable response rates. This variability was likely because the participants noted that they could memorize the sequence and then stop consistently attending to the stimuli on the screen. Participants noted they would make several errors before noticing.

For this reason and as evidenced by research in this area (Cohen et al., 1990) it is important that the order of presentation of the paired associates in each sequence vary. Conversely, each participant reported using different strategies to memorize the sequences; there was a great deal of variability as well as high response rates, which limited the sensitivity of measurement when using the simple sequences. A benefit to having conducted Experiments 1 and 2 with the simple response sequences is that the outcome was consistent with what prior research using computer based evaluation tools has found regarding the necessity of having presentation sequences vary to ensure attention to the stimuli on the screen (Cohen et.al1990).

All participants had lower response rates during distractor conditions; this is consistent with the literature (Demeter et al., 2008; Hirsh & Burk, 2013). In Experiment 2, screen flash distractors were presented on a fixed schedule. However, since Hirsh and Burk also commented on the characteristics of the distractors such as duration, frequency, and intensity as being important to whether or not distractions impact performance, during Experiment 3 the software was modified to allow experimenters to put the distractors on a variable schedule of duration and presentation.

Experiment 3 data demonstrated that a greater number of steps in the task resulted in more trials with errors before perfect accuracy was achieved across all participants, regardless of the training target (see Table 7). Additionally, many of the trials with errors in the accuracy only condition happened during the distractor phase. In other words, consistent with Hirsh and Burk's findings, participants of Experiment 3 were able to eventually reach perfect accuracy despite the presence of distractors.

Social validity surveys were completed by each participant at the end of the study. There were notable differences between Experiments 1 and 2 (included simple sequences) and Experiment 3 (did not include simple sequences) regarding the perceived difficulty of the sequences. Participants for Experiment 3 noted a dislike only for the sequences during which they were stopped prior to getting “0” errors; the dislike seemed to be related to interruption of performance goals. All participants for Experiments 1 and 2 did not express dislike for portions of the method, and instead indicated preferences for the sequences that did not have color associations, noting observations such as, “I liked the easy ones because I can get a higher score,” and, “It’s fun to see how fast I can go.” In summary, participants seemed to enjoy the sequences they could memorize more easily and respond quickly; when these were removed in Experiment 3 participants did not respond at all with indications of liking the task.

Experiment 4 data indicate that the use of immediate feedback could be useful for reducing errors more quickly. This is an important finding because of the fatigue that can occur when using this evaluation method in a within-session design. The less time it takes a participant to reach high response rates without errors the more quickly the experimenter can intervene without observing a decrease in performance as a result of fatigue. In Phase 1 of Experiment 4, we also discovered that the overlap of some paired associates made the task slightly more difficult; participants responded at rates between 40 and 60 versus 60 and 80 responses per minute, as previously observed. This phenomenon deserves future investigation especially as it may lead to a method for quantifying the effects of overlap in relational frame arrangements.

Experiment 5 focused on the different modality of distractors' effects on the previously observed effects of distraction on performance in a within session laboratory preparation. The findings have a much broader scope with respect to implications for stimulus control, definitions of "distraction", and variables that results in response suppression. While in experiment 3 we were able to indicate that the one type of distractor we used did suppress responding, without the quantifiable suppression ratios of more than one type of distractor across multiple participants and that was really all that could be said. In experiment 5, we were able to introduce distractors with different characteristics and generate suppression ratios that had quantifiably different suppression rates across possible different stimulus control categories. We had 4 participants in this experiment and without exception one particular type of distractor that prompted a competing response suppressed responding the most, across two different modalities.

The studies each individually had limitations. In experiment 1, we used some simple sequences that did not vary in presentation order; this resulted in participants making errors and having really high response rates resulting from memorizing the sequences. This is consistent with patterns found in other research indicated that sequences need to be varied (Nissen & Bullemer, 1987; Cohen et al., 1990). In experiment 2, as mentioned previously, the distractors were presented on a fixed schedule and retention checks were needed prior to introduction of distractors to ensure perfect accuracy; this issue can be eliminated if aims are developed for each sequence. Another limitation was inherent in the research design of Experiment 3. There was a need for retention checks on perfect accuracy plus practice prior to introducing distractors that was not met because we did not establish frequency aim windows for each of the sequences.

An additional limitation of all experiments conducted is that all participant data were collected within session. Experiment 4's limitation was that we introduced immediate feedback after errors were removed for two of the sequences in an attempt to see if the immediate feedback would suppress responding as distractors did. However, it would be of interest to modify the method to investigate learning with and without immediate feedback the whole time. Experiment 5 had the limitation of preparation. While the preparation did produce sensitive data our method could be improved such that there is no break in continuous responding from before and after distractors are being introduced. Additionally, a better method would be having the distractor continuously presented without interruption, this would yield a more accurate true suppression rate because in the calculation you divide the rate prior to distraction by the rate after it is introduced, but in the current method there were periods of time during the 1 minute timing that there were no distractors present.

Previously, distractors were categorized in three different ways and, using a basic preparation, these were evaluated in a most sensitive manner. Dinsmoor (1995a, 1995b) and Wyckoff (1952) describe stimulus control as occurring when multiple aspects (the rate, latency, duration, or amplitude) of a response are altered in the presence of an antecedent stimulus (environmental event). This preparation and evaluation is simple and controlled and leaves us with more questions to investigate. If there is no disruption in performance, is there not a distractor? If we train someone to perfect accuracy on a skill, introduce loud noise as a distractor, and there is no change in responding – is this really distraction? Based on this research, and holding true to the definition of stimulus control, my suggestion is that terminology, measurement systems, and the conditions under which measurement of distraction is occurring are not sensitive enough to catch the evidence if this is the case (the rate, latency, duration, or amplitude of a response are altered). I would suggest that a technical definition of distraction has to include that there is *joint* stimulus control *as evidenced by a change in rate, latency, duration or amplitude of a response*.

This research has implications relevant for applications of Precision Teaching in general education and methods of staff training, as well. In experiments 1 and 2 we found that tasks being trained that are completed in the same order every time and have a short number of steps are easier to acquire in a shorter period of training. This research suggests the need for using more sensitive measures and training targets when evaluating the efficacy of treatment procedures and methods that aim to produce enduring accurate performances. In experiments 1 and 2 we made changes to eliminate the simple sequences because our data was detailed enough that we could see where the errors were occurring and identify the problem. In our case we found that the multiple errors were a result of the participant not attending to the screen, so we made an adjustment to the sequence to correct the error.

Evidence from this research supports that using only the term 'natural environment' to describe a condition is not sufficient for empirical demonstrations. In experiment 5 we found that different environmental stimuli, depending on the type of stimulus, will have different suppressive effects on responding. This is likened to researchers who are investigating how to train people to drive. The instructor says, "After X training was completed we had the driver perform in the 'natural environment' and he still performed at 100% correct on all skills," as evidence to support the effectiveness of the training. Without any further information on the natural environment, this training approach could certainly not be considered with any merit. If given the information on possible distractors present, such as that the driver was asked to perform in an unfamiliar, high-population, metropolitan area during rush hour, we could begin drawing some more accurate conclusions on training efficacy.

Having a way to quantify the amount of response suppression that might occur under certain circumstances is certainly worthy of further clarification and evaluation within our scientific community. In this study we did quantify the amount of suppression with the suppression ratio. This ratio provides a quantifiable comparison between the types of variables introduced in the environment that effect responding. Without this level of direct inspection of the behavior of interest, interpretations of findings are limited.

Future Directions

This inductive research endeavor has generated many questions and resulted in a software program equipped to continue exploring them. Primarily, future research should include investigating further refinement and variation to the way in which we introduce distractors in such a preparation. One option might be using a narrative distractor that is presented for a longer period of time versus a short discrete presentation multiple times. Additionally, we should look at the addition of even more types of distractors, perhaps leading to the development of a suppression index based on repeated evaluations of distractors with similar characteristics. Researchers should focus on types, contexts, histories etc. related to distraction. An additional variable that could be identified is whether participants have any historical attention deficit diagnoses. Before these continued evaluations are able to occur, the software would need to be modified in order to develop the cumulative records more easily to allow for instant, ongoing performance evaluation and providing a substantial advantage to the researcher.

A complete behavior analytic treatment of attending and distraction is still needed. In a recent paper, Lotfizadeh, Edward, Redner and Poling (2012) suggested that a largely overlooked phenomenon in discrimination learning is that motivating operations *change* stimulus control. Studies have recently explored what Michael (1982) termed the value-altering and behavior-altering effects of motivating operations. Lotfizadeh et al., state that "One aspect of the behavior-altering effect that has garnered no recent attention involves the changes in stimulus control produced by motivating operations" (2012). The authors reviewed 11 basic studies concerned with the influence of varying levels of food or water deprivation on stimulus generalization. Findings suggest that motivating operations influence stimulus control (a) by changing the evocative strength of not just an established discriminative stimulus, but also of stimuli that are physically similar to it; (b) by changing the range of stimuli that evoke the operant in question; and (c) by exerting these effects in a graded fashion. The bold statement might be made that there is *never* a time that stimulus control is not jointly present with some degree.

A wise man once articulated that the goal of a science of behavior is to improve our ability to predict and control it. This research has done just that, offering a real time, quantitative view of distractors. Stepping back to a laboratory preparation in the investigation of distraction is important if we are forever skeptics; it is necessary to evaluate this over-used, and as yet, poorly understood descriptor in a basic and well controlled laboratory preparation.

In closing, there is currently no better way to look at the phenomena of distraction than through the use of a cumulative chart to establish functional relations and evaluate the suppression of real time responding in a quantitative way, as has been done in this dissertation and was started in 1979 by Binder. Cognitive psychologists and some behavior analysts have attempted repeatedly, and unsuccessfully, to evaluate the phenomena of distraction with insensitive measurement tools that limit research conclusions. In addition to the contribution of a quantification of stimuli we call “distractors,” which interrupt and suppress responding at different levels that are reliably demonstrated in our data, the use of the cumulative record was demonstrated as a powerful tool in this endeavor. In 1976, Skinner wrote an editorial in the *Journal of Experimental Analysis of Behavior* called “Farewell, my LOVELY,” in which he said, “What has happened to experiments where rate changed from moment to moment in interesting ways, where a cumulative record told more at a glance than could be described in a page? Shall we never again see things as fascinating as the slight overshooting when a pigeon switches from the ratio to the interval phase of a mixed schedule?” I say, “Yes, we will.” Presented evidence shows that the cumulative record can add value because some of the things important in Precision Teaching and other behavior analytic applications, e.g., distractibility and "attention," are moment-to-moment, and can only *really* be seen with the cumulative record. Brief timings charted on the Standard Celeration Chart show decrements in response rate, but not in the way that a continuous frequency that is influenced by introduction of a competing stimulus. As our instrumentation gets better, we should begin introducing cumulative record technology back into our science, and perhaps even our education and clinical practice.

Continued demonstration of the power of this tool provides support for resurrecting "my lovely" from the archives.

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Tables

Table 1

Simple Sequence Example

A = D
S = K
J = L
M = P
T = Y
C = N
O = Q
R = E
F = H
G = W

Table 2

Conditional Sequence Example

R = E
T = Y
F = H
C = N , C= J, C= Q
M = P
A= D
S = K
G-W

Table 3

Discrete Trial Analog Steps Comparison

Step Number	Description	Discrimination	Computer Program
1	Appropriate materials ready based on program	Simple	Letter
2	Make eye contact with the learner	Simple	Letter
3	Deliver the instruction.	Simple	Letter
4	Present the materials.	Simple	Letter
	Wait at least 3 seconds for a response.	Simple	Letter
5	If incorrect learner response If no-response learner response: If correct learner response:	Conditional	Letter/Color
6	Provide appropriate reinforcement for the response.	Conditional	Letter/Color
8	Record correct/incorrect data Trainer should circle accurately whether the trial was correct or incorrect	Simple	Letter
9	Record prompt strength Trainer should circle the accurate prompt used to assist the learner	Simple	Letter
10	Provide a 5 second interval between each trial.	Simple	Letter

Table 4

Method – Experiment 1 Experimental Design

Participant	Sequence A: 10 step simple	Sequence B: 10 step conditional	Sequence C: 6 step simple	Sequence D: 6 step conditional
1	1	2	4	3
2	2	1	3	4
3	3	4	1	2
4	3	4	2	1
5	1	2	3	4

Table 5
Experiment 2 – Experimental Design

Participant	Sequence A1 – 10 step simple	Sequence A2 – 10 step conditional	Sequence B1 – 10 step simple	Sequence B2 – 10 step conditional
1	Perfect Accuracy	Perfect Accuracy	Accuracy	Accuracy
2	Perfect Accuracy	Perfect Accuracy	Accuracy	Accuracy
3	Accuracy	Accuracy	Perfect Accuracy	Perfect Accuracy
4	Accuracy	Accuracy	Perfect Accuracy	Perfect Accuracy

Table 6
Experiment 3 – Experimental Design

	Perfect Accuracy Plus Practice		80% Accuracy	
Participant	Sequence A1 6 step conditional	Sequence A2 10 step conditional	Sequence B1 6 step conditional	Sequence B2 10 step conditional
1	1	2	3	4
2	3	4	1	2
3	4	3	2	1
4	2	1	4	3

Table 7
Experiment 3 – Trials with Errors Until Perfect Accuracy plus Practice

	Perfect Accuracy Plus Practice		80% Accuracy	
Participant	Sequence A1 6 step conditional	Sequence A2 10 step conditional	Sequence B1 6 step conditional	Sequence B2 10 step conditional
1	15	10	18	20
2	12	13	19	20
3	8	13	18	23
4	10	14	19	18

Table 8

Experiment 3 – Accuracy Ratios: Differences Before and After Distractors

	Perfect Accuracy Plus Practice		80% Accuracy	
Participant	Sequence 1	Sequence 2	Sequence 3	Sequence 4
1	5.2	6.3	2.7	3.3
2	6.3	3.8	2.4	8.0
3	8.0	3.8	4.2	3.0
4	44.5	7.0	2.0	3.3

Table 9

Method – Experiment 4, Phase 1 Experimental Design

Participant	Sequence 1 10 step conditional	Sequence 2 10 step conditional	Sequence 3 10 step conditional	Sequence 4 10 step conditional
1	1	2	3	4
2	3	4	1	2
3	4	3	2	1
4	2	1	4	3

Table 10

Sequences – Experiments 4 and 5

Sequence 1 10 step conditional	Sequence 2 10 step conditional	Sequence 3 10 step conditional	Sequence 4 10 step conditional
S – N	A – P	Y – G	R – B
L - B	B – F	B – Z	D – X
N – Y	O - L	L - P	W – N
D – V	Q –T	Z - S	C – U
X – J	L – G	G - A	B – H
V – O	G –H	E - I	E – G
G – M	S – R	U – M	N – J
N – I	D – B	H – N	L – P
V – X	C – M	V – R	F – T
C - A	F - E	S – K	A – K

Table 11

Method – Experiment 4, Phase 2

	Immediate Feedback Whole Time		Immediate Feedback after 100% Accuracy + Practice	
Participant	Sequence 1 10 step conditional	Sequence 2 10 step conditional	Sequence 3 10 step conditional	Sequence 4 10 step conditional
1	1	2	3	4
2	3	4	1	2
3	4	3	2	1
4	2	1	4	3

Table 12

Method – Experiment 5

Participant	Sequence 1 10 step conditional	Sequence 2 10 step conditional	Sequence 3 10 step conditional	Sequence 4 10 step conditional
1	1 Aud, Vis	2 Vis, Aud	3 Vis, Aud	4 Aud, Vis
2	3 Vis, Aud	4 Aud, Vis	1 Aud, Vis	2 Vis, Aud
3	4 Aud, Vis	3 Vis, Aud	2 Vis, Aud	1 Aud, Vis
4	2 Vis, Aud	1 Aud, Vis	4 Aud, Vis	3 Vis, Aud

Table 13

Type of Distractors – Experiment 5

Modality	1	2	3
Visual	Letters appear on Screen	Screen Animations	Transparent overlay of Random Number Stimuli
Audible	Letters being read out loud	Random Talking words aren't clear	Alert Siren

Table 14
Distraction Ratios – Experiment 5

	Participant	1	2	3	4
Modality	Sequence				
Visual: Letters Appear on Screen	1	.859	.812	.784	.892
	2	.906	.781	.812	.836
	3	.741	.836	.775	.719
	4	.724	.872	.810	.885
	Median	.8	.824	.797	.861
Visual: Transparent Screen Flash with Random Letter	1	.906	.857	.815	.923
	2	.906	.890	.843	.918
	3	.897	.945	.965	.807
	4	.741	.945	.823	.951
	Median	.902	.918	.833	.921
Visual: Screen Animation	1	.984	.984	.937	.938
	2	.984	.953	.953	1.0
	3	.982	1.0	.982	.964
	4	.948	1.02	.983	.967
	Median	.983	.992	.968	.966
Auditory: Hearing Letter Read Out Loud	1	.813	.797	.703	.846
	2	.812	.75	.766	.787
	3	.724	.8	.793	.789
	4	.759	.818	.759	.705
	Median	.786	.775	.763	.788
Auditory: Alarm Sound	1	.906	.843	.846	.862
	2	.906	.812	.921	.902
	3	.896	.8	.931	.982
	4	.823	1.0	.896	.787
	Median	.902	.823	.909	.882
Auditory: Unclear Talking	1	.938	.968	.906	.892
	2	.937	.843	.984	1.0
	3	.983	1.01	.948	1.0
	4	.983	1.1	.965	.951
	Median	.961	.989	.957	.975

Table 15

Medians of Medians – Experiment 5

Modality	Directly Competing	Contextual Stimuli	Possible Observing Response
Visual	Letters appear on Screen	Screen Animations	Transparent overlay of Random Number Stimuli
Medians	.812	.976	.910
Audible	Letters being read out loud	Random Talking words aren't clear	Alert Siren
Medians	.781	.968	.892

Figures

Figure 1. Sample of Participants Experience through Experiment 1.

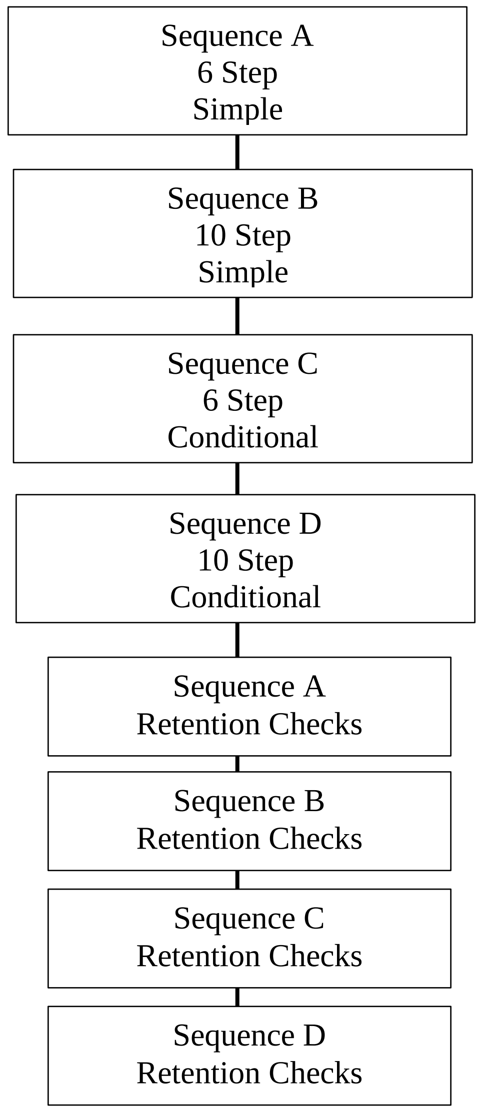


Figure 1. Participants went through each of the above phases but in randomly assigned order. During this experiment participants only completed each sequence until they completed a total of 10 trials per sequence and then retention checks were completed for each of the sequences.

Figure 2. Experiment 1, Participant 1 data.

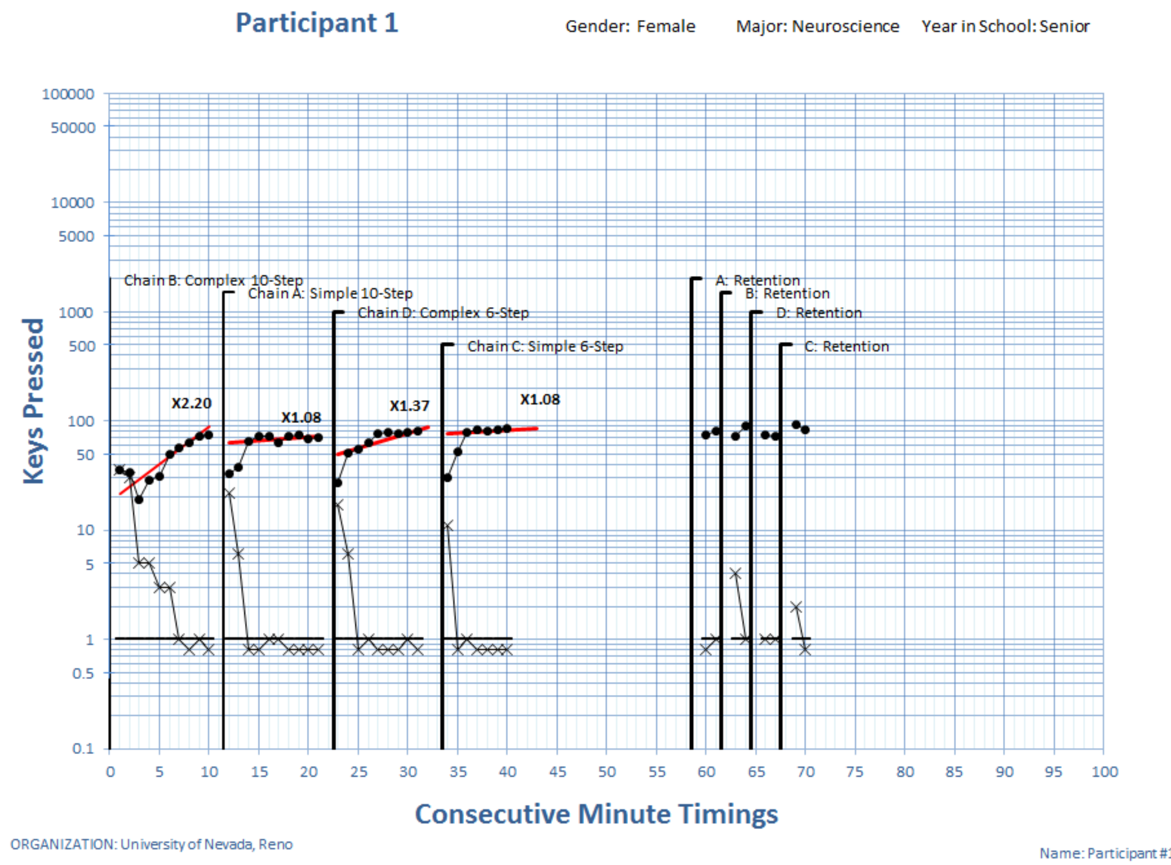


Figure 2. This figure illustrates the data from participant one's performance on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 3. Experiment 1, Participant 2 data.

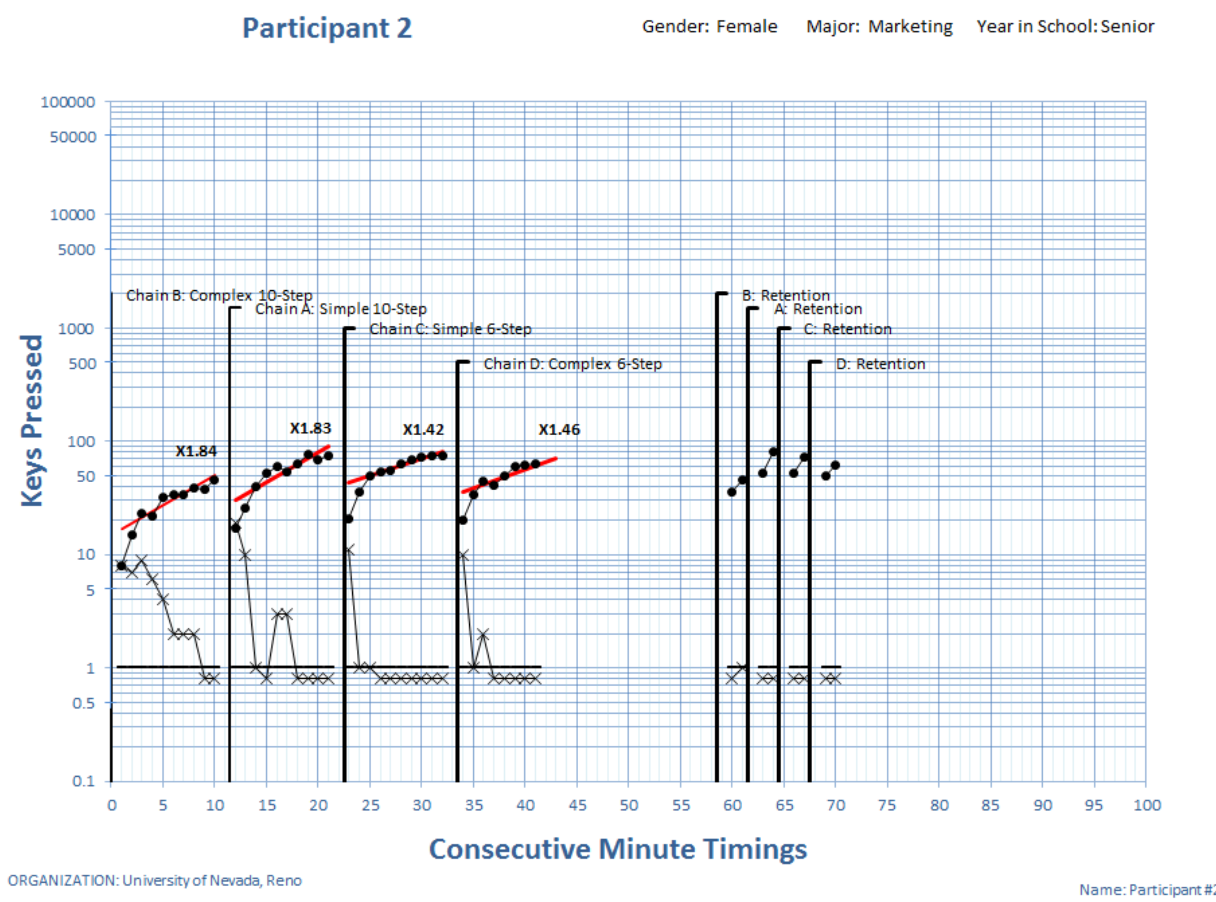


Figure 3. This figure illustrates the data from participant two's performance on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 4. Experiment 1, Participant 3 data.

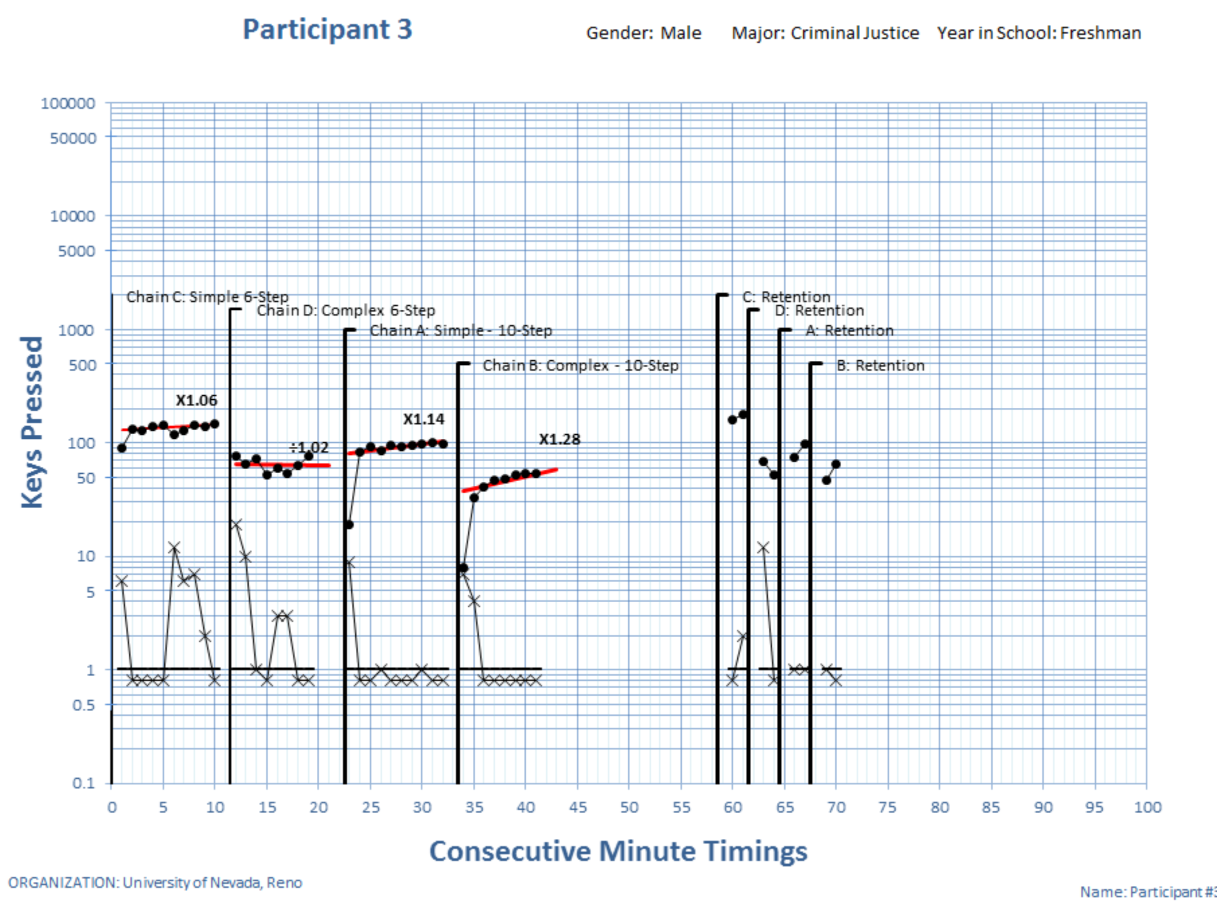


Figure 4. This figure illustrates the data from participant three's performance on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 5. Experiment 1, Participant 4 data.

