AN EXAMINATION OF THE EFFECTS OF ACCURACY+RATE VERSUS ACCURACY+OBSERVING RESPONSE TRAINING METHODS ON MATCHING-TO-SAMPLE PERFORMANCE

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The relative efficacy of training procedures emphasizing accuracy versus those which add a rate criterion is a topic of debate. The desired learning outcome is fluent responding, assessed by measures of retention, endurance, stability, and application. The current study examined the effects of these two procedures on fluency outcomes using a matching-to-sample paradigm to train participants to match English to Japanese characters. An explicit FR-3 observing response was added to an accuracy-only condition to assess the extent to which it may facilitate learning. Total time spent responding in practice drills in accuracy-only conditions was yoked to total time spent in drills achieving rate aims in accuracy+rate (AR) conditions. One participant clearly demonstrated superior fluency outcomes after AR training while another displayed superior endurance and stability outcomes after such training. The remaining two participants did not demonstrate significantly different fluency outcomes across conditions.

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CHAPTER 1

INTRODUCTION

Basic research, including that conducted by Eckerman, Lanson, and Cumming (1968), Hogan, Zentall and Pace (1983) and Lyderson, Perkins, and Chairez (1977), has demonstrated that the matching-to-sample (MTS) performance of pigeons improved when an explicit observing response to the sample stimulus was required relative to when no observing response was required. Such studies have demonstrated these effects using identity matching as well as oddity/arbitrary matching procedures. Lyderson, Perkins and Chairez (1977) reported that a higher fixed-ratio observing response requirement increased accuracy and "appeared to facilitate control by stimuli serving an instructional function" (p. 97) when comparing a range of fixed-ratio observing response requirements from 1 to 32. Paul (1983) found that such fixed-ratio schedules also served a discriminative function in that performance was more accurate when using the same ratio as was used in initial training compared with another ratio. Additionally, Nelson and Wasserman (1978) found that retention in pigeons was an increasing function of sample duration.

Despite such a body of evidence in the experimental literature using nonhuman subjects, the role of the observing response in human MTS responding remains "laboratory lore" aside from a limited number of studies. One such study, conducted by Dube and colleagues (2006), found that typically developing adult human participants performed the MTS task with greater accuracy when they exhibited longer sample-stimulus observing durations and less variability in observing patterns as measured by monitoring participants' eye movements with miniature video cameras. It is also noteworthy that participants in this study did not exhibit a greater degree of accuracy as a function of observing frequency, indicating that observation duration was a better predictor of accuracy than observing frequency.

Although such research has demonstrated the effects of extended exposure to sample stimuli, Tomanari and colleagues (2006), found that it was not necessary in the emergence of equivalence relations in adult humans. The authors programmed limited-hold contingencies to ensure very rapid responding and found that some participants nonetheless demonstrated equivalence classes. This led the authors to suggest that "longer time intervals of the typical laboratory procedure are not necessary conditions to produce equivalence (although they may be facilitative)" (p. 363).

One application of matching-to-sample procedures with humans is in training the learner basic reading or language skills via precision teaching methods. Such performance may then be compared to performance engendered by a more traditional approach to teaching, which explicitly trains accuracy without criteria for rate of responding. Chase, Doughty, and O'Shields (2004) published a review of the precision teaching literature and concluded that a body of experimental research supporting claims of the superiority of precision teaching methods as opposed to accuracy-only methods is lacking, and they called for more experimentation in this area. Of the 48 articles reviewed by Chase et al (2004) ,the authors were able to find only 29 articles that met their criteria for an empirical investigation, with the rest relating to conceptual issues. Published responses to this review (Binder, 2004; Kubina 2005) tended to question the authors' use of terminology and pointed out such errors, but did not present additional empirical evidence to support the claims of precision teaching practitioners. Much of the literature and discourse in this area seems to be composed of expert opinions and “argument from authority” (Chase, Doughty, & O’Shields, 2005, p. 163) which does little to advance scientific knowledge, and is “the antithesis of science and evidence-based decision making” (p. 164).

In response to the concerns raised by Chase, et al., Wheetley (2005) used an MTS procedure with humans to examine differences in retention, endurance, stability, and application of performance when stimulus sets were trained according to either an accuracy-only (AO) or accuracy+rate (AR) paradigm. This was done to examine differences in efficacy between precision teaching, which emphasizes both accuracy and rate, and a more common (Kubina & Morrison, 2000) training approach which emphasizes only accuracy (percent correct) of the performance. Though it has been suggested that “almost any practice activity can qualify as rate building” (Kubina, 2005 p. 75), for the present discussion, the author will consider only those methods explicitly concerned with increasing rate to a criterion as an outcome to be “rate building.”

High rates of responding have long been considered the key reason for the perceived superiority of precision teaching, “but to say that a range of rate measures is better than a range of trial measures (i.e., practice) is an empirical generalization which is not supported by the literature” (Chase, Doughty, & O’Shields, 2005, p. 167). When accuracy criteria are not in place researchers have found a higher degree of accuracy in AO conditions than in rate-only conditions as a “speed-accuracy trade-off” (Mulligan & Hirshman, 1995, p. 1).

A central tenet of precision teaching is that rate of response is critical to the learning process. Lindsley (1997), when specifically addressing the issue of precision teaching specifically, suggested that achievement of fluency may in fact be hindered by emphasizing accuracy. However, simply citing this as evidence of the superiority of training methods involving rate criteria is an insufficient over simplification of the topic at hand. We must also strive to uncover the most effective practices within such global paradigms as percent correct and accuracy+rate. That is, we must eventually move beyond simple comparisons of percent correct vs. percent correct with rate criteria to find more effective practices within the global paradigm.

Wheetley (2005) addressed the question of whether AR may be superior simply due to a greater exposure to stimuli in the same time period by holding number of correct trials and unprompted error corrections constant across conditions. The results of the study demonstrated mixed outcomes, with small differences between the two approaches and each appearing to be the superior method in some areas and with some participants.

Because the current study sought to examine the comparative efficiency of the two training methods, the number of correct trials and unprompted error corrections was not held constant. Instead, only total time spent responding in training was held constant. This allowed for a comparison of efficiency in terms of time spent in training between methods.

Fitzgerald (2000) obtained results similar to Wheetley (2005) when using an MTS paradigm and training participants to meet either AR criteria or simply to be exposed to the same number of trials as was required for pilot subjects to meet the AR criteria. The author found that fluency procedures did not produce response patterns that significantly differed from those engendered by the yoked practice condition.

Another study which did not support the claims of superiority of AR methods was conducted by McCarty (1999). The study used an MTS procedure which trained participants to match Kanji characters to Morse Code via either selection-based or topography-based training conditions while emphasizing either speed and accuracy or accuracy alone (participants were told not to sacrifice accuracy for speed). The author reported that on tests examining retention, equivalence, and endurance "subjects scored higher on relationships learned at a slow speed than those learned at a fast speed 75% of the time" (p. 81) and they scored an average of 2.8% higher on such tests.

