THE EFFECTS OF RATE OF RESPONDING ON RETENTION, ENDURANCE, STABILITY, AND APPLICATION OF PERFORMANCE ON A MATCH-TO-SAMPLE TASK

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Fluent performance has been described as the retention, endurance, stability, and application of the material learned. Fluent performers not only respond quickly during training, they also make many correct responses during training. The current study used a within-subject design to analyze the effects of increased response rates on Retention, Endurance, Stability, and Application tests. Number of correct responses and number of unprompted, correct responses in error correction procedures were yoked for individual participants across an Accuracy-plus-Rate training condition and an Accuracy-Only training condition. One participant scored better in tests that followed the Accuracy-Only condition. One participant showed results that slightly favor the Accuracy-plus-Rate training condition. The two participants whose response rates were successfully reduced in the Accuracy-Only condition performed better on all tests that followed the Accuracy-plus-Rate condition.

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CHAPTER 1

INTRODUCTION

The most common method used to measure learning is number correct out of total number of responses -- percent correct (Kubina & Morrison, 2000). Some behavior analysts have claimed that percent correct is not a powerful or meaningful measure of behavior because it does not include the element of time (Johnson & Pennypacker, 1993). Another disadvantage of percent correct scores as discussed by West, Young, and Spooner (1995) is that it provides no information about the nature of errors and therefore does not give educators the information necessary to remedy the errors. Skinner himself proclaimed rate of responding to be the most important measure of behavior in relation to the "learning process" (Skinner, 1959).

After learning from Skinner to change operant behavior through consequences, to use frequency to measure observable behavior daily, and that "the organism knows best", Ogden Lindsley began teaching others to apply these principles through the use of Precision Teaching (Potts, Eshleman, & Cooper, 1993). Precision Teaching is an instructional method that utilizes response rates measured daily and recorded on Standard Celeration Charts to make individualized decisions about instructional changes (Binder, 2004). Educators using Precision Teaching report that performances occurring at specific rates as well as high levels of accuracy show Endurance, Stability, Retention, and Application (Fabrizio & Moors, 2004).

The term *fluency* has been used both to refer to experimental groups in which participants practice skills accurately and at a high rate (Bucklin, Dickinson, & Brethower, 2000; Doughty, Chase, & O' Shields, 2004, p. 8) and also to designate

purported outcomes of high rate performances: Retention, Endurance, Stability, Application and Adduction, (Johnson and Layng, 1996). Retention refers to the ability of the learner to perform accurately at a previously established rate after a period of time has passed without practice. Endurance is observed when the learner performs a task, at a previously established rate, for a time period that is longer than practice periods. Stability is evident when the learner performs the trained skill at the rate achieved in practice when distractions are introduced to the environment. Application describes the learner's ability to perform novel composite tasks after learning component skills to a certain rate. Adduction occurs when lower level skills are taught to fluency and higher level composite skills emerge without the usual training required (Johnson and Layng, 1996). Building performances to certain response rates has been said to produce the five outcomes listed above. The appearance of these outcomes has been used to designate performance as "fluent." In this paper Johnson and Layng's definition of fluency will be used. Therefore, the term "high response rates" will be used to describe performance that has been produced by rate building procedures, a performance which may or may not result in the outcomes of Endurance, Stability, Retention, and Application, or fluency.

When a teacher presents instructional stimuli in a discrete-trial format the rate at which the learner can respond is governed by the rate at which the teacher presents the next instructional stimulus. Since the rate at which responses are made is considered critical to the learning, precision teachers in the natural environment typically allow the learner to have control over when the next instructional stimulus is presented. Allowing the learner to present the next instructional stimulus removes the lag associated with

the behavior of the teacher in presenting instructional stimuli.

In 1996, Spencer and Chase measured speed as the inverse of response latency. Speed of responding can be thought of as the combination of response latency plus response duration. For some responses, durations can vary significantly, but other responses, such as touching a symbol on a computer screen, can have little if any variation in response durations (that is, the time between the beginning and ending of the touching response). In the latter case, measures of response latency can provide significant information about response rates. That is, given constant durations, long response latencies are an attribute of low response rates while short response latencies are an attribute of high response rates.

Doughty, Chase, and O'Shields (2004) reviewed the behavior analysis literature published over the last several decades in order to determine whether there is experimental evidence to support the claim of Precision Teachers that high rates of responding are prerequisites to the outcomes defining fluency. The articles those authors included in their review were located by three different methods. Doughty et al. searched the PSYCInfo psychological research and ERIC EBSCO Host educational databases using key words such as Fluency and Endurance, Fluency and Adduction, Fluency and Retention, Fluency and Practice and Education, Behavioral Fluency, Repeated Readings, Timings and Education, Fluency Training, Rate Building, and Precision Teaching. They also located articles by communicating with other professionals likely to have knowledge of relevant articles. Finally, they searched the reference lists of the articles they had already obtained. The authors grouped the articles that addressed Stability, Adduction, or Application into one category that they

labeled extension. Articles were defined as empirical if they “reported original and previously unpublished data, either experimental or correlational, and outlined specific procedures” (Doughty et al., 2004, p. 11). Articles were defined as conceptual if they gave descriptions “of proposed methods or reviews of previously implemented methods” (Doughty et al. pg. 11). Forty-eight articles were in the review. Of these, 29 were classified as empirical.

Doughty et al. (2004) examined the 29 empirical articles for the adequacy of their experimental control over the amount of practice and the amount of reinforcement given when outcomes of high rate of accurate responding were compared to outcomes of merely accurate responding. They identified three studies that controlled for the amount of time spent practicing the skills between the high rate and the accuracy-only conditions, three controlled for the number of exposures to stimuli between the high rate condition and the accuracy-only condition, and three controlled for the amount of reinforcement delivered in the fluency condition and the accuracy-only conditions. The three articles that controlled for amount of reinforcement were the same three articles that controlled for number of exposures to stimuli.

The three articles Doughty et al. (2004) reported as controlling for the amount of time spent in practiced were Bucklin et al., (2000); Chiesa & Robertson, (2000); and Jones, Torgesen, & Sexton, (2001). The Bucklin et al., (2000) experiment used a conditional discrimination task to teach participants to match nonsense symbols to Hebrew symbols and to match those same nonsense symbols to Arabic numerals. They assigned participants to either the accuracy group or the high rate group. Once training was complete they tested each group for Application of learned skills to new

tasks and Retention of trained skills. It is not clear that they controlled for the amount of time spent in practice because their article states that after accuracy was reached for the participants in the accuracy group, training ended; but the participants in the fluency group had to continue with drills until they had reached the rate aim. Participants in the fluency group and participants in the Accuracy-Only group did have the same number of 1-minute timings on both of two worksheets. Results of this experiment show that participants in the high rate group made more correct responses per minute on the Application test than participants in the Accuracy-Only group. This difference was statistically significant. Scores for Retention tests on component skills and composite skills favored participants in the high rate group over the Accuracy-Only group but these scores were not statistically significant. This experiment did not control for number of practice exposures or rate of reinforcement. Therefore, it is likely that participants in the high-rate group received more practice opportunities and more reinforcement which is possibly why their results favored the high-rate group.

Chiesa and Robertson's experiment (2000) used 9- and 10-year-old students and taught basic math skills of multiplication and division. The children who were required to meet a rate criterion on component skills and the children who were taught the composite skill in the traditional way spent equal time practicing. Five students from a math class were identified by two staff members as in need of help with math skills. These five students (accuracy plus rate group) were removed from their math class and taught until the components skills were accurate at high rates while the other children (accuracy-only group) stayed in math class. Results showed precision teaching and building component skills to a high rate improved the composite skill performance of

these five students to above the composite skill performance of almost all the other students in the math class. This experiment controlled for amount of time spent in practice but learners practicing in a rate building format are likely to make more responses than learners in the accuracy-only group in the same amount of time. Also, this study did not control for the number of reinforcements. These two variables may influence performance outcomes.

Jones et al. (2001) taught spelling words to learning disabled children. Students were assigned to an experimental or a control group. In the control group students used a computer and responded to spelling lists. They spent 15 minutes a day on the computer for five days a week over a ten month period. The students who were assigned to the experimental group also responded to spelling words on a computer but used a program called “Hint and Hunt”, which required them to spell words accurately and then increase their speed before they could advance to the next level. Students in the experimental group also spent 15 minutes a day for five days a week on this program over a ten month period. Results show that students in the experimental group (accuracy plus rate) improved more than students in the control group in accuracy of reading target and generalization words, and speed and accuracy of paragraph reading. As with the two experiments discussed previously, this experiment did not control for the number of practice exposures or for rate of reinforcement. It is likely that number of practice exposures and rate of reinforcement were higher for participants in the accuracy plus rate group. If so, this could have affected the results obtained.

A few of the articles reviewed by Doughty et al. (2004) and one article that was not included in their review controlled for number of exposures to stimuli in practice and

amount of reinforcement that participants in each group received. The articles in this category kept the number of trials in each condition the same instead of controlling the amount of time spent practicing. Due to the nature of rate building, learners responding as fast as they can will have more practice with a task than learners responding at a leisurely pace for the same amount of time. Another important question that has been asked about precision teaching and fluent performance regards the rate of reinforcement. By definition, reinforcement increases the future probability of a response occurring. Behavior analysts have asked whether Retention, Endurance, Stability, Adduction and Application can be explained by the high rate of reinforcement during practice and acquisition of a new skill. The articles in this category used experimental arrangements that held the rate of reinforcement constant between the conditions of accuracy-only and accuracy plus rate.

In 1983 Evans, Merger, and Evans published an article in the Journal of Precision Teaching titled “The relationship of frequency to subsequent skill acquisition”. They were investigating “…the relationship of different ending frequencies on a particular skill, saying letter sounds, and subsequent ending frequencies on a related skill, saying CVC (consonant-vowel-consonant) trigrams when amount of practice is controlled” (Evens et al. pg. 29). They gave all participants a pretest on saying CVC trigrams. Then they randomly divided the participants into high, medium, and low groups based on the rate at which participants were required to say letter sounds. Once each participant reached the rate aim set for the group they were assigned to, they stayed on a controlled reader that kept their rate the same until they had said 940 letter sounds. All participants received praise and feedback after each 1-minute drill. A

post-test on the composite skill of saying CVC trigrams was given to all participants. Results showed that participants in the high frequency group had a higher total word gain from pre to post test of the composite skill than participants in the medium frequency or low frequency groups. There was no accuracy-only group in this study (although the low rate responding may have approximated an accuracy-only condition), so the question of whether amount of practice or rate of reinforcement contributes to the benefits of fluent performance could not be answered.

Evans and Evans, (1985) described two studies on identifying frequencies needed to achieve competency in a skill. Once again, participants were assigned to groups requiring high, medium, or low frequency responding. Participants received praise and feedback after each timed drill. The question being asked was “At what rate for each of these skills is the most benefit attained?” In the first study the task was saying letter sounds and saying CVC trigrams. Participants in the medium frequency group (saying letter sounds at 90 per minute) showed most growth in saying CVC trigrams. In the second study the task was writing addition facts with sums up to 10. Results show that participants in the high frequency group mastered more composite math skills related to number skills, operations, problem solving, measurement, and shapes and graphs than participants in the low or medium frequency groups. There was no accuracy-only group so even though Evans and Evans controlled for the amount of practice each participant received as well as the rate of reinforcement they did not answer how these two variables are related to the benefits of fluent performance.

Shirley and Pennypacker (1994) trained learners in writing spelling words. The final phase of this experiment is the most relevant to this paper. In the final phase, each

participant had two spelling lists, each containing ten words. Participants practiced both of these lists daily until they were performing at 100% accuracy on both lists and had reached the fluency aim on one of the lists. They were then presented with two new lists and continued practicing the new lists until they had reached 100% accuracy on both lists and had reached the fluency aim on one of the lists. Individual rate aims were set for each participant based on measures of the frequency at which they wrote the letters of their name. In this way, the effects of rate of responding could be compared within subjects and the numbers of practice trials were controlled. Participants were then tested 10 days later for Retention. Students did produce modestly higher accuracy ratios and more correct responses on spelling words that they had mastered to the rate aim, but the authors mentioned that results might have been clearer and Retention might have been better if they had required participants to respond at the rate aim for more than one session. Shirley and Pennypacker mentioned delivering feedback to participants following performance sessions during “Baseline I” but there is no other mention of whether reinforcement and feedback were controlled for on each of the two spelling lists. This article was listed in Doughty et al.’s table as controlling for reinforcement.