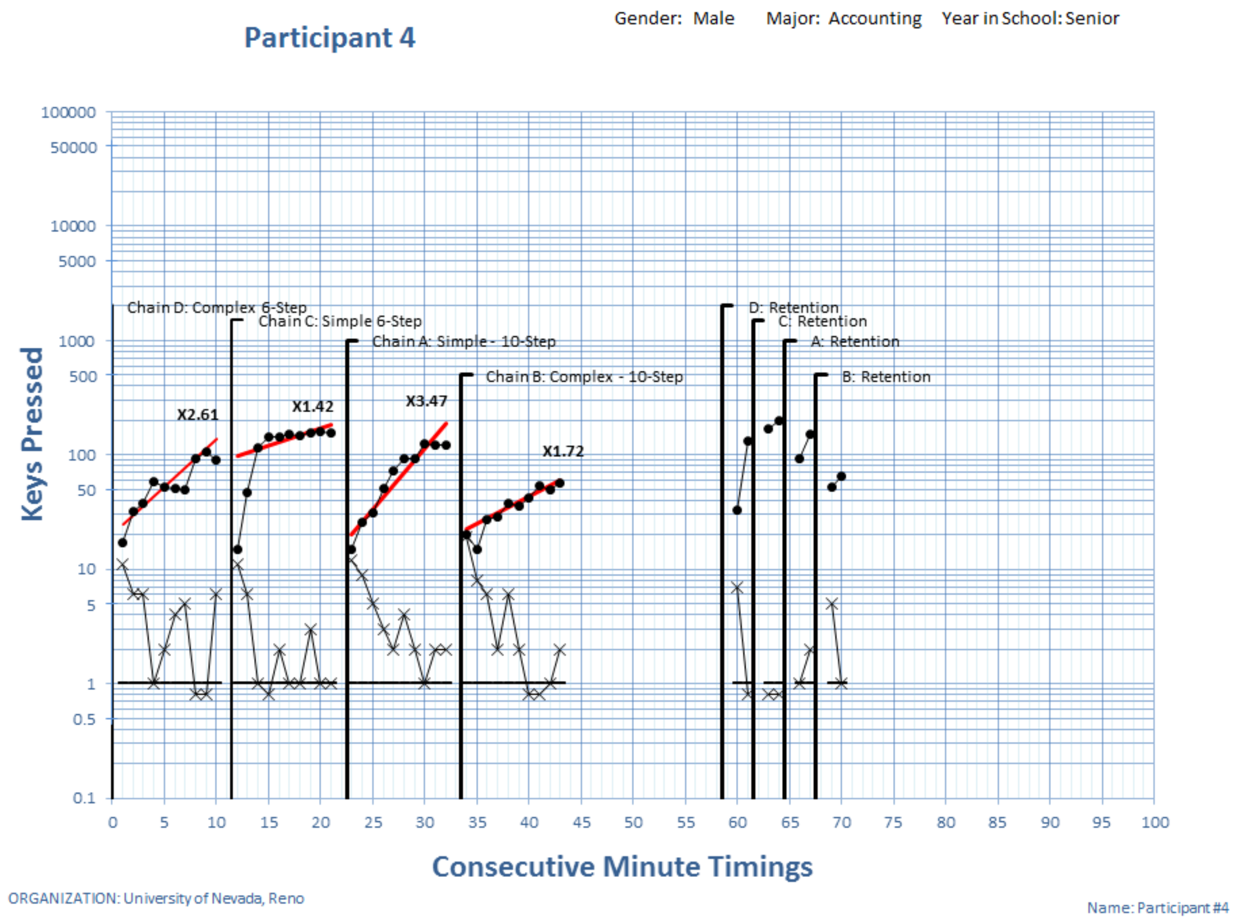


Figure 5. This figure illustrates the data from participant four's performance on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 6. Experiment 1, Participant 5 data.

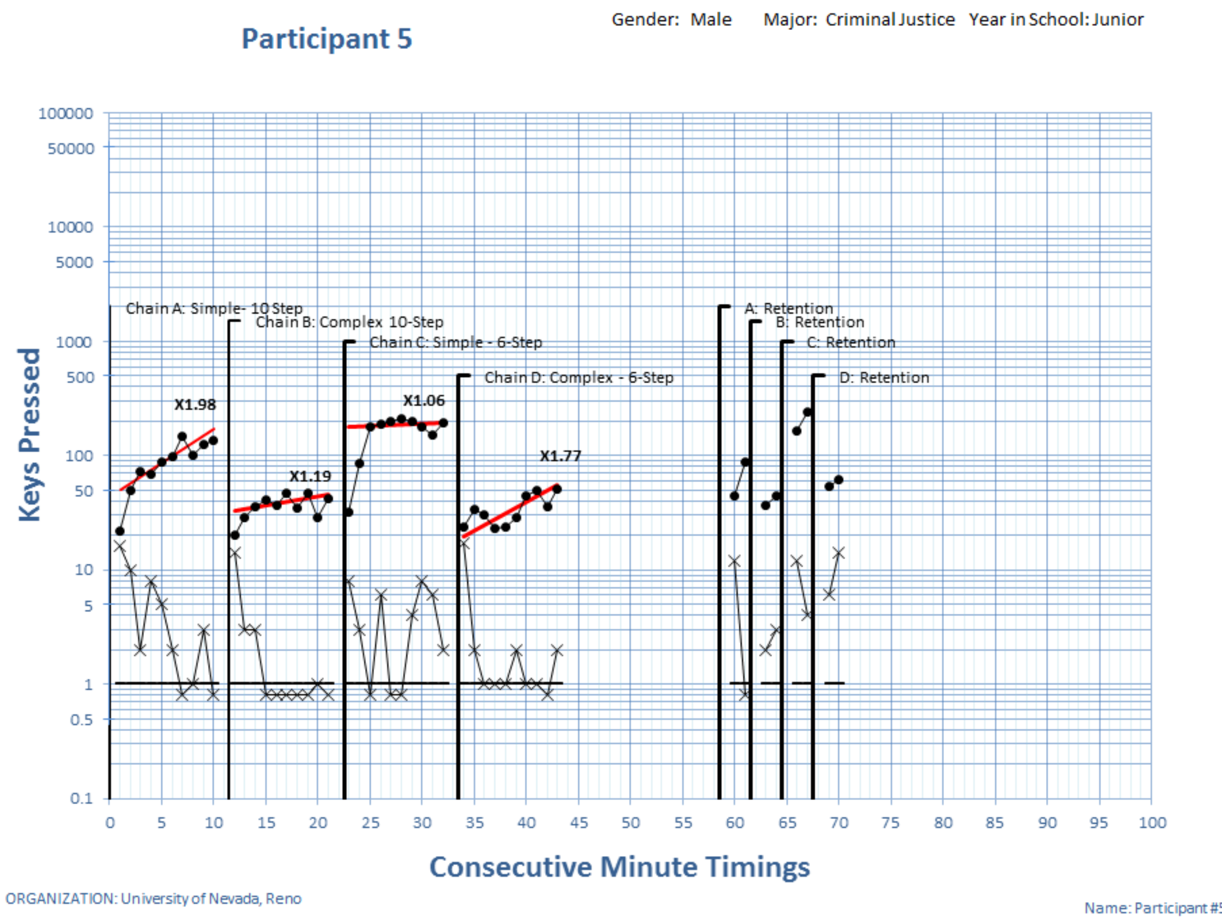


Figure 6. This figure illustrates the data from participant five's performance on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 7. Experiment 1, Sequence A Across Participants.

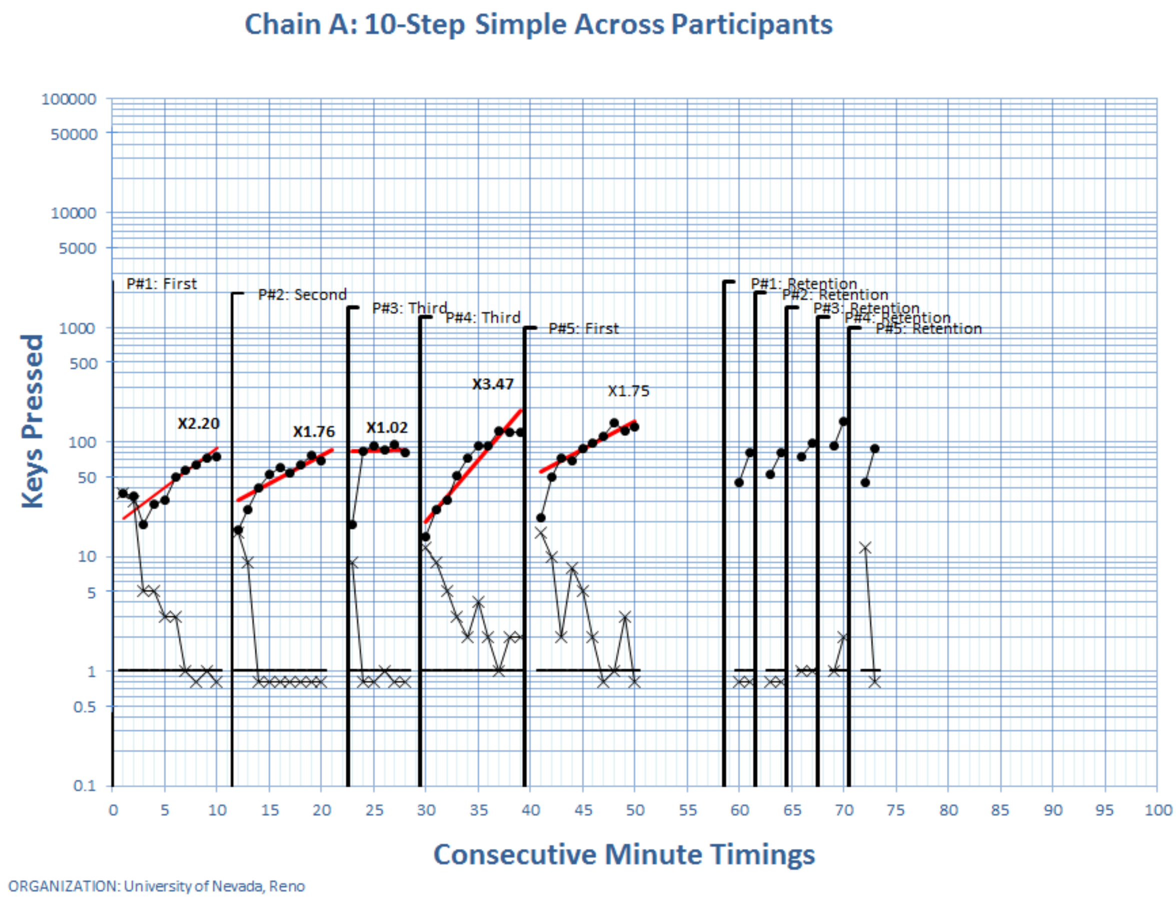


Figure 7. This figure illustrates the data from all participants' performance on Sequence A on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 8. Experiment 1, Sequence B Across Participants.

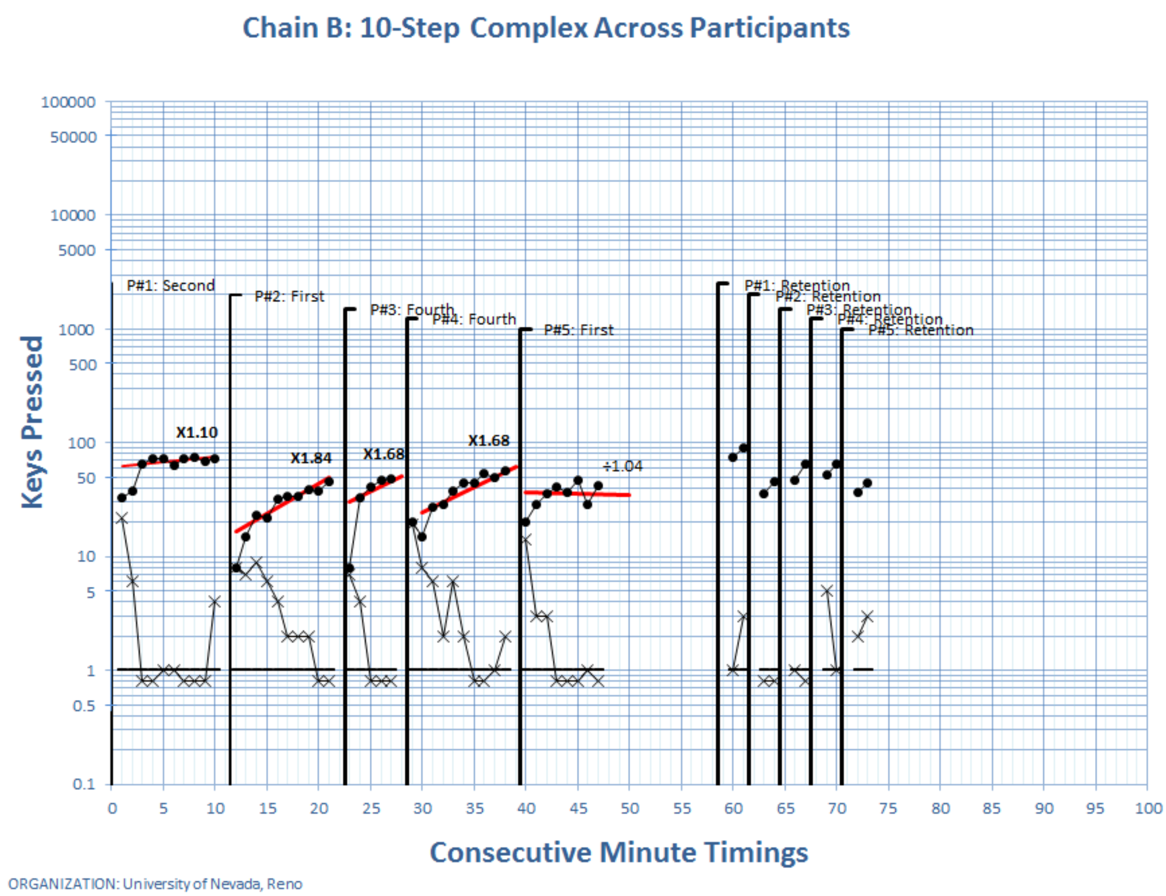


Figure 8. This figure illustrates the data from all participants' performance on Sequence B on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 9. Experiment 1, Sequence C Across Participants.

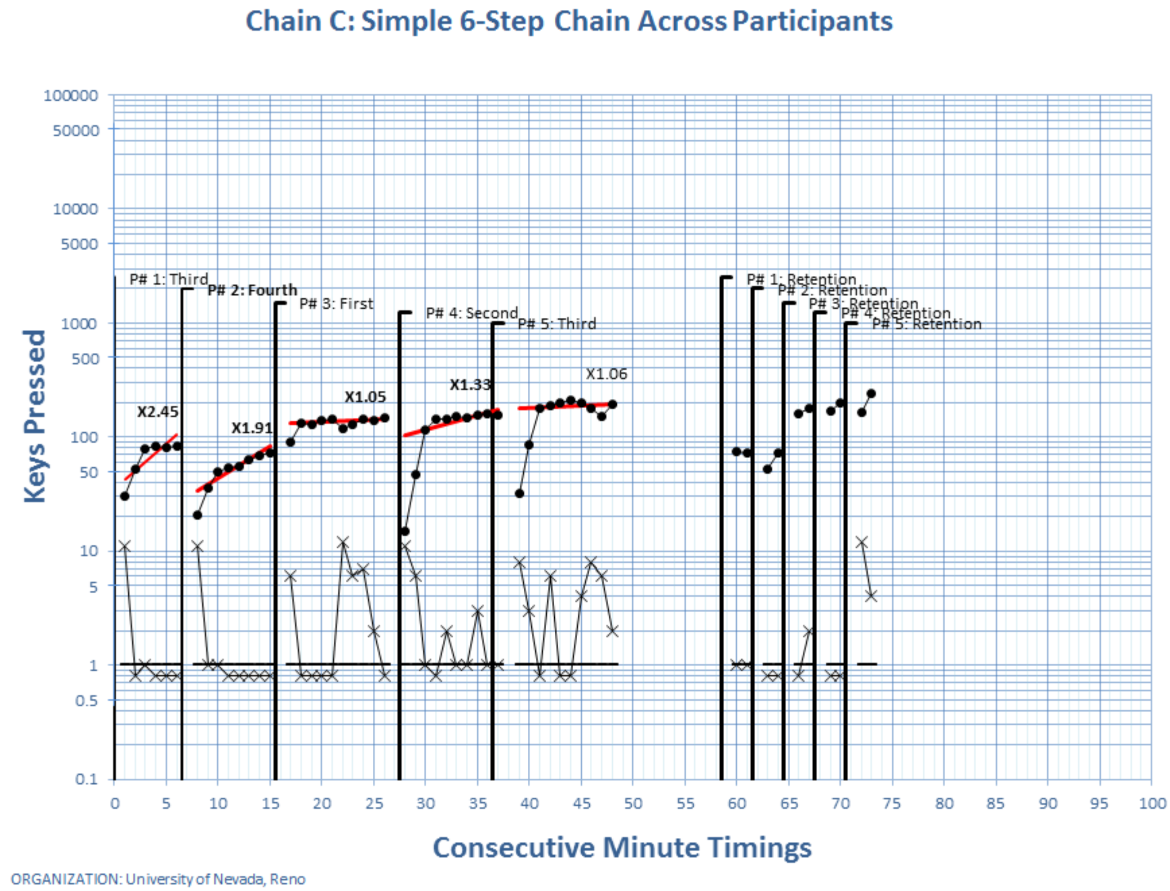


Figure 9 . This figure illustrates the data from all participants' performance on Sequence C on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 10. Experiment 1, Sequence D Across Participants.

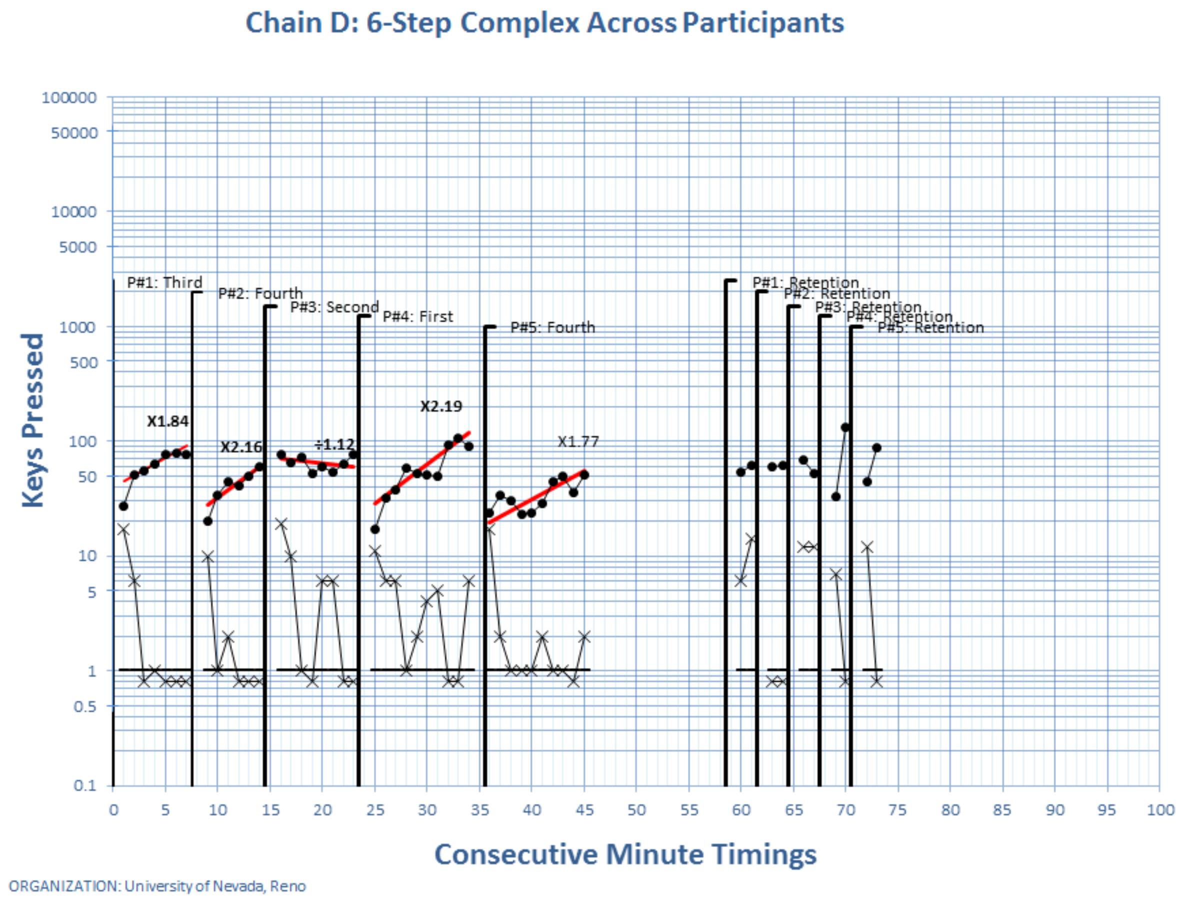


Figure 10 . This figure illustrates the data from all participants' performance on Sequence D on the timings from experiment 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 11. Sample of Participants Experience through Experiment 2

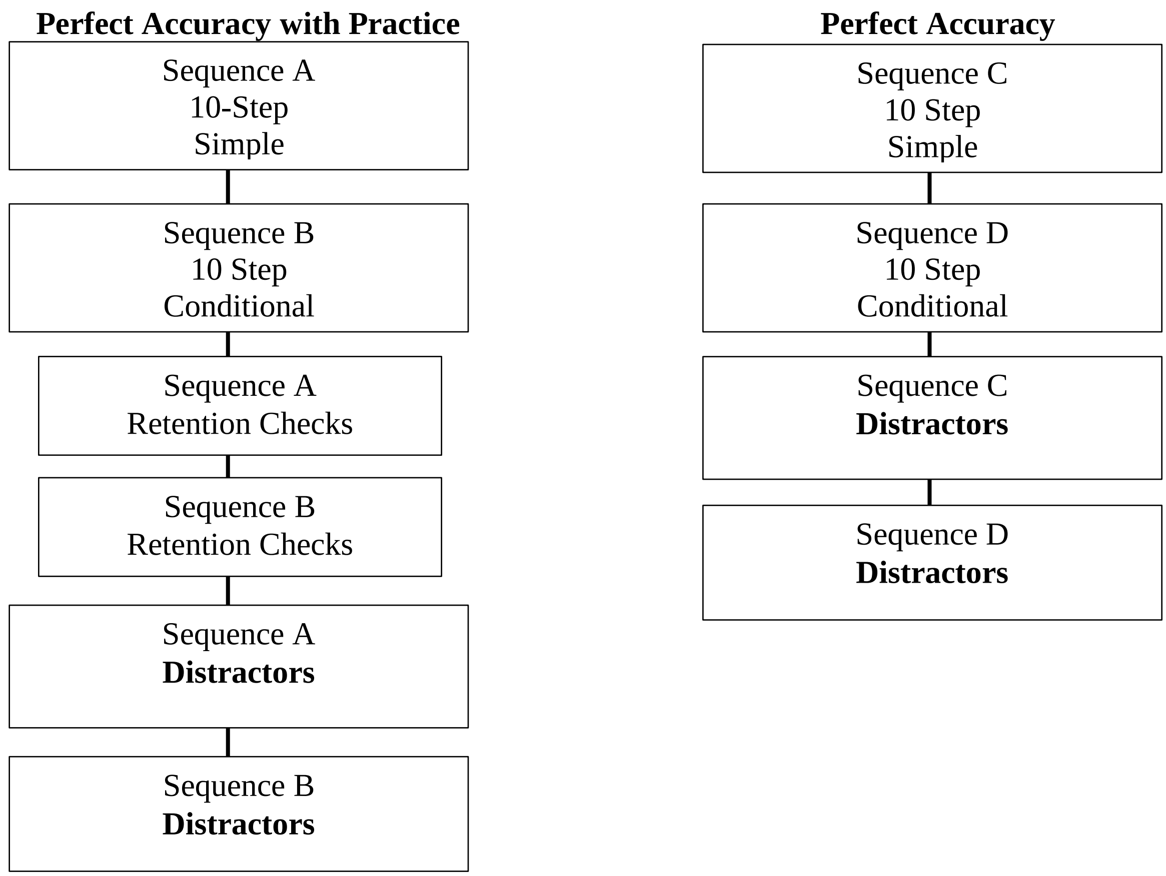


Figure 11. Participants went through each of the above phases but in randomly assigned order. During this experiment two sequences were performed to perfect accuracy with practice and some to perfect accuracy only.

Figure 12. Experiment 2, Participant 1.

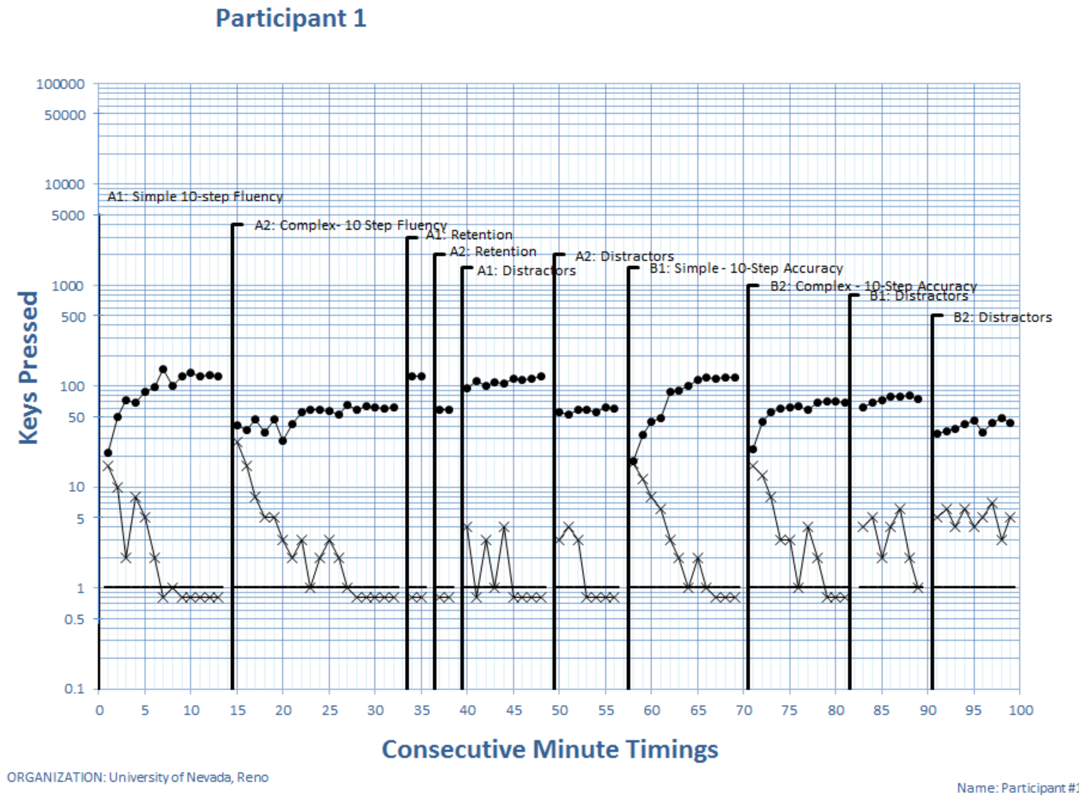


Figure 12. This figure illustrates participant one's data on the timings from experiment 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 13. Experiment 2, Participant 2.

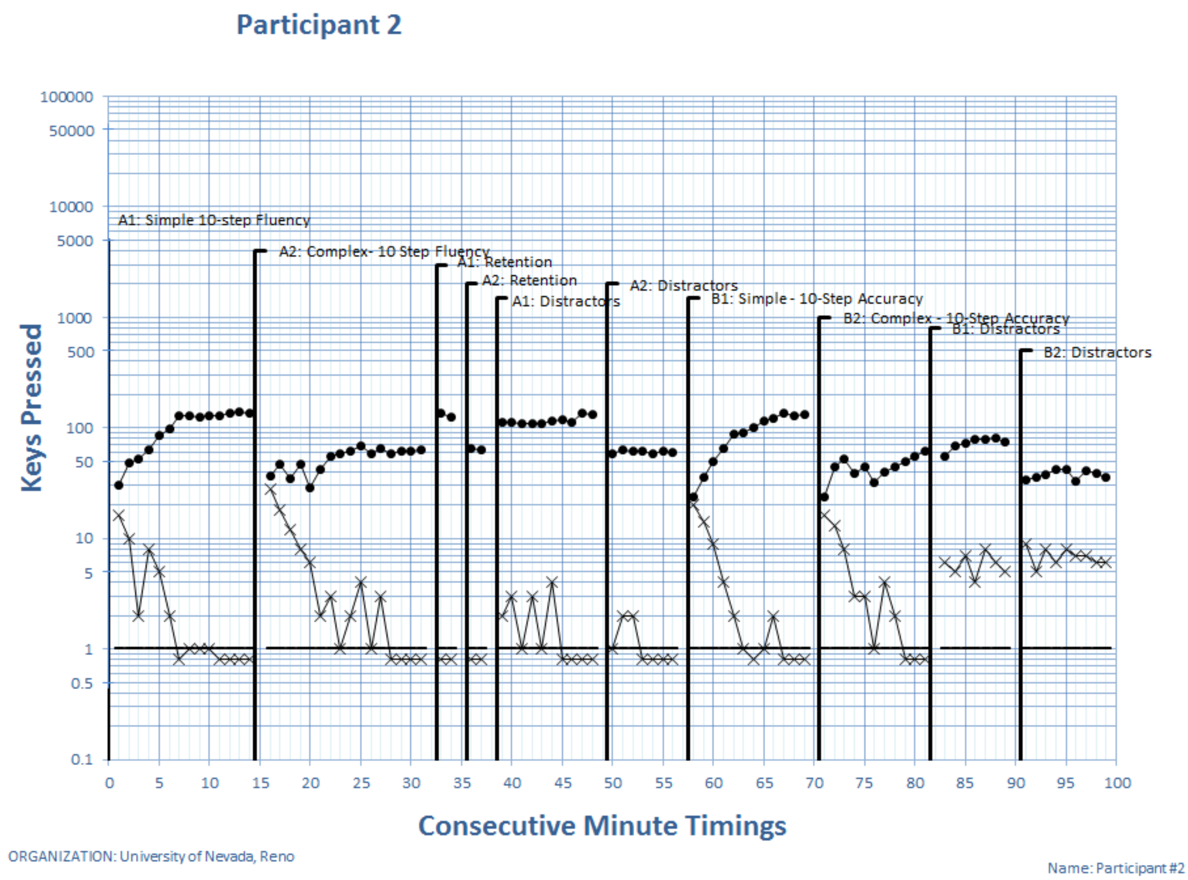


Figure 13. This figure illustrates participant two's data on the timings from experiment 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 14. Experiment 2, Participant 3.