The aim of the current study was to extend recent research conducted by Wheetley and others to examine differences in efficacy between precision teaching and an accuracy-only approach. The aim of that research has generally been to test the claims of the superiority of rate training on retention, endurance, stability, and application. In the present study, the aim is to examine whether there are conditions under which accuracy-only training may actually produce greater retention, endurance, stability, and application even though these outcomes are purported to be best facilitated by the learner meeting a fluency aim (Binder, 1988; Binder, 1996). Regardless, it is a widely held opinion among practitioners of precision teaching, and, seemingly, of the majority of behavior analysts, that data regarding such outcomes are necessary in comparing or assessing the utility of training methods. This point was summarized by Johnson and Layngas follows:

> To move beyond a mostly metaphorical use of the term fluency, we need to specify outcomes that indicate fluent performance and select dimensions of behavior in time that will indicate that fluency has been achieved. Five functional fluency criteria have evolved over the last 20 years. These fluency standards have

> been empirically linked to various frequency aims, depending upon the task. (1996, p. 285)

These five criteria are: retention, endurance, stability, application and adduction, commonly known by the acronym RESAA. Retention may be defined as the ability of the learner to perform a task with the same degree of accuracy and at the same rate as they had in training after a period has passed without training or practice. Endurance refers to the learner performing the task with the same degree of accuracy and rate as during training, but doing so for a duration longer than that which was required during training. Stability is demonstrated when the learner performs with the same rate and accuracy as during training, but does so in the presence of distractions. Application is the learner's ability to perform untrained tasks after having learned component skills. Finally, adduction refers to novel performance meeting new instructional criteria after component skills and prerequisites were trained (Johnson & Layng, 1996). Of these five elements, only adduction was not assessed in the current study, as the objective was a comparison of the use of two methods to train a simple matching-to-sample task, and not to train a variety of component skills and examine untrained emergent composite skills.

Because matching to sample research with animals has shown that the addition of an observing response produces greater accuracy, and more rapid acquisition of the matching task (Eckerman, Lanson, & Cumming, 1968), the role of this variable in human learning was examined and compared to precision teaching methods that do not include an explicit observing response.

There seems to be a general consensus among practitioners of precision teaching that regardless of whether or not AR techniques have a greater degree of efficacy *per se*, such approaches are nonetheless more efficient and can achieve favorable results after less time training, which may be accounted for by greater exposure to the task via rate-building methods (Kim, Carr, & Templeton, 2001). To address suggestions that AR's superiority lies within efficiency in terms of a greater number of trials within a given time (Binder, 2004; Chase, Doughty & O'Shields, 2005; Kubina 2005) , the present experiment yoked only total time spent responding in practice drills between conditions. This is in contrast to the procedure of yoking total number of correct responses to control for amount of practice and reinforcement as was used by Wheetley. Comparing efficacy solely in terms of time spent in each training condition will help evaluate the assertions of both precision teaching literature and literature concerned more generally with matching to sample and stimulus control, such as Dinsmoor's 1985 article in which he suggests that stimulus control depends on how much contact the organism has with the stimuli. This assertion is in line with results obtained by Maki and Leith (1973) and Maki and Leuin (1972), which demonstrated that increased sample stimulus duration increased accuracy in a matching-to-sample task – a solid demonstration of the powerful stimulus control engendered by increased sample stimulus exposure. If such findings hold true in a procedure designed to build accurate performance in humans (such as the current study) and produce equal or superior RESAA outcomes, the number of exposures and correct answers will be less relevant in predicting highly accurate outcomes than total time exposed to all relevant stimuli. A highly accurate performance engendered by such exposure to the sample may also meet the criteria for fluent performance, although such a suggestion requires further empirical investigation.

To assess the relative efficacy of each method of training in the current experiment tests for retention, endurance, and application were administered after each participant either met the mastery criterion (accuracy+rate) or spent a yoked amount of time in practice (accuracy+observing response) for each training condition. Data obtained for tests were compared both as number of correct and incorrect responses as well as rate of correct and incorrect responses/min. As is often noted, it is not sufficient simply to compare the speed and accuracy of responding in order to proclaim one method superior in producing fluent performance – RESAA outcomes must also be taken into account. As stated by Binder:

> A possibly more interesting way to frame rate-building research than as a comparison of the effects of controlled trials with the effects of self-paced practice on retention, application, and other learning outcomes is to ask if rate of freely emitted responding better predicts these learning outcomes, whether that rate is the product of controlled-trials practice, self-paced practice, or some combination. Does it tell us more than percentage correct? (2004, p. 282)

CHAPTER 2

METHOD

Participants

Four adults were recruited via handouts circulated in introductory behavior analysis classes as well as via word-of-mouth through a colleague. All participants were native speakers of a language that exclusively used the English/Latin alphabet and had no prior knowledge of the Japanese language or alphabet (specifically the Hiragana Syllabary). Each participant read, signed, and received a printed copy of the IRB-approved consent form prior to participation in this study. Participants in the study were compensated at a rate of $8.00/session at the end of each session as well as a bonus upon completion of their participation in the study. The bonus amount was $25.00 plus an additional $1.00 for each session the participant attended.

Setting

Participants worked in a 7′ x 8′ room in the Department of Behavior Analysis at the University of North Texas. Within the room was a 40″ x 40″ table with two office chairs located on opposite sides of the table and a JVC® VHS-C camcorder on a tripod located at the head of the table to record sessions.

All responses were made on 8.5″ by 11″ sheets of paper inside of Oxford® Crystal Clear Standard Weight Sheet Protectors (henceforth referred to as laminated sheets) with a dry erase marker.

Stimuli

The study used three sets of stimuli, each composed of 7 English characters and 7 Japanese (Hiragana Syllabary) characters. The first stimulus set, Set 1, was composed of the English letters N, Z, C, T, S, P, and A, which were associated with the Japanese characters い, せ, ふ, お, む, め, and き, respectively. Set 2 was composed of the English letters D, G, I, J, L, R, and V, which were associated with the Japanese symbols そ, ほ, な, ゆ, を, ぬ, and こ. Set 3 was composed of the English letters B, F, K, M, O, Q, and, which were associated with the Japanese characters ね, て, ゑ, や, す, み, and は. These particular stimulus pairings were used as Wheetley (2005) found, in pretesting for a similar experiment, that these stimuli were not reliably matched correctly prior to exposure to training.

Laminated sheets were divided into four quadrants by bolded black borders. Each quadrant contained a problem consisting of 1 Japanese character (sample) presented in the center of the quadrant and the 7 English characters (comparisons) presented in a circle around the sample, with the exception of application test arrangements (see Figures 1-4). Sheets for each condition contained four stimulus arrangements with the exception of error correction sheets, which contained only one arrangement. All comparison stimuli were of equal distance from the sample stimulus. The stack of sheets was shuffled prior to each block of trials to randomize the presentation of sample stimuli. All sheets for each drill or test were presented to participants in a three-ring binder. Participants began with the first page in the binder and proceeded to subsequent pages upon completion of each page. If a page were skipped, all trials on that page would be scored as incorrect, although this never occurred in the study.

Responses

Participants used a dry erase marker to draw a line through an English comparison to match the Japanese sample on each of the four quadrants of the laminated sheets of paper.

Dependent Variables

Dependent variables were accuracy and rate of responding during tests for retention, endurance, stability, and application. Accuracy was calculated as the number of correct responses divided by the total number of responses. Rate was calculated as the number of correct responses divided by the number of minutes spent on the test and expressed as responses/min. The experimenter recorded data on rate and accuracy immediately following each practice drill or test.

Independent Variables

The independent variable was the method used to train participants. Each participant was trained to match three sets of sample and comparison stimuli using two different methods of training. In the accuracy+observing response (AOR) condition, the rate at which responses were made was slowed down by the time spent engaging the observing response. In the accuracy+rate (AR) condition, rate of responding was not controlled and the rate/mastery criteria were the same as used by Wheetley (2005).