An article by Fox and Ghezzi, (2003) was not included in Doughty et al.’s review, but it is relevant to the current experiment. The tasks trained in Fox and Ghezzi’s experiment were to identify definitions of logical fallacies and to identify examples of logical fallacies. Participants were assigned to one of four groups: fluency-definitions, fluency-examples, practice-definitions, or practice- examples. Each participant in the practice-definitions group was yoked with a participant in the fluency-definitions group.

Each participant in the practice-examples group was yoked with a participant in the fluency-examples group. If a participant in the fluency-definitions group required 400 responses to reach the fluency aim then their matched counterpart in the practice definitions group was required to respond 400 times. Participants in both of the fluency groups were told to work as quickly and as accurately as possible during 1-minute timings and that they would receive feedback regarding their accuracy and speed at the end of each 1-minute timing. Participants in both of the practice groups were also told to work as quickly and as accurately as possible but they were not given 1-minute timings. Instead they performed the task until they had made the required number of responses. Participants in all four groups were told that they would hear a tone after each incorrect response. In this experiment results of different instructional situations were evaluated across subjects instead of within subjects and no significant differences were found between the fluency groups and the practice (or "overtraining") groups. There was no specific mention of keeping the rate of reinforcement constant. During practices it appeared that participants in the fluency groups received feedback after each 1-minute timing but participants in the practice groups simply continued responding until they had reached the required number of responses.

The research comparing the effect of high and accurate response rates to mere accurate practicing of a task has generally been lacking in experimental controls and conclusive results. Very few of these studies make use of within-subject designs. Within-subject designs may allow us to examine potential differences in outcomes of the two instructional techniques. Another element that is lacking in the current research in this area is the control over variables other than response rate, such as number of error

corrections and number of correct responses. Whether high response rates themselves account for the salutary outcomes of Precision Teaching can only be determined by controlling these two variables. Doughty et al. (2004) called for new research:

> Researchers might consider teaching some skills in a rate-building format while teaching others in a rate-controlled format using a within-subject design. By keeping number of exposures and reinforcement rate constant across conditions, the effects of high-rate responding are isolated. (Doughty et al., pg. 20)

An important question about the benefits of high rate performances is whether rate of responding itself predicts fluency or whether fluency is simply the outcome of extended practice. Answering this question would provide information to teachers and behavior analysts regarding the crucial elements to include in their instructional methods. Due to the nature of training methods involving rate building they necessarily include an element of differential reinforcement for high rates of responding. Given this fact, the only reinforcement that can be controlled across conditions is that programmed by the experimenter. Even when the experimenter controls some of the reinforcers, the rate-building condition always ultimately provides more reinforcement to the learner. Therefore, the purpose of this experiment is to evaluate the effects of two different training methods (accuracy plus rate and accuracy-only) on the outcomes of Retention, Endurance, Stability, and Application while yoking number of correct responses and number of unprompted correct responses during training in a within-subject design.

CHAPTER 2

METHOD

Participants

Information about participation in this study was provided to participants by fliers passed out in their undergraduate behavior analysis courses or by an ad placed in the daily University paper. The four participants in this experiment were female undergraduates attending the University of North Texas. Participants ranged in age from 20 to 26 years old. All participants had some experience using a computer touch-screen and none of the participants knew how to speak or read Japanese. Each participant read, signed and received a copy of the IRB approved consent form before starting this experiment. Participants were paid $8.00/hour paid at the end of daily sessions plus $25.00 when their participation in the study ended. Additionally, $1.00 went into a bonus pot each time a participant showed up for a session. This money was given to the participants at the end of their participation in the experiment.

Setting

Participants worked in a 7'x 8' room in the Department of Behavior Analysis at the University of North Texas. The room contained a table, office chair and book shelf. The computer tower was on the floor under the table, the monitor was on the table, and the keyboard and mouse were on the back, right corner of the table. The bookcase contained items that were not being used such as old computer equipment, books, empty boxes, etc. A one-way window with blinds was in the wall to the right of the participant. Participants could not see out of this window but while standing in the

adjacent room, the experimenter could see the participants as they were responding in a session.

Participants made all responses on a new Intel ®, Pentium ®, 4 CPC, 3.20 GHz, 3.19 GHz, with 1.00 GB of RAM and a flat-screen monitor. A Keytec ® MagicTouch ® touch screen was attached to the computer's monitor. Participants responded by touching the touch screen with the felt-tipped pointer that came with the MagicTouch® touch screen. The computer program that ran the experiment was written in Visual Basic Dotnet ®. A macro was created in WiNdows® Excel so that the experimenter could organize, calculate and graph the data generated by participants.

Stimuli

Three sets of stimuli were used. Set 1 contained the letters A, P, S, T, C, Z, and N. The associated Japanese symbols for this set were い, せ, ふ, お, む, め, and き. Set 2 contained the letters I, R, D, J, V, G and L. The associated Japanese symbols for this set were そ, ほ, な, ゆ, を, ぬ, and こ. Set 3 contained the letters O, B, F, Q, W, K, and M. The associated Japanese symbols in Set 3 were ね, て, ゑ, や, す, み, and は. In each problem, one letter (sample) was presented in the middle of the computer screen and the seven Japanese symbols (comparisons) appeared in a circle around the sample. Each comparison was an equal distance from the sample stimulus. The position of comparison stimuli was random on each problem and the sample stimuli were presented quasi-randomly (controlling for equal number of presentations). Refer to Figure 1 for screen layout sample.

Responses

Participants touched Japanese symbols on the computer screen using the felt-tipped pointer provided.

Dependent Variables

The dependent variables in this experiment were rate of responding and accuracy on tests for Retention, Endurance, Stability, and Application. Accuracy was calculated as the ratio of correct responses to total responses. Rate was calculated as correct responses per minute. The computer recorded data on both rate and accuracy.

Independent Variables

The independent variable was training method. Each participant was trained on three match-to-sample tasks using two different training methods. In the Accuracy-Only condition the rate at which responses were made was controlled by a 1-sec delay between presentation of the sample stimulus and presentation of the comparison stimuli. In the Accuracy plus Rate condition the rate of responding was not controlled by the experimenter and rate criteria were set based on discussions with precision teachers currently working in the field and data collected from pilot participants.

Experimental Design

A reversal (ABA') design was used for Participants 1 and 2. For Participants 3 and 4 the order of the conditions was reversed (BAB'). These two different sequences were used in an attempt to obviate the impact of order on the results. Refer to Table 1

for stimulus sets and order of conditions for each participant.

Table 1

Participant Condition Sequence and Stimulus Set

	1st Condition	2nd Condition	3rd Condition
Participant 1	Accuracy + Rate set 2	Accuracy-Only set 1	Accuracy + Rate set 3
Participant 2	Accuracy + Rate set 1	Accuracy-Only set 2	Accuracy + Rate set 3
Participant 3	Accuracy-Only set 1	Accuracy + Rate set 2	Accuracy-Only set 3
Participant 4	Accuracy-Only set 2	Accuracy + Rate set 1	Accuracy-Only set 3

In order to control for number of practice problems and number of correct responses made in the Error Correction procedure an Accuracy-Only condition was yoked to the initial Accuracy plus Rate condition for each participant. This was accomplished by yoking the number of presentations given in drills in an Accuracy-Only condition to the number of presentations that participant required to meet the rate criterion in the previous Accuracy plus Rate condition. Similarly, the number of unprompted responses in Error Correction was yoked in the same manner. Specifically, in a yoked Accuracy-Only condition, the computer stopped giving Error Correction problems when the participant had as many unprompted correct responses as in the previous Accuracy plus Rate condition and also had reached the number of practice (drill) problems it had taken to meet the Accuracy plus Rate criterion. Because either component (Error Corrections and Practice Drills) could continue after the other component was discontinued, it was possible to hold constant across the yoked conditions both the number of unprompted correct responses in error correction and the number of correct practice problems in drills. Tests of Retention, Endurance, Stability,

and Application occurred at specified points in the training process for all four participants throughout the experiment.

Pretest

Each participant was given a pretest on the computer to determine which English letters would be trained to which Japanese symbols. While the participant was seated in a student office in the Department of Behavior Analysis the experimenter read the following instructions.

> Each time you come here you will be in a room for several minutes so if you need to go to the restroom or get a drink of water please do that before you go in. A touch-screen is attached to the computer monitor. You will be making all your responses by touching the items on the computer screen using the pen provided. Make sure that you touch the screen hard enough for the computer to register the touch. Please read carefully the instructions that appear on the screen and touch "start" only when you are ready to start. There are no right or wrong answers for this portion of the procedure. Please stay in the room until the computer screen tells you that you are done for the day.

The experimenter then accompanied the participant to the experimental room, gestured to the seat, and left the room with the following instructions showing on the computer.

> Please read the following instructions and when you are ready to begin, touch "start". Touch one of the Japanese symbols on the screen when you see an English letter in the middle of the screen. Continue doing this until the computer tells you that you are done for the day.

Each of the 21 English letters was presented 3 times, in quasi random order, for a total of 63 problems, and the participant touched one Japanese symbol each time. If a participant selected the pre-established correct comparison for an English letter sample during all three presentations of that sample, the letter and symbol association was changed. Some predetermined letter and symbol associations were selected correctly at least once by more than one participant so these letter and symbol

associations were changed as well. Please see Figures 3, 4, 5, and 6 for lists of the final letter and symbol associations trained for each participant.

Training

Training Condition A: Accuracy plus Rate

Accuracy plus Rate training began for Participants 1 and 2 immediately after the pretest. Each session comprised repeated 20-sec Practice Drills with interspersed Error Corrections. Drills and Error Corrections alternated until 15 Practice Drills were completed, at which time the participant was instructed by the computer to exit the room. After the experimenter reset the computer, the participant began another session and this continued for up to 1 hour.

The first session began with an Error Correction in which the 7 sample stimuli in the current stimulus set were presented one at a time. After the first drill, the Error Correction component in this condition included only the sample stimuli that were followed by incorrect matches in the previous Practice Drill.

Error Correction Component

Before the beginning of an Accuracy plus Rate condition and while the participant was seated in a student office in the Department of Behavior Analysis the experimenter read the following instructions.

> In each session you will be responding during program components such as "learning" and "practice." At the start of a new phase, instructions will appear on the screen. Please make sure to read the instructions for each phase. Touch the "begin" button on the instruction screen only when you are ready to start responding. A "touch screen" is attached to the computer monitor. You will be making all your responses by touching the items on the computer screen using

> the pen provided. Make sure that you touch the screen hard enough for the computer to register the touch. There are three phases in this experiment. Some of the sessions will be timed and you will be told when a session is timed. You are about to start the _____ phase (1^{st}, 2^{nd}, or 3^{rd}). In this phase there are two goals, to respond as quickly and also as accurately as you can. Therefore, it is important to learn the information and then build your speed up. When trying to build up your speed it might help to try and see the whole computer screen at once instead of looking at each symbol one-by-one. It might also help to hold the touch-screen-pen near the computer screen. Sitting up straight will also help increase your speed. Keep trying to beat your own score. Please stay in the room until the computer tells you to go find the experimenter. Throughout the experiment, I will occasionally check through the window to make sure the computer program is running correctly. The computer will first show you the correct answers.

When the participant went into the experimental room, the following instructions were showing on the computer screen.

> This is a chance to learn the ones you missed. First, touch the English letter and then touch the Japanese symbol that goes with it.