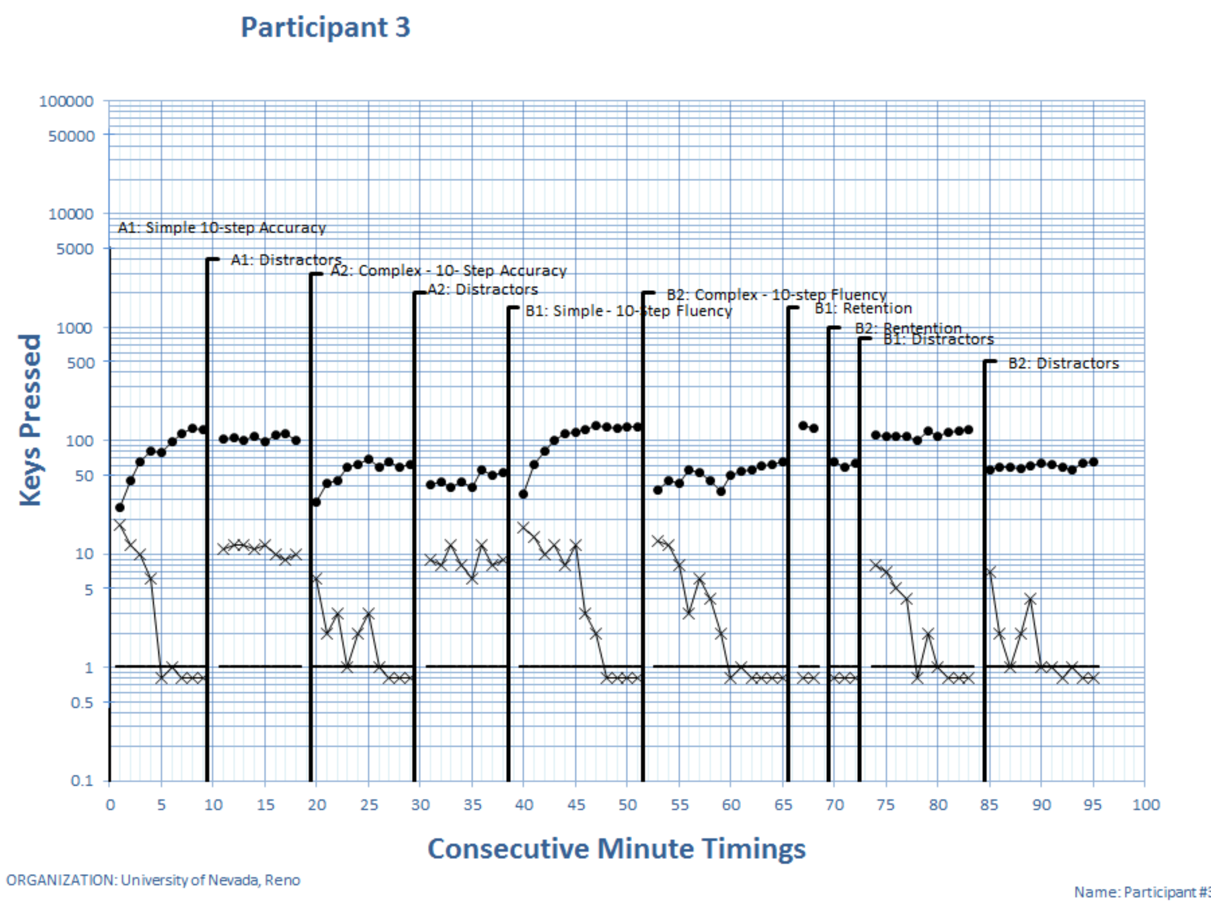


Figure 14. This figure illustrates participant three's data on the timings from experiment 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 15. Experiment 2, Participant 4.

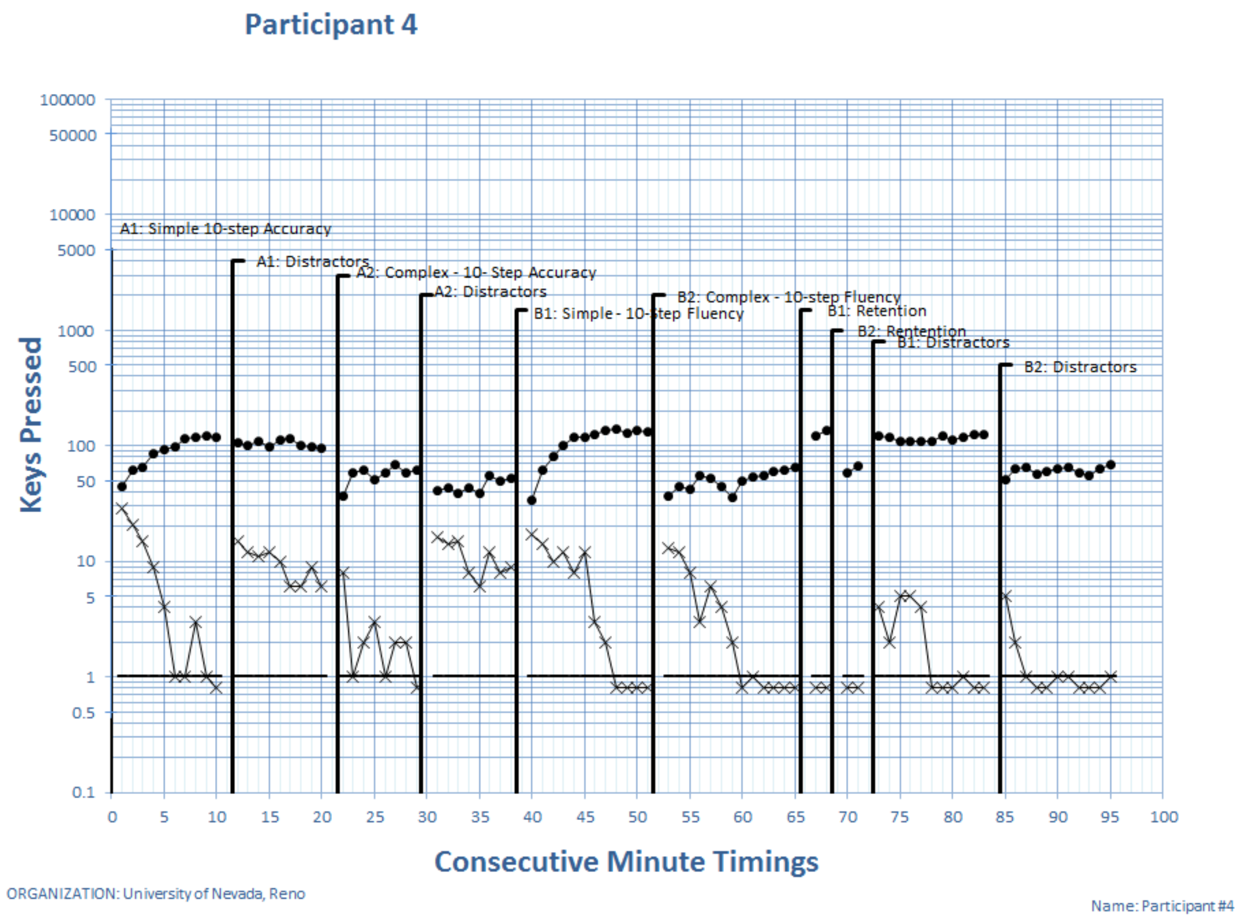


Figure 15. This figure illustrates participant four's data on the timings from experiment 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 16. Sample of Participants Experience through Experiment 3.

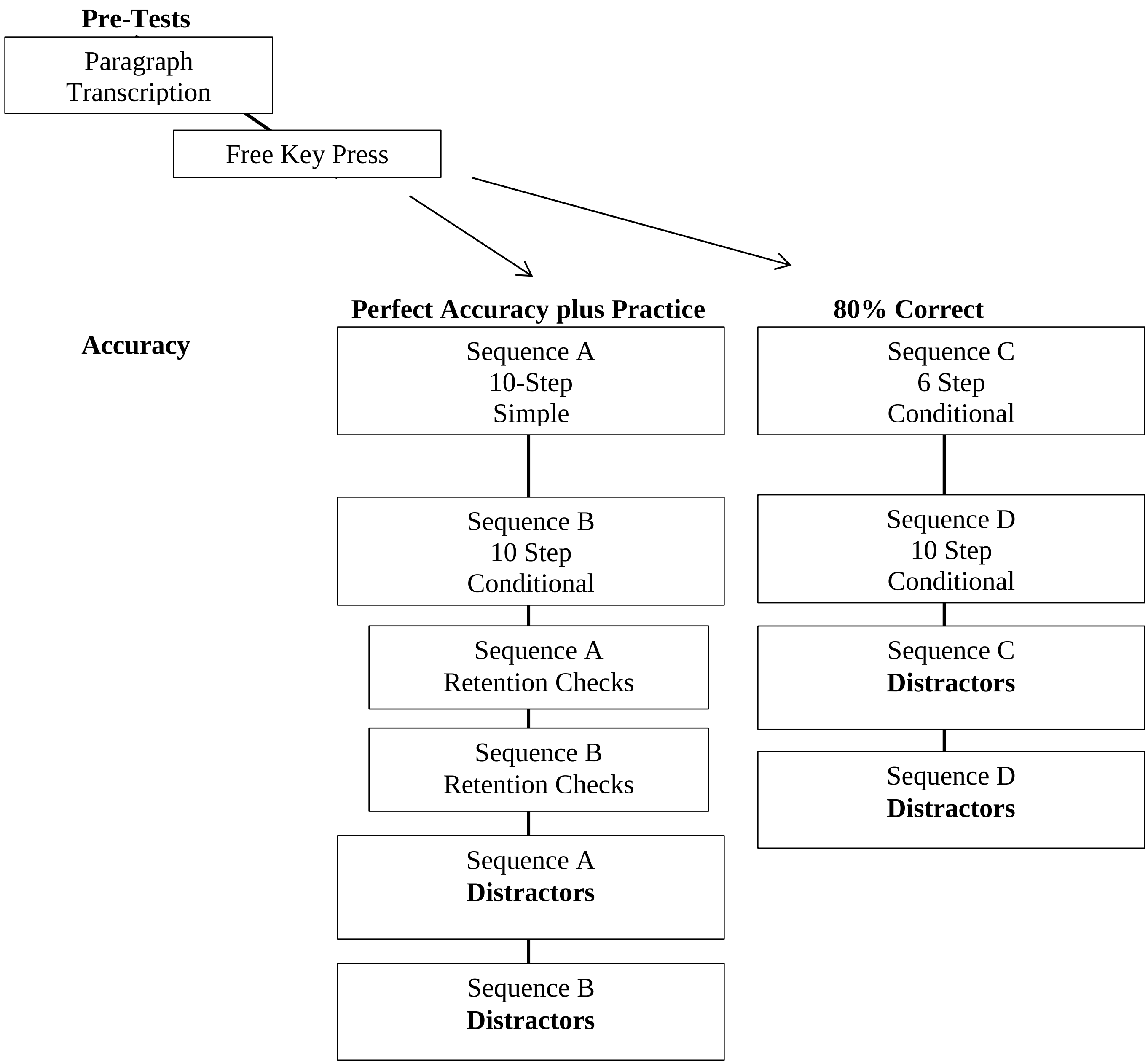


Figure 16. Participants went through each of the above phases but in randomly assigned order. During this experiment two sequences were performed to perfect accuracy and some to less-perfect accuracy, pre-tests were still completed with the addition of a random transcription test.

Figure 17. Participant 1 Data through Experiment 3

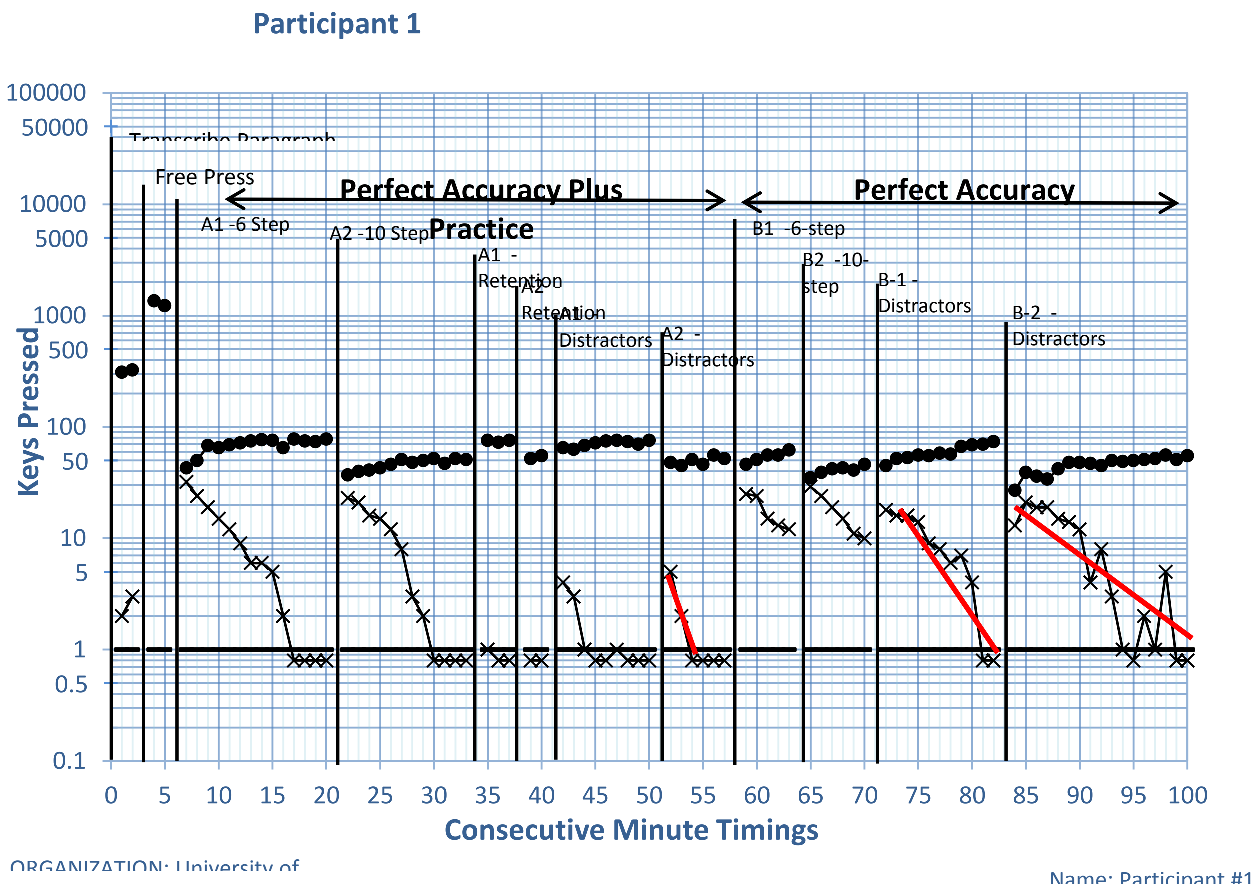


Figure 17. This figure illustrates participant one's data on the timings from experiment 3. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 18. Participant 2 Data through Experiment 3.

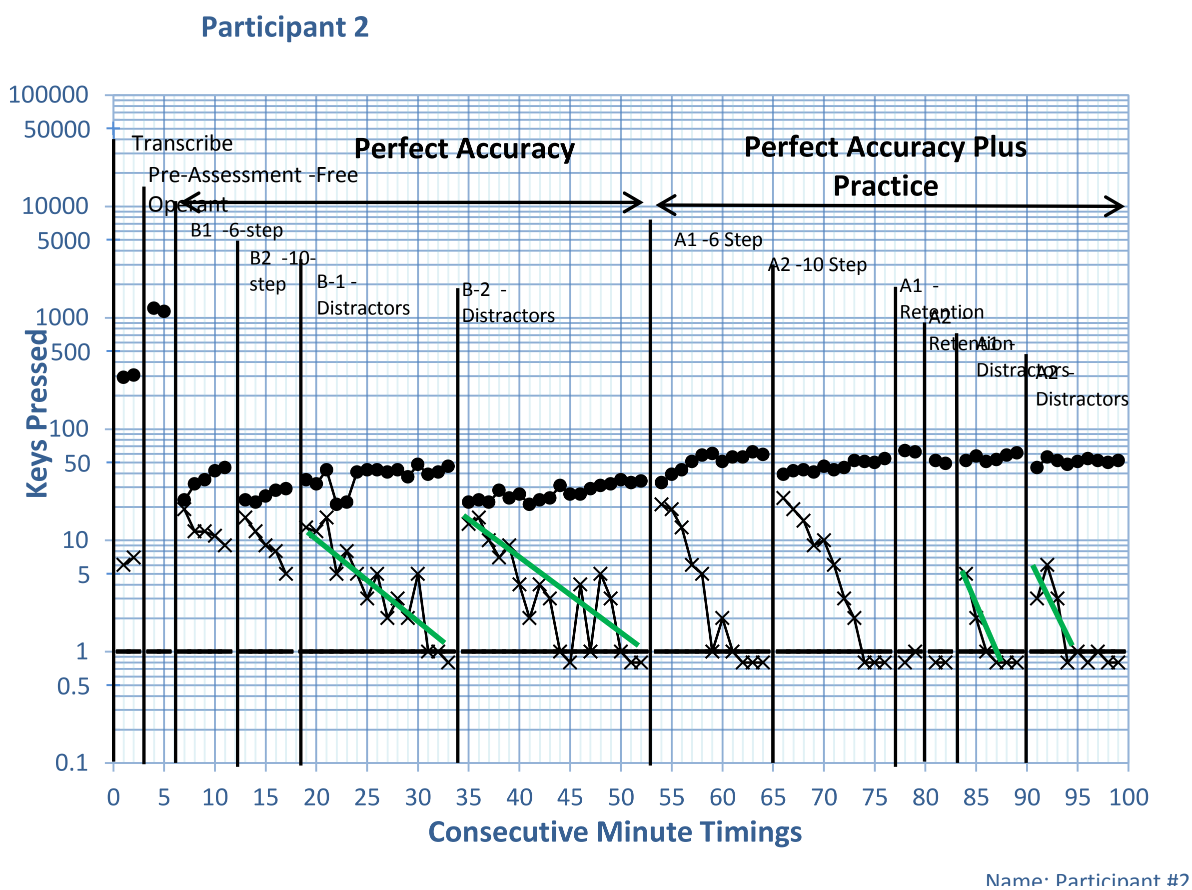


Figure 18. This figure illustrates participant two's data on the timings from experiment 3. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 19. Participant 3 Data through Experiment 3.

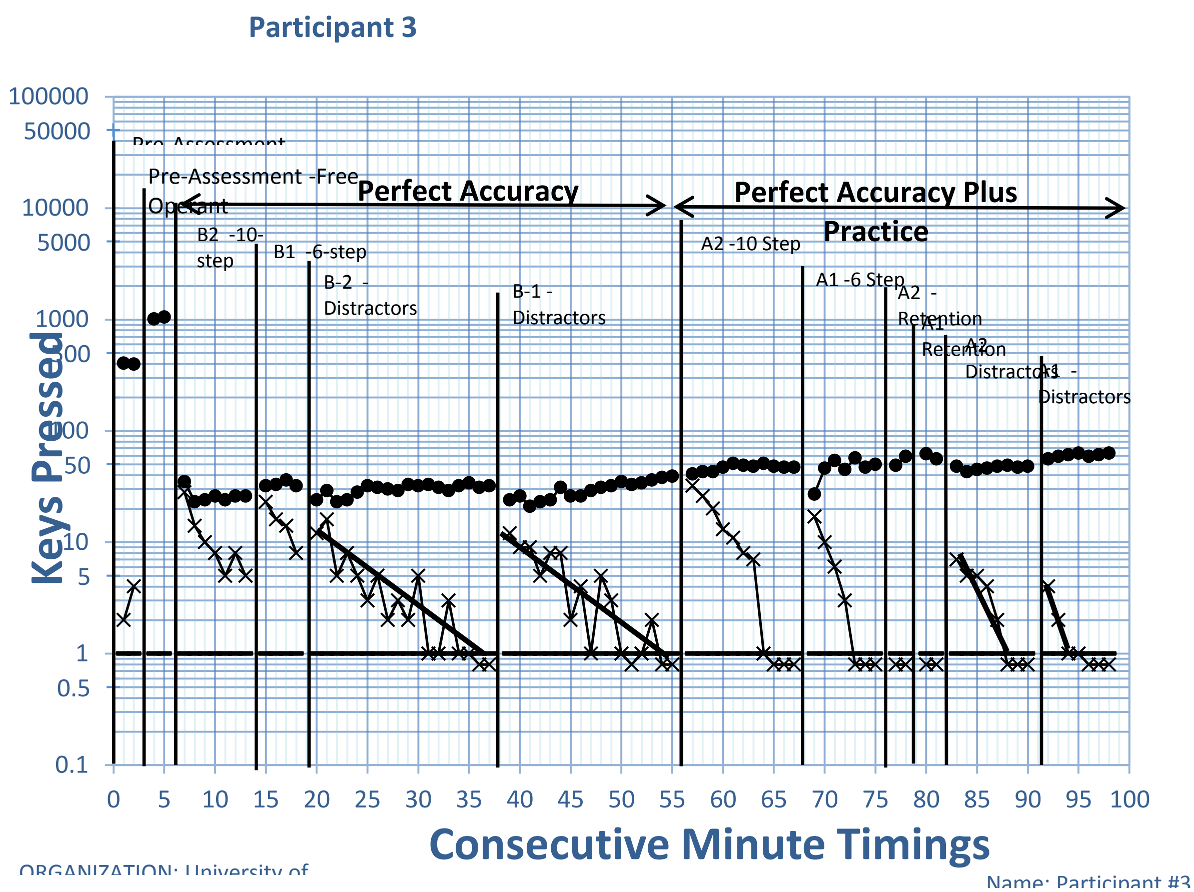


Figure 19 . This figure illustrates participant three's data on the timings from experiment 3. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 20. Participant 4 Data Through Experiment 3.

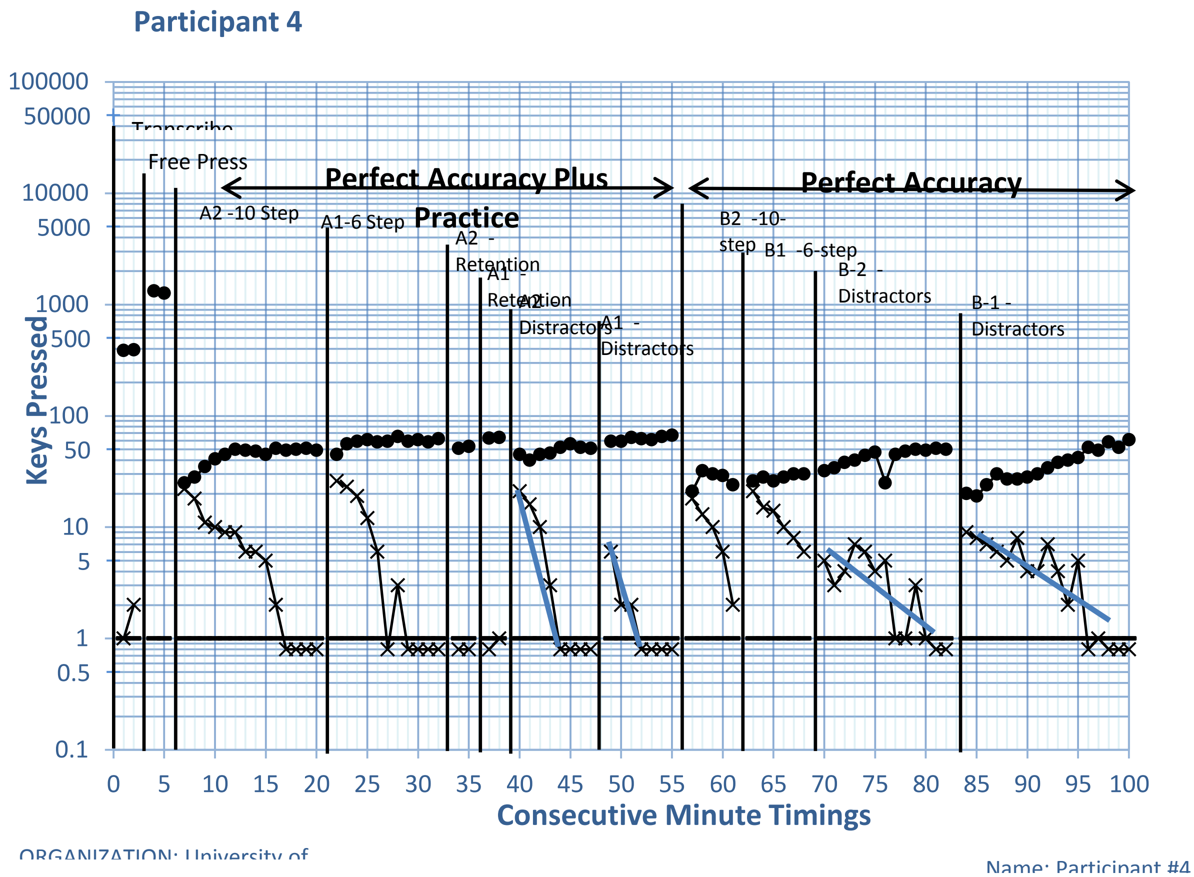


Figure 20. This figure illustrates participant four's data on the timings from experiment 3. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 21. Stacked Error Divide Lines through Experiment 3.

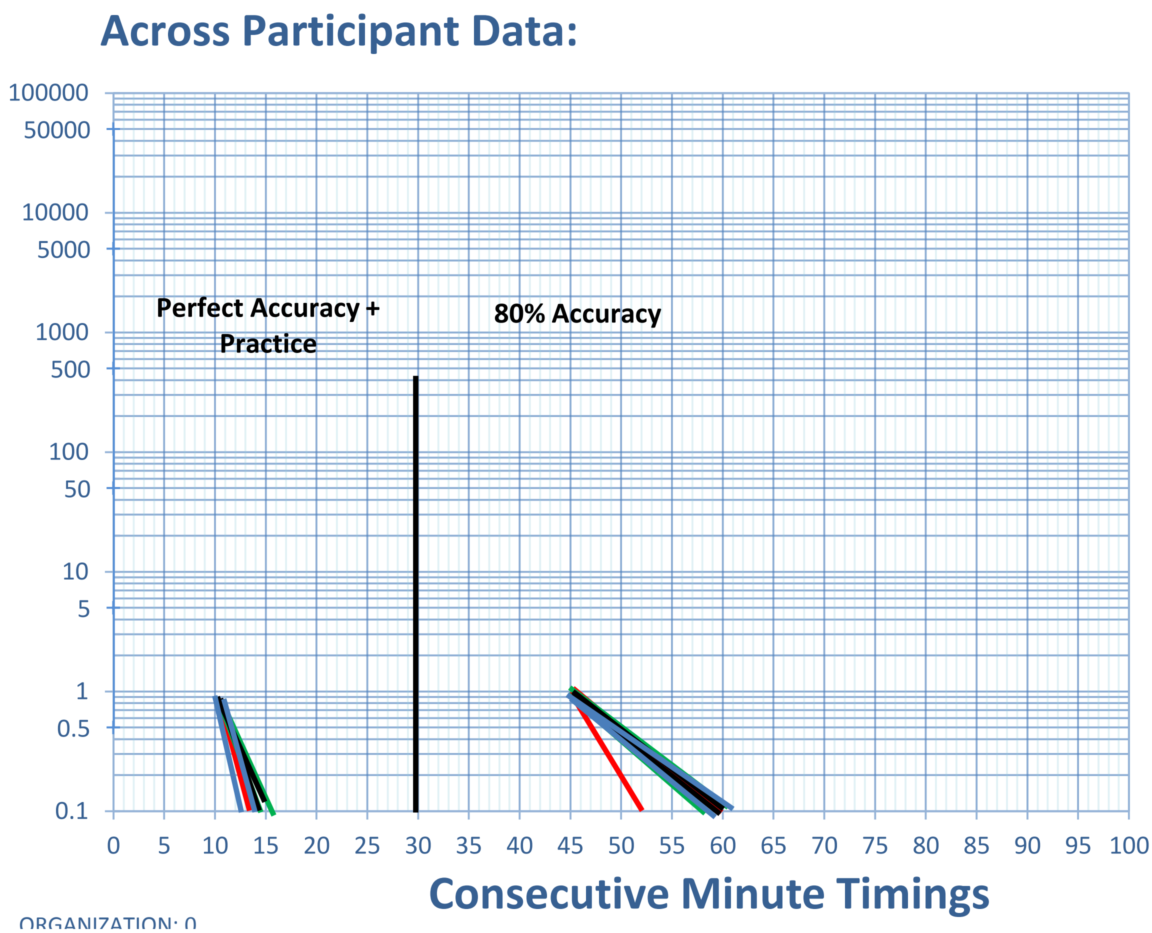


Figure 21. This figure illustrates stacked error deceleration/divide lines for all participants. Each line color is a different participant's deceleration on each relevant condition.

Figure 22. Total Trials with Errors between conditions through Experiment 3.

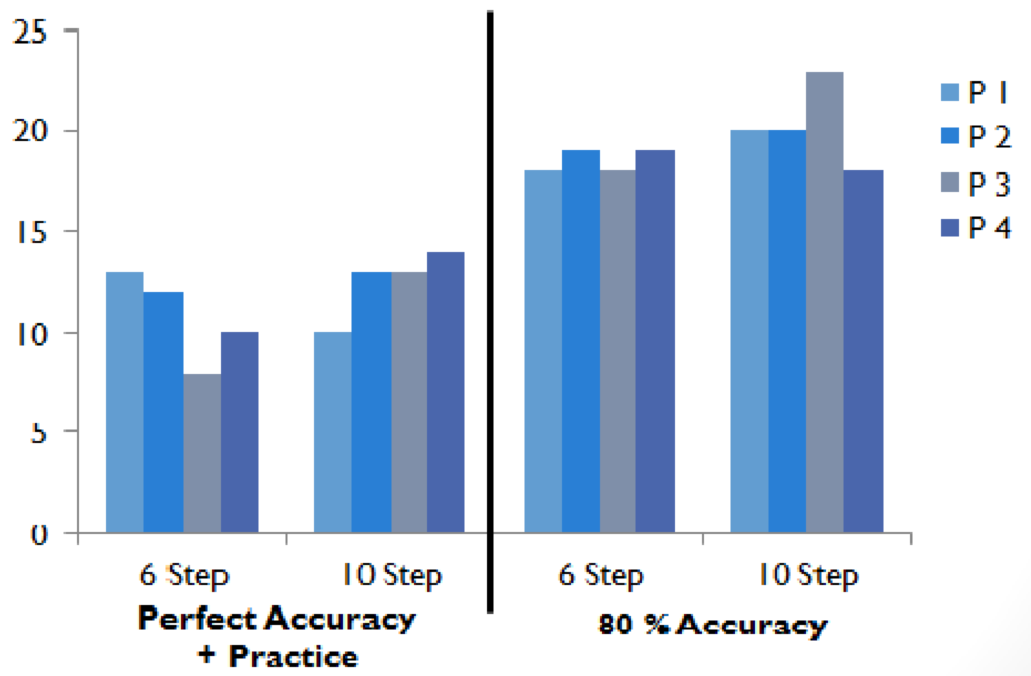


Figure 22. This figure illustrates a bar graph depicting the number of trials with errors that were required before perfect accuracy. The vertical axis represents the number of trials and the horizontal axis indicates the training target and the sequence type.