Experimental Design

A reversal (ABA′) experimental design was used for Participants 1 and 2.

Participants 3 and 4 were exposed to a reversed order of conditions (BAB′). The order of conditions was reversed for some participants to assess order effects. Refer to Table 1 for order of conditions and stimulus sets used for each participant.

Table 1

Participant Condition Sequence and Stimulus Set

	1st Condition	2nd Condition	3rd Condition
Participant 1	AR Set 2	AOR Set 1	AR Set 3
Participant 2	AR Set 1	AOR Set 2	AR Set 3
Participant 3	AOR Set 1	AR Set 2	AOR Set 3
Participant 4	AOR Set 2	AR Set 1	AOR Set 3

Note: AR = accuracy+rate condition; AOR = accuracy+observing response condition.

Wheetley (2005) examined relative efficacy of the two methods, addressing the question of whether AR may be superior simply due to a greater exposure to stimuli in the same time period by holding number of correct trials and unprompted error corrections constant across conditions. Because the current study sought to compare efficiency of the two training methods, the number of correct trials and unprompted error corrections was not held constant. Instead, only total time spent responding in training and error corrections was held constant. This allowed for a comparison of the efficiency in terms of time spent in training between methods.

Training

Training Condition A: Accuracy plus Rate (AR)

Accuracy+rate (AR) was trained first for Participants 1 and 2. Each session consisted of repeated 20-sec practice drills with interspersed error corrections. Participants engaged in alternating practice drills and error corrections each session for up to 1 hr/day of participation.

Participants began the first session with an error correction procedure consisting of the seven sample stimuli in the current stimulus set presented one at a time. Subsequently, error corrections in each condition included only those sample stimuli to which an incorrect response was made during the preceding practice drill.

Error Correction Component

Prior to the beginning of the first condition and while the participant was seated with the experimenter at the table in the room in which sessions were conducted, the experimenter read the following instructions.

> Each session you participate in will include components such as "learning," "practice," and "tests." At the beginning of a new phase, you will be handed a sheet of paper with instructions for that phase printed on it. Please be sure to read all instructions for each phase. Hand the instruction sheet to the experimenter and say "begin" when you have read the instructions. All responses made during your participation will be made by using the provided dry erase marker to draw a line through the correct symbol on a laminated sheet. Make sure that the lines you draw only touch the symbol you have selected and are dark enough to be visible. Please disregard any residue or imprints that may be on or around a certain character, as all choices, both correct and incorrect, have been repeatedly marked prior to your participation. All sessions and responding during the study will be timed. In some phases, there will be a time limit for responding, and you will be notified when there is a time limit. Your participation in the study will proceed in three distinct phases. You are about to begin the ____ phase (1^{st}, 2^{nd}, 3^{rd}). During this phase, your objectives are to respond both as rapidly and accurately as you can. It is therefore important that you increase your speed of responding as you

> learn the task and try to improve your personal best score during every timing. Please remain seated at the table until you are told your session is complete. I will remain seated across the table throughout your participation. I will begin by handing you a set of cards which contain the correct answers after you have read the instructions.

After reading these instructions to the participant, the experimenter handed them a sheet with the following printed instructions.

> This is a chance to learn the correct answers. First, draw a line through the Japanese character in the center the first sheet, then draw a line through the English letter in the box that goes with it. On the next sheet, again draw a line through the Japanese character in the center before drawing a line through the correct English letter.

Each problem presented in the error correction component required two correct responses, the first of which was always prompted. The first sheet presented contained a Japanese character sample stimulus in the center which was surrounded by the seven comparison stimuli for that condition with the correct comparison stimulus inside a bolded box. After the participant drew a line through the sample, they drew a line through the correct, bolded comparison stimulus. Then the second sheet was handed to them, which contained an identical sample stimulus surrounded by the seven comparison stimuli arranged in a circle around it, but without a prompt. If the correct comparison was selected, the experimenter said “correct” in a neutral voice.

Practice Drills

After the 7 problems in the initial error correction were completed, the experimenter immediately handed participants a sheet which contained the instructions.

> It’s time to practice what you’ve learned. Only draw a line through the English letter that matches the Japanese character in the center.

During practice drills, a Japanese character appeared in the center of each stimulus arrangement within each quadrant of a white laminated sheet. The 7 English letters appeared in a circle surrounding the Japanese character within the same quadrant. The Japanese comparison stimulus presented and the location of English comparison stimuli for each trial was quasi-random. After participants drew a line through comparison stimuli for all trials on a sheet, they flipped to the next sheet, which contained another set of arrangements of Japanese samples and English comparisons.

Each practice drill during this condition had a duration of 20 s. Following each 20-s practice drill, verbal feedback was presented informing the participant of the number of correct and incorrect trials during that practice drill. If the participant did not make any errors during that practice drill, they proceeded directly to another drill, skipping the error correction procedure. Participants completed as many drills as possible each day, for an amount of time not to exceed 1 hr from the time they arrived.

Training Condition B: Accuracy plus Observing Response (AOR)

Accuracy+observing response (AOR) training began immediately for Participants 3 and 4, and followed AR training for Participants 1 and 2. Sessions within this condition were similar to the AR condition, in that they included practice drills and error corrections. Participants engaged in alternating practice drills and error corrections during each session for up to 1 hr/day of participation.

Error Corrections

Error corrections in this condition proceeded exactly as in the AR condition.

Instructions varied little from the AR condition. Prior to beginning the first condition, and while the participant was seated with the experimenter at the table in the room in which sessions were conducted, the experimenter read the following instructions.

> Each session you participate in will include components such as "learning," "practice," and "tests." At the beginning of a new phase, you will be handed a sheet of paper with instructions for that phase printed on it. Please be sure to read all instructions for each phase. Hand the instruction sheet to the experimenter and say "begin" when you have read the instructions. All responses made during your participation will be made by using the provided dry erase marker to draw a line through the correct symbol on a laminated sheet. Make sure that the lines you draw only touch the symbol you have selected and are dark enough to be visible Please disregard any residue or imprints that may be on or around a certain character, as all choices, both correct and incorrect, have been repeatedly marked prior to your participation. All sessions and responding during the study will be timed. In some phases, there will be a time limit for responding, and you will be notified when there is a time limit.. Your participation in the study will proceed in three distinct phases. You are about to begin the ____ phase (1^{st}, 2^{nd}, 3^{rd}). Your only goal in this phase is to respond as accurately as you can. Please remain seated at the table until you are told your session is complete. I will remain seated across the table throughout your participation. I will begin by handing you a set of cards which contain the correct answers after you have read the instructions.

Practice Drills

After the 7 problems in the initial error correction were completed, the experimenter immediately handed participants a laminated sheet of paper which contained the following instructions:

> It's time to practice what you've learned. Draw an X through each of the three Japanese characters inside of the boxes. Your lines must touch the corners of the square, but not extend outside of the borders of the square to touch any other lines or characters. After drawing an X through each box, draw a line through the English letter that matches the Japanese character in the center.