The initial screen had a yellow background and contained only a sample stimulus. After at least 1 sec elapsed and the participant touched the sample, the 7 comparisons were presented. The correct comparison was bolded and outlined in red to prompt the correct response. After the participant touched the bolded comparison and 0.1 sec elapsed the same sample appeared again. After at least 1 sec elapsed and the participant touched the sample the, 7 comparisons appeared in a different arrangement and no prompt was provided. If the participant selected the correct comparison a tone was presented and at the same time the word “Correct!” appeared on the screen and remained there for 1 sec. If the participant selected an incorrect comparison the computer screen went black for 1 sec.

Practice Drills

After 7 problems the initial Error Correction component ended and the computer program immediately switched to a Practice Drill with the appearance on the screen of the following instructions.

> Now you can practice what you have learned. Touch only the Japanese symbol that goes with the English letter you see.

The background screen color was white during Practice Drills. In Practice Drills a letter appeared in the middle of the screen and 7 Japanese symbols appeared in a circle around the letter. The letter and the Japanese symbols appeared simultaneously. English letters and Japanese symbols were presented in a quasi- random order. After the participant selected a comparison Japanese symbol and 0.1 sec elapsed, a different English letter appeared with the 7 Japanese symbols in a different arrangement. The very brief interval was programmed to cue the participants that the computer screen had changed.

Each Practice Drill during this condition lasted for 20 sec. At the end of each 20-sec Practice Drill a feedback screen appeared and remained visible for 3 sec. The feedback screen showed the number correct and the number incorrect in the previous 20-sec Practice Drill. If a participant did not make any errors during a particular Practice Drill they skipped the Error Correction component and went directly into another 20-sec drill.

Training Condition B: Accuracy-Only

Accuracy-Only training began immediately after the pretests for Participants 3 and 4 and occurred after Accuracy plus Rate training for Participants 1 and 2. Training

sessions comprised Practice Drills and Error Corrections as in Training Condition A.

Error Correction

The first session in condition B began with an initial Error Correction in which each of the 7 sample stimuli were presented and prompts were provided for the correct response, as described above in the Accuracy plus Rate condition.

While the participant was seated in a student office in the Department of Behavior Analysis, the experimenter read the following instructions.

> In each session you will be responding during program components such as "learning" and "practice". At the start of a new phase, instructions will appear on the screen. Please make sure to read the instructions for each phase. Touch the "begin" button on the instruction screen only when you are ready to start responding. A "touch screen" is attached to the computer monitor. You will be making all your responses by touching the items on the computer screen using the pen provided. Make sure that you touch the screen hard enough for the computer to register the touch. There are three phases in this experiment. Some of the sessions will be timed and you will be told when a session is timed. You are about to start the _____ phase (1^{st}, 2^{nd}, or 3^{rd}). In this phase there is one goal, to respond as accurately as you can. Please stay in the room until the computer tells you to go find the experimenter. Throughout the experiment, I will occasionally check through the window to make sure the computer program is running correctly. The computer will first show you the correct answers.

When the participant went into the experimental room the following instructions were showing on the computer screen.

> This is a chance to learn the ones you missed. First, touch the English letter and then touch the Japanese symbol that goes with it.

Design and format of Error Corrections in the Accuracy-Only condition were identical to Error Corrections in the Accuracy plus Rate condition. After the initial exposure to the Error Correction component all subsequent Error Corrections in the Accuracy-Only condition included only the sample stimuli that were followed by incorrect

matches in the previous Practice Drill. The only exception to this was at the end of Practice Drills in a yoked Accuracy-Only condition when the participant had not yet made an equal number of unprompted correct responses in Error Correction as she had made in the Error Correction component of the Accuracy plus Rate condition.

Practice Drills

Following the initial Error Correction the computer screen immediately began a Practice Drill with the appearance on the screen of the following instruction.

> Now you can practice what you have learned. Touch only the Japanese symbol that goes with the English letter you see.

In Practice Drills for the Accuracy-Only condition an English letter appeared in the middle of the screen. After 1 sec elapsed, the seven comparison Japanese symbols appeared. This 1-sec interval was programmed in an attempt to prevent participants from responding at a high rate in the Accuracy-Only condition. After the participant touched a comparison stimulus and 0.1 sec elapsed, the next sample stimulus appeared. Each drill in the Accuracy-Only condition consisted of seven responses. At the end of each 7-response Practice Drill a feedback screen appeared and remained visible for 3 sec. The feedback screen showed the number correct and the number incorrect in the previous 7-response Practice Drill. For the remainder of the session, 7-response Practice Drills alternated with Error Corrections. If a participant did not make any errors during a particular Practice Drill they skipped the Error Correction component and went directly into another 7-response drill. A session in the Accuracy-Only condition included ten, 7-response drills. Participants completed as many sessions as necessary not to exceed one hour from the time they arrived.

Testing

Tests of Endurance, Stability, Application, and Retention were conducted to compare performances following exposure to different training methods. Each participant was given two Endurance tests, two Stability tests, one Application test, and one Retention test on each of the three stimulus sets.

Endurance tests and Stability tests were conducted two times for each stimulus set in order to compare endurance and stability of performance within-subject and before and after extended practice in each condition. Endurance and Stability tests were initially administered immediately following acceptably accurate performance of a skill and administered again following a period of extended practice of the skill regardless of whether or not a rate criterion was in place for the condition. Application tests were given only one time during each condition and were administered after completion of training in each condition so participants could not have the opportunity to practice applying the skills they learned before taking an application test. Retention tests in the first two conditions were administered after training was underway in the next condition. Retention tests for the third condition were conducted at the end of the experiment.

When participants reached a point in the experiment where it was time for tests to be administered, they were sent home for the day and the scheduled tests were administered at the beginning of the participant's next session. In this way, tests could be administered without participants receiving differing amounts of practice immediately before tests were administered. Refer to Table 2 for training and testing sequence and training criteria for Participants 1 and 2.

Table 2

Order of Conditions, Learning Criteria, and Testing Sequences for Participants 1 and 2

Accuracy Criterion	Initial Tests	Rate/Practice Criterion	Final Tests
Accuracy + Rate (A) Condition 7 correct 0 incorrect over 2 consecutive 20-sec drills	3-min Endurance 1-min Stability	10 correct responses no more than 1 incorrect across 4 consecutive 20-sec Practice Drills	3-min Endurance 1-min Stability 2-min Application
Accuracy-Only (B) Condition 7 correct 0 incorrect over 2 consecutive 7-response drills	3-min Endurance 1-min Stability 20-sec Retention on stimulus set from previous condition	Error Correction problems until same # of unprompted, correct responses in (A) above and Same number of correct responses as needed to meet rate criterion in (A)	3-min Endurance 1-min Stability 2- min Application
Accuracy + Rate (A) Condition 7 correct responses 0 incorrect over 2 consecutive 20-sec drills	3-min Endurance 1-min Stability 20-sec Retention test on stimulus set from previous condition	10 correct responses no more than 1 incorrect across 4 consecutive 20-sec Practice Drills	3-min Endurance 1-min Stability 2-min Application 20-sec Retention on current stimulus set

Note: The yoked conditions are identified by red italics.

Refer to Table 3 for training and testing sequence and training criteria for Participants 3 and 4.

Table 3

Order of Conditions, Learning Criteria, and Testing Sequences for Participants 3 and 4

Accuracy Criterion	Initial Tests	Rate/Practice Criterion	Final Tests
Accuracy-Only (B) Condition 7 correct responses 0 incorrect over 2 consecutive 7-response drills	3-min Endurance 1-min Stability	628 correct responses during Practice Drills 26 reinforced responses during Error Correction	3-min Endurance 1-min Stability 2-min Application
Accuracy + Rate (A) Condition 7 correct 0 incorrect over 2 consecutive 20-sec drills	3-min Endurance 1-min Stability 20-sec retention test on stimulus set from previous condition	10 correct responses no more than 1 incorrect across 4 consecutive 20-sec Practice Drills	3-min Endurance 1-min Stability 2-min Application
Accuracy-Only (B) Condition 7 correct 0 incorrect over 2 consecutive 7-response drills	3-min Endurance 1-min Stability 20-sec Retention on stimulus set from previous condition	Error Correction problems until same # of unprompted, correct responses in (A) above and Same number of correct responses as needed to meet rate criterion in (A)	3-min Endurance 1-min Stability 2- min Application 20-sec Retention on current stimulus set

Note: The yoked conditions are identified by red italics.

Endurance and Stability Tests

Endurance tests were conducted to determine if participants could perform the trained tasks for a significantly longer time than during training. The participants matched the English letters to Japanese symbols for three minutes during which problems were presented one after another separated by a 0.1 ITI. Stability tests were conducted to determine if participants could maintain their newly learned skills in the presence of distractions such as people walking in to the test room, etc. These tests lasted for 1 min during which problems were presented one after another separated by a 0.1 ITI.

The Endurance and Stability tests were first administered after the participant had made at least 7 correct responses and 0 errors across two consecutive Practice Drills regardless of the condition they were currently in. While the participant was seated in the student office and before an Endurance or Stability test was conducted, the following instructions were read to the participant.

> Today you will be showing us what you have learned. Please respond as quickly and as accurately as you can. Only press the "begin" button when you are ready to start responding. Today you will receive a few short breaks. The computer will tell you when to come and get me.

When the participant went into the experimental room for an Endurance or a Stability test the following instructions were showing on the computer screen.

> Now we want you to show us what you have learned. Please answer as correctly and as fast as you can. Touch only the Japanese symbol that goes with the English letter.

After the initial tests participants were returned to training. When participants in the Accuracy plus Rate condition reached the rate aim of at least 10 correct responses with no more than 1 error across four consecutive 20-sec Practice Drills, the Endurance and Stability tests were administered again. When participants in the yoked Accuracy-Only condition made the same number of correct responses in the Practice Drills plus the same number of unprompted correct responses in Error Corrections as they had made in the previous Accuracy plus Rate condition the Endurance and Stability tests were administered again in that condition. Participants 3 and 4, whose first condition was Accuracy-Only, were given the final Endurance and Stability tests for this first Accuracy-Only condition after they had made 628 correct responses in Practice Drills and 28 unprompted correct responses in Error Corrections. These two numbers were selected because they were required by a pilot participant to reach a rate of 12 correct

responses with no more than 1 error across four consecutive 20-sec drills. These numbers were considered to be more than what would be required for a typical participant to reach the rate of 10 correct responses and no more than 1 error across four consecutive Practice Drills. The instructions and procedures for the final Endurance and Stability tests were the same as those for the initial Endurance and Stability tests.

Application Test

An Application test was conducted after each training condition to determine if participants could transfer what they had learned to a new task. Participants saw a row of 4 previously learned Japanese symbols at the top of the computer screen. Below the symbols were 7 English letters. The participants touched the English letters in the order in which the Japanese symbols were arranged (working from left to right). Refer to Figure 2 for an application test screen layout sample. Application tests lasted two minutes and were administered immediately following the final Endurance and Stability tests in a condition. While the participant was seated in the student office and before an application test was administered, the experimenter read the following instructions.

> In this session the computer screen will look different from how it has looked in the past. This is what the screen will look like. [show participant screen print out (see Figure 2)]. In this task you will only be touching the English letters on the bottom half of the computer screen. Four Japanese symbols will appear in a line at the top of the screen. Touch the English letter that goes with the Japanese symbol starting with the Japanese symbol on the left (demonstrate for participant). Each time you touch an English letter that letter will turn gray. Once you have touched an English letter and it has turned gray you will not be able to select that letter again. Make sure that you touch the letters hard enough to register. It is easy to think you have adequately touched a letter and then continue touching the other letters only to find out that the computer did not register your first letter touch. This will make all of your answers on that screen

> incorrect so make sure that your letter touch registers with the computer. Please respond as quickly and as accurately as you can. Please leave the room when the computer screen tells you to go find the experimenter.

When the participant entered the experimental room the following instructions were showing on the computer screen.

> Now it is time to show us what you have learned. Please answer as correctly and as fast as you can. You will see 4 Japanese symbols at the top of the screen. You do not need to touch them. You will also see 7 English letters at the bottom of the screen. Touch the English letters in the order of the Japanese symbols.

Retention Test

The purpose of the Retention test was to determine if participants retained the information they had learned in the previous condition following a period of time without practice and (for the first two stimulus sets learned) following the learning of a new stimulus set. These tests lasted 20-sec and presented problems separated by 0.1 sec.