Figure 23. Sample of Participants Experience through Experiment 4, Phase 1

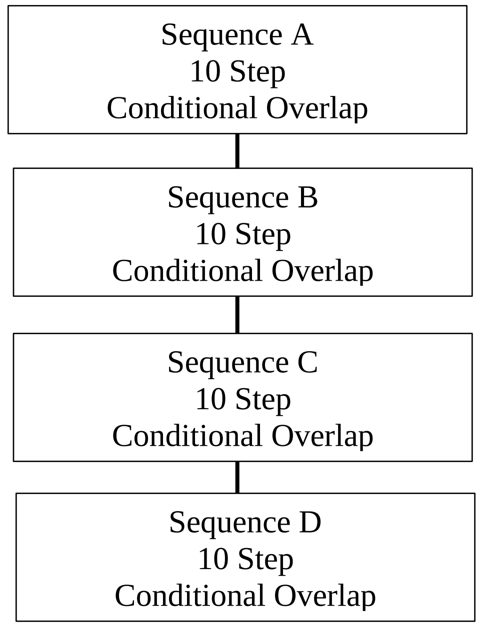


Figure 23. Participants went through each of the above phases but in randomly assigned order. During this experiment participants completed each sequence until they reached perfect accuracy.

Figure 24. Example of Experiment 4, Phase 1, Sequence 1 Performance.

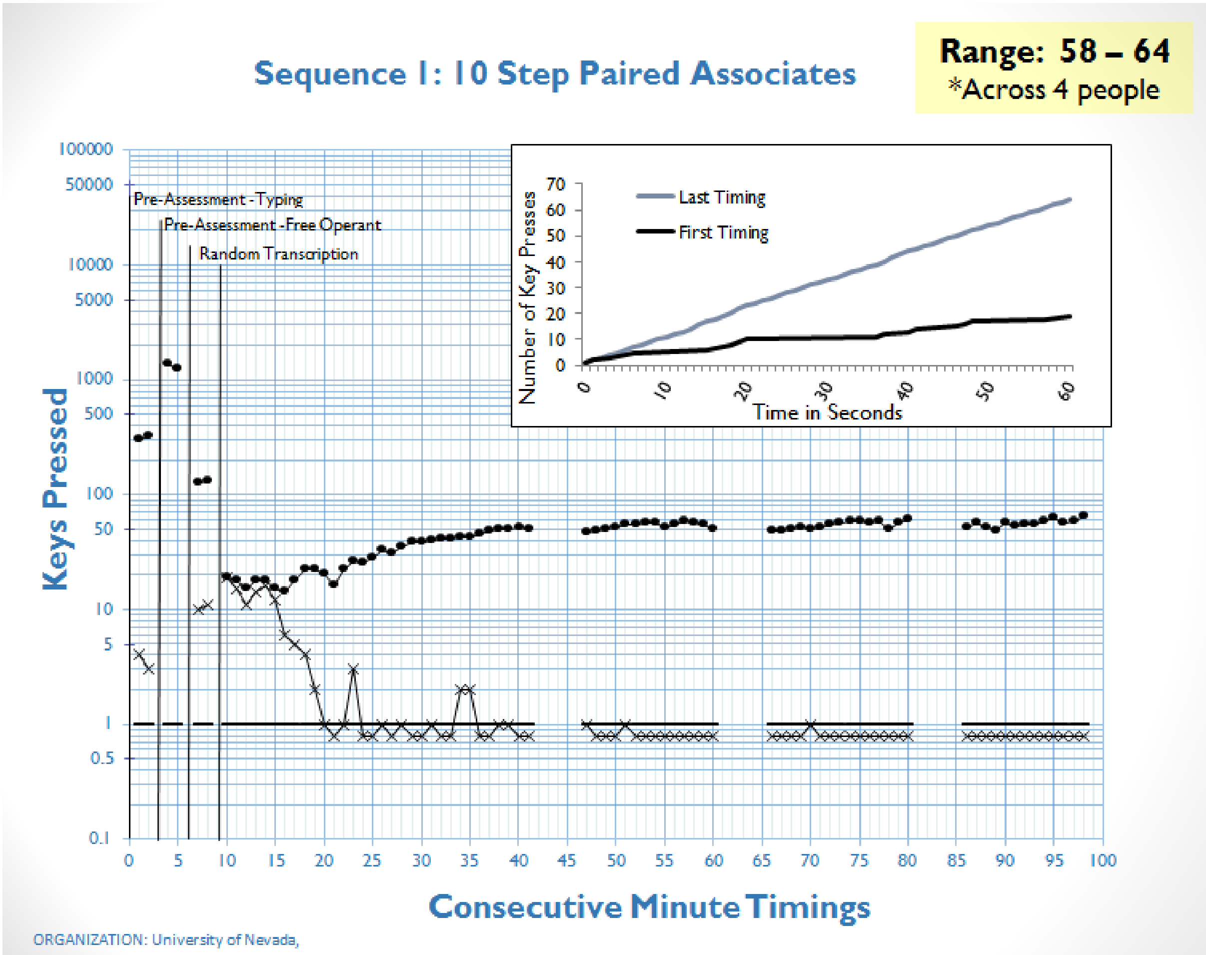


Figure 24. This figure illustrates an example of performance on Sequence 1. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. In the right corner there is a cumulative record which on the horizontal axis is time in seconds and the vertical axis is responses. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

Figure 25. Example of Experiment 4, Phase 1, Sequence 2 Performance.

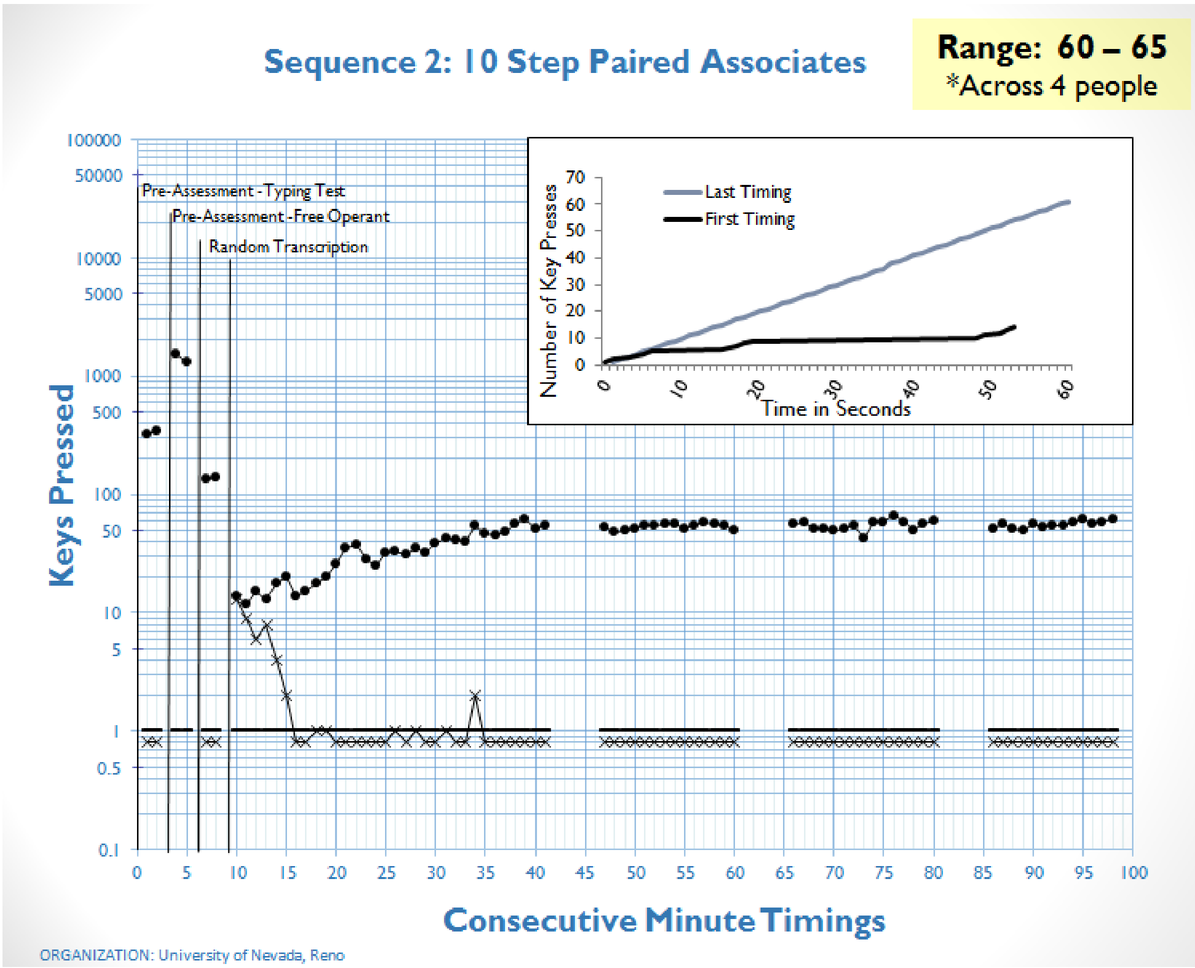


Figure 25. This figure illustrates an example of performance on Sequence 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. In the right corner there is a cumulative record which on the horizontal axis is time in seconds and the vertical axis is responses. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

Figure 26. Example of Experiment 4, Phase 1, Sequence 3 Performance.

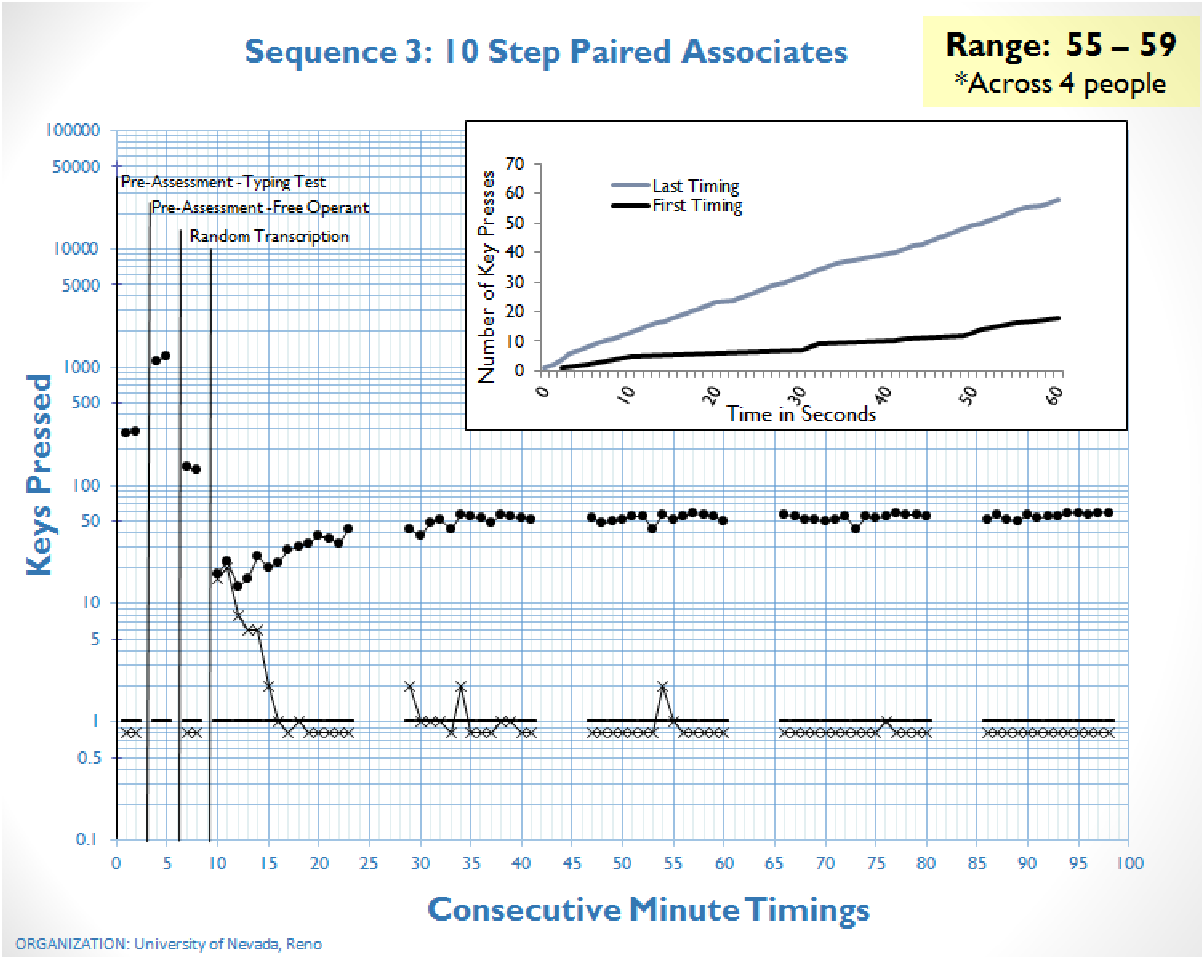


Figure 26. This figure illustrates an example of performance on Sequence 4. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. In the right corner there is a cumulative record which on the horizontal axis is time in seconds and the vertical axis is responses. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

Figure 27. Example of Experiment 4, Phase 1, Sequence 4 Performance.

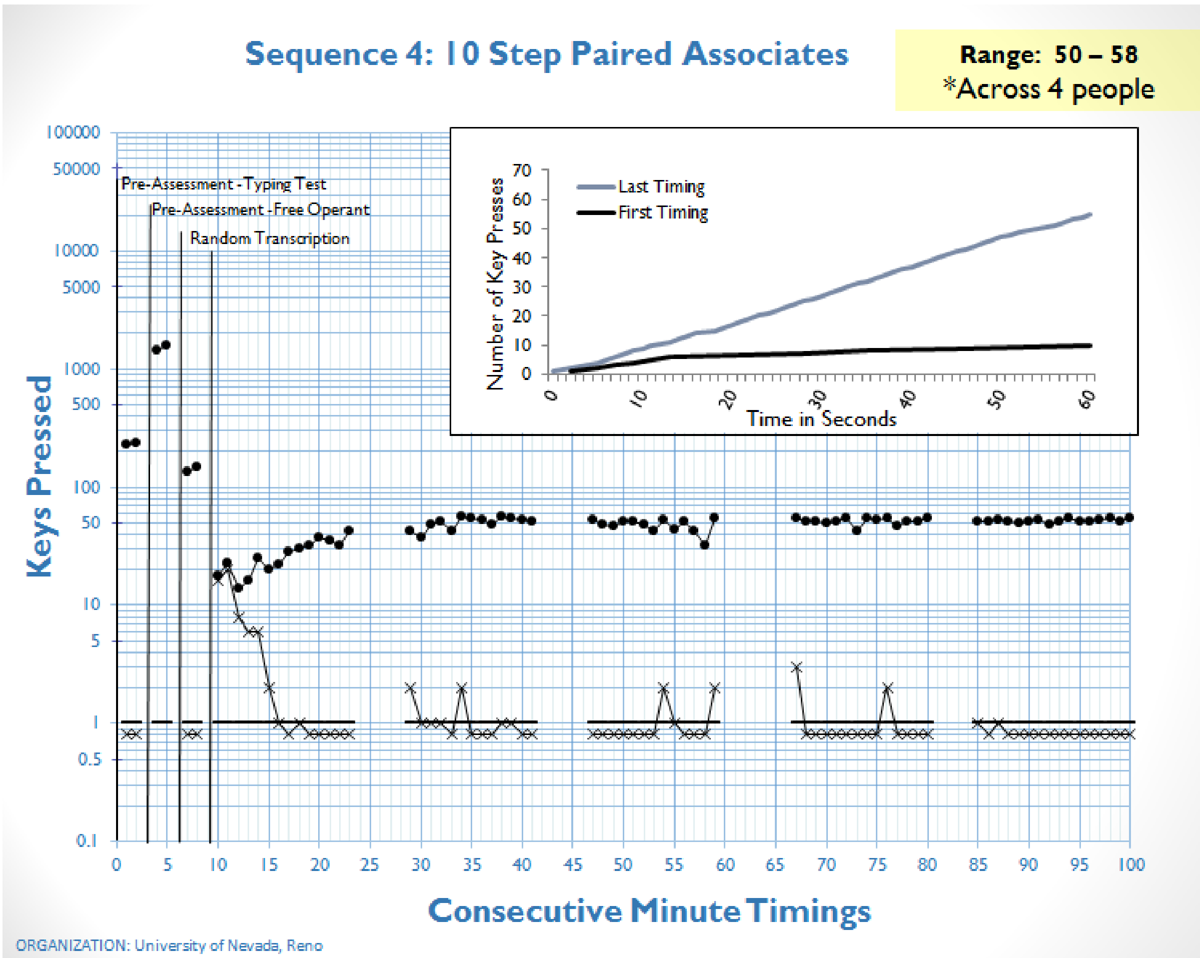


Figure 27. This figure illustrates an example of performance on Sequence 4. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. In the right corner there is a cumulative record which on the horizontal axis is time in seconds and the vertical axis is responses. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

Figure 28. Example of Frequency Ranges across Different Arrangements

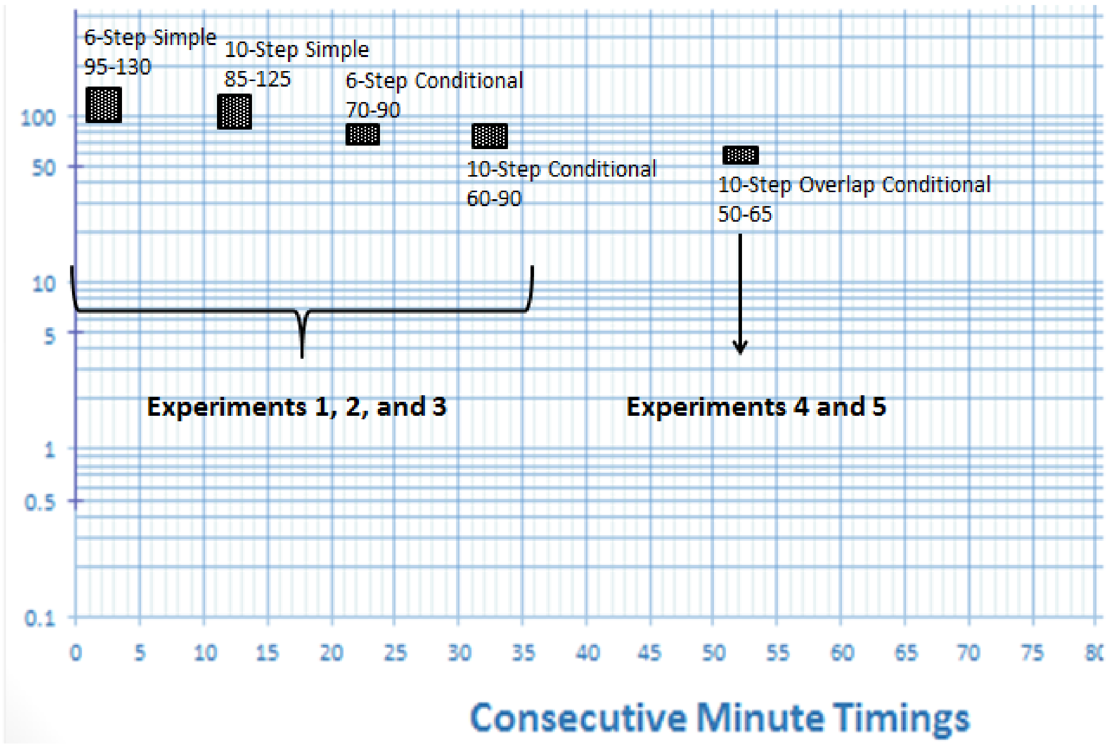


Figure 28. This figure illustrates frequency ranges for all participants on the different types of sequences evaluated throughout the development of this preparation.

Figure 29. Sample of Participants Experience through Experiment 4, Phase 2

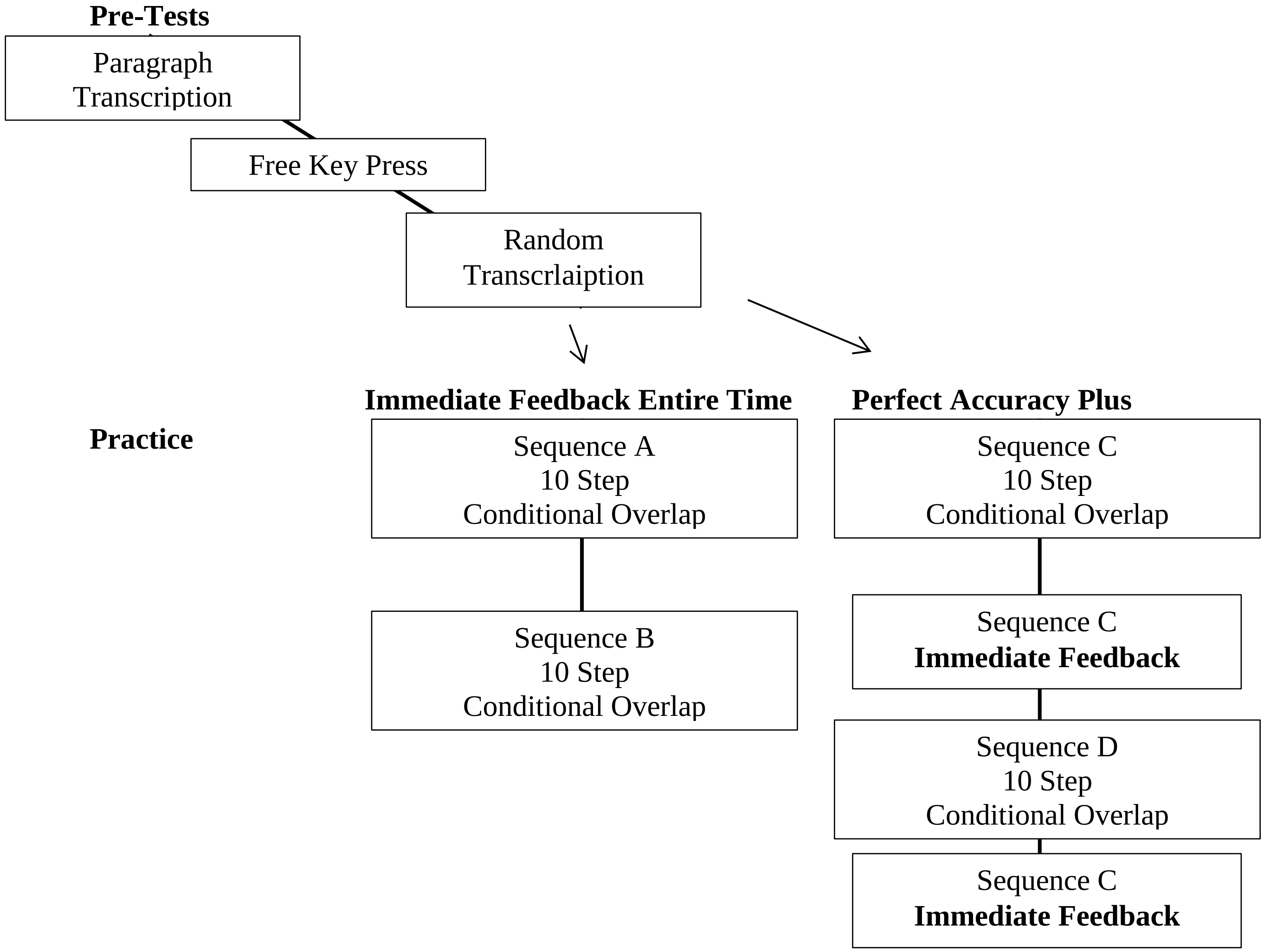


Figure 29. Participants went through each of the above phases but in randomly assigned order. During this experiment two sequences were performed with immediate feedback present the entire time and two sequences were performed without immediate feedback until errors had disappeared and then immediate feedback added. Pre-tests were still completed with the addition of a random transcription test. We did not introduce distractors in this phase.

Figure 30. Participant 1 Data, Experiment 4, Phase 2

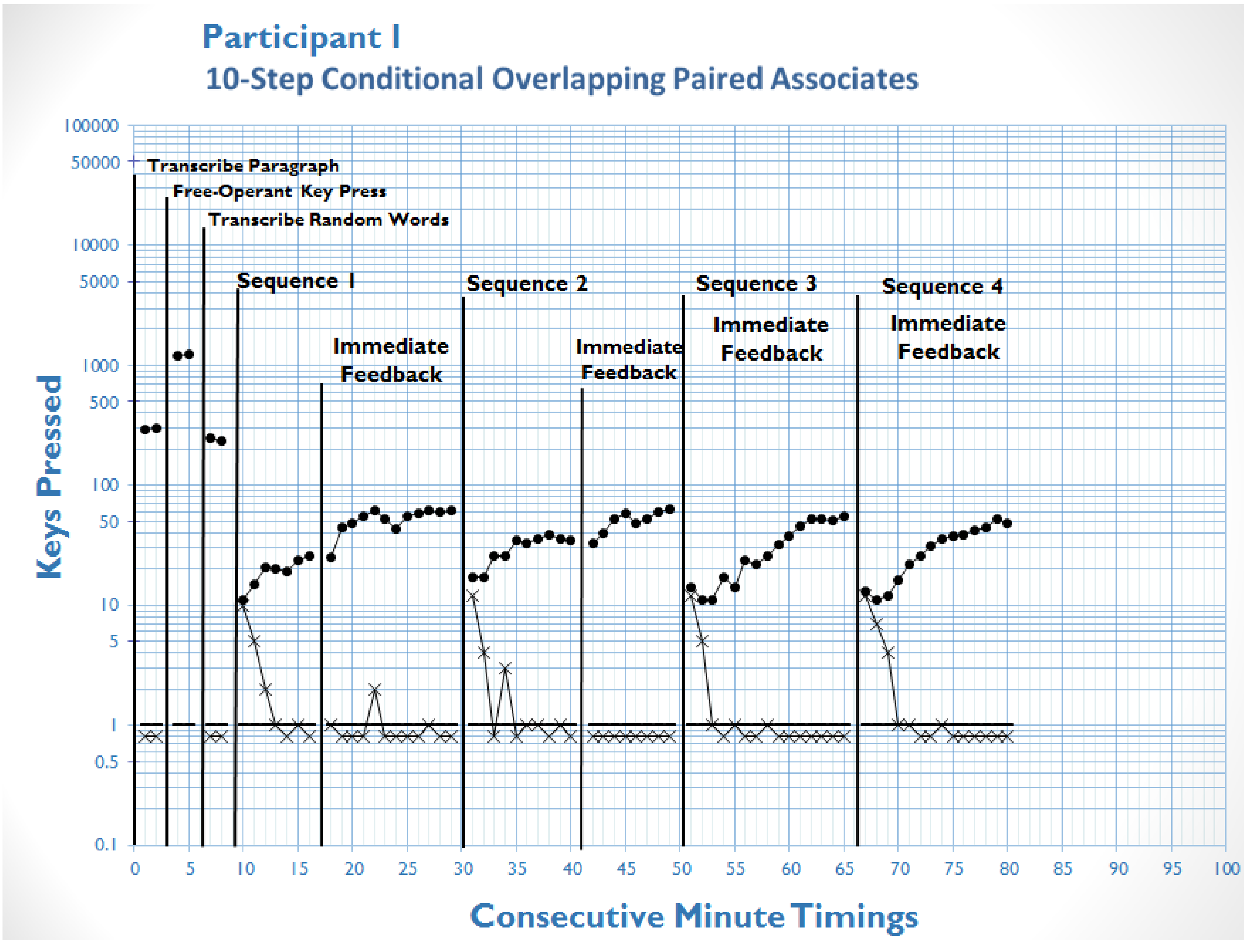


Figure 30. This figure illustrates participants 1 data in Experiment 4, Phase 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 31. Participant 2 Data, Experiment 4, Phase 2

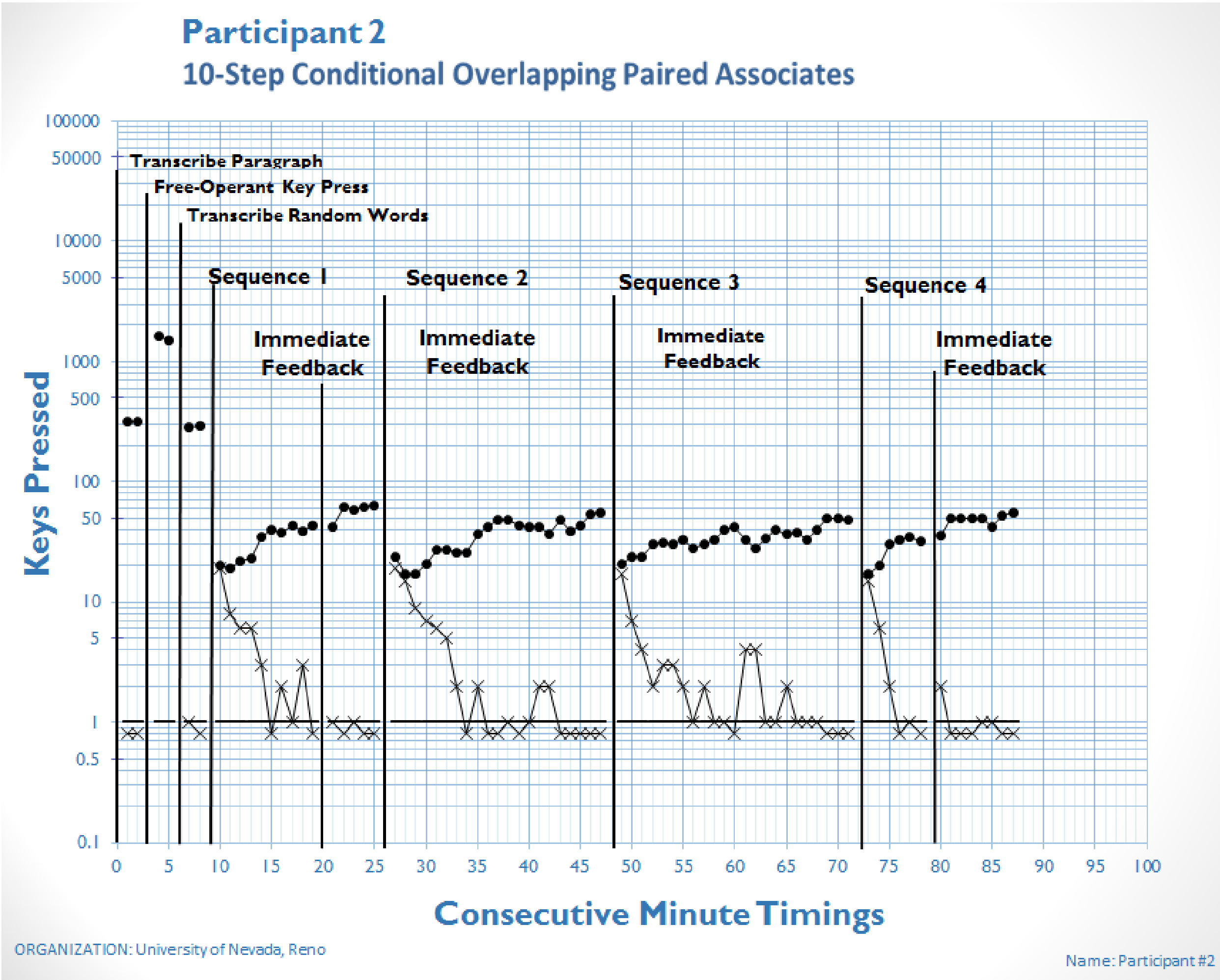


Figure 31. This figure illustrates participants 2 data in Experiment 4, Phase 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 32. Participant 3 Data, Experiment 4, Phase 2