During practice drills, three identical Japanese sample stimuli, each inside a bolded black box, were presented in random locations against the white background within the borders of each stimulus arrangement. Participants marked an "X" through the sample stimuli within each of the three boxes. Drawing X's through the boxes was the observing response unique to this condition. This topography was chosen to serve as the observing response since it was presumed that drawing these X's, and stipulating that the lines touch the corners, but not extend beyond the borders would ensure that participants looked at each sample stimulus for several seconds prior to each trial. The 7 English letters appeared in a circle surrounding the Japanese character within the same stimulus arrangement. The Japanese comparison stimulus presented and location of English comparison stimuli for each trial was quasi-random.

Each practice drill during this condition was timed by the experimenter, but did not end until the participant had completed 7 problems. Following each 7-response practice drill, verbal feedback was presented informing the participant of the number of correct and incorrect trials during that practice drill. If the participant did not make any errors during that practice drill they proceeded directly to another drill, skipping the error correction procedure. Each session in this condition was composed of repeated 7-response practice drills. Participants completed as many sessions as possible each day, for an amount of time not to exceed 1 hr from the time they arrived. The amount of time spent responding in this phase was yoked to the amount of time spent responding in either a previously completed AR phase (if the participant had already completed an AR phase) or the average amount of time spent responding in a completed AR phase by participants who were exposed to AR training as their initial phase.

Testing

During each condition, tests of retention, endurance, stability, and application were administered to each participant. Each participant completed two endurance tests, two stability tests, one application test, and one retention test or each stimulus set. Tables 2 and 3 specify criteria participants met before tests were administered.

Tests of endurance and stability were administered twice for each stimulus set in order to make a within-condition comparison for each subject by comparing scores after limited and extended exposure to each training method. In the AR condition, participants first took tests of endurance and stability after meeting criteria of moderate accuracy and then took them again upon meeting the mastery criteria for that condition. In the AOR condition, participants took each set of tests after an amount of time yoked to the amount of time spent in training prior to each round of tests in the AR phase.

Tests of application were administered one time in each condition, following completion of training. These tests were administered only once because they were designed to assess novel performances after completion of the original training. Retention tests for the first two conditions were administered after training had begun for the following condition. The final retention test for each participant was administered following a period after completion of training that was equal to the mean latency to test administration for the first two conditions for that participant

Upon reaching a point where tests were scheduled to be administered, participants were told that their participation for that day was complete. Scheduled tests were then administered at the beginning of the following session. This was done in order to ensure that participants did not have varying amounts of practice on the day they took a test. Refer to Tables 2 and 3 for training and test order, and training criteria for test administration.

Table 2

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

Accuracy Criterion	Initial Tests	Rate/Practice Criterion	Final Tests
AR (A) Condition 7 correct responses 0 incorrect over 2 consecutive 20-s drills	1-min Endurance 20-s Stability	10 correct responses No more than 1 error across 4 consecutive 20-s practice drills	1-min Endurance 20- s Stability 20-s Application
AOR (B) Condition [respond until total time = same as for participant to achieve initial AR criterion listed above]	1-min Endurance 20-s Stability 20-s Retention on stimulus set from previous condition	[respond until total time = same as for participant to achieve mastery AR criterion listed above]	1-min Endurance 20- s Stability 20-s Application
AR (A') Condition 7 correct responses 0 incorrect over 2 consecutive 20-s drills	1-min Endurance 20-s Stability 20-s Retention on stimulus set from previous condition	10 correct responses No more than 1 error across 4 consecutive 20-s Practice Drills	1-min Endurance 20- s Stability 20-s Application 20-s Retention on current stimulus set.

Note: Yoked conditions are identified by italics. AR = accuracy+rate; AOR = accuracy+observing response.

Endurance and Stability Tests

Tests for endurance were administered to assess the degree to which participants could perform the trained task for a duration longer than they had experienced in training. Participants matched Japanese characters to English letters for 1 min with no observing responses or delays between trials. Stability tests were administered to assess the extent to which participants could perform the trained task in the presence of distracting stimuli. Stimuli used as distractions were additional Hiragana characters which were not otherwise used during the study. Stability tests lasted 20 s.

Table 3

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

Accuracy Criterion	Initial Tests	Rate/Practice Criterion	Final Tests
AOR(B) Condition [respond until total time = average time for participants 1 and 2 to achieve initial AR criterion]	1-min Endurance 20-s Stability	[respond until total time = average time for participants 1 and 2 to achieve AR mastery criterion]	1-min Endurance 20-s Stability 20-s Application
AR (A) Condition 7 correct responses 0 incorrect over 2 consecutive 20-s drills	1-min Endurance 20-s Stability 20-s Retention on stimulus set from previous condition	10 correct responses No more than 1 error across 4 consecutive 20-s practice drills	1-min Endurance 20-s Stability 20-s Application
AOR (B') Condition [respond until total time = average time for the participant to achieve initial AR criterion in condition A above]	1-min Endurance 20-s Stability 20-s Retention on stimulus set from previous condition	[respond until total time = same as for the participant to achieve mastery AR criterion in condition A above]	1-min Endurance 20- sec Stability 20-s Application 20-s Retention on current stimulus set.

Note: Yoked conditions are identified by italics. AR = accuracy+rate; AOR = accuracy+observing response.

Tests for endurance and stability were initially administered when the participant made 7 or more correct responses with 0 errors across 2 consecutive practice drills in the AR condition. In the AOR condition, initial tests were administered after an amount of time yoked to the amount of time spent responding prior to initial tests in the AR condition. Prior to administration of these tests, the experimenter read the following instructions to the participants.

> These tests will be used to show us what you have learned. Please respond as quickly and accurately as you can. Mark only the English letter that goes with the Japanese character in the center. The time limit for this test is (20 or 60) seconds. As soon as you open the binder, your time will begin.

After completion of these initial tests, training continued. Upon reaching the rate aim of at least 10 consecutive correct responses with no more than 1 error across 4 consecutive 20-s response drills, participants in the AR condition took another round of endurance and stability tests. Participants 3 and 4, who were first trained in the AOR condition, were given the first endurance and stability tests after spending 190 s responding in practice drills, a number yoked to the average performance of Participants 1 and 2. The instructions presented for the final endurance and stability tests were identical to those used in the first set.

Application Test

A single application test was administered following each condition in order to assess the extent to which participants could transfer what they had learned to a novel task. One English symbol was presented at the top of each stimulus arrangement. Below it were the 7 Japanese characters from that stimulus set. Participants drew a line from the English letter to the Japanese character. Refer to Figure 3 for a sample of the application test layout. Application tests lasted 20-s, and immediately followed the final endurance and stability tests for each condition. The experimenter read the following instructions to participants before administering the application test.

> Sheets for this task will appear different than those you have used in practice. In this task, an English letter will appear at the top of the card with seven Japanese characters in a line below it. Draw a line from the English letter to the appropriate Japanese character. Please respond as accurately and quickly as you can. The time

> limit for this test is 20 seconds. Your time will begin as soon as you open the binder.

Retention Test

Retention tests were administered to assess the extent to which participants retained the relations they had learned during the previous condition after a period of time without practice. Retention tests lasted 20-s. Retention tests for the first and second stimulus sets were administered immediately following the initial endurance and stability tests for the following stimulus sets. The retention test for the final stimulus set was administered after a number of days had passed since the final training session for that set which was equal to the mean time between final session and retention tests for the first two stimulus sets. Prior to administering retention tests, the experimenter read the following instructions to participants.

> You will be going back to a short practice drill for the symbols you learned in the previous phase of this study. Please respond as accurately and quickly as you can. The time limit for this test is 20 seconds. Your time will begin as soon as you open the binder.