The Retention test for the first stimulus set was given immediately after the initial Endurance and Stability tests for the subsequent condition. The Retention test for the second stimulus set was given immediately after the initial Endurance and Stability tests for the subsequent condition. The Retention test for the third stimulus set was given at the end of the experiment immediately after the Application test for the current condition. While the participant was seated in the student office and before a Retention test was administered, the experimenter read the following instructions.

> Now you are going to go back to a short Practice Drill on the set of letters and symbols you learned in the previous phase. Please respond as quickly and as accurately as you can. Please touch the “begin” button only when you are ready to start. Please stay in the room until the computer screen tells you to come and find me. This drill will be very short so make sure you are ready to start when you touch the “begin” button.

Then the participant was taken to the experimental room, where the following instructions were showing on the computer screen.

> Now we want you to show us what you have learned. Please answer as correctly and as fast as you can. Touch only the Japanese symbol that goes with the English letter.

After a participant took the last Retention test, she was escorted to an office in the Department of Behavior Analysis where she was asked to read the post-experiment questions and write her answers on the sheet provided (see Appendix for list of questions). If the participant did not understand a question, the experimenter provided further explanation. After writing the answers to these questions the participant was paid for the current session as well as paid all one-dollar session bonuses accrued and $25 study completion bonus. At this time the participant was debriefed and asked if they had any questions about the experiment.

CHAPTER 3

RESULTS

Participants have been assigned numbers that reflect the order in which their results will be presented (not the order in which they were run). Training data are presented first, followed by data on fluency tests and responses of participants to post-experimental questions.

Training

As seen in Figures 7 and 8, Participants 1 and 2 were trained first in the Accuracy plus Rate condition (top graphs). Participant 1 met the accuracy criterion (with stimulus set 2) in the 17th 20-sec Practice Drill and Participant 2 met the accuracy criterion (with stimulus set 1) in the 14th 20-sec Practice Drill. In subsequent rate building drills, Participant 1 met the rate criterion by responding at rates of at least 10 correct responses and no more than 1 incorrect response in 20 sec across 4 consecutive Practice Drills. This required 252 correct responses in Practice Drills and 14 unprompted correct responses in Error Correction. Participant 2 met the rate criterion by responding at rates of at least 10 correct responses and no more than 1 incorrect response in 20-sec across 4 consecutive Practice Drills. This required 236 correct responses in Practice Drills and 22 unprompted correct responses in Error Correction. Participant 1 made a total of 1 error in this condition, whereas Participant 2 made a total of 18 errors.

These subjects then went on to the yoked Accuracy-Only condition (with stimulus sets reversed), in which the total number of problems they correctly answered in

Practice Drills and the total number of unprompted correct responses they made in Error Correction were both equal to the totals they had in the previous Accuracy plus Rate condition. Both subjects met the accuracy criterion after the second Practice Drill. Participant 1 made 2 errors in Practice Drills whereas Participant 2 made 0 errors. In this condition, the time taken by the subject to complete the various 7-problem delayed comparison drills could vary. The considerable variation in response rates in the middle graphs of Figures 7 and 8 are due to the variation in times (shown by record floors) that the participants took to complete the 7 problems in each drill.

When these subjects began the last Accuracy plus Rate condition (both with stimulus set 3), Participant 1 met the accuracy criterion in 9 Practice Drills and Participant 2 in 7 Practice Drills. Participant 1 then went on to meet the rate criterion after 24 Practice Drills with a total of 175 correct and 4 incorrect responses. Participant 2 met the rate criterion after 52 Practice Drills with a total of 449 correct and 14 incorrect responses in Practice Drills.

As seen in Figures 9 and 10, Participants 3 and 4 were trained first in the Accuracy-Only condition (top graphs). Participant 3 met the accuracy criterion (with stimulus set 1) in the 6^{th} 7-response Practice Drill and Participant 4 met the accuracy criterion (with stimulus set 2) in the 5^{th} 7-response Practice Drill. These participants continued responding in Practice Drills until they had made 628 correct responses in drills and 26 unprompted correct responses in Error Corrections. Participant 3 made a total of 15 errors in this condition, whereas Participant 4 made a total of 3 errors.

Then these subjects began the Accuracy plus Rate condition (with stimulus sets reversed). Both Participant 3 and Participant 4 met the accuracy criterion in 7 Practice

Drills. Participant 3 then went on to meet the rate criterion after 64 Practice Drills with a total of 530 correct and 11 incorrect responses. Participant 4 met the rate criterion after 18 Practice Drills with a total of 147 correct and 2 incorrect responses in Practice Drills.

These subjects then went on to the yoked Accuracy-Only condition (both with stimulus set 3), in which the total number of problems they correctly answered in Practice Drills and the total number of unprompted correct responses they made in Error Correction were both equal to the totals they had in the previous Accuracy plus Rate condition. Participants 3 and 4 both met the accuracy criterion after the 3rd drill. Participant 3 made 12 errors in Practice Drills whereas Participant 4 made 91 errors. In this condition, the time taken by the subject to complete the various 7-problem delayed comparison drills could vary. The considerable variation in response rates in the top and bottom graphs of Figures 9 and 10 are due to the variation in times (shown by record floors) that the participants took to complete the 7 problems in each drill.

In this experiment, the yoked training conditions were implemented within-subjects in order to compare the effects of higher vs lower performance rates on fluency (defined as Endurance, Stability, Retention and Application). This comparison requires that the training conditions actually produce different performance rates. In the Accuracy-Only condition, the intervals between presentations were designed to put a low ceiling on response rates. If time between intervals is subtracted from total time a drill took, the remaining time is taken up by the sum of the latencies and durations. Because response durations were the same on all problems (i.e., instantaneous), average latencies of responses in each condition can be used as the reciprocal of rate.

Figure 11 shows the average latencies to touch the comparison stimulus during

Practice Drills in the first Accuracy plus Rate condition and in the Yoked Accuracy-Only condition for all participants. The first data point for each participant shows the average latency for all problems in that condition. The second data point for each participant shows the average latency for the last 40 problems in that condition. These latency data for Practice Drills allow us to compare the effectiveness of the programmed procedure in making participants respond quickly in the Accuracy plus Rate conditions and respond more slowly in the Accuracy-Only conditions.

As seen in Figure 11, average latencies for all four participants in all but one condition were shorter for the last 40 problems than they were on average throughout each condition, indicating that rates increased with practice during these conditions. The exception was Subject 4's yoked Accuracy-Only data, which showed the same latencies for the last 40 problems as for all problems in the condition.

In comparing latencies between training conditions, Participant 3's average latencies were nearly identical overall (first data point for each condition) and her average latencies on the last 40 problems (second data points) differed only slightly, with the Accuracy-Only condition showing slightly shorter latencies. Participant 2 showed no difference in response latencies in the Accuracy plus Rate and the yoked Accuracy-Only conditions. Based on these data we cannot say that the procedure was effective in generating different response rates in the yoked conditions for these two subjects.

The data for the other two participants show marked differences in response latencies in the two training conditions. Participant 1 showed significantly shorter average latencies during the Accuracy plus Rate condition, both overall and for the last

40 problems, than she showed in the Accuracy-Only condition. We can say with some degree of certainty that the Accuracy-Only and Accuracy plus Rate conditions produced differential response rates for Participant 1.

Participant 4's latency results appear similar to those of Participant 1. However, Participant 4 had not learned to respond correctly to all symbols in the yoked Accuracy-Only when the yoking requirement precluded her access to Error Correction. Thus, her longer latencies in subsequent Practice Drills were likely the result of not having achieved accuracy rather than the effect of slowing down her responding. Support is added to this statement by the dotted line on Figure 11 which shows that Participant 4's average latencies during Practice Drills in the first, un-yoked Accuracy-Only condition are only slightly longer than her average latencies in the Accuracy plus Rate condition.

Testing

The following is a description of the results of Endurance, Stability, Application, and Retention tests administered to each participant following practice in the three phases of the experiment.

Figures 12-15 show, for one participant each, the count per minute of correct and incorrect responses for all tests in all conditions. The data from yoked conditions are shown in red. The data on Endurance and Stability tests include two data points, the first for the test administered after the accuracy criterion was met and the second for the test given at the end of the condition. Application tests were given only once, at the end of each condition. Retention tests also were given only once.

Figure 12 depicts corrects and errors as count per minute for all tests

administered to Participant 1, the only one who demonstrated significantly different rates of highly accurate performance during training. Participant 1 consistently responded in the final tests of the Accuracy plus Rate condition at higher numbers of correct per minute than in the yoked Accuracy-Only condition. The numerical data may be seen in Table 4.

Table 4

Count per Minute of Corrects and Errors in Tests

Parti.	Cond.	Endurance		Stability		Application		Retention	
		correct	error	correct	error	correct	error	correct	error
1	AR	14.67	0.33	14	4				
		26	0.33	27	1	23.5	0	24	3
	AO	17	0.67	12	0				
		21.67	0	23	0	22	0	9	0
	AR	19	1	9	1				
		23.33	0.33	21	1	18	0	24	3
2	AR	18.33	2.33	21	0				
		30	0	29	0	38.5	0	27	0
	AO	22.33	1	26	2				
		28.67	0.33	26	0	43	1	30	0
	AR	10.33	11.7	16	8				
		31	0.33	31	0	36	0	49	1
3	AO	14.67	1.33	11	1				
		22.67	0.33	20	0	35	1	27	0
	AR	14	2.67	11	2				
		29	0.67	24	2	48	0	12	0
	AO	11.33	4	7	3				
		27	0	25	0	48.5	0	33	0
4	AO	19	0	19	0				
		33.67	1	32	1	41.5	0.5	30	0
	AR	23.33	0.33	29	0				
		32.67	0	31	1	52	0	21	0
	AO	10.67	3.67	9	6				
		15.33	11.7	11	9	19	15	18	12

Figure 12 also shows that for the two tests that were administered twice per condition (Endurance and Stability) the greatest increase in performance from initial test in a condition to final test in a condition occurred during the first (yoked) Accuracy plus Rate condition. Another interesting point in Figure 13 is the decreasing trend in count-per-minute for Application tests across conditions. A possible reason why this participant performed best on tests in the first condition is that the amount of money she earned for participating was not directly linked to her performance. Another possible explanation is that interference of previous stimulus sets affected her performance on stimulus sets in the second and third conditions.

Figure 13 shows corrects and errors as count per minute for all tests administered to Participant 2. This participant performed slightly better on Endurance and Stability tests following the Accuracy plus Rate condition and slightly better on the Application and Retention tests that followed the Accuracy-Only condition. The numerical data may be seen in Table 4.

Figure 13 also shows that for the two tests that were administered twice per condition (Endurance and Stability) the greatest increase in performance from initial test in a condition to final test in a condition occurred during the last condition which was the not-yoked Accuracy plus Rate condition. There is also and increasing trend across conditions for Application tests and Retention tests. A possible explanation for these data is that Participant 2 was continuing to learn and practice the basic task of the experiment as she progressed through the conditions. This participant's first condition (Accuracy plus Rate) was one of the yoked conditions, therefore she did not have the advantage of practice with the task that Participants 3 and 4 had.

Figure 14 depicts corrects and errors as count per minute for all tests administered to Participant 3. Her test results show very small differences between conditions and are generally slightly better following Accuracy-Only training. Participant 3's results are slightly better on the Stability and Application tests following Accuracy-Only training and are significantly better on the Retention test following Accuracy-Only training. For this participant, the yoked Accuracy-Only condition was the last condition in the sequence so her Retention test for this condition was given immediately after training ended. The numerical data may be seen in Table 4.

Figure 14 also depicts that for the two tests that were administered twice per condition (Endurance and Stability) the greatest increase in performance from initial test in a condition to final test in a condition occurred during the yoked Accuracy-Only condition. Participant 3 made the highest number of correct responses on the final Endurance test during the Accuracy plus Rate condition and the highest number of correct responses on the Stability, Application and Retention tests during the last condition which was yoked Accuracy-Only. As with Participant 2, it is possible that practice effects account for the high scores seen in Participant 3's last condition.