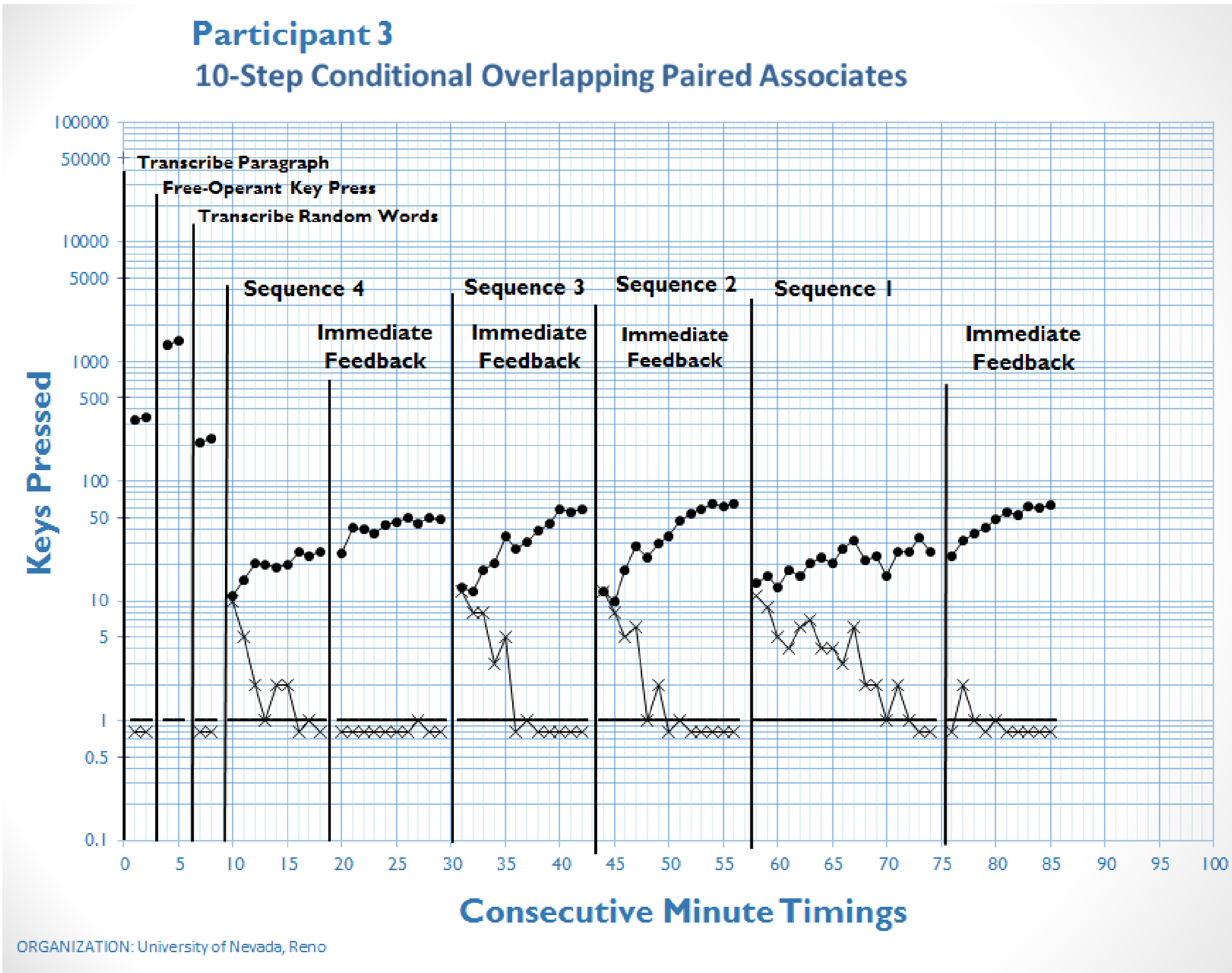


Figure 32. This figure illustrates participants 3 data in Experiment 4, Phase 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 33. Participant 4 Data, Experiment 4, Phase 2

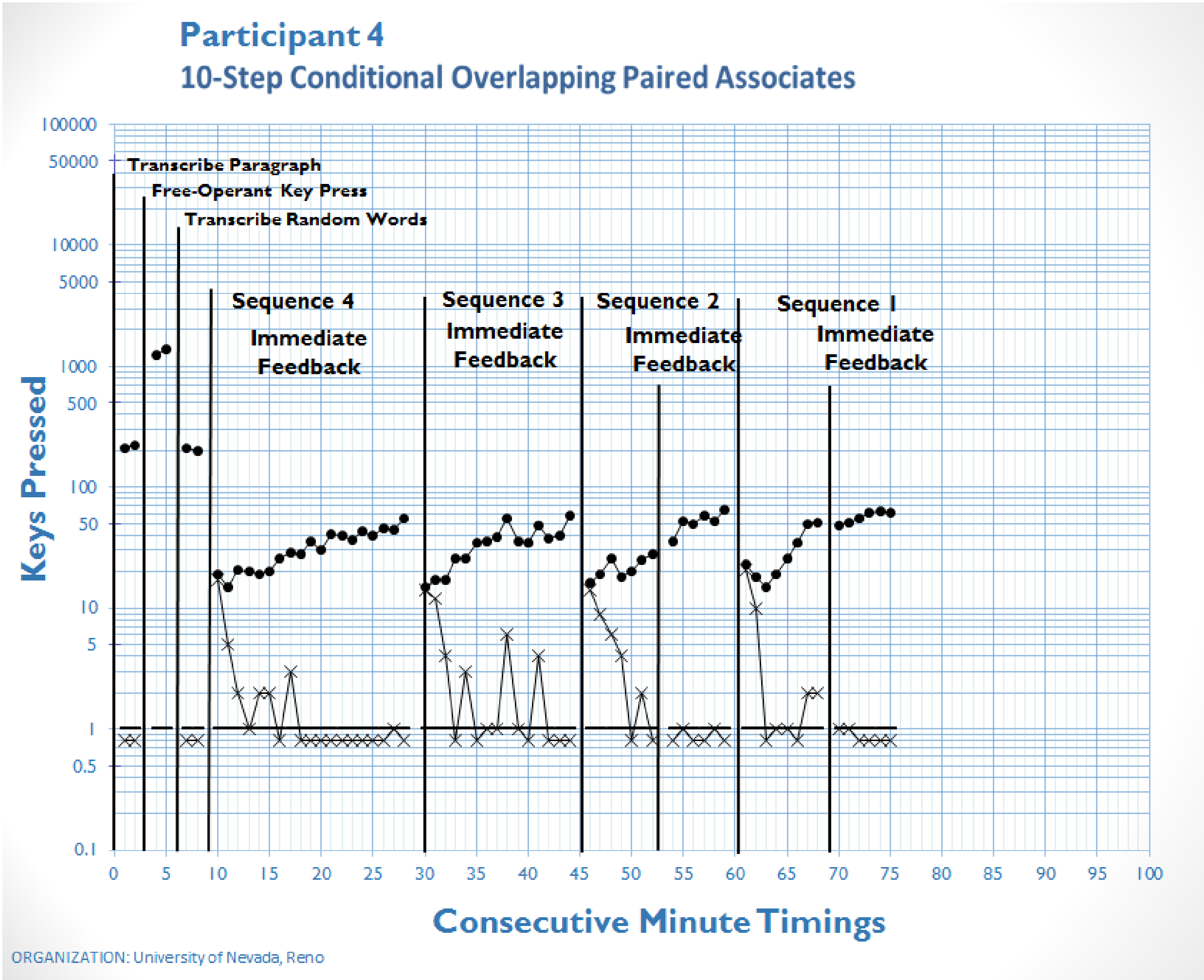


Figure 33. This figure illustrates participants 4 data in Experiment 4, Phase 2. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors.

Figure 34. Stacked Error Divide Lines through Experiment 4, Phase 2.

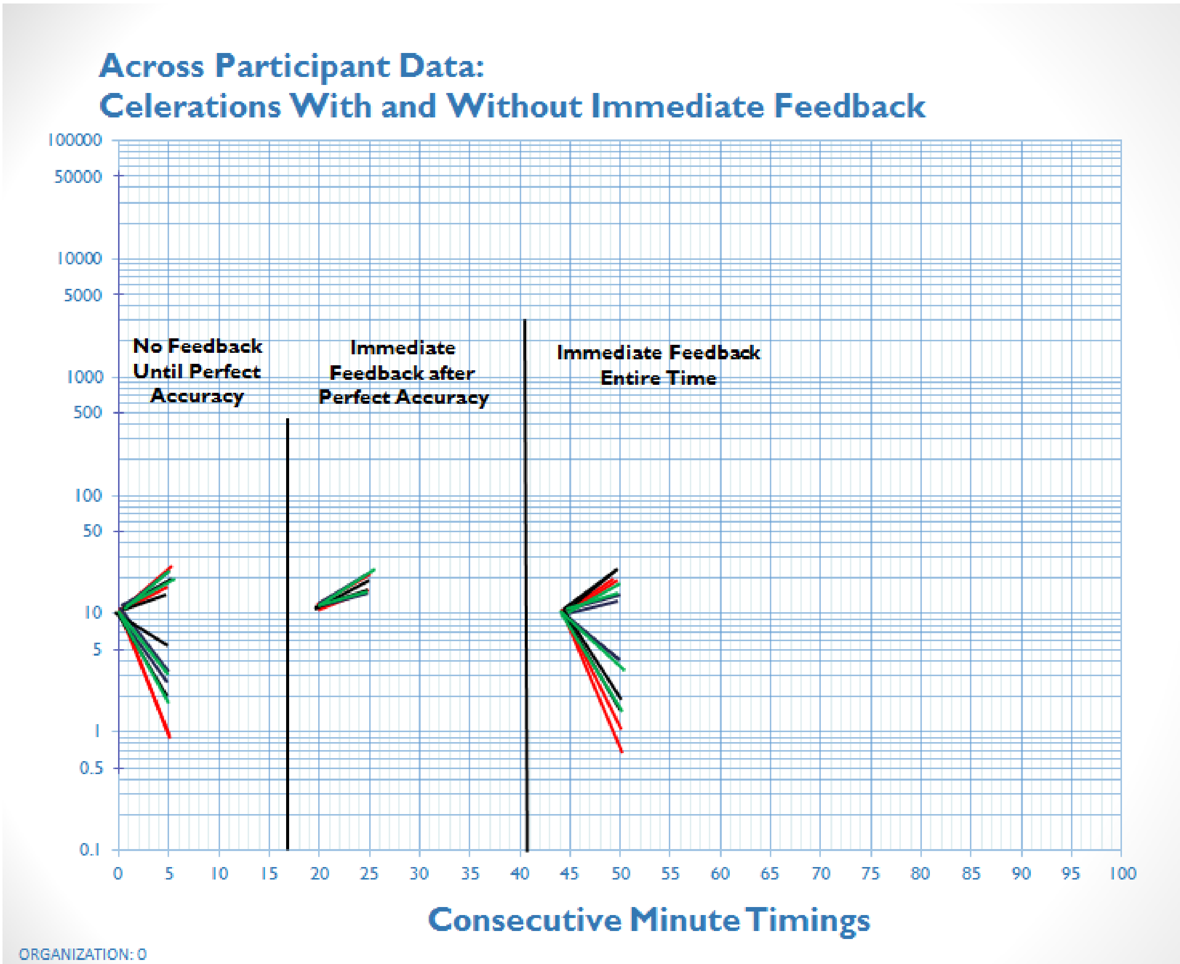


Figure 34. This figure illustrates stacked error celeration and divide lines for all participants. Each line color is a different participant performance on each relevant condition.

Figure 35. Sample of Participants Experience through Experiment 5

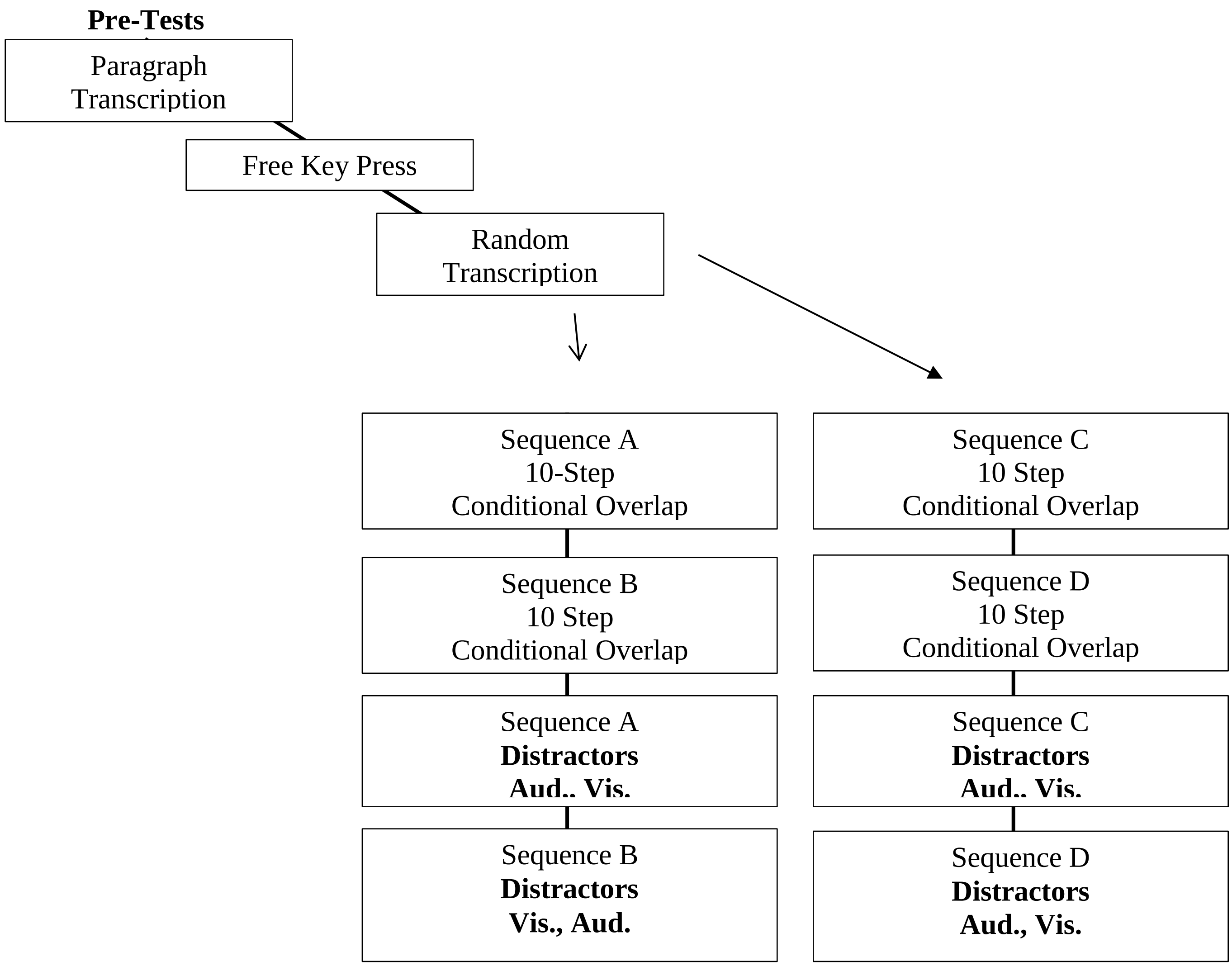
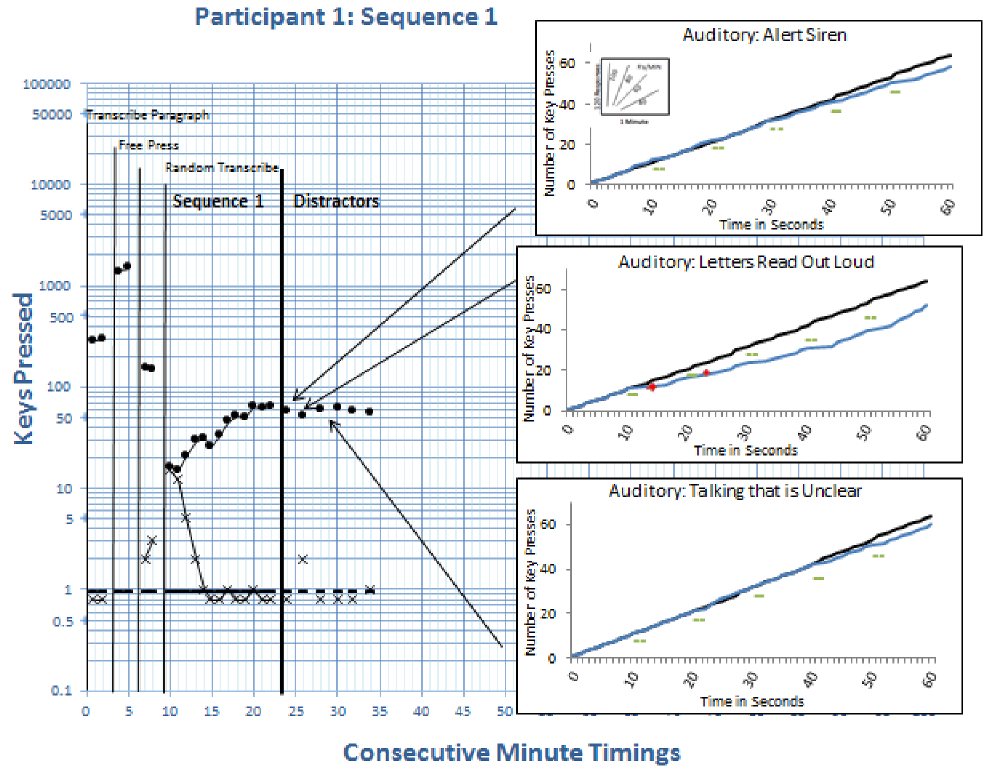
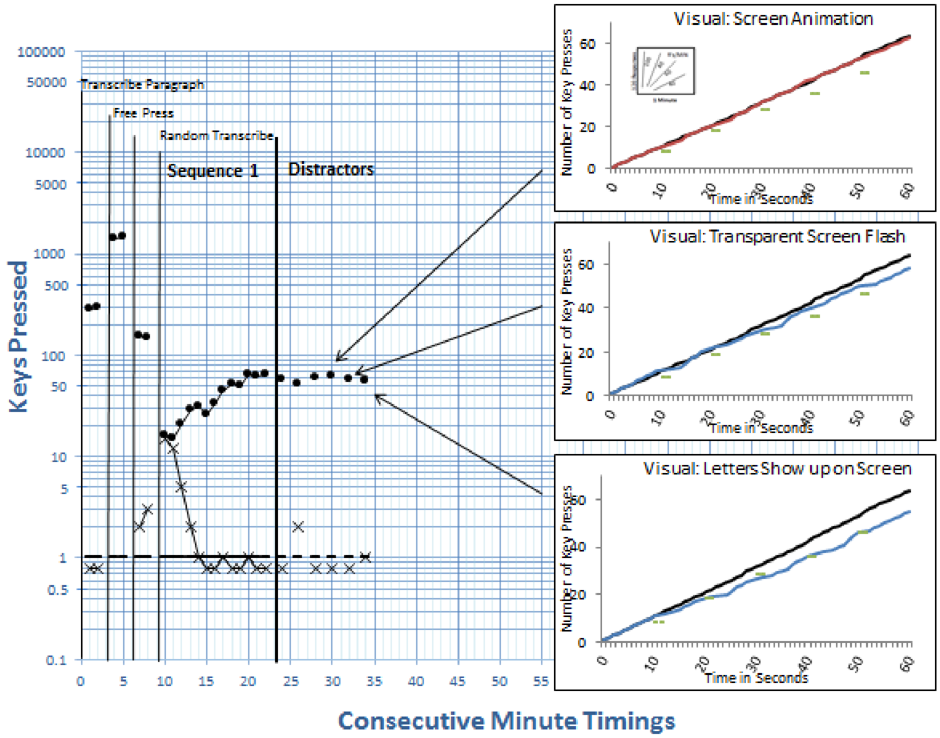


Figure 35. Participants went through each of the above phases but in randomly assigned order. During this experiment four sequences were performed to perfect accuracy plus practice and then distractors were introduced, pre-tests were still completed with the addition of a random transcription test.

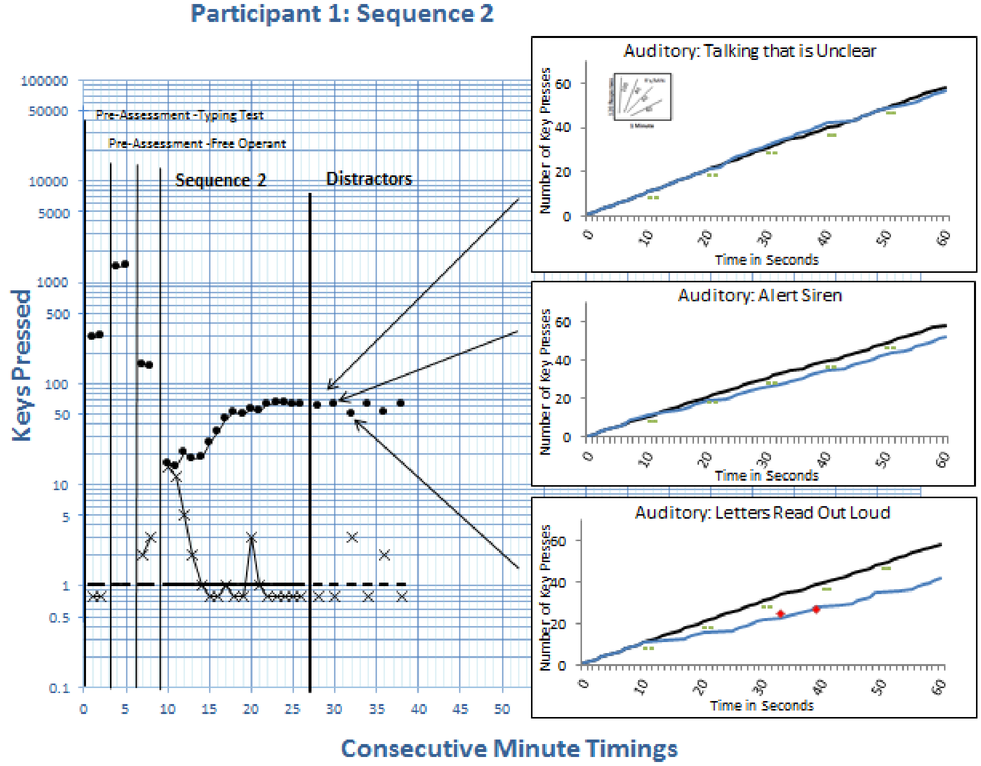
Figure 36. Participant 1 Data, Experiment 5

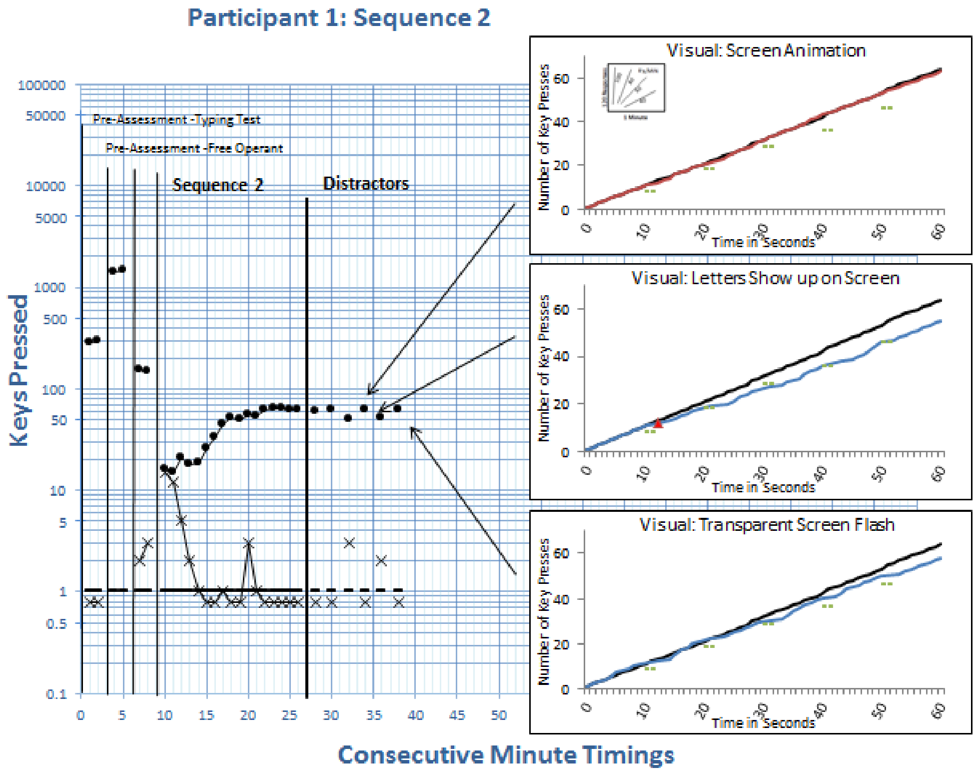


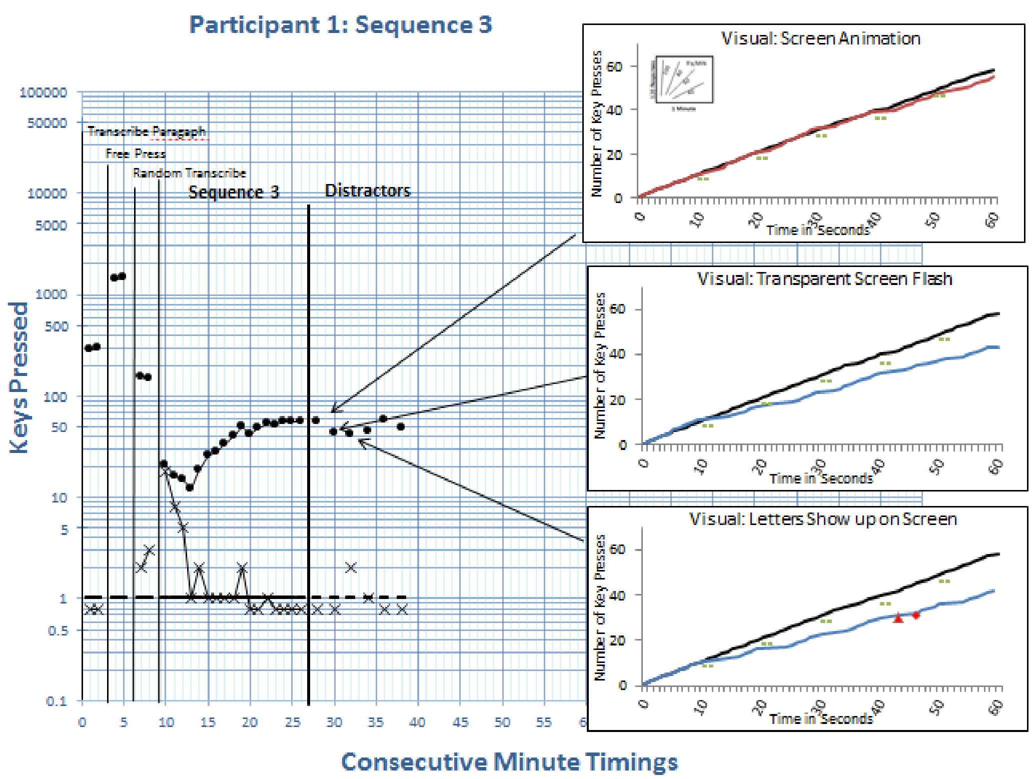
Participant 1: Sequence 1

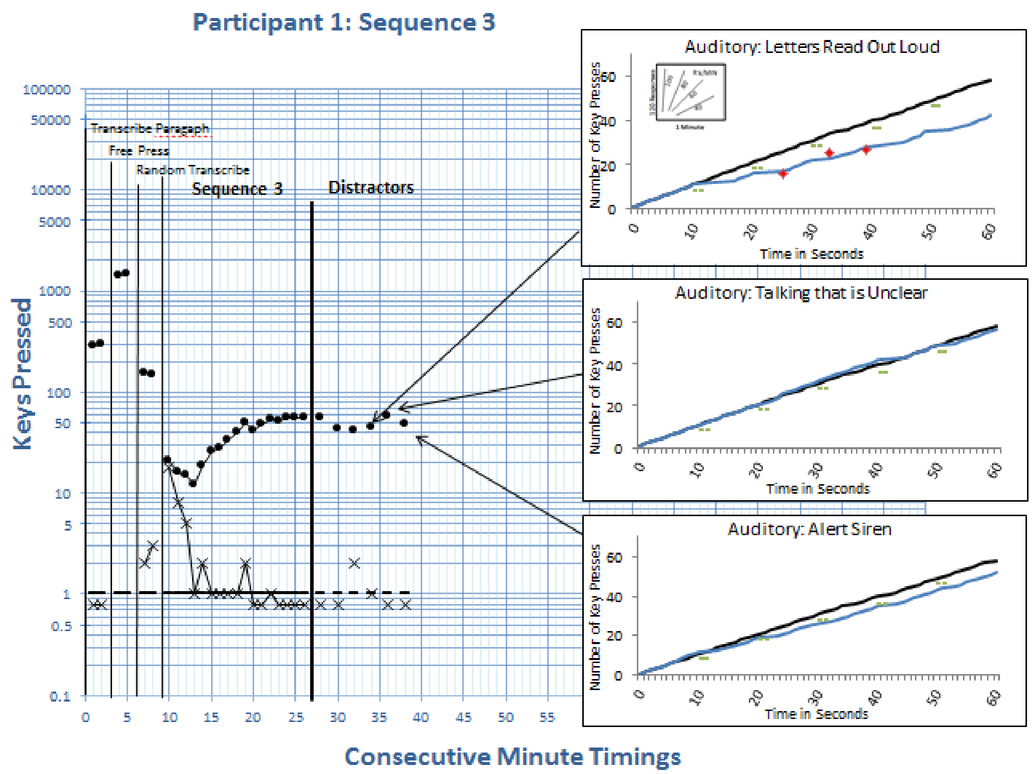


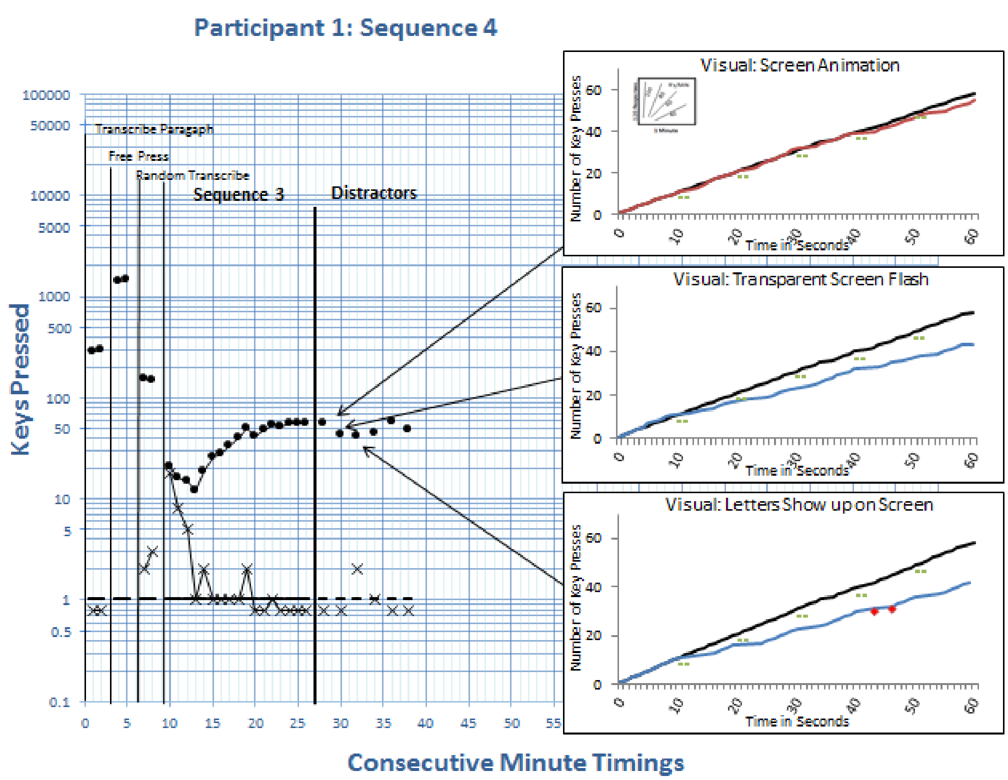
Participant 1: Sequence 2




Participant 1: Sequence 2
Keys Pressed
Consecutive Minute Timings
Pre-Assessment -Typing Test
Pre-Assessment -Free Operant
Sequence 2
Distractors
Visual: Screen Animation
Visual: Letters Show up on Screen
Visual: Transparent Screen Flash
Number of Key Presses
Time in Seconds