Upon completion of the final retention test, participants were asked to read the post-experimental questionnaire and write their answers on the attached sheet (see appendix for a list of questions). If a participant did not understand a question, the experimenter explained further until the participant reported that they fully understood. After answering the questionnaire, participants were awarded a study completion bonus equal to $25 plus $1/session attended. As each participant attended 6 sessions, the completion bonus was $31 for each participant. Then participants were debriefed and asked if they had any further questions.

CHAPTER 3

RESULTS

Participant data are presented in numerical order according to the number assigned to each participant. Data for training sessions are presented first followed by data for tests and concluding with responses to the post-experimental questionnaire. Interobserver agreement was calculated for 48% of practice drills and for all tests and was 100%.

Training

Figures 6 and 7 display practice drill data for Participants 1 and 2, both of whom were initially trained in the accuracy+rate (AR) condition. The top graph for each participant represents practice drill data in the first condition. Participant 1 met the accuracy criterion of 7 correct with no errors across two consecutive 20-s drills in the 11th 20-s drill. Participant 2 met this criterion in the 8th drill. After meeting this initial criterion, Participants 1 and 2 met the rate criterion of 10 or more correct responses with 1 or fewer errors across four consecutive 20-s drills in their first four 20-s drills. Meeting this criterion required a total of 150 correct responses with 20 errors for Participant 1, and 85 correct responses with 13 errors for Participant 2.

These participants then proceeded to the yoked accuracy+observing response (AOR) condition, using a new stimulus set. In this condition tests were administered to participants after responding in practice drills for an amount of time equal to their responding in practice drills prior to testing in the initial AR condition. For Participant 1, these times were 220 s of responding prior to the first set of tests and an additional 80 s of responding (total of 300 s) prior to the second set of tests for the phase. Participant 2 responded in practice drills for 160 s before the first set of tests and an additional 80 s (total of 240 s) before the second set of tests. These tests were administered regardless of accuracy or rate of responding, as only time spent responding was yoked. In this condition, participants completed repeated 7-response practice drills until the yoked time prior to tests had elapsed. Participant 1 made a total of 43 correct responses with 1 error prior to the first set of tests and an additional 26 correct responses with no errors prior to administration of the second set of tests. Participant 2 made a total of 30 correct responses with zero errors before the first set of tests and an additional 19 correct responses with zero errors prior to the second set of tests.

Participants 1 and 2 completed participation with a return to the AR condition using a new stimulus set (both now learning set 3). In this condition, Participant 1 made a total of 27 correct responses with 0 errors before the initial set of tests and an additional 120 correct responses with 3 errors before the second set of tests. Participant 2 made 16 correct responses with no errors prior to the first set of tests and an additional 59 correct responses with no errors prior to the second set.

Figures 8 and 9 display practice drill data for Participants 3 and 4, both of whom were initially trained in the AOR condition. The top graph for each participant represents practice drill data in the first condition. Because these participants had not yet responded in the AR condition, the total amount of time responding prior to the first and second set of tests was yoked to the average time Participants 1 and 2 spent responding in practice drills prior to tests in the initial AR condition. These times were 190 s prior to the first set of tests and an additional 80 s (total of 270 s) prior to the second set of tests. Participant 3 made a total of 6 correct responses with 11 errors prior to the initial set of tests and an additional 4 correct responses with 5 errors prior to the second set of tests. Participant 4 made a total of 4 correct responses with 10 errors prior to the first set of tests and an additional 5 correct responses with 5 errors prior to the second set of tests.

These participants then proceeded to the AR condition, using a new stimulus set. Participant 3 made a total of 12 correct responses with one error prior to the first set of tests and an additional 56 correct responses with no errors prior to the second set of tests. Participant 4 made 22 correct responses with 6 errors prior to the first set of tests and an additional 64 correct responses with no errors prior to the second set of tests.

Participants 3 and 4 concluded their participation with a return to the AOR condition with a new stimulus set (Set 3 for both). In this condition, time spent responding in practice drills prior to tests was yoked to the amount of time spent responding prior to tests in the preceding AR phase for that participant. For Participant 3, this was 60 s before administering the first set of tests, in which he made 4 correct responses and 3 errors, and an additional 80 s (total of 140 s) prior to the second set of tests, on which he made 11 correct responses and 1 error. Participant 4 responded for 60 s prior to the first set of tests, on which he made 7 correct responses and 2 errors, and an additional 100 s (total of 160 s) prior to the second set of tests, on which 12 correct responses and 7 errors were made.

Testing

Tests of retention, endurance, stability, and application were administered for each phase of the study to compare the effects of the training methods in engendering fluent performance.

Figures 10 through 13 display test results for each participant in each condition. Each graph represents performance on one test across all three conditions for that participant. Tests for endurance and stability were administered twice per condition: once after either meeting the initial criterion or responding in drills for a yoked amount of time. These tests were administered again upon achievement of the final criterion or after responding in drills for a yoked amount of time. Tests of application and retention were administered once per condition. A numerical representation of these data may be found in Table 4. While Figures 10 through 13 express the number of correct and incorrect responses made in each test, Table 4 expresses these data in rate-per-min form.

Figure 10 displays the number of correct and incorrect responses in all tests for Participant 1. Errors were consistently low across all tests and conditions for this participant. Numbers of correct answers vary little across tests of the same type. Of interest within these data is the slightly increasing trend in correct responses during the final endurance test for each phase. Also of note is the slight spike in application test scores and slight regression in retention test scores during the AOR condition before a return toward previous levels in the final AOR condition. However, the tests demonstrate little difference between AR and AOR conditions overall.

Figure 11 displays the number of correct and incorrect responses made by Participant 2 during tests. Like Participant 1, her number of errors across tests and conditions was consistently low. The most noticeable pattern within these data is the decreasing trend in performance across the three application tests. This is noteworthy as no other participant showed a similar decreasing trend across conditions in any of the tests administered. Aside from this unexpected trend, test data for Participant 2 display little variation across conditions.

Table 4

Rate per Minute of Correct and Incorrect during Tests

Participant	Condition	Endurance		Stability		Application		Retention	
		Correct	Error	Correct	Error	Correct	Error	Correct	Error
1	AR	39	0	33	0	18	0	51	0
		42	1	39	0				
	AOR	34	1	30	0	27	0	48	0
		46	0	42	0				
	AR	35	1	39	0	24	0	60	0
		49	0	42	0				
2	AR	31	1	30	0	27	0	48	0
		40	0	39	0				
	AOR	36	0	36	0	21	0	45	0
		37	0	36	0				
	AR	34	0	36	0	15	0	48	0
		44	0	42	0				
3	AOR	1	10	6	12	12	3	15	6
		2	9	12	6				
	AR	17	1	21	3	18	0	36	0
		40	0	36	0				
	AOR	12	7	21	9	12	1	21	3
		15	10	16	6				
4	AOR	7	2	12	0	0	12	6	15
		12	5	6	12				
	AR	27	1	33	0	21	0	39	0
		43	0	33	3				
	AOR	6	16	6	18	18	0	42	0
		19	5	39	0				

.Figure 12 displays the number of correct and incorrect responses made by Participant 3 during tests. Here, there is a very clear discrepancy between test data across conditions, as there is virtually no overlap in the data across conditions. Also of note is the possible display of a carryover effect from the AR condition to the final AOR condition, as illustrated by the general increase in correct answers across tests from the first to final AOR conditions. This may, however, be partially due to the participant becoming familiar with the tasks and not necessarily a display of the second AOR condition appearing more effective because it followed exposure to the AR training method. However, as this participant still made more errors in tests following AOR conditions than in those following the AR condition, it is clear that the AR condition was superior in engendering fluency outcomes.