Figure 15 shows corrects and errors as count per minute for all tests administered to Participant 4. This participant's average response latencies during Practice Drills were shorter in the Accuracy plus Rate condition than in the Accuracy-Only condition and her test scores are significantly better for tests that followed the Accuracy plus Rate condition. After observing the number of errors made in the Accuracy-Only Practice Drills as well as the number of errors made in the tests that followed this condition it appears likely that Participant 4 did not adequately learn the

stimulus set in the yoked Accuracy-Only condition. The numerical data may be seen in Table 4.

Figure 15 also shows that for the two tests that were administered twice per condition (Endurance and Stability) the greatest increase in performance from initial test in a condition to final test in a condition occurred during the first Accuracy-Only condition. Also, Participant 4 made the highest number of correct responses on Endurance, Stability, and Retention tests during this first Accuracy-Only condition. Participant 4 made the highest number of correct responses on the Application test in the Accuracy plus Rate condition. Participant 4 received a significantly larger number of Practice Drills in her first Accuracy-Only condition when compared to the other two conditions. This large amount of practice could account for her better performance on tests in this condition. Also, because this participant did not adequately learn the stimulus set used in her yoked Accuracy-Only condition, any practice effects across conditions or differences between yoked conditions cannot be seen.

Post-Experiment Questions

Table 5 summarizes the responses of all participants to the post-experiment questionnaire.

Table 5

Post-Experiment Participant Report

Particip.	Sequence	Style Enjoyed Most	Style Learned Most	Most Difficult Set	Easiest Set
1	AR set 2 AO set 1 AR set 3	Accuracy-Only	Accuracy-Only	Set 2	Set 1
2	AR set 1 AO set 2 AR set 3	Accuracy + Rate	Accuracy + Rate	Set 1	Set 2
3	AO set 1 AR set 2 AO set 3	Accuracy + Rate	Accuracy-Only	Set 3	Set 2
4	AO set 2 AR set 1 AO set 3	Accuracy + Rate	Accuracy + Rate	Set 3	Set 1

Three out of four participants said that they enjoyed learning in the Accuracy plus Rate condition more than in the Accuracy-Only condition. Participants were equally divided as to the condition in which they learned the most.

As for the relative difficulty of stimulus sets, both participants who started and ended in the Accuracy-Only condition considered the stimulus set they learned in the yoked Accuracy-Only condition to be the most difficult. In both cases, this was Stimulus Set 3. The two participants who started and ended in an Accuracy plus Rate condition said that the most difficult stimulus set was the one they learned in the first Accuracy plus Rate condition. These were Sets 1 and 2. All four participants said that the easiest stimulus set was the one they learned in their second condition, regardless of whether that condition was Accuracy-Only or Accuracy plus Rate, or whether the stimulus set was Set 1 or Set 2.

CHAPTER 4

DISCUSSION

This experiment used a within-subject design to analyze the effects of two different training conditions while yoking number of correct responses in Practice Drills and number of unprompted correct responses in Error Correction across these conditions. The success of the computer program at reducing participants' response rates in the Accuracy-Only training condition can be clearly observed only in Participant 1's data. Her subsequent test data strongly support the notion that rate of correct practice positively influences Endurance, Stability, Retention and Application of the learned performance. Since Participant 1 was the only participant who showed shorter latencies in Accuracy-plus Rate drills and also performed better on tests following the Accuracy plus Rate condition, this participant's data are the only data that can be said unequivocally to demonstrate the effect of higher rates on fluency. Future research should examine different experimental designs and stimulus presentation techniques that can ensure differential rates or latencies in performances produced by different training methods.

Regardless of the lack of success in producing different response rates by different training conditions, overall test data for the yoked conditions slightly favors Accuracy plus Rate training. All four participants performed best in the Endurance test following the yoked Accuracy plus Rate condition when compared to the yoked Accuracy-Only condition. Participants 1 and 4 performed significantly better on the Endurance test following the yoked Accuracy plus Rate condition and Participants 2 and 3 performed slightly better on the Endurance test following the yoked Accuracy plus

Rate condition. Participants 1 and 2 responded in the yoked Accuracy plus Rate condition first, therefore no practice effect could account for their better performance in this condition. Since better performance was observed in all participants' Endurance tests following the yoked Accuracy plus Rate condition it is possible that the differential reinforcement for high rates of responding inherent in accuracy plus rate training increased the likelihood that participants would be able to respond at high rates over a longer period of time.

Participants 1, 2, and 4 performed better in the Stability test that followed the yoked Accuracy plus Rate condition as compared to performance in the yoked Accuracy-Only condition. Participants 1 and 2 responded in the yoked Accuracy plus Rate condition first, therefore no practice effect could account for their better performance in this condition. Participant 1's Stability test score was significantly better following the Accuracy plus Rate condition and Stability test performances of Participants 2 and 4 were slightly better following this condition. On the other hand, Participant 3's Stability test score was slightly better following the yoked Accuracy-Only condition. The Stability tests conducted in this experiment were 3 times as long as the 20-sec Practice Drills participants experienced during Accuracy plus Rate training. Therefore, these Stability tests were confounded with an element of endurance. If Stability tests had only lasted for 20-sec, these test results might have shown a larger number of correct responses. Future researchers should conduct stability tests that are equal in duration to practice drills.

Participants 1 and 4 performed better in the Application test following the yoked Accuracy plus Rate condition when compared to the yoked Accuracy-Only condition.

Participant 1's Application test score was slightly better following the yoked Accuracy plus rate condition and Participant 4's Application test score was significantly better following this condition. Participant 1 was run in the yoked Accuracy plus Rate condition first, therefore no practice effect could account for her better performance in this condition. Participant 2's Application test score was significantly better in the yoked Accuracy-Only condition when compared with both the yoked and unyoked Accuracy plus Rate conditions. Participant 3's Application test score was slightly better in the yoked Accuracy-Only condition when compared to the yoked Accuracy plus rate condition.

Participants 1 and 4 performed better in the Retention test following the yoked Accuracy plus Rate condition as compared to the yoked Accuracy-Only condition. Retention test scores for Participants 1 and 4 were significantly better following the yoked Accuracy plus Rate condition. Participant 2's Retention test was significantly better following the yoked Accuracy-Only condition when compared to the yoked Accuracy plus Rate condition but her best Retention test score followed the unyoked Accuracy plus Rate condition. Participant 3's Retention test score was significantly better following the yoked Accuracy-Only condition when compared to the yoked Accuracy plus Rate condition. Based on these data, task endurance appears to be the performance attribute that is the most sensitive to rate building procedures. The average latency data coupled with the test data shows that average latency to respond is a good predictor of future test performance.

Participant 4's average latency data appeared to show that the experimental arrangement was successful at reducing her response rate in the yoked Accuracy-Only

condition. Further examination of the errors she made in Practice Drills showed that the longer latencies in this condition were most likely due to the fact that she did not learn to match the stimuli in that condition before she had used all of her yoked Error Correction opportunities and therefore had to continue responding without being shown the correct responses. The yoked number of Error Correction opportunities for Participant 4 was 9, which includes the 7 required responses at the beginning of each condition. In order to avoid this problem, future researchers should consider setting a minimum number (20) of Error Correction opportunities for all participants.

Practice effects can be seen in test scores for Participants 2 and 3. When examining Stability and Application test scores, an increasing trend of correct responses can be seen as Participant 3 progressed from the first experimental condition through the third experimental condition. This trend suggests that instructional technique (Accuracy-Only or Accuracy plus Rate) was not responsible for the difference in test scores. It appears that the stronger variable affecting performance was practice across the different tests–a “learning to learn” effect. This trend is also apparent in Participant 2’s scores for Application tests and Retention tests. However, if test conditions for the final Retention test had been identical to test conditions for the first two Retention tests this trend might not have been present. Future research should keep Retention test conditions identical and increase the amount of time that passes before Retention tests are given. Another factor that may have contributed to the results is the rate aim that was set in the Accuracy-plus-Rate condition. In order to terminate Practice Drills in the Accuracy Plus Rate condition at the correct point, the rate aim in this experiment was at least 10 correct responses with no more than 1 incorrect response across four

consecutive 20-sec Practice Drills (30 corrects per minute). This aim might not have been an adequate rate for some participants. Many of the response rates in tests were lower than response rates during Practice Drills. Future research could run pre-experiment drills with different stimuli in order to establish individualized rate aims for participants.

On the other hand, running participants until they reached higher rates would have increased the total number of trials required in each condition. If participants respond correctly to a massive number of practice trials in both conditions, such extensive practice could obscure any effects of rate building on fluency. This kind of practice effect could have contributed to Participant 3's test scores. Participant 3 required the largest number of correct responses in Practice Drills for the two conditions that were yoked (530) and she scored better on the Stability, Retention, and Application tests that followed the yoked Accuracy-Only condition.

It is possible that the greatest benefit to training high rate performances is the shortening of learning time in applied settings. Future research could be directed toward systematically determining the most efficient rates for various types of learning tasks, or to determine whether individual learners have characteristic rates that predict fluency in a variety of tasks. Ultimately the rate to strive for would appear to be that which produces substantial benefit to the learner while requiring the fewest number of Practice Drills.

In summary, due to the suspected influence of uncontrolled variables, the strongest statement that can be made regarding the results of this experiment is that one of four learners benefited slightly from training in the Accuracy plus Rate condition.

This statement coupled with three out of four participants stating that they preferred the Accuracy plus Rate training method and with the fact that an Accuracy plus Rate training method is the fastest technique to complete a large amount of practice adds strength to the value of Accuracy plus Rate training over Accuracy-Only training in applied settings.

Figure 1. Computer screen layout for Practice Drills.

Figure 2. Computer screen layout for application test.

1st Condition
Accuracy Plus Rate
Stimulus Set #2

D G I L J R V

2nd Condition
Accuracy-Only
Stimulus Set #1

A C N Z S T P

3rd Condition
Accuracy Plus Rate
Stimulus Set #3

B F K M O Q W

Figure 3. Participant 1's English letter and Japanese symbol stimulus sets.

1st Condition
Accuracy Plus Rate
Stimulus Set #1

Z C N P S T A

2nd Condition
Accuracy-Only
Stimulus Set #2

D G I J L R V

3rd Condition
Accuracy Plus Rate
Stimulus Set #3

B F K M O Q W

Figure 4. Participant 2's English letter and Japanese symbol stimulus sets.

1st Condition
Accuracy-Only
Stimulus Set #1

A C N P S T Z

2nd Condition
Accuracy Plus Rate
Stimulus Set #2

D G I J L R V

3rd Condition
Accuracy-Only
Stimulus Set #3

B F K M O Q W

Figure 5. Participant 3's English letter and Japanese symbol stimulus sets.

1st Condition
Accuracy-Only
Stimulus Set #2

D G I L J R V

2nd Condition
Accuracy Plus Rate
Stimulus Set #1

A C N Z S T P

3rd Condition
Accuracy-Only
Stimulus Set #3

B F K M O Q W

Figure 6. Participant 4's English letter and Japanese symbol stimulus sets.