Participant 1: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 1: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 3
Distractors
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Auditory: Alert Siren
Number of Key Presses
Time in Seconds


Participant 1: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds

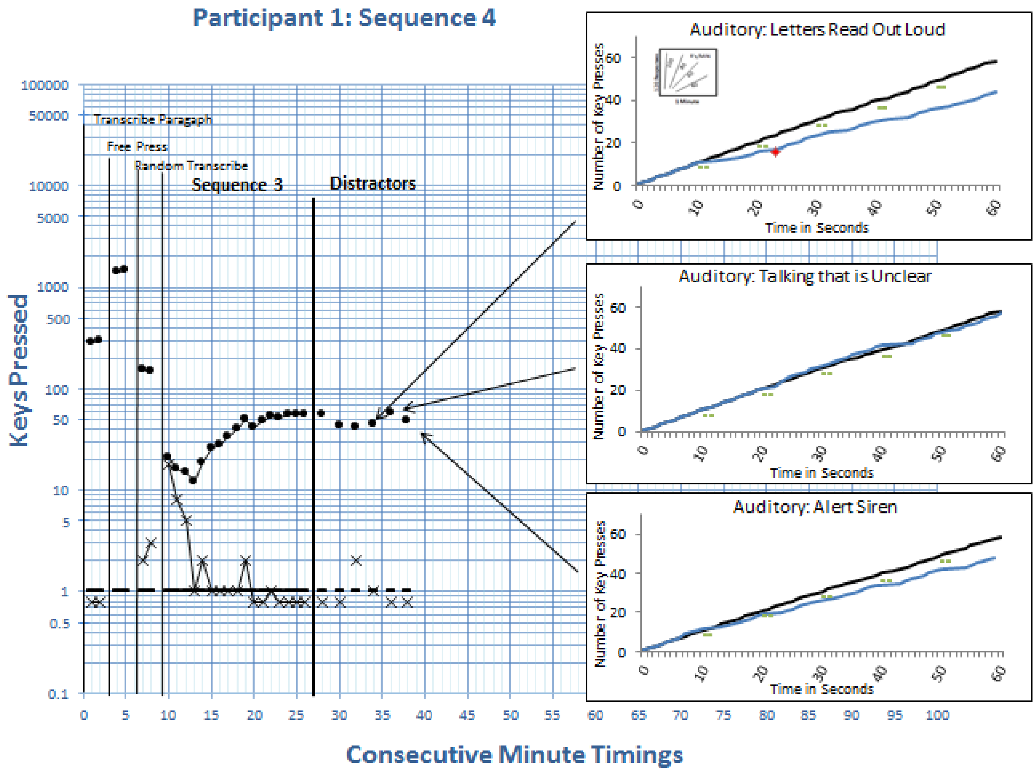
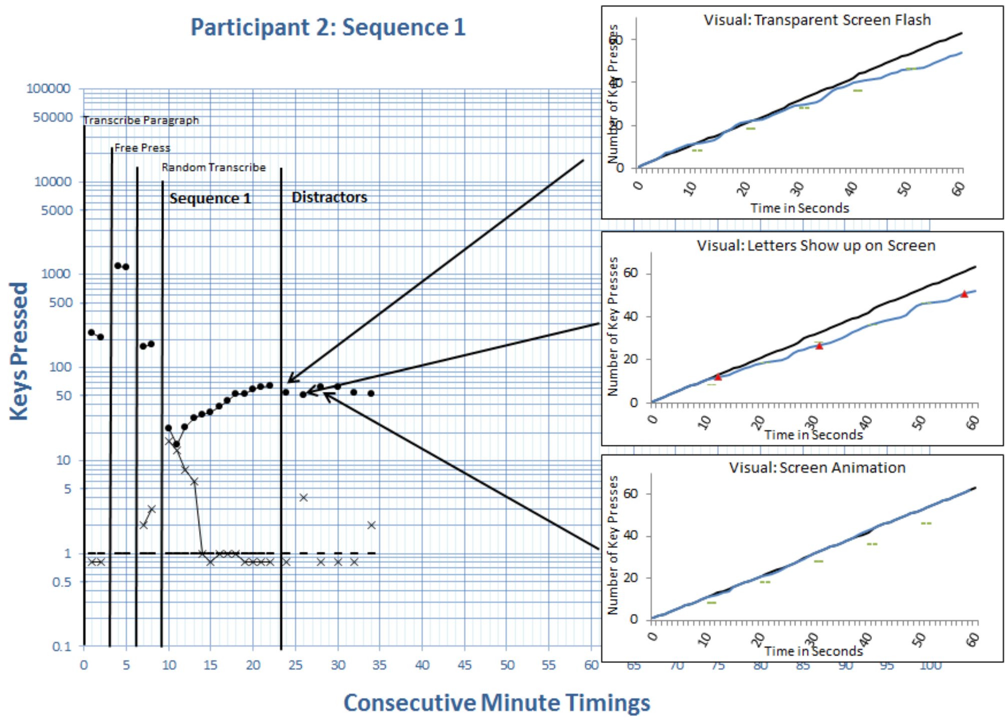
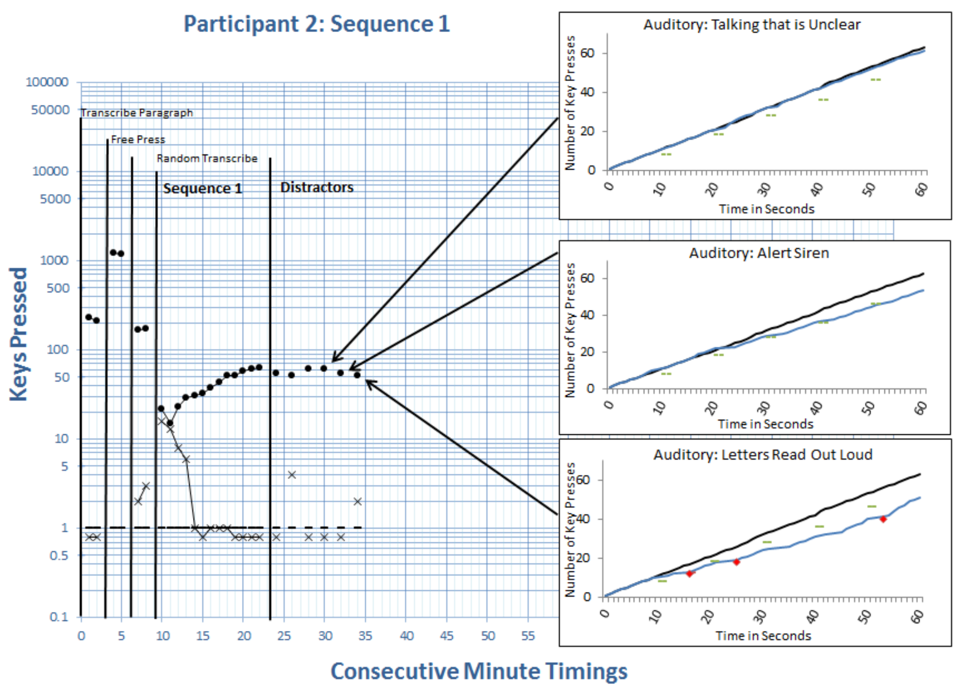
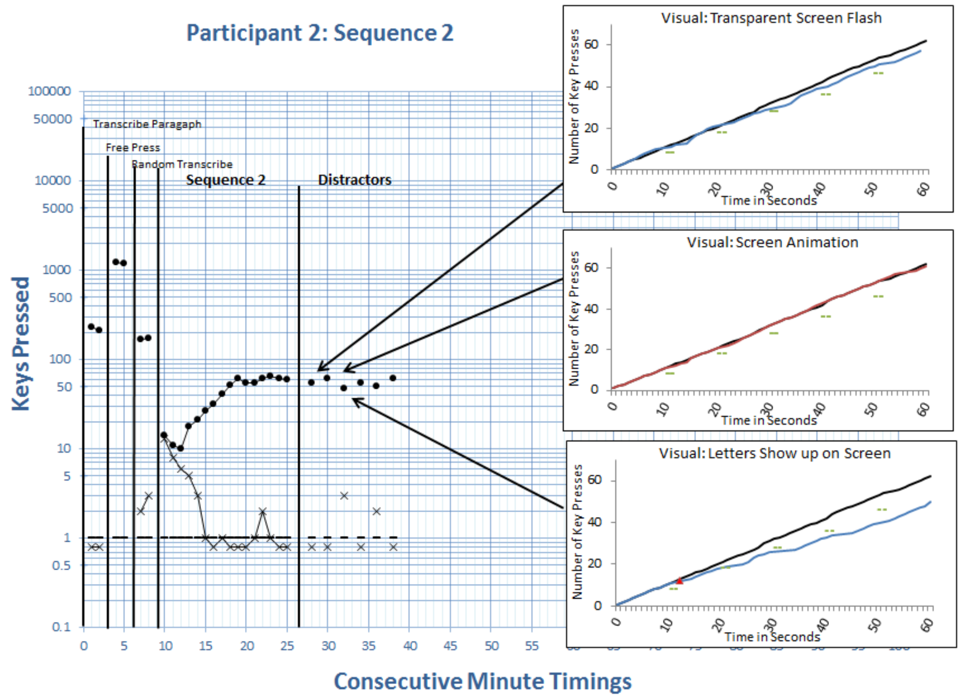


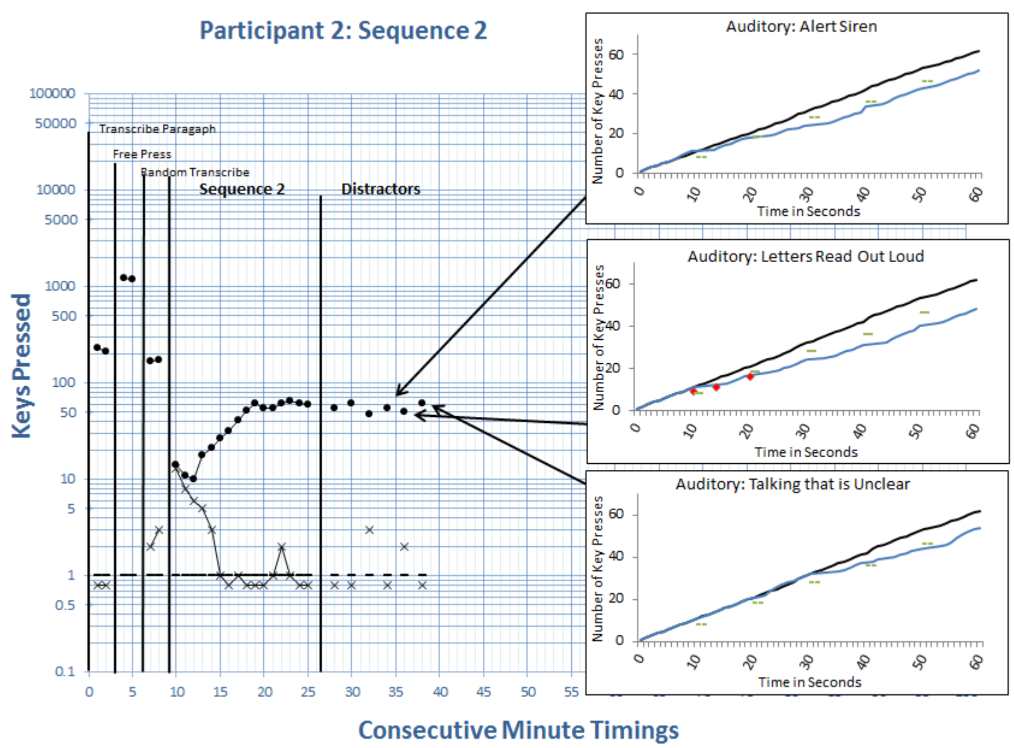
Figure 36. This figure illustrates participant 1 data in Experiment 5. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. There are cumulative records on which the horizontal axis is time in seconds and the vertical axis is responses. Each distractor is plotted on the cumulative charts. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

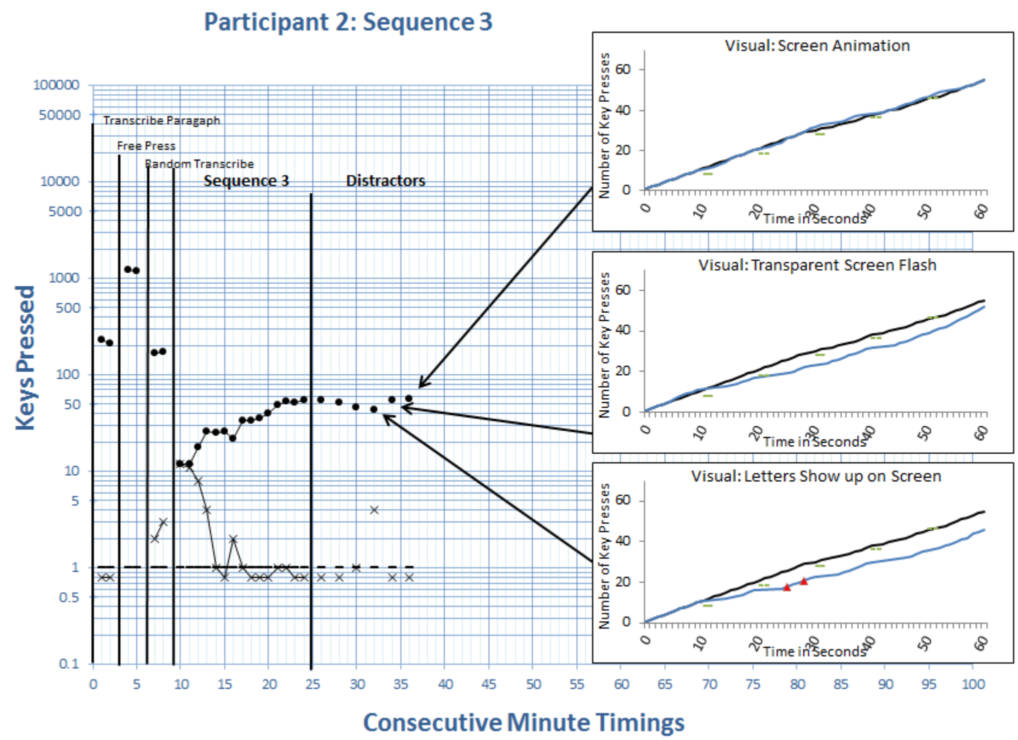
Figure 37. Participant 2 Data, Experiment 5

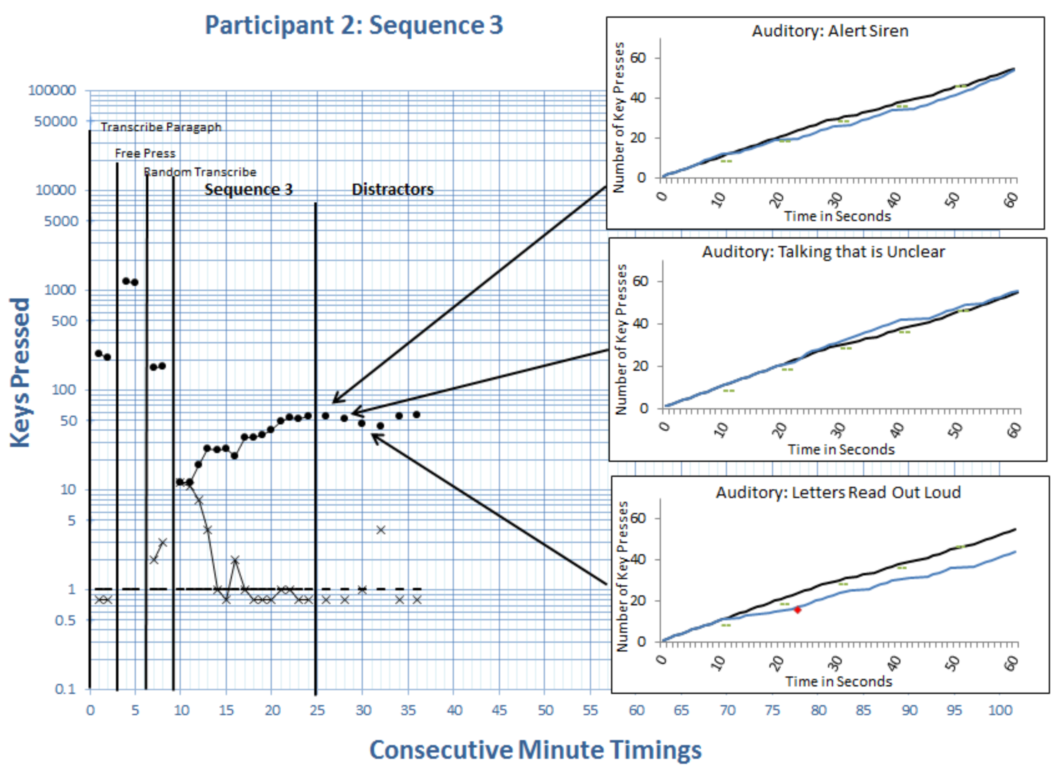

Participant 2: Sequence 1
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 1
Distractors
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Visual: Screen Animation
Number of Key Presses
Time in Seconds

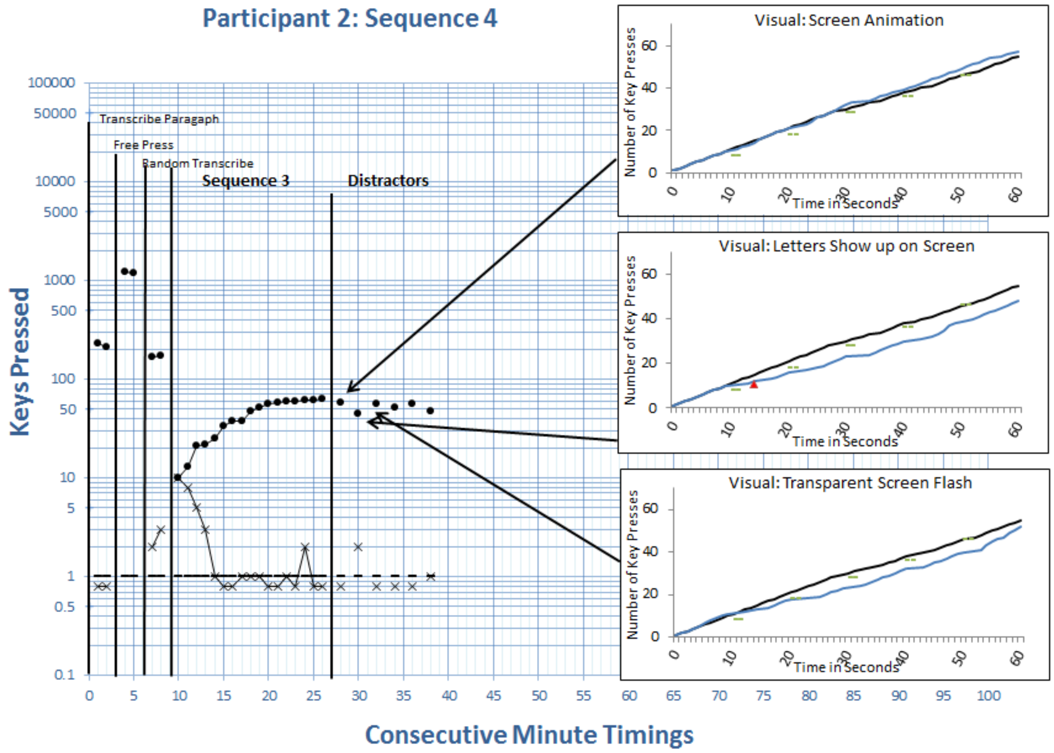

Participant 2: Sequence 1
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 1
Distractors
Auditory: Talking that is Unclear
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Number of Key Presses
Time in Seconds


Participant 2: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 2
Distractors
Visual: Transparent Screen Flash
Visual: Screen Animation
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 2: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 2
Distractors
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds


Participant 2: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 2: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Auditory: Alert Siren
Auditory: Talking that is Unclear
Auditory: Letters Read Out Loud
Number of Key Presses
Time in Seconds


Participant 2: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Letters Show up on Screen
Visual: Transparent Screen Flash
Number of Key Presses
Time in Seconds

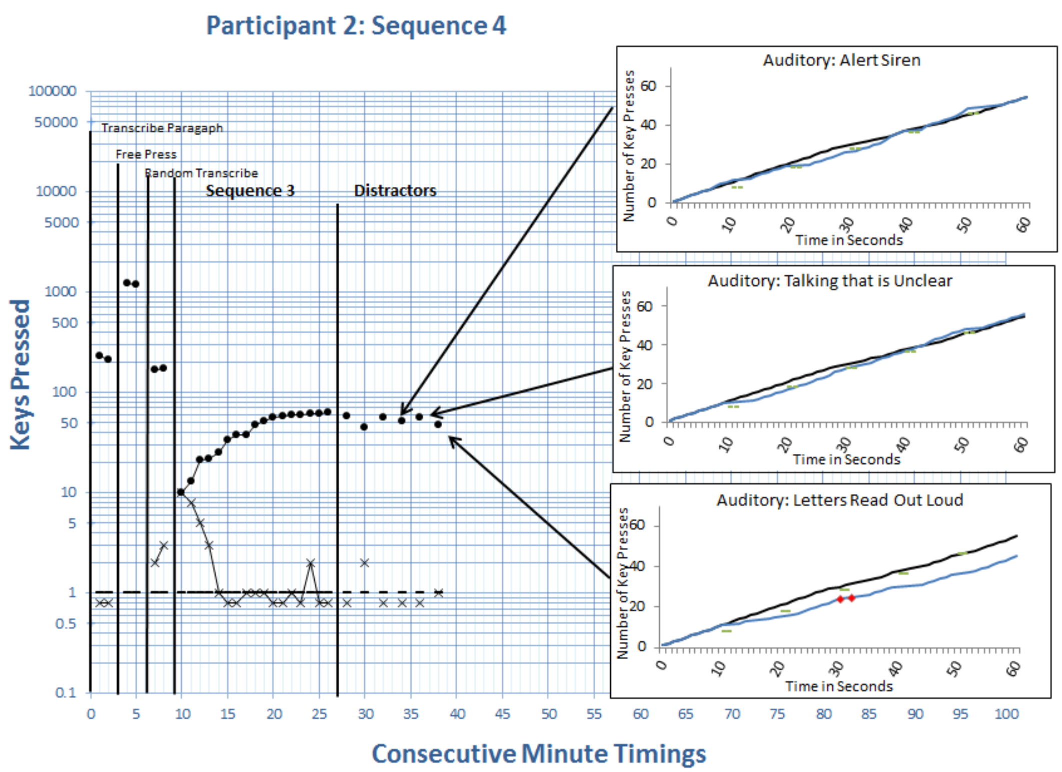
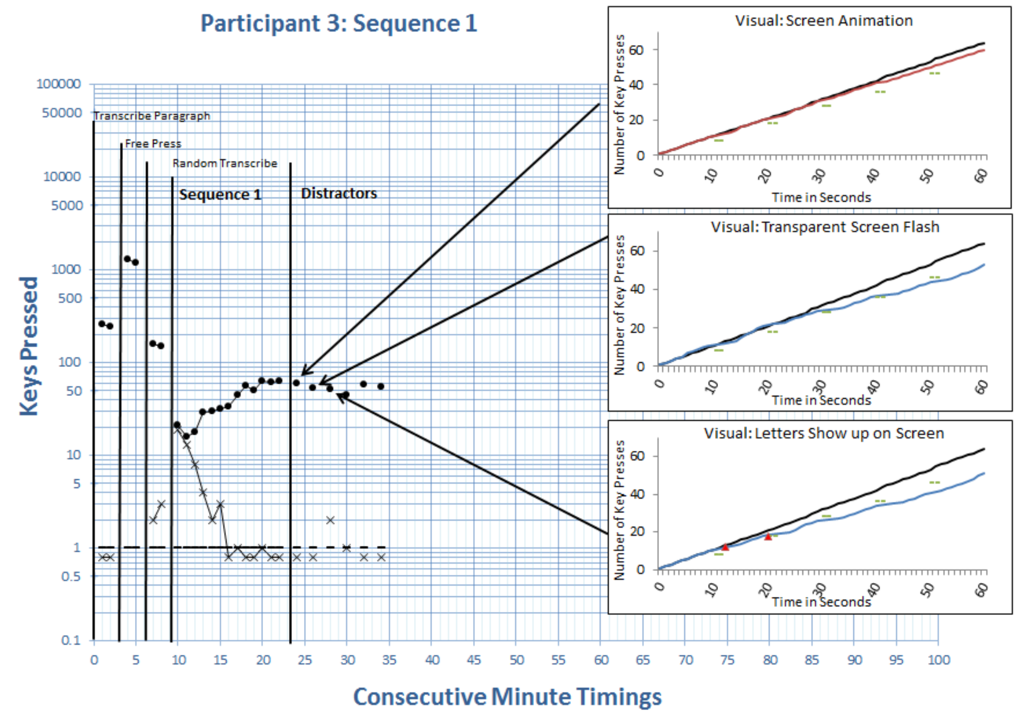
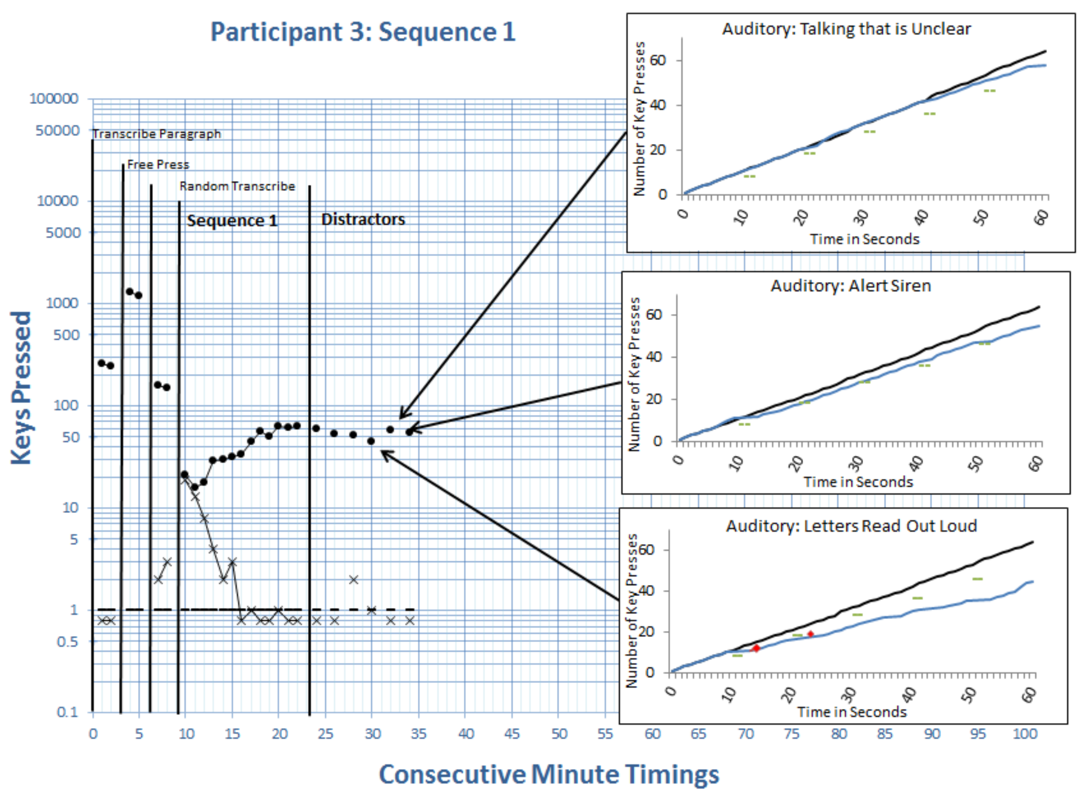
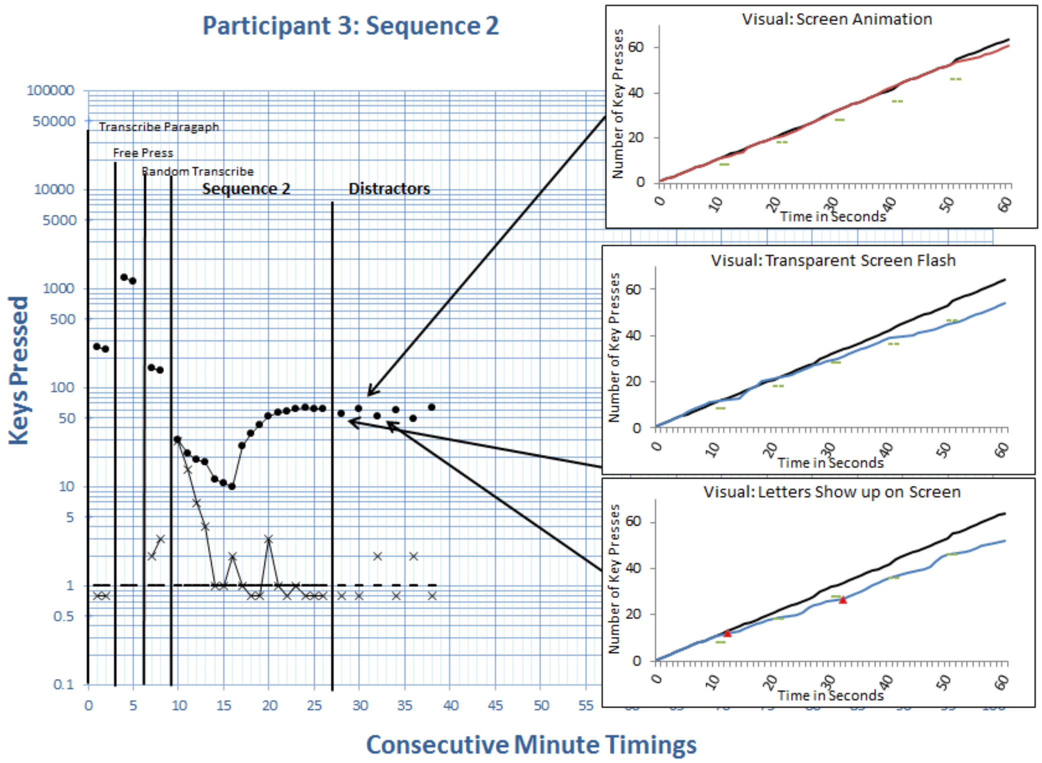