The data for Participant 4, as shown in Figure 13, display patterns similar to those displayed by Participant 3. The number of correct responses within each test was invariably higher, and the number of errors invariably lower from the first (AOR) condition to the second (AR). However, scores on tests of application and retention vary less between the AR condition and the final AOR condition. Generally, test scores for Participant 4 generally display a higher number of correct responses and fewer errors during the AR condition, although this is not as pronounced as the data for Participant 3. Like Participant 3, Participant 4's performance also may have displayed a carryover effect from the AR to final AOR condition, as application and retention test scores in the second AOR condition indicate an increased number of correct responses and decreased number of incorrect responses when compared with test scores during the initial AOR condition. Also of note is that Participant 4 was the only participant to make more incorrect than correct responses during a test, which occurred in both the application and retention tests for the first (AOR) condition. Finally, stability test data for Participant 4 during the final AOR condition show the most drastic within-condition increase in the number of correct responses on any test form for any participant.

Post-Experiment Questionnaire

Table 5 provides a summary of the answers given by participants to the post-experiment questionnaire. Questions addressed the condition in which participants reported having learned and enjoyed the most, as well as which stimulus sets they reported to be the easiest and most difficult.

Table 5

Responses to Post-Experiment Questionnaire

Partici-pant	Sequence	Style Enjoyed Most	Style Learned Most	Most Difficult Set	Easiest Set
1	AR Set 2 AOR Set 1 AR Set 3	No Preference	No Preference	Set 2	Set 3
2	AR Set 1 AOR Set 2 AR Set 3	AOR	AR	Set 3	Set 1
3	AOR Set 1 AR Set 2 AOR Set 3	AR	AR	Set 3	Set 2
4	AOR Set 2 AR Set 1 AOR Set 3	AR	AR	Set 2	Set 1

Participant 1 reported no preference regarding having learned more or enjoying a condition more. Two of the 3 participants reported enjoying the AR condition the most, while all three who reported learning more in one condition agreed that it was the AR condition. Regarding difficulty of stimulus sets, Participants 1 and 2, whose test scores varied little across conditions, reported that both the easiest and most difficult sets were the ones they were exposed to in an AR condition. Participants 3 and 4, who both displayed notable differences in test scores between conditions, reported that the easiest set was one they had encountered in the AR condition and the most difficult was a set they encountered in the an AOR condition. It is, of course, impossible to determine from these data whether or not a given stimulus set was reported as more or less difficult as a function of the difficulty a participant had in that condition rather than the relative difficulty of the stimulus set itself.

CHAPTER 4

DISCUSSION

By utilizing a within-subject design and yoking the time spent responding in accuracy+observing response (AOR) practice drills to the time spent in accuracy+rate (AR) practice drills, this experiment addressed both the relative efficacy and efficiency of accuracy-only and AOR procedures. As the observing response successfully limited rate of responding in the AOR condition, participants demonstrated noticeably higher rates of responding prior to tests in AR conditions compared to AOR conditions. However, only the data for Participants 3 and 4 demonstrate a facilitative effect of response rate on fluency measures, and this effect was only clearly observed in two of the four tests for Participant 4. Future research should further investigate such effects by exposing participants to each condition for a greater number of trials while holding the number of trials constant across conditions. As participants made a greater number of responses during the AR condition, they were thus exposed to a greater number of error corrections during this condition. Future research should aim to hold error corrections constant to eliminate the possibility that this served as a confound.

Because Participants 1 and 2 did not produce test data that varied significantly across conditions, it is possible that initial exposure to an AR paradigm facilitates fluency engendered by subsequent percent correct training. Additionally, as test performance did not vary, although these two participants were exposed to fewer trials within practice drills and error corrections during the AOR condition, the role of the observing response must be addressed. If the observing response were removed, it is unknown what effect this would have on fluency outcomes. If there in fact, is continuity with nonhumans in this regard, and the observing response facilitated performance in the current study as it has in studies with nonhumans, it may be reasonable to suggest that the removal of the observing response from the procedures may have produced performance that varied significantly, or at least to a greater extent, between conditions for all subjects.

As Participants 3 and 4 demonstrated superior fluency outcomes on several tests in the second AOR condition as compared to the first, sequence and carryover effects of AR training must be addressed. Additionally, Participants 1 and 2 demonstrated higher response rates than Participants 3 and 4 during practice drills in the AOR condition, and, thus, had more opportunities for error corrections. It is possible that a history of AR training may have influenced their rate of responding in subsequent conditions even though they were instructed only to respond as accurately as possible. An investigation into the effects of such history or possible rule-governance on rate of responding during conditions emphasizing only accuracy is in order. To address the extent to which such history influences future performance, research should address both such effects as well as the durability of the effect. By interspersing AR probes in an accuracy-only training paradigm, such durability could be assessed. It may be that even limited exposure to AR procedures would facilitate superior fluency outcomes when using a percent correct approach.

As percent correct is the most commonly used approach in education, finding ways in which such procedures can be modified to facilitate superior fluency outcomes is vital. The current study suggests that both the addition of an explicit observing response and a history of AR training may be of considerable benefit to learners trained using a percent correct method. Since it is assumed that percent correct procedures are easier for teachers to implement because they involve less-frequent observation, it is critical that methods which are most effective while not involving a high effort that would lead to teachers abandoning the method be investigated .

Another factor of the current study that should be addressed is the rate aim used in the AR condition. This aim may not have been sufficient to facilitate truly superior performance possible when using an AR paradigm. In several cases, participants reached the criterion to advance to testing in the AR condition without greatly exceeding the minimum number of required drills to meet that criterion. Thus, it could not be said that overlearning or substantial practice occurred after the participant had learned to correctly match the stimulus pairs. Additionally, participants often met this aim in such a short amount of time spent in practice drills during the AR condition that they were able to make only a very low number of correct responses during practice drills in the yoked AOR condition, leading to a lower number of error corrections. To address these two concerns, future research in this area must increase the rate aim used in AR conditions.

These data are best summarized by stating that only one participant unequivocally demonstrated that AR training methods produce superior fluency outcomes, while the data of another participant to a lesser extent demonstrated the superiority of an AR approach. It may also be said that no participant demonstrated superior performance in the AOR condition. Additionally, it may be tentatively stated that in the absence of data indicating otherwise, when using percent correct methods, it may be most effective to initially expose percent correct learners to an AR training paradigm for that task before moving to percent correct training methods.

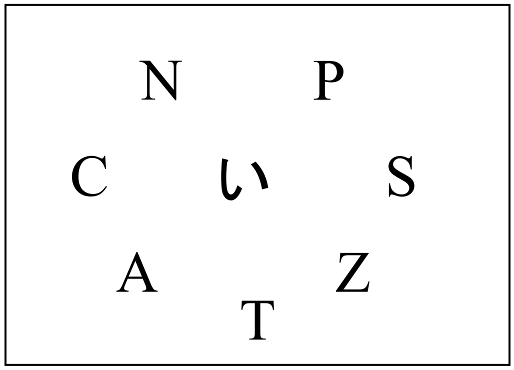


Figure 1. Stimulus arrangement for practice drills in the AR condition and tests for endurance and retention.