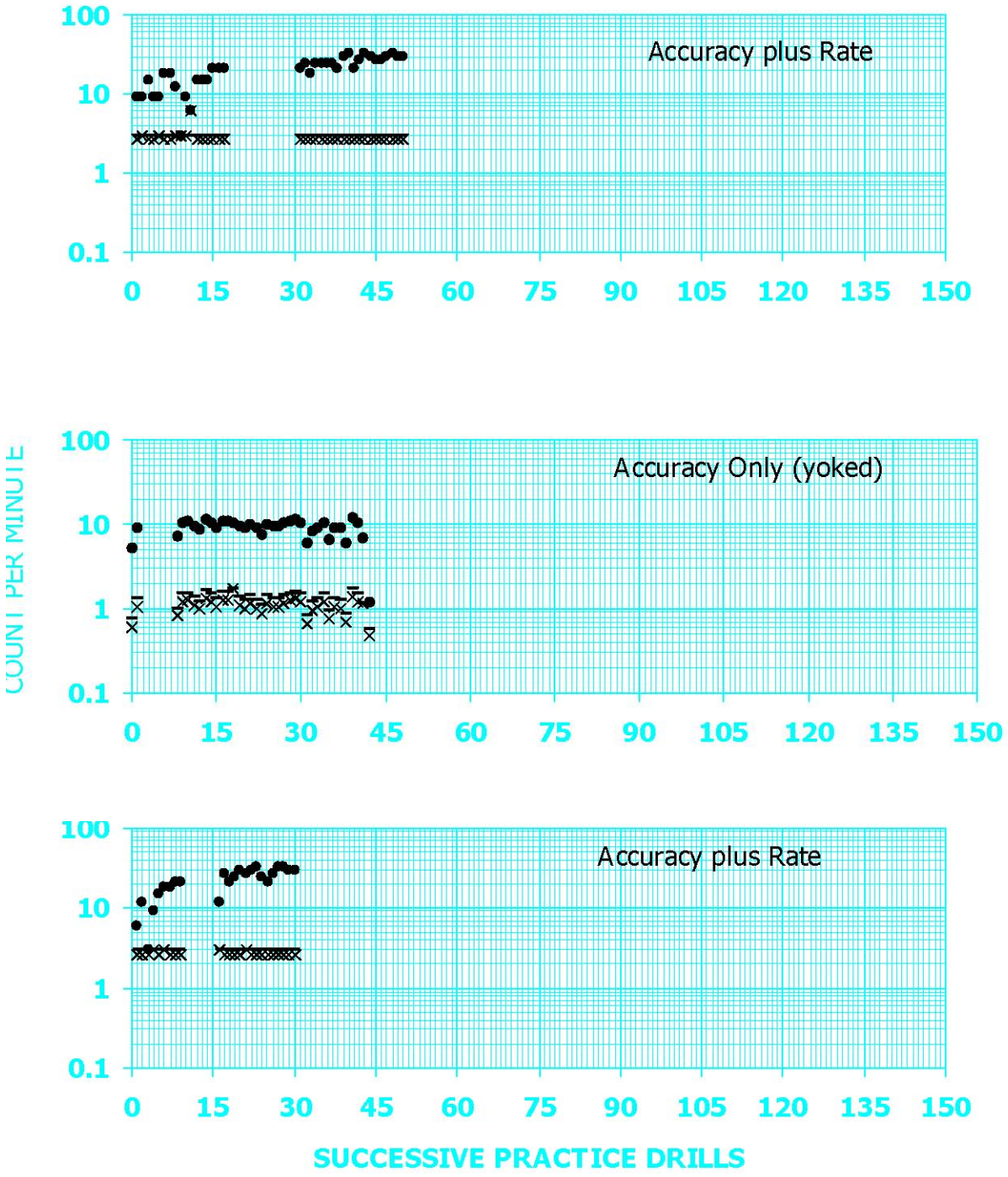

Figure 7. Top graph - Participant 1's count per minute of corrects and incorrects during Practice Drills in the first accuracy plus rate condition. Middle graph - Participant 1's count per minute of corrects and incorrects during Practice Drills in the yoked Accuracy-Only condition. Bottom graph – Participant 1's count per minute of corrects and incorrects during Practice Drills in the second accuracy plus rate condition.

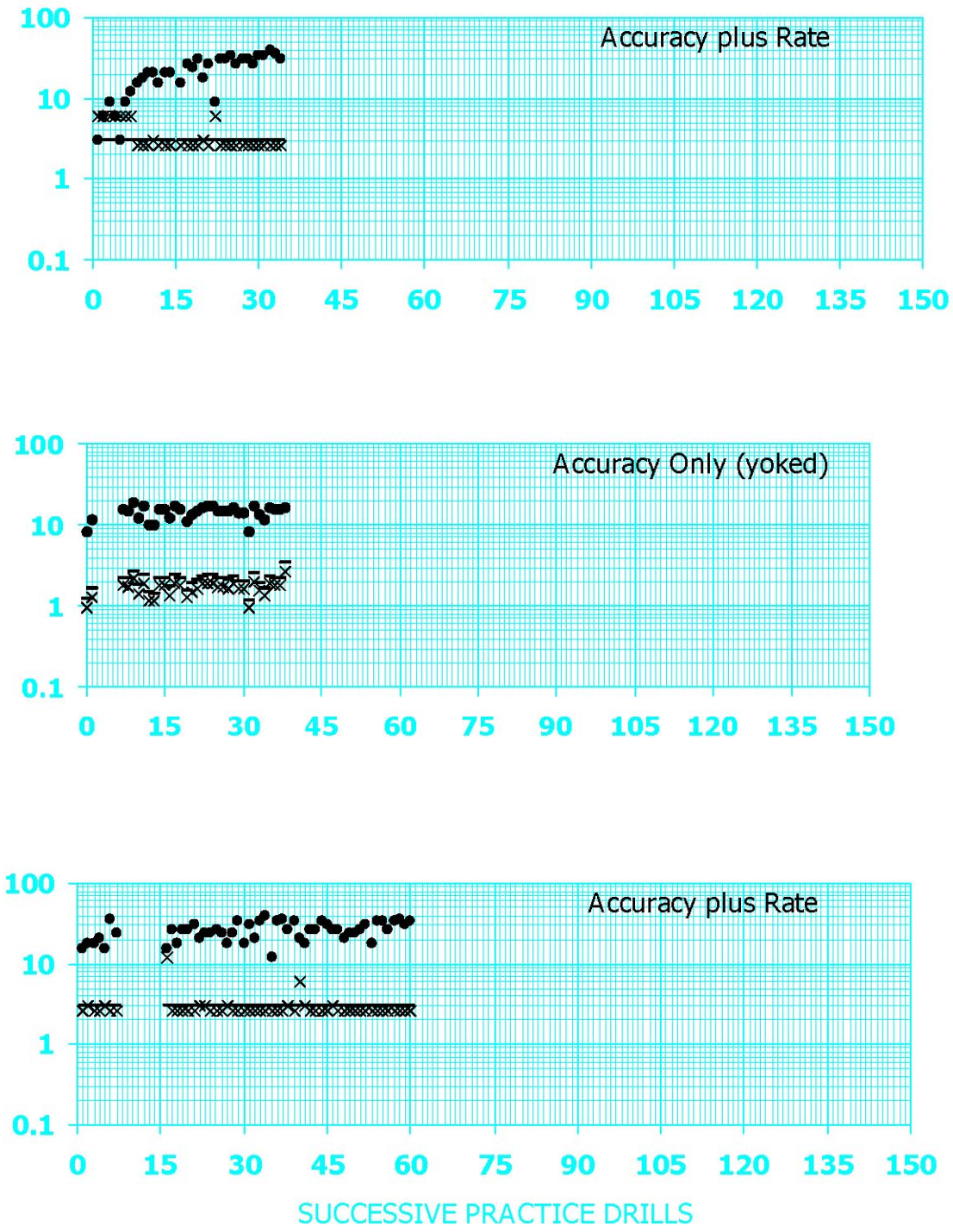

Figure 8. Top graph - Participant 2's count per minute of corrects and incorrects during Practice Drills in the first accuracy plus rate condition. Middle graph - Participant 2's count per minute of corrects and incorrects during Practice Drills in the yoked Accuracy-Only condition. Bottom graph – Participant 2's count per minute of corrects and incorrects during Practice Drills in the second accuracy plus rate condition.

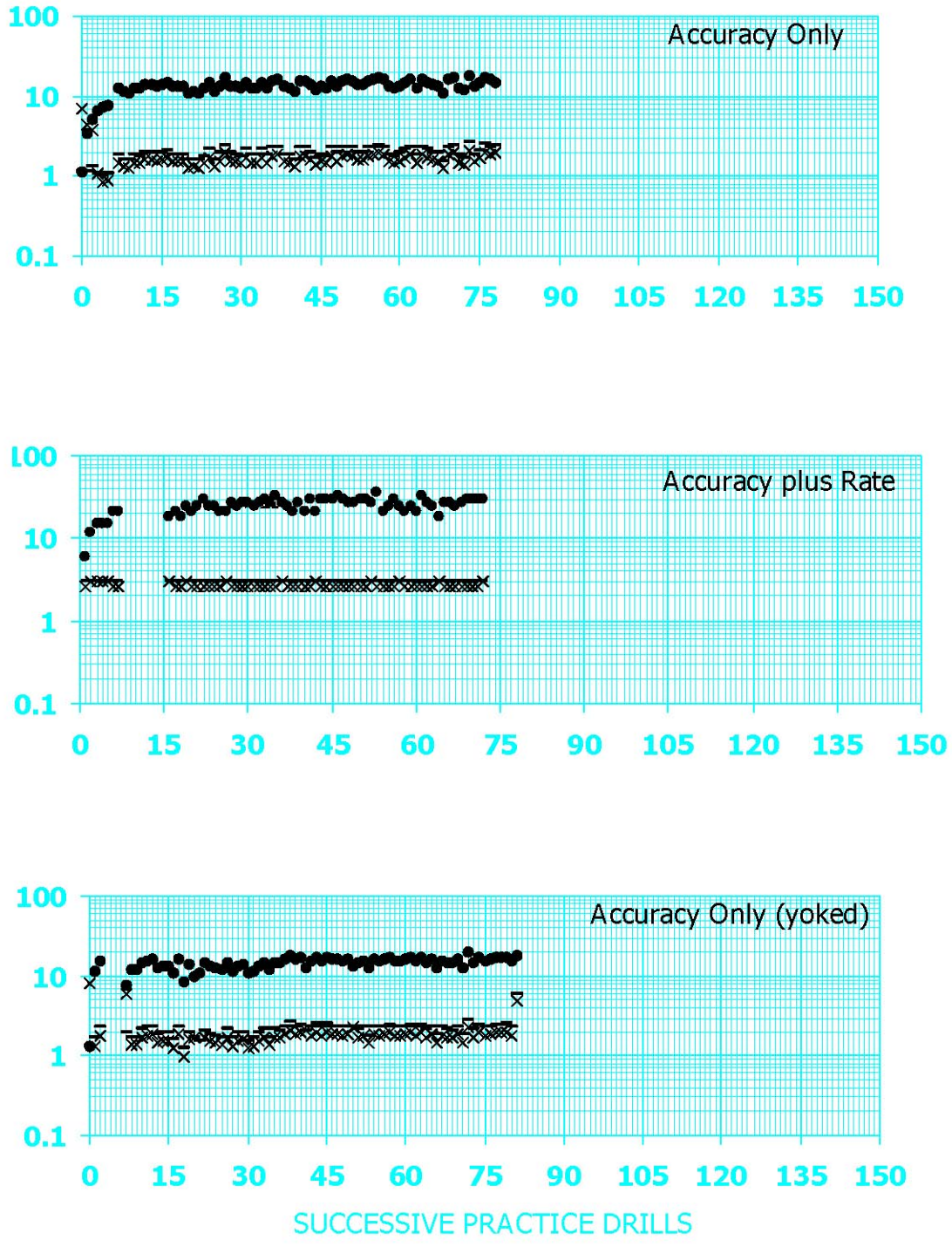

Figure 9. Top graph - Participant 3's count per minute of corrects and incorrects during Practice Drills in the first Accuracy-Only condition. Middle graph - Participant 3's count per minute of corrects and incorrects during Practice Drills in the accuracy plus rate condition. Bottom graph – Participant 3's count per minute of corrects and incorrects during Practice Drills in the yoked Accuracy-Only condition.