Participant 2: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Auditory: Alert Siren
Auditory: Talking that is Unclear
Auditory: Letters Read Out Loud
Number of Key Presses
Time in Seconds

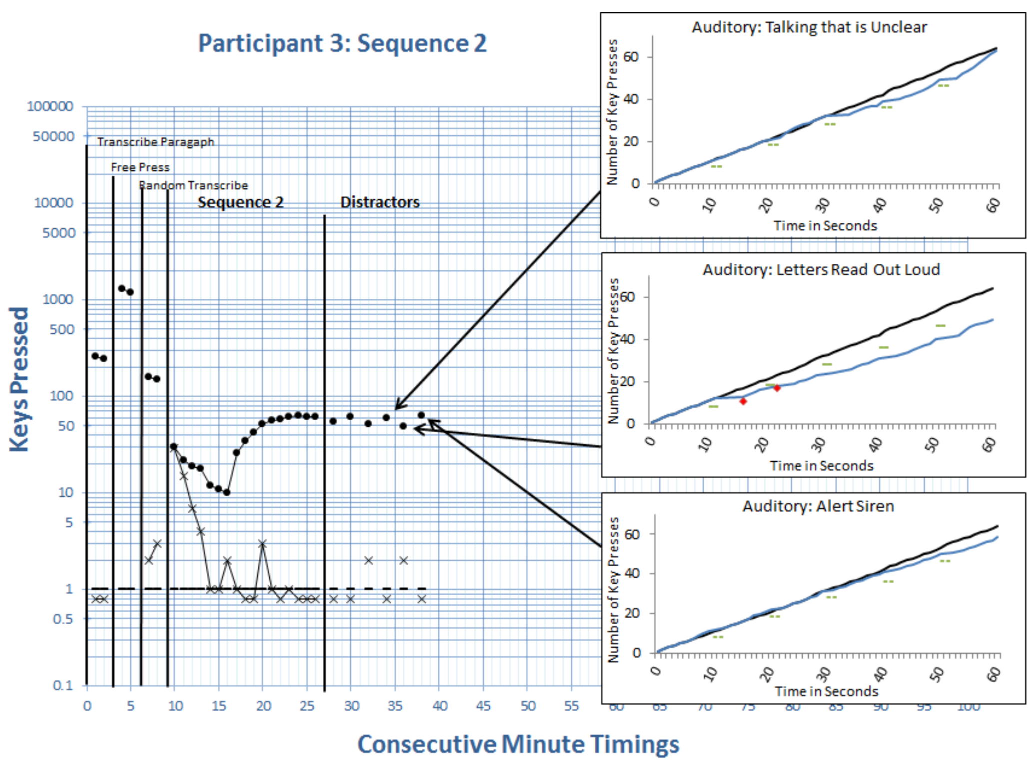
Figure 37. This figure illustrates participant 2 data in Experiment 5. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each “x” represents the total errors. There are cumulative records on which the horizontal axis is time in seconds and the vertical axis is responses. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

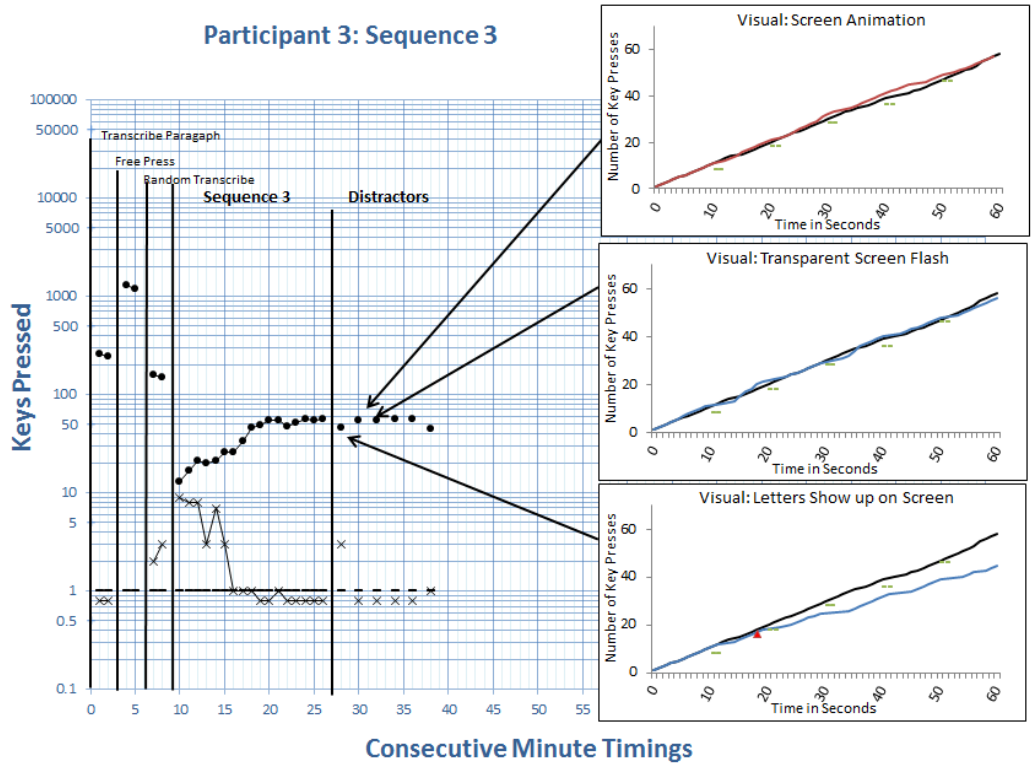
Figure 38. Participant 3 Data, Experiment 5

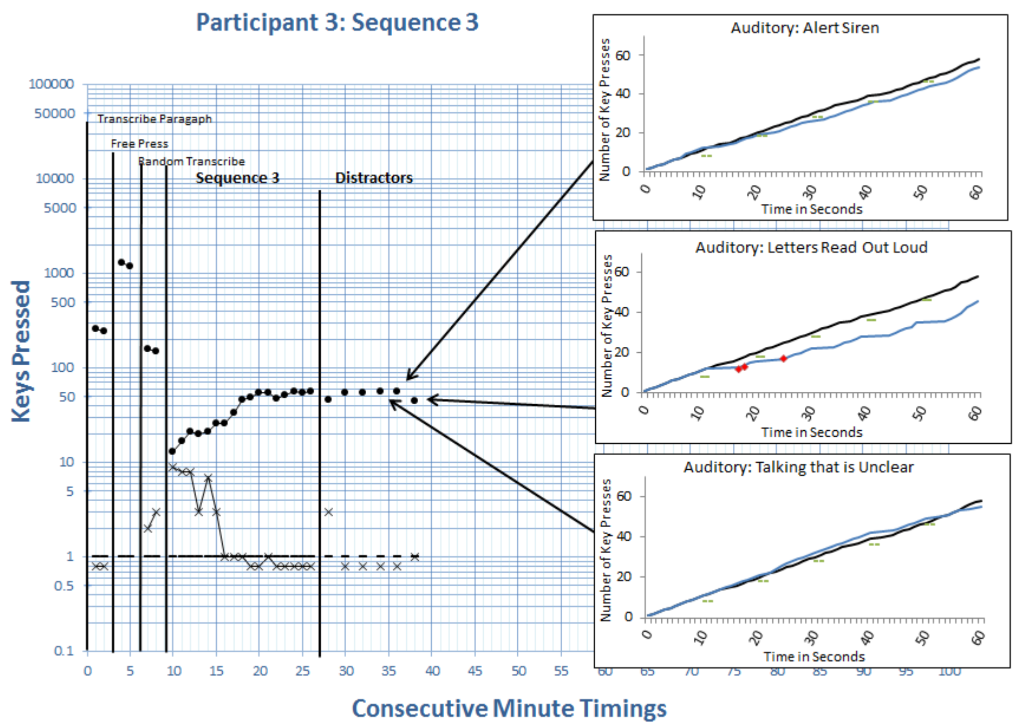


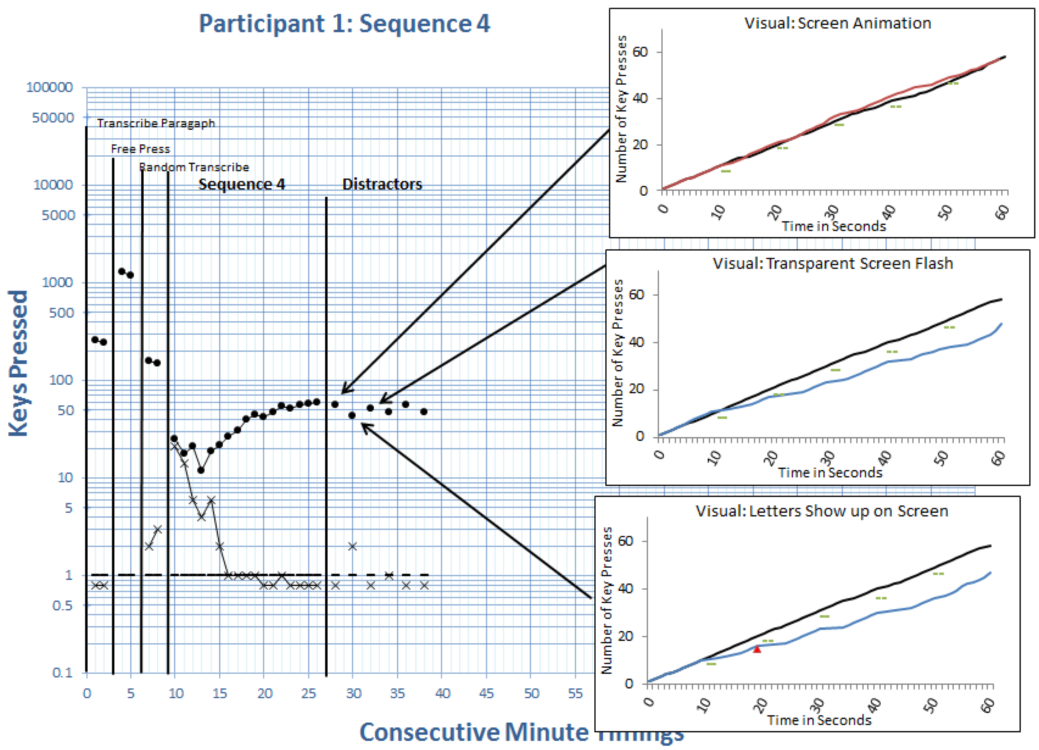



Participant 3: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 2
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 3: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 2
Distractors
Auditory: Talking that is Unclear
Auditory: Letters Read Out Loud
Auditory: Alert Siren
Number of Key Presses
Time in Seconds


Participant 3: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 3: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 3
Distractors
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds



Participant 1: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 4
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds

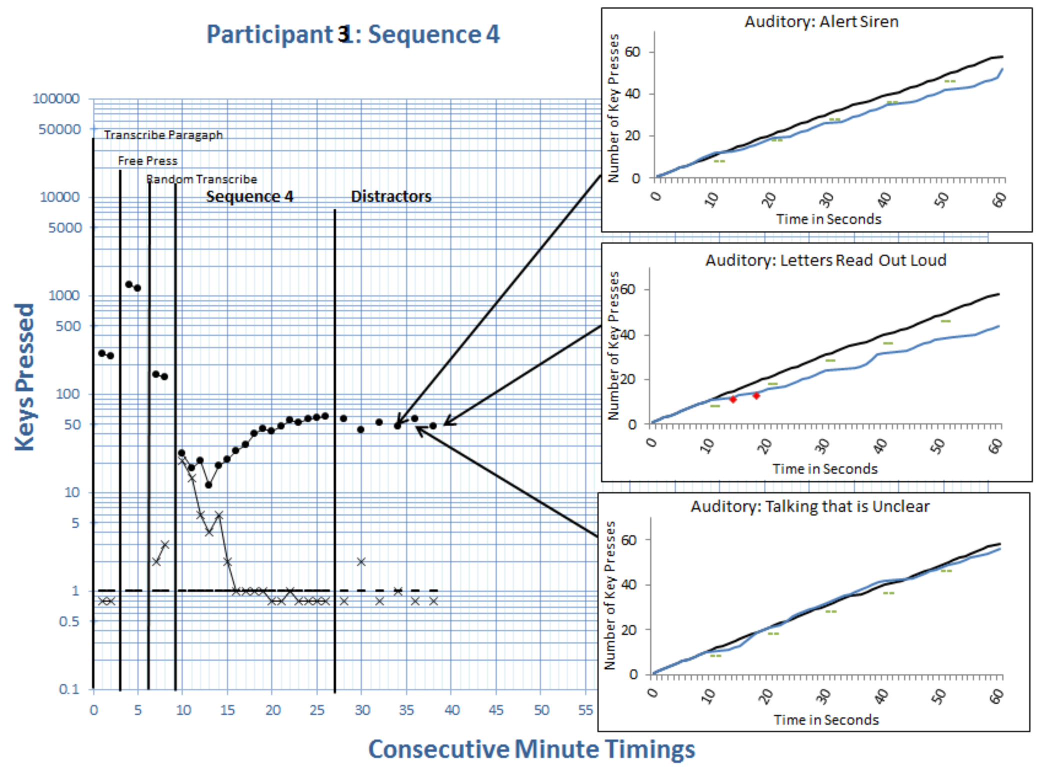
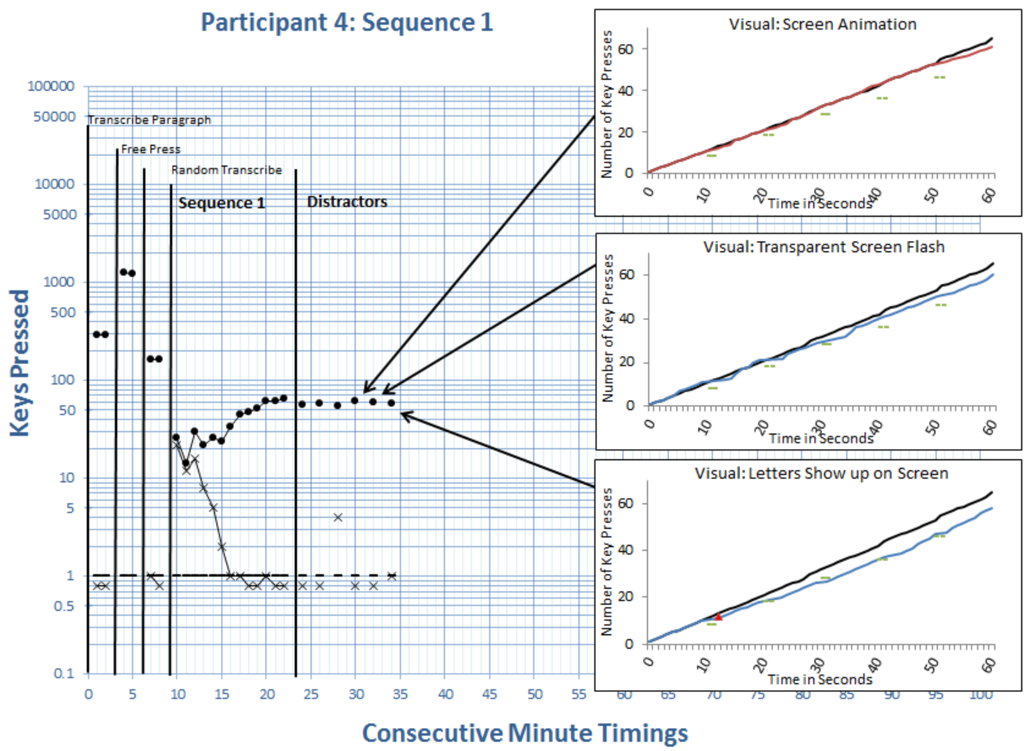
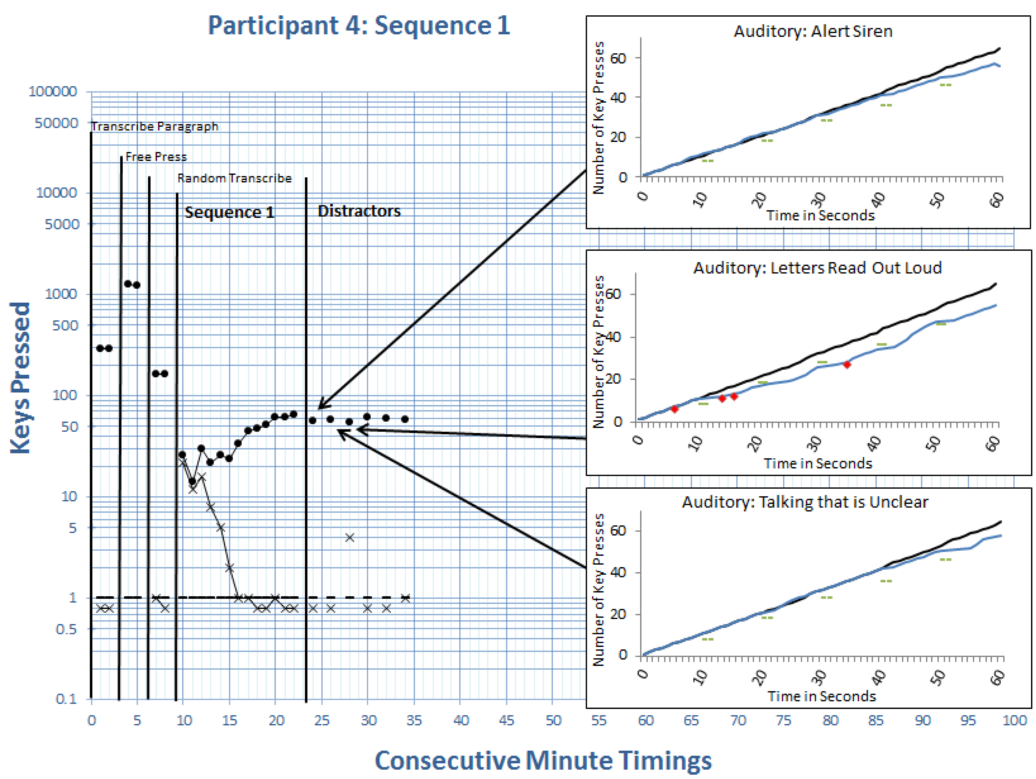
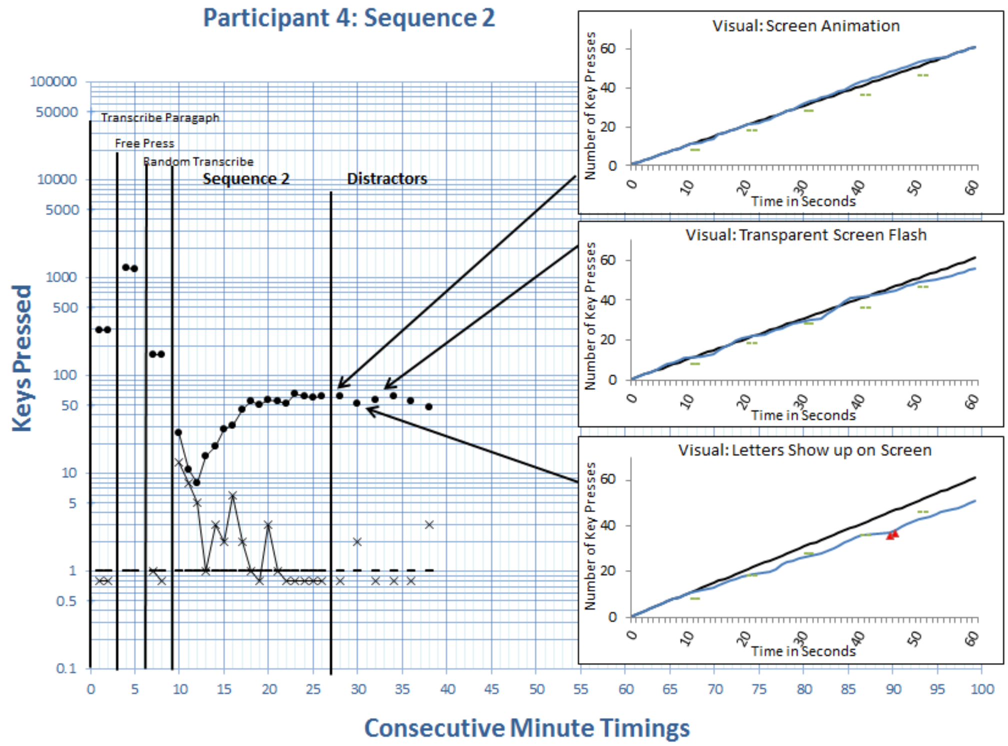


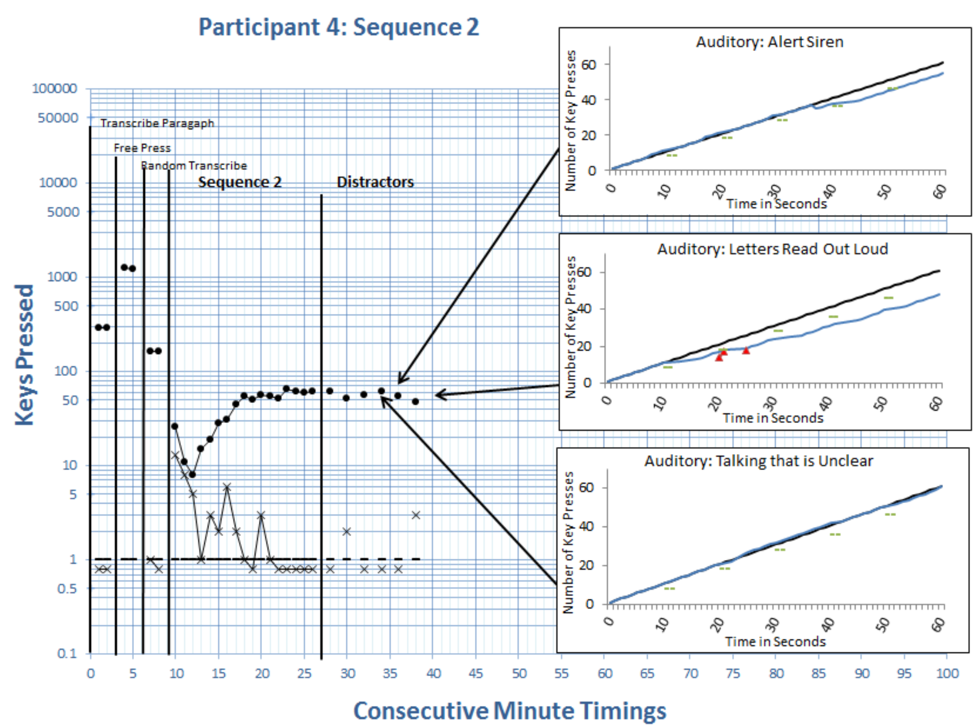
Figure 38. This figure illustrates participant 3 data in Experiment 5. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. There are cumulative records on which the horizontal axis is time in seconds and the vertical axis is responses. Each distractor is plotted on the cumulative charts. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

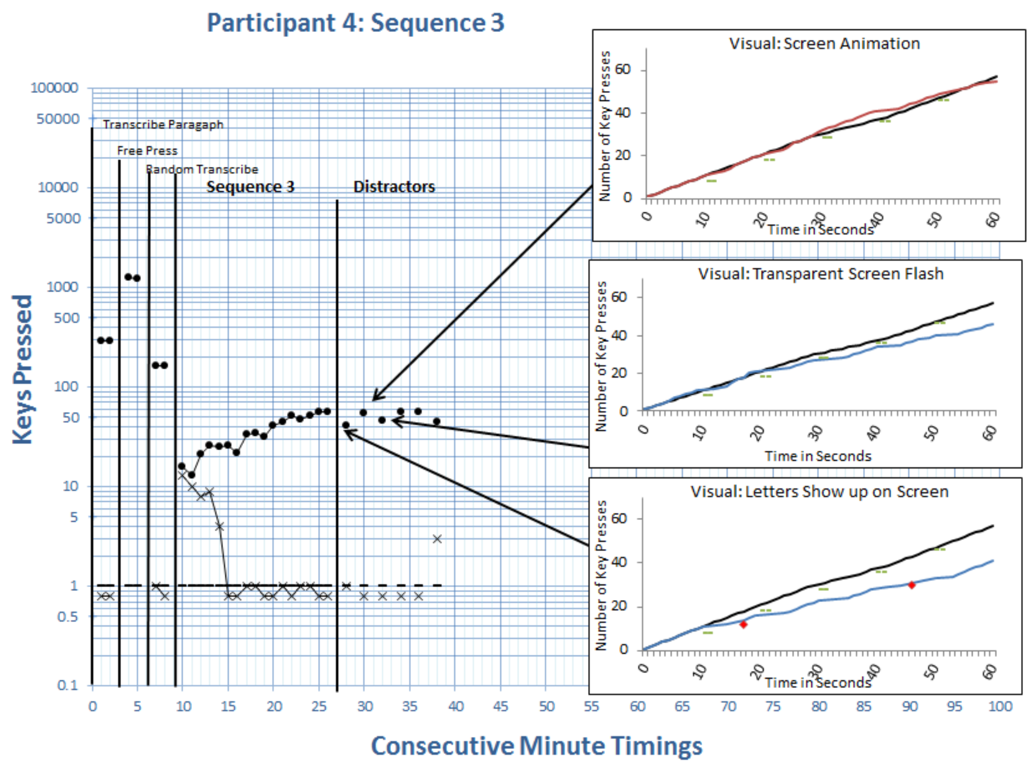
Figure 39. Participant 4 Data, Experiment 5

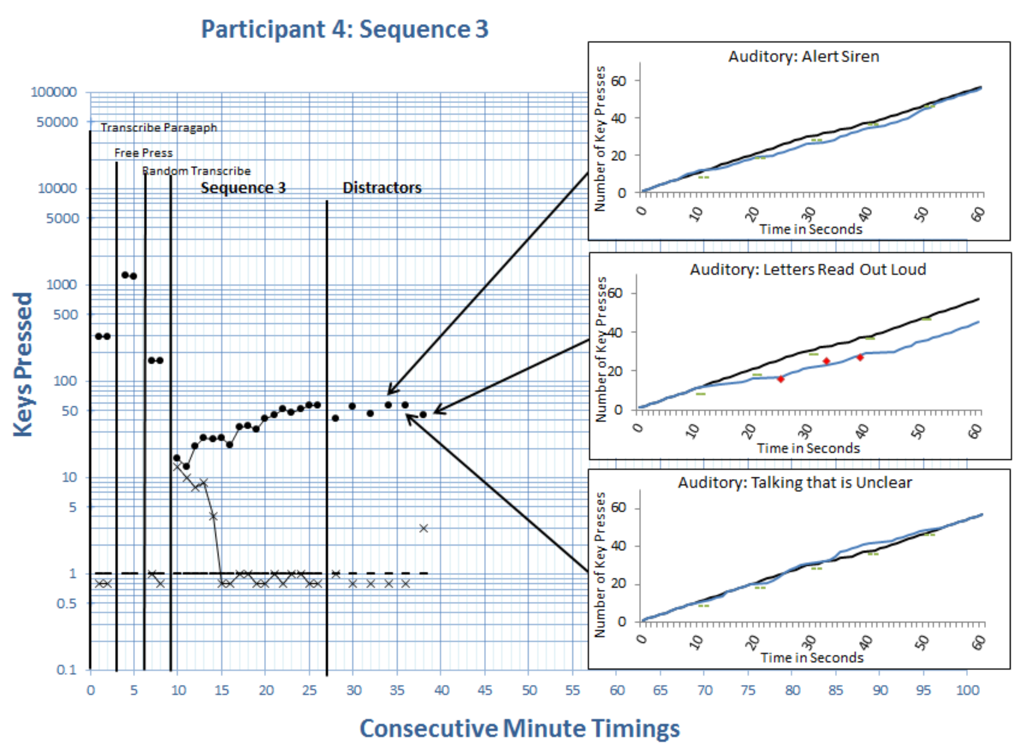

Participant 4: Sequence 1
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 1
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds