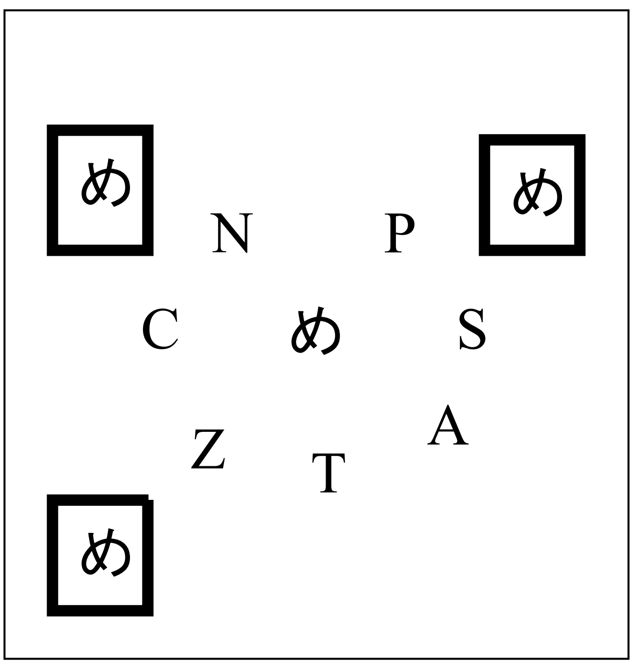


Figure 2. Stimulus arrangement for AOR practice drills.

Figure 3. Stimulus arrangement for application tests.

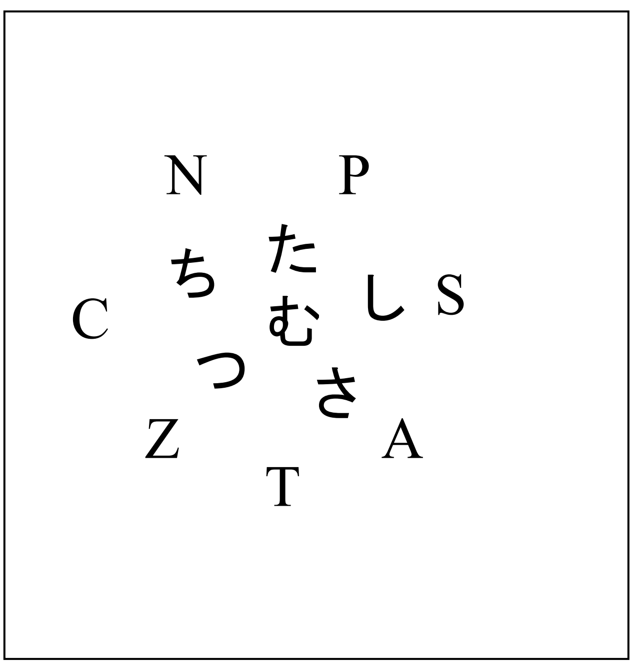


Figure 4. Stimulus arrangement for stability tests.

Set 1

1	2	3	4	5	6	7
い	せ	ふ	お	む	め	き
Z	C	N	P	S	T	A

Set 2

1	2	3	4	5	6	7
そ	ほ	な	ゆ	を	ぬ	こ
D	G	I	J	L	R	V

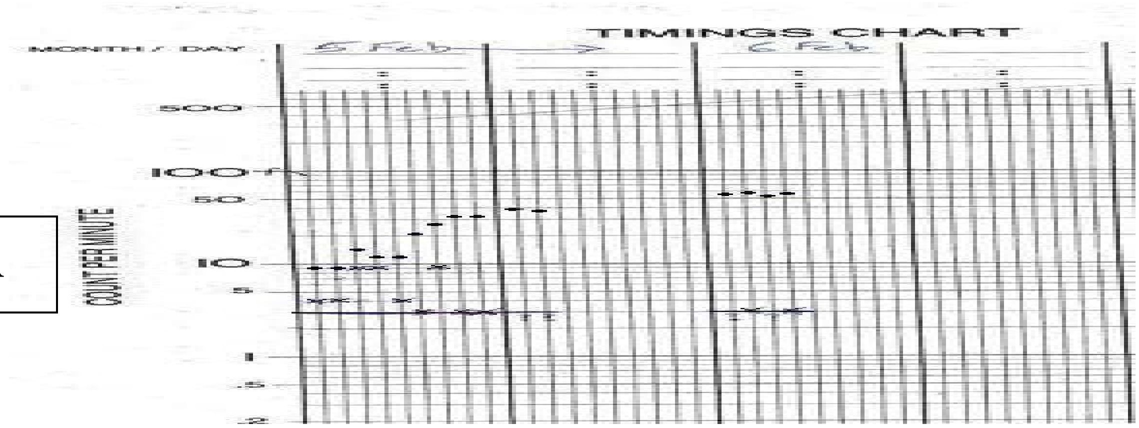
Set 3

1	2	3	4	5	6	7
ね	て	ゑ	や	す	み	は
B	F	K	M	O	Q	W

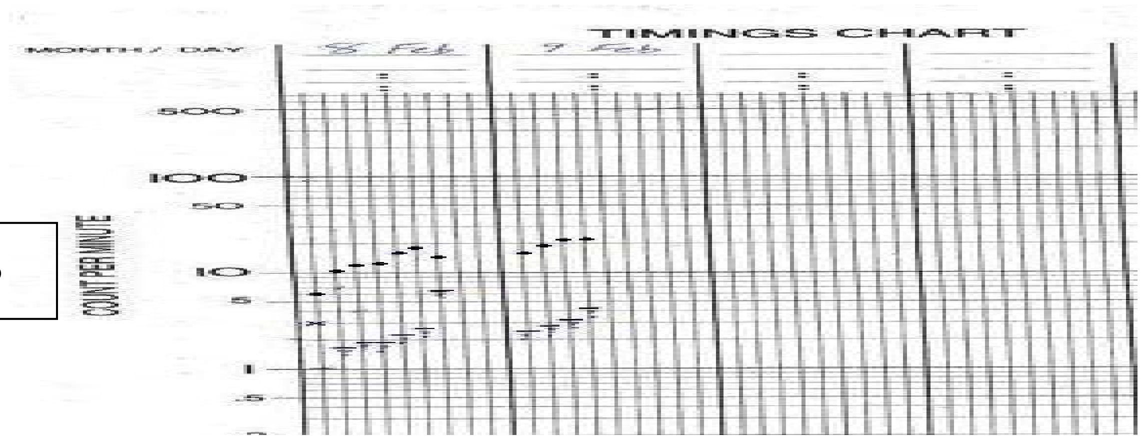
Figure 5. English and Japanese stimuli and pairings by set.