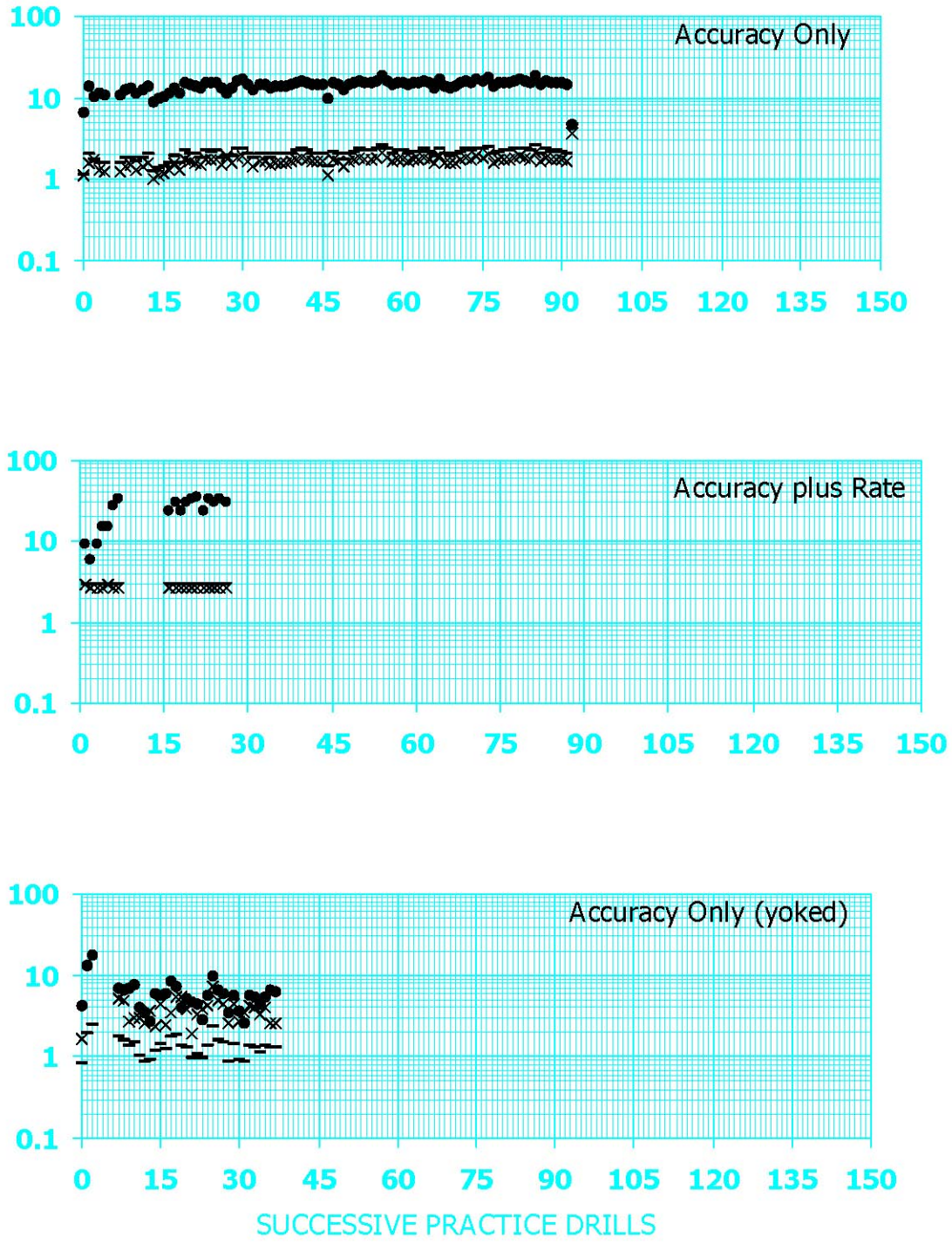

Figure 10. Top graph - Participant 4's count per minute of corrects and incorrects during Practice Drills in the first Accuracy-Only condition. Middle graph - Participant 4's count per minute of corrects and incorrects during Practice Drills in the accuracy plus rate condition. Bottom graph – Participant 4's count per minute of corrects and incorrects during Practice Drills in the yoked Accuracy-Only condition.

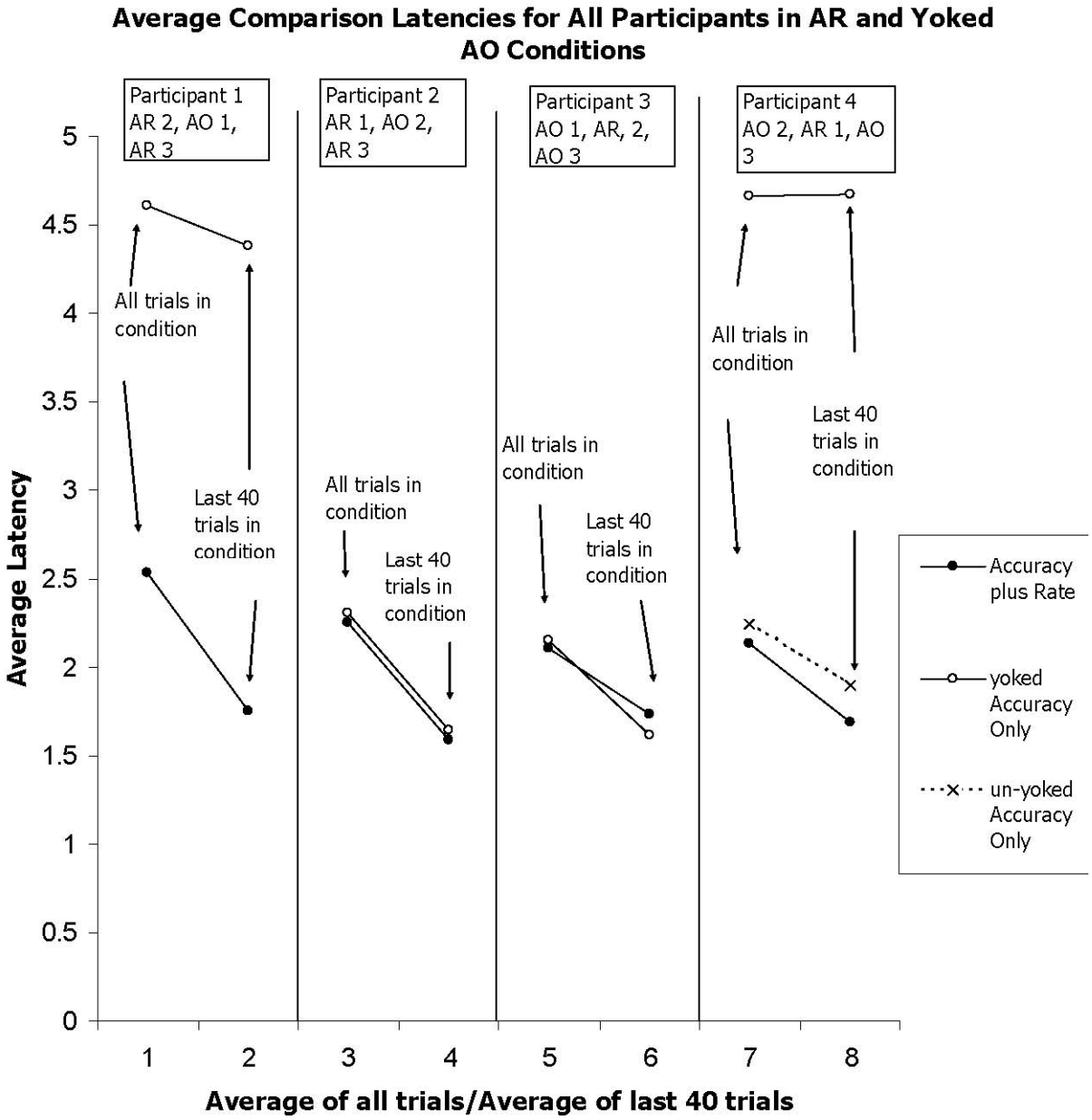

Figure 11. Average comparison latency during Practice Drills for all participants during yoked accuracy plus rate and Accuracy-Only conditions. Average comparison latency for each participant and in each of the two conditions is displayed for the total trials in each condition and for the last 40 trials in each condition.

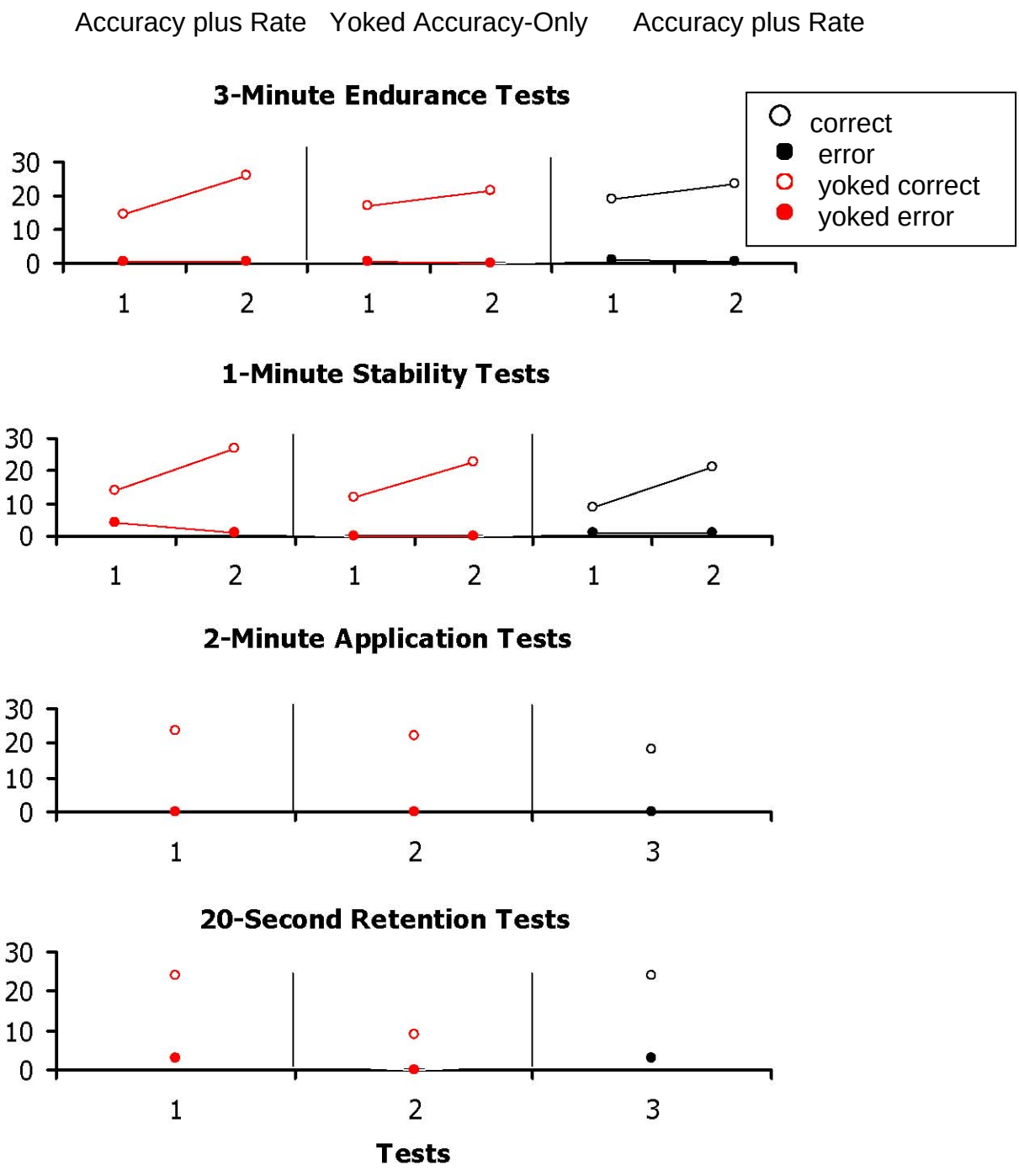

Figure 12. Participant 1's count per minute of corrects and incorrects during Endurance, Stability, Application, and Retention tests for all three conditions.