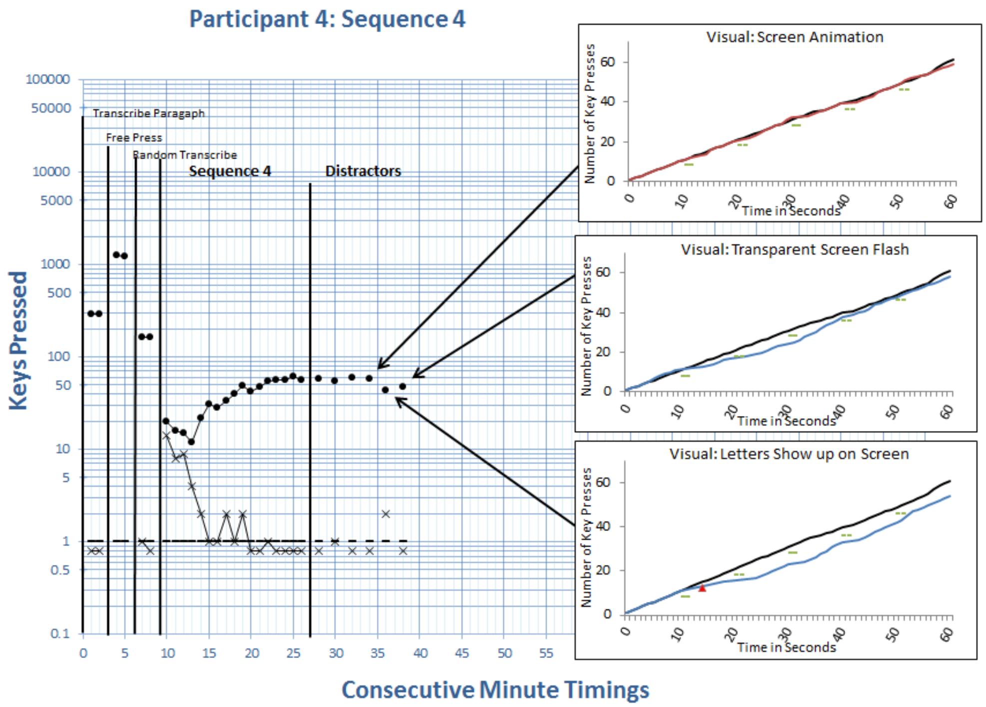

Participant 4: Sequence 1
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 1
Distractors
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds


Participant 4: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 2
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 4: Sequence 2
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 2
Distractors
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds


Participant 4: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 3
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds


Participant 4: Sequence 3
Keys Pressed
Consecutive Minute Timings
Transcribe Paragraph
Free Press
Random Transcribe
Sequence 3
Distractors
Auditory: Alert Siren
Auditory: Letters Read Out Loud
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds


Participant 4: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 4
Distractors
Visual: Screen Animation
Visual: Transparent Screen Flash
Visual: Letters Show up on Screen
Number of Key Presses
Time in Seconds

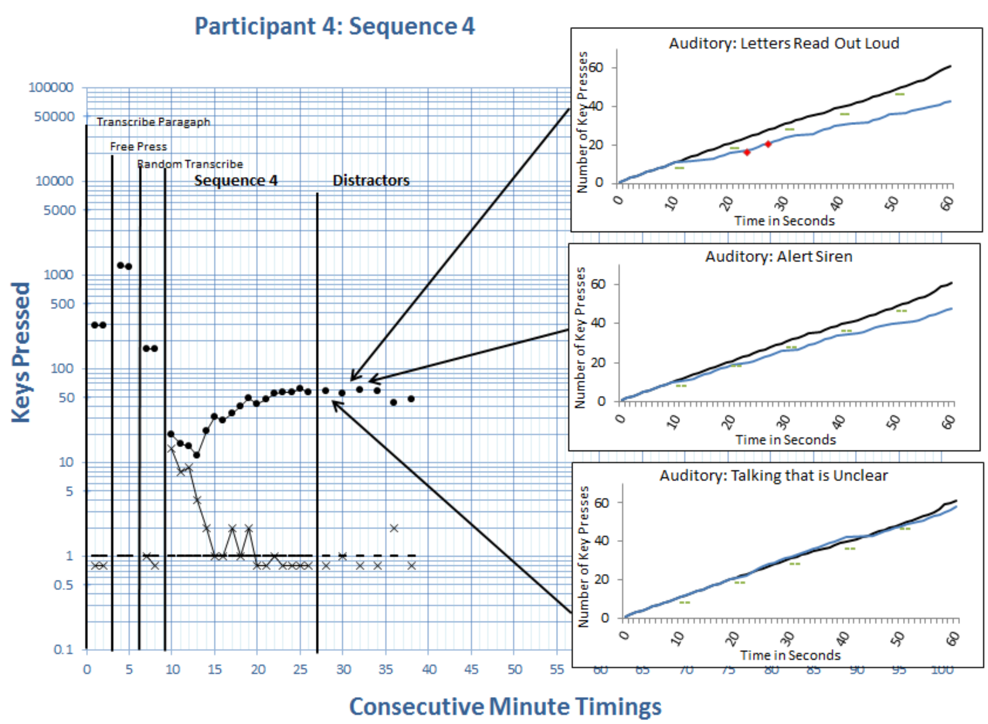

Participant 4: Sequence 4
Keys Pressed
Consecutive Minute Timings
Transcribe Paragaph
Free Press
Random Transcribe
Sequence 4
Distractors
Auditory: Letters Read Out Loud
Auditory: Alert Siren
Auditory: Talking that is Unclear
Number of Key Presses
Time in Seconds

Figure 39. This figure illustrates participant 4 data in Experiment 5. The ordinate indicates the rate and the abscissa represents one-minute in length timing. Each circular data point represents the rate of total responses and each "x" represents the total errors. There are cumulative records on which the horizontal axis is time in seconds and the vertical axis is responses. Each distractor is plotted on the cumulative charts. The line indicates accumulated responses over time. The first and last timing are indicated by the lines on the cumulative chart.

Figure 40. Correlation data between pre-tests and sequence performance experiment 4 and 5.

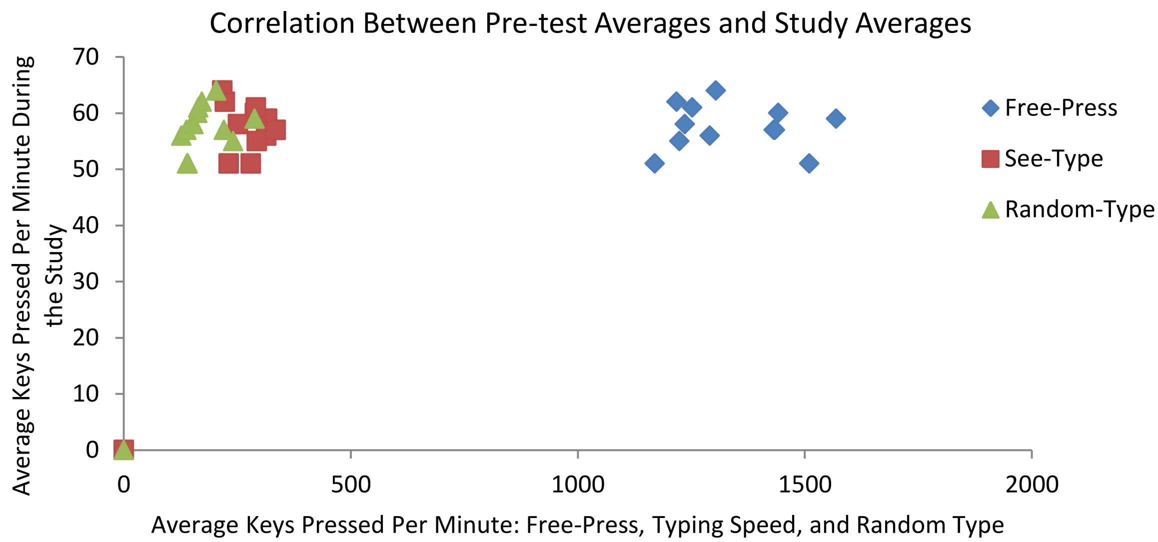
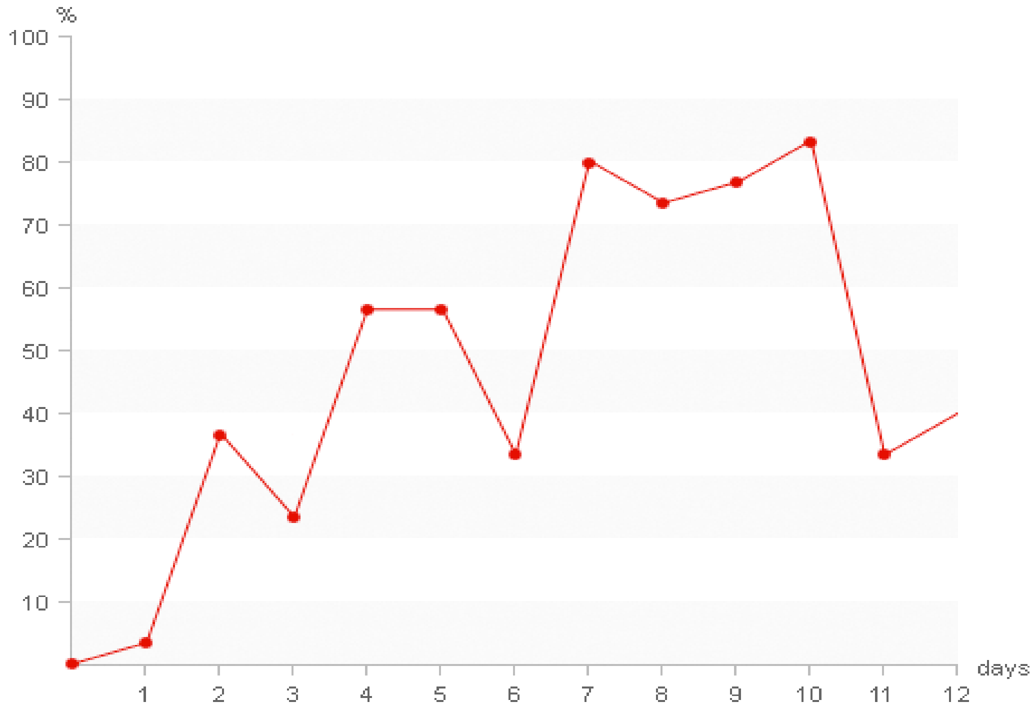
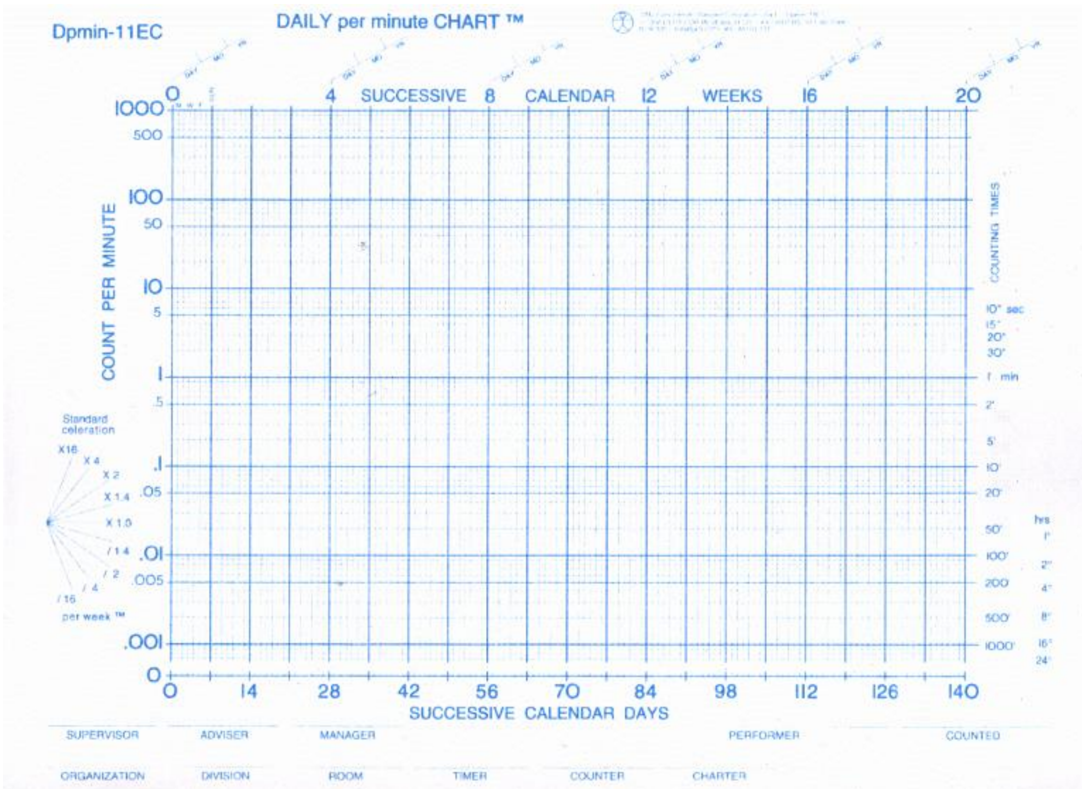


Figure 40. This figure illustrates correlation data for participants in experiment 4 and 5 on both free operant key pressing and typing speed. The horizontal axis represents typing speed and free operant pre-test scores and the vertical axis represent the average key pressing speed during the study.

Appendix 1

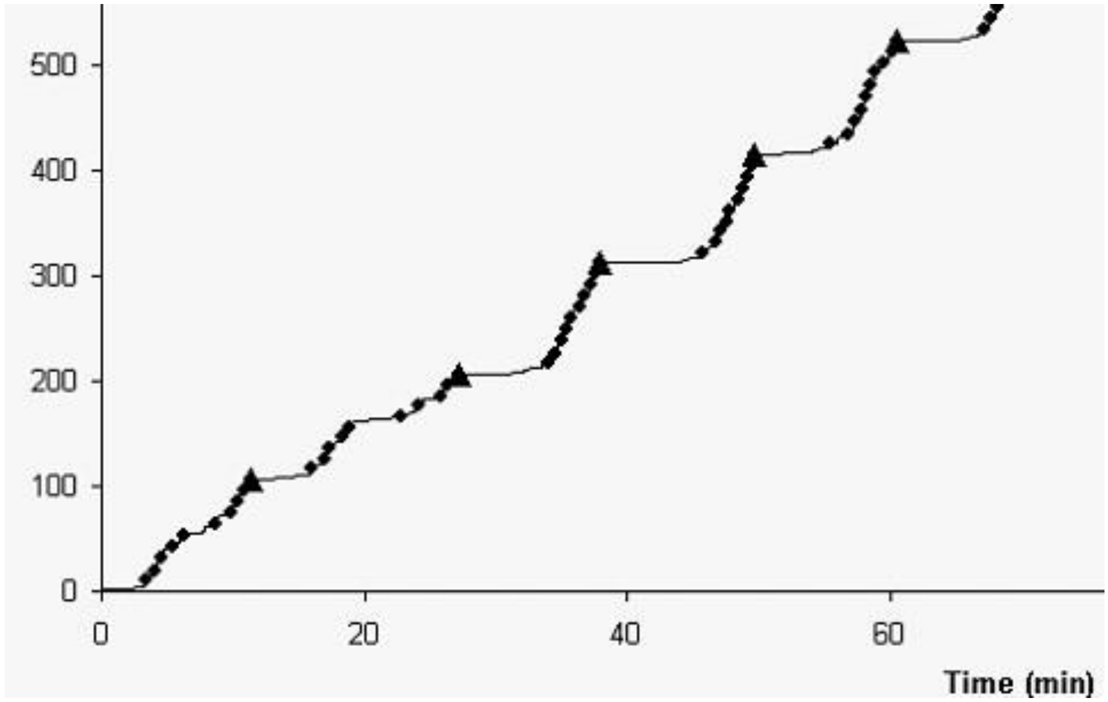


Appendix 2



Dpmin-11EC
DAILY per minute CHART ™
0 4 SUCCESSIVE 8 CALENDAR 12 WEEKS 16 20
COUNT PER MINUTE
1000
500
100
50
10
5
1
.5
.1
.05
.01
.005
.001
0
COUNTING TIMES
10" sec
15"
20"
30"
1' min
2'
5'
10'
20'
50'
100'
200
500'
1000'
hrs
1'
2'
4'
8'
16'
24'
Standard celeration
X16
X4
X2
X1.4
X1.0
/1.4
/2
/4
/16
per week ™
0 14 28 42 56 70 84 98 112 126 140
SUCCESSIVE CALENDAR DAYS
SUPERVISOR
ADVISER
MANAGER
PERFORMER
COUNTED
ORGANIZATION
DIVISION
ROOM
TIMER
COUNTER
CHARTER

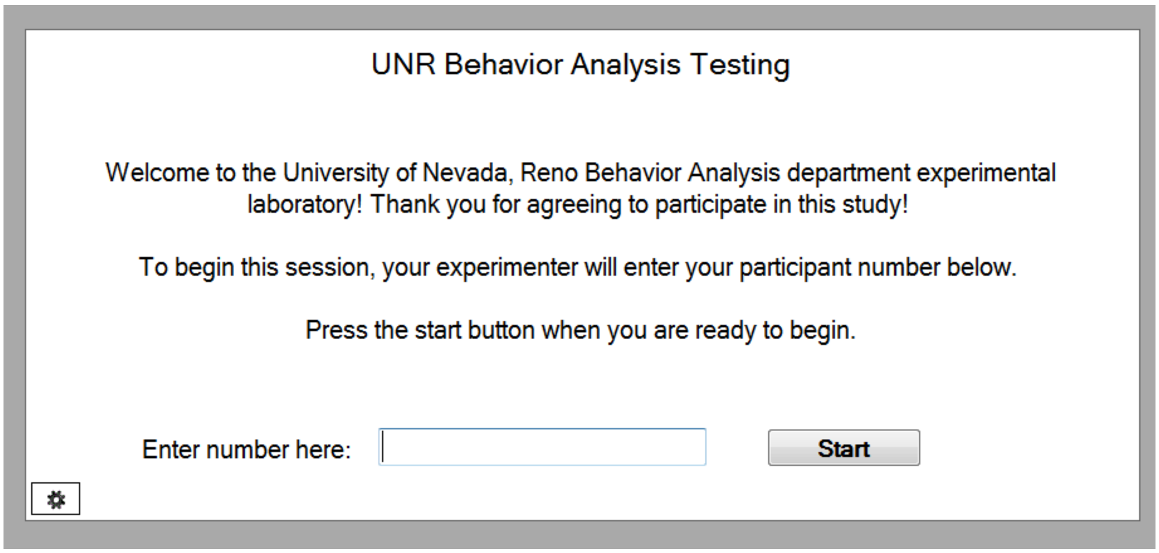
Appendix 3



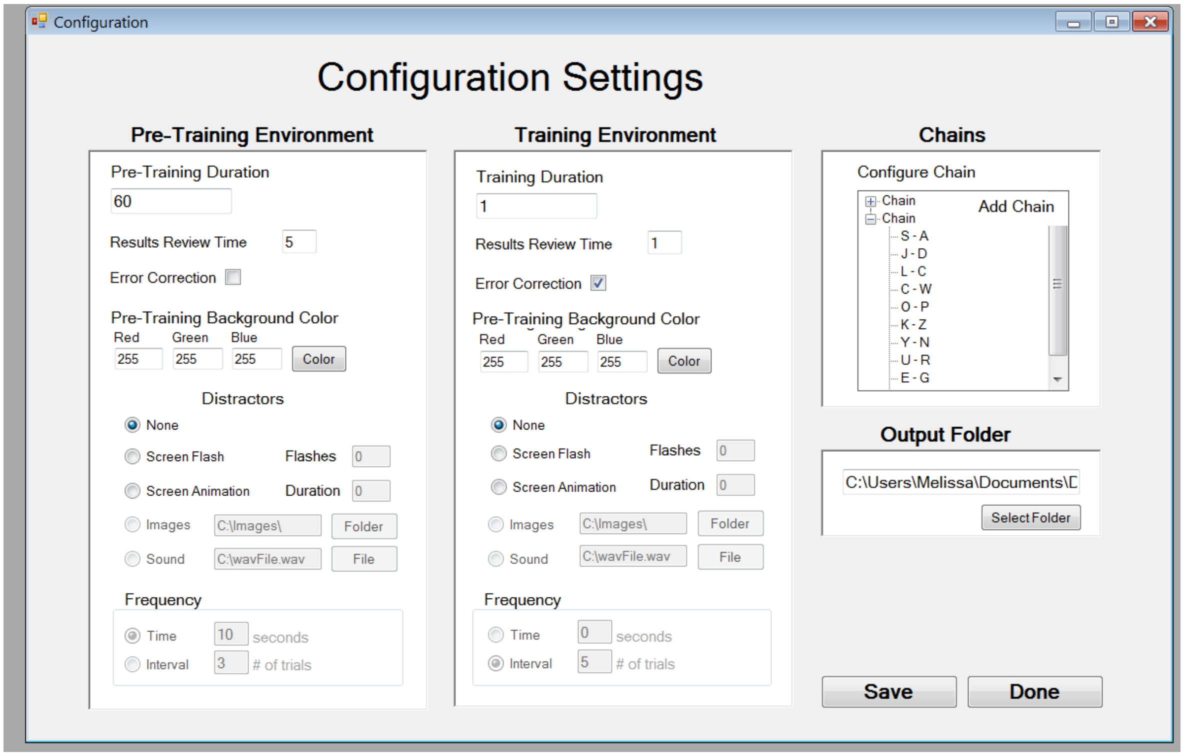
Appendix 4

Software Program

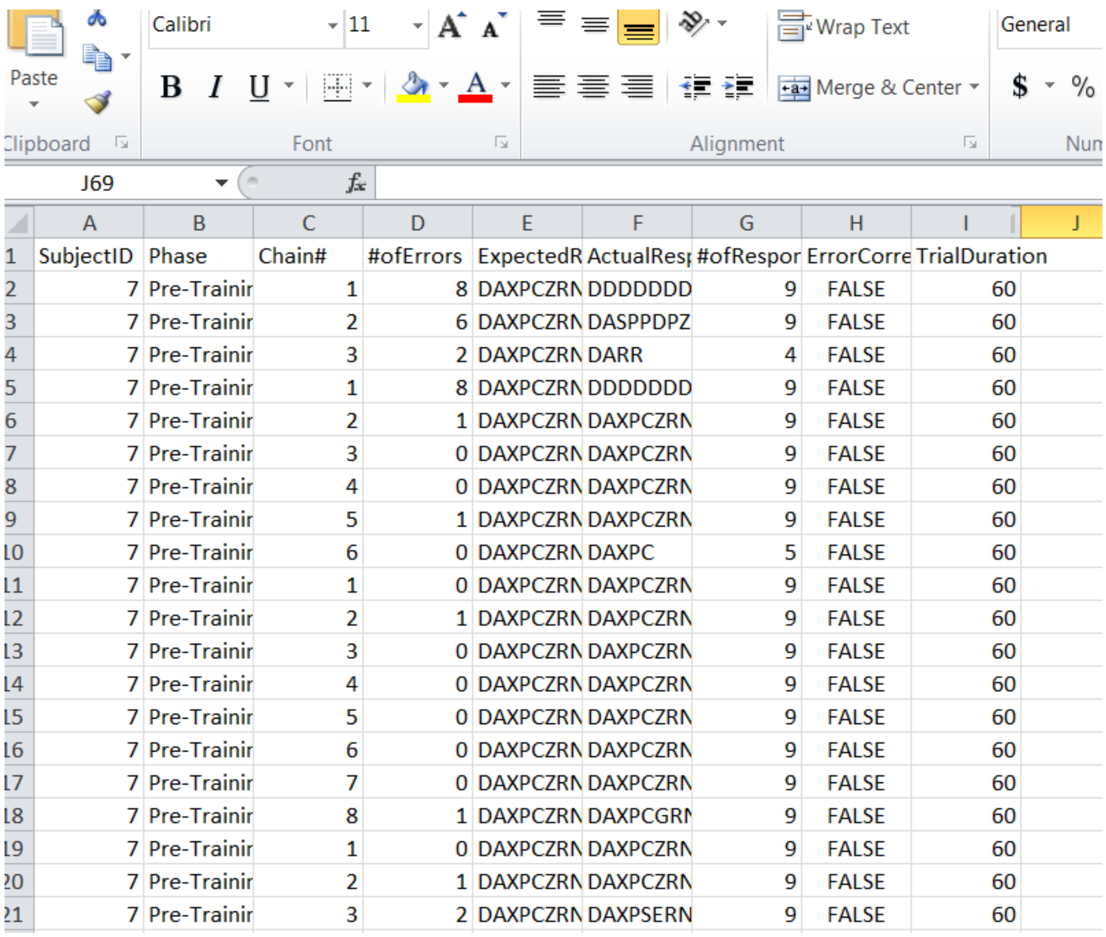
Initial Screen



Configuration Settings


Configuration
Configuration Settings
Pre-Training Environment
Pre-Training Duration
60
Results Review Time
5
Error Correction
Pre-Training Background Color
Red Green Blue
255 255 255
Color
Distractors
None
Screen Flash
Flashes
0
Screen Animation
Duration
0
Images
C:\Images\
Folder
Sound
C:\wavFile.wav
File
Frequency
Time
10
seconds
Interval
3
# of trials
Training Environment
Training Duration
1
Results Review Time
1
Error Correction
Pre-Training Background Color
Red Green Blue
255 255 255
Color
Distractors
None
Screen Flash
Flashes
0
Screen Animation
Duration
0
Images
C:\Images\
Folder
Sound
C:\wavFile.wav
File
Frequency
Time
0
seconds
Interval
5
# of trials
Chains
Configure Chain
Chain
Chain
S - A
J - D
L - C
C - W
O - P
K - Z
Y - N
U - R
E - G
Add Chain
Output Folder
C:\Users\Melissa\Documents\D
Select Folder
Save
Done

Output File



	A	B	C	D	E	F	G	H	I	J
1	SubjectID	Phase	Chain#	#ofErrors	ExpectedR	ActualRes	#ofRespor	ErrorCorre	TrialDuration	
2	7	Pre-Trainir	1	8	DAXPCZRN	DDDDDDD	9	FALSE	60	
3	7	Pre-Trainir	2	6	DAXPCZRN	DASPPDPZ	9	FALSE	60	
4	7	Pre-Trainir	3	2	DAXPCZRN	DARR	4	FALSE	60	
5	7	Pre-Trainir	1	8	DAXPCZRN	DDDDDDD	9	FALSE	60	
6	7	Pre-Trainir	2	1	DAXPCZRN	DAXPCZRN	9	FALSE	60	
7	7	Pre-Trainir	3	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
8	7	Pre-Trainir	4	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
9	7	Pre-Trainir	5	1	DAXPCZRN	DAXPCZRN	9	FALSE	60	
10	7	Pre-Trainir	6	0	DAXPCZRN	DAXPC	5	FALSE	60	
11	7	Pre-Trainir	1	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
12	7	Pre-Trainir	2	1	DAXPCZRN	DAXPCZRN	9	FALSE	60	
13	7	Pre-Trainir	3	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
14	7	Pre-Trainir	4	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
15	7	Pre-Trainir	5	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
16	7	Pre-Trainir	6	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
17	7	Pre-Trainir	7	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
18	7	Pre-Trainir	8	1	DAXPCZRN	DAXPCGRN	9	FALSE	60	
19	7	Pre-Trainir	1	0	DAXPCZRN	DAXPCZRN	9	FALSE	60	
20	7	Pre-Trainir	2	1	DAXPCZRN	DAXPCZRN	9	FALSE	60	
21	7	Pre-Trainir	3	2	DAXPCZRN	DAXPSERN	9	FALSE	60	

Feedback Screen

The PRE-TRAINING phase is now complete.
Please wait for the TRAINING phase to begin.

Chains Completed: 12 Errors: 102

Appendix 5

Evaluation Survey

Date: ________________

The intent of this form is to give you an opportunity to comment on the study you just participated in. You were asked to complete sequences either accurately or fast or both. Please respond to the questions below accordingly.

ITEM	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
1. The computer program asked me to enter a series of arbitrary letter relations.	1	2	3	4	5
2. It was difficult at first to learn the relations.	1	2	3	4	5
3. After a few practice opportunities completing the sequence was much easier.	1	2	3	4	5
4. I preferred some sequences over the other ones.	1	2	3	4	5
5. By the end of the study I felt tired of doing the sequences.	1	2	3	4	5
6. All of the sequences were easy to learn.	1	2	3	4	5
7. The color relations were the most difficult part.	1	2	3	4	5
8. After several trials I could complete the sequences quickly and without thinking.	1	2	3	4	5
9. There seemed to be no difference in difficulty learning each of the sequences.	1	2	3	4	5
10. It was really hard to complete the sequences when some of the distractors were introduced.	1	2	3	4	5
11. Some of the distractors made it more difficult than others	1	2	3	4	5
12. The audible distractors were more difficult to ignore	1	2	3	4	5
13. The visual distractors were more difficult to ignore	1	2	3	4	5

What year are you in college? Sophomore Freshman Junior Senior

What is your major? ______________________________

Which distractor was the easiest to ignore? ______________________

Which distractor was the most difficult to ignore? ______________________

Were there distractors you found your-self liking better than others? If so, Why?

____

____

Was there anything about this study that you did like?

____

____

Appendix 6

Typing Test

Once upon a time there was an honest shoemaker, who was very poor. He worked as hard as he could, and still he could not earn enough to keep himself and his wife. At last there came a day when he had nothing left but one piece of leather, big enough to make one pair of shoes. He cut out the shoes, ready to stitch, and left them on the bench; then he said his prayers and went to bed, trusting that he could finish the shoes on the next day and sell them. Bright and early the next morning, he rose and went to his work bench. There lay a pair of shoes, beautifully made, and the leather was gone!

Total Words: 121

Characters with Spaces: 601

Characters without Spaces: 677

Appendix 7

Random Typing Test

Like Size fee plea amaze to key a see lead drive. pay sit mountain jack Mary kid laundry ball couch bottle coffee drive. Gary purse cold tea told between keep lift Disney cup ball lawn tree hanger plate apple candle yellow floor blue cucumber napkin drip computer light dog Walter behavior Seattle market. desk lid wood temple department skirt football vent dryer sketch wallet bulb flower ant purple mail? knife scissors blank write tool purchase fruit hair copy marker printer white phone bold dew night funny bottom!

Total Words: 87

Characters with Spaces: 519

Characters without Spaces: 433