Participant 1 Practice Drill Data

A



B



A′

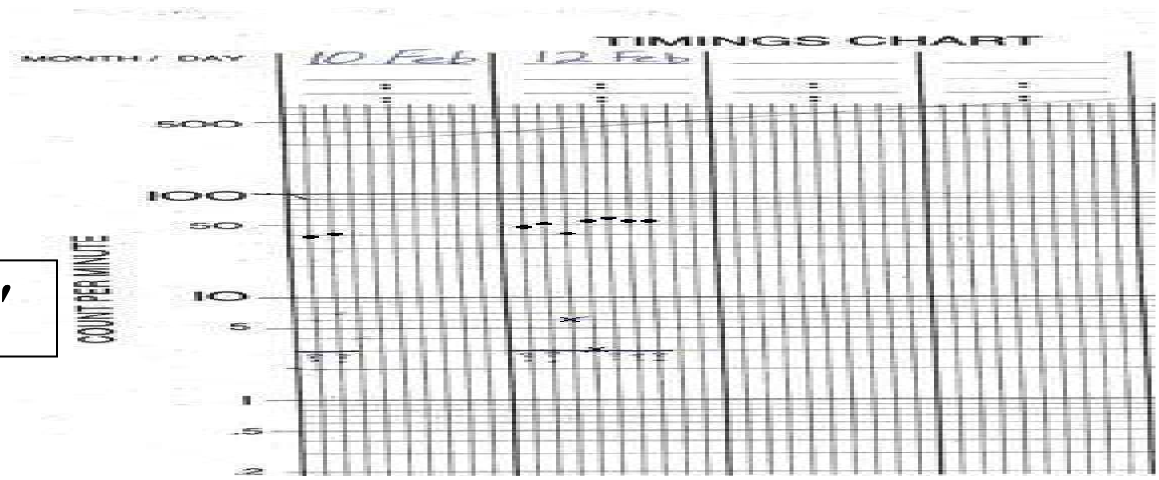


Figure 6. Top – Count/min of correct and incorrect responses for Participant 1 in practice drills during the first AR condition. Middle – Participant 1's count/min of correct and incorrect responses during practice drills in the yoked AOR condition. Bottom – Participant 1's count/min of correct and incorrect responses in practice drills during the second AR condition. (AR = accuracy+rate; AOR = accuracy+observing response)

Participant 2 Practice Drill Data

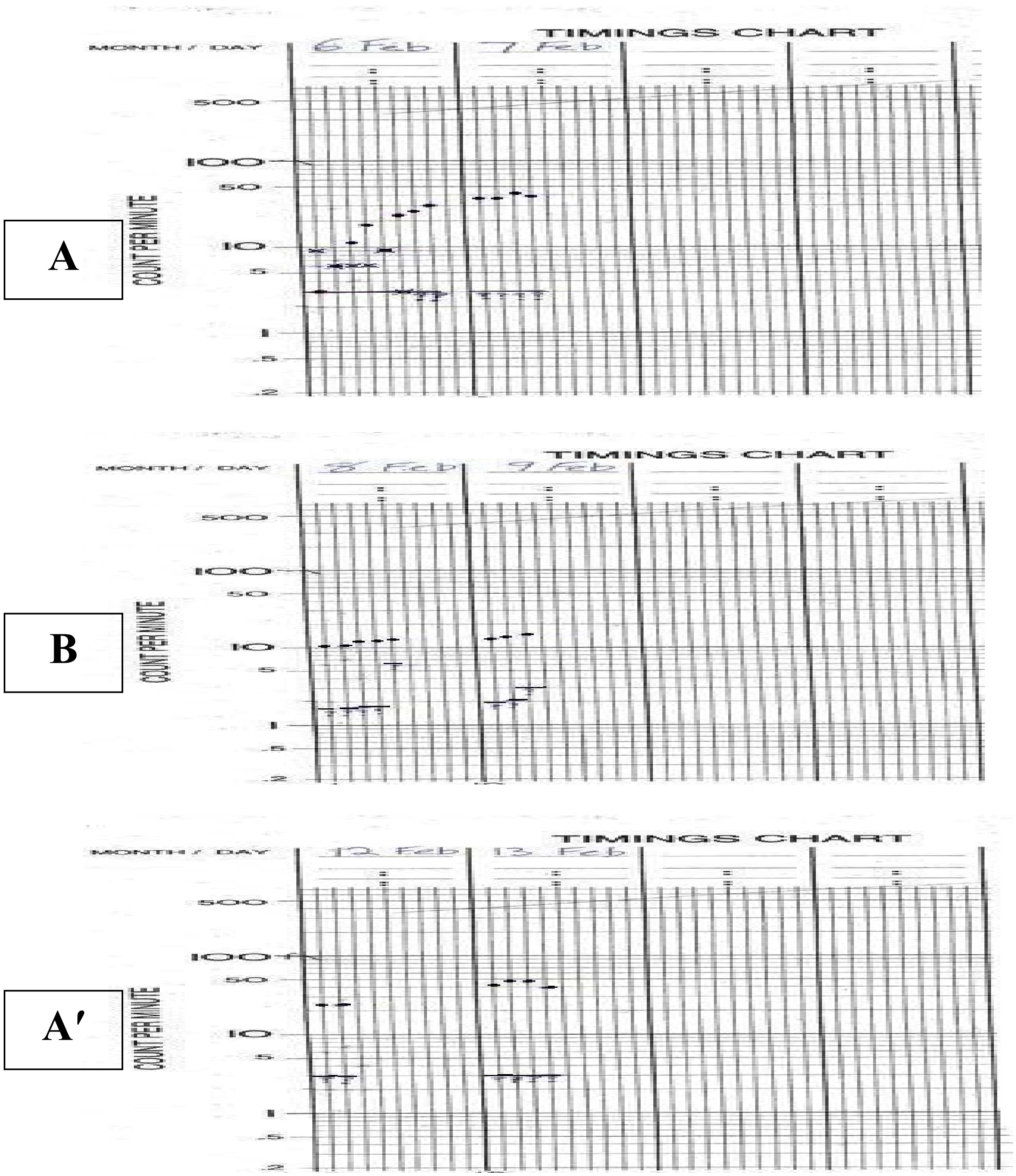
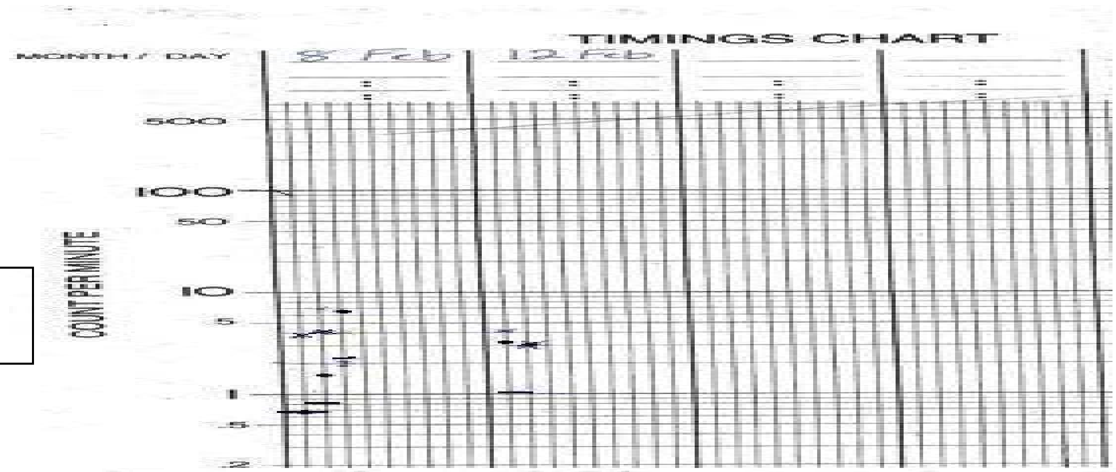