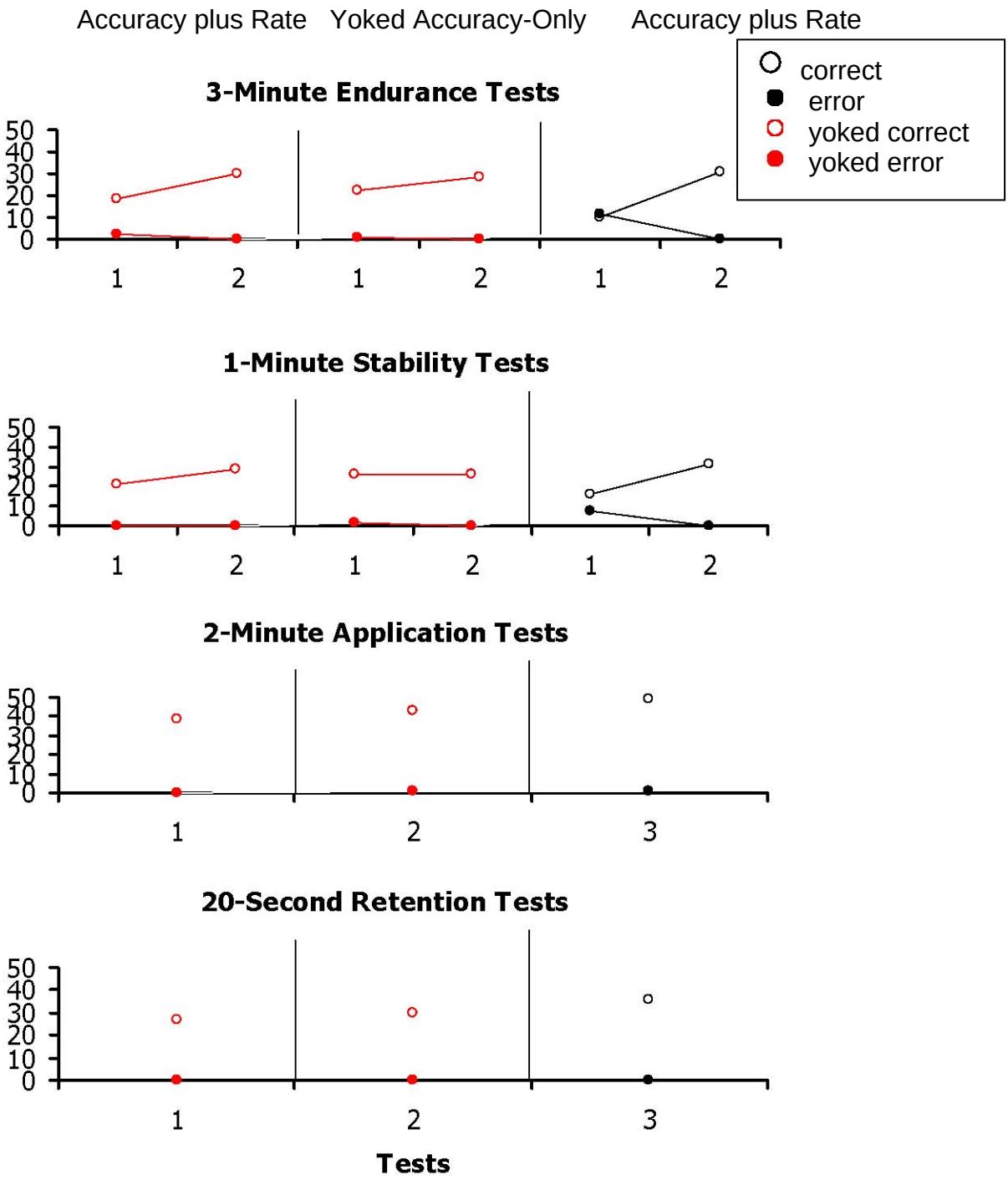

Figure 13. Participant 2's count per minute of corrects and incorrects during Endurance, Stability, Application, and Retention tests for all three conditions.

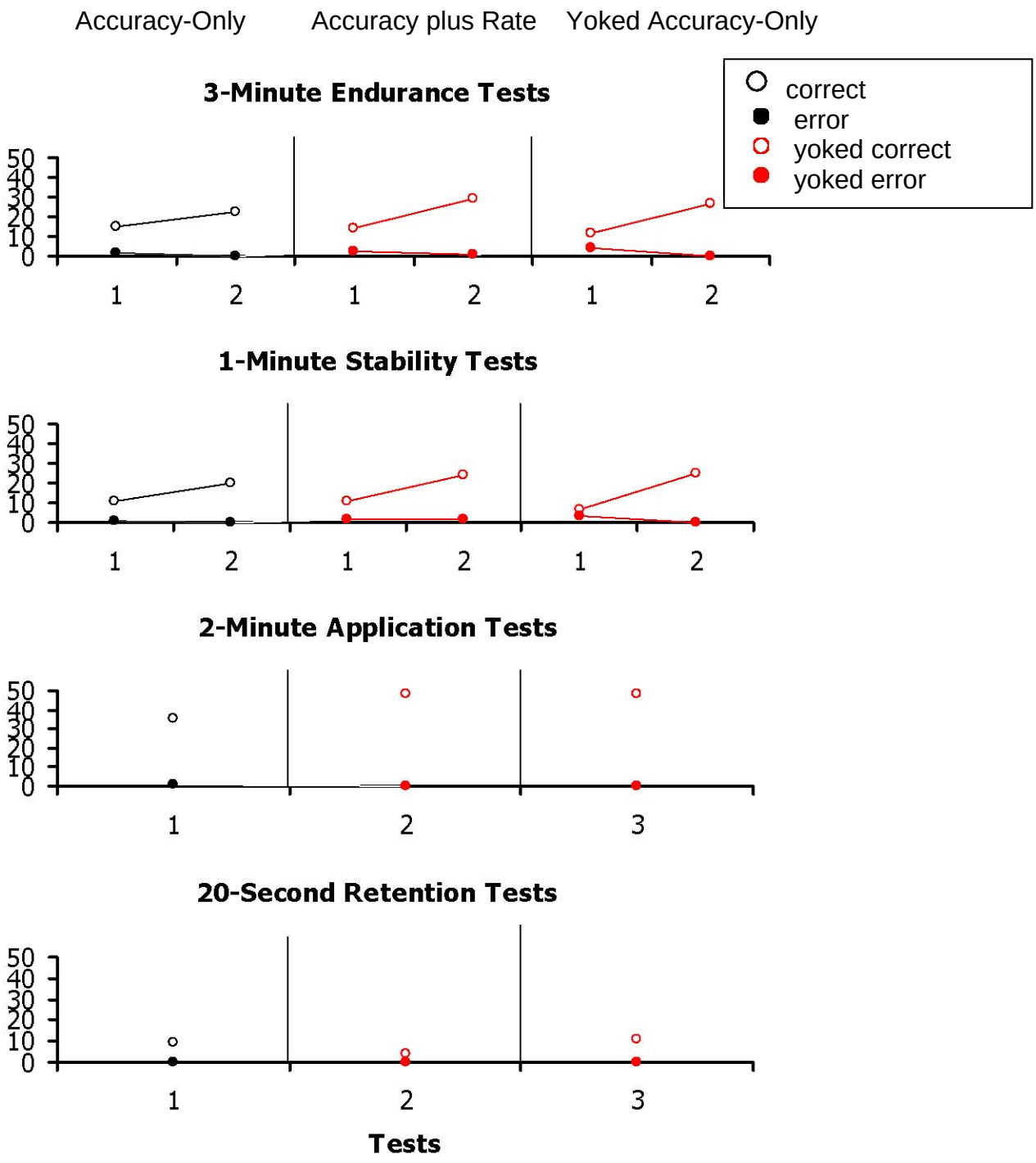

Figure 14. Participant 3's count per minute of corrects and incorrects during Endurance, Stability, Application, and Retention tests for all three conditions.

Accuracy-Only Accuracy plus Rate Yoked Accuracy-Only

Participant 4 Test Performance

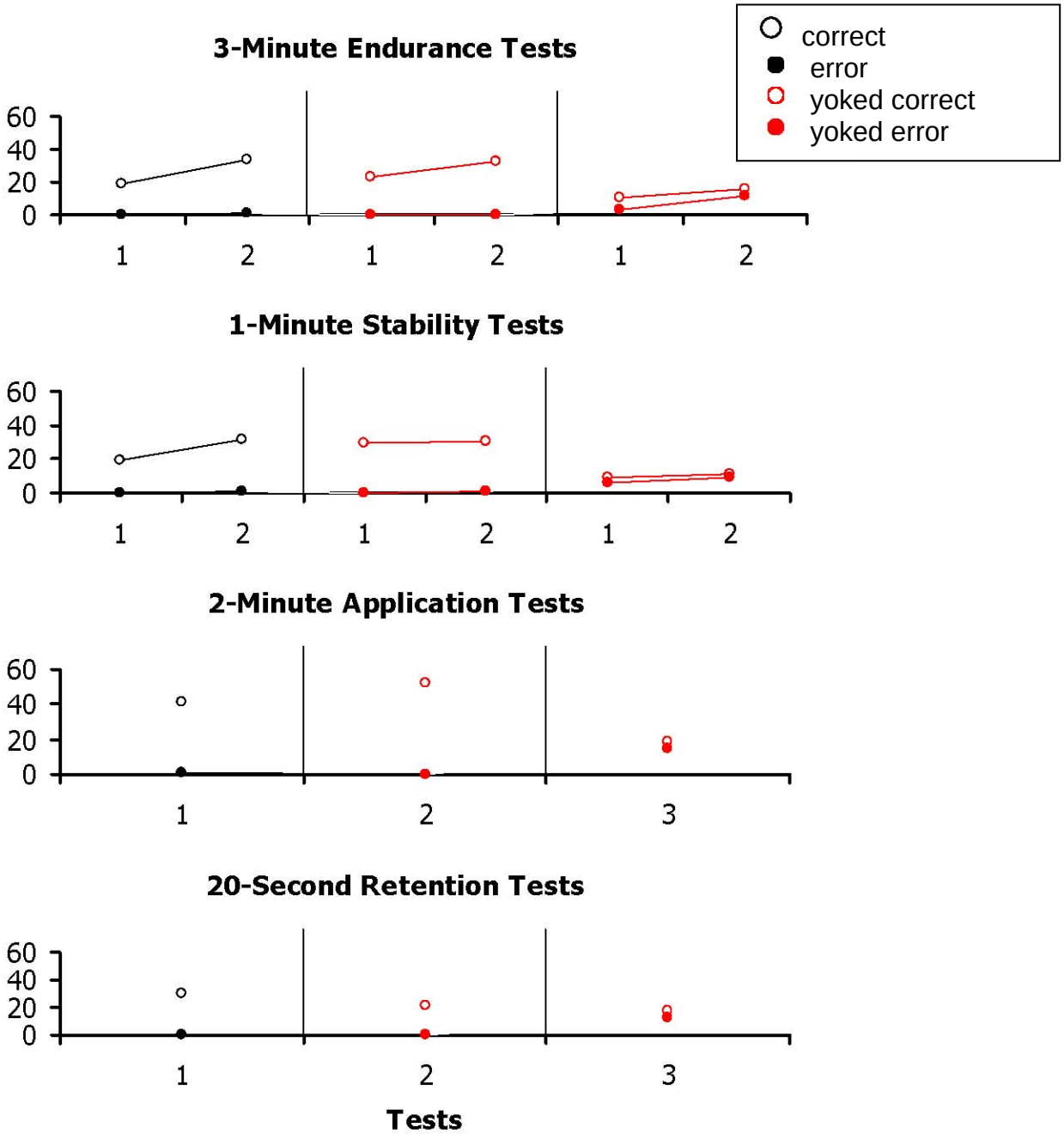

Figure 15. Participant 4's count per minute of corrects and incorrects during Endurance, Stability, Application, and Retention tests for all three conditions.

APPENDIX

POST-EXPERIMENT QUESTIONNAIRE

Post Experiment Questions Participant #_____

1 Which learning style did you enjoy the most? Focusing only on accuracy or focusing on both accuracy and speed?_____

2 Which learning style do you feel you learned the most from?_____

3 Which set of letters and symbols was the hardest to learn? See attached sheet. Circle one: Set A/ Set B/ Set C

4 Which set of letters and symbols was the easiest to learn? See attached sheet. Circle one: Set A/ Set B/ Set C

5 Was there something you did to remember which symbol went with which letter? If so, please describe what you did. _____

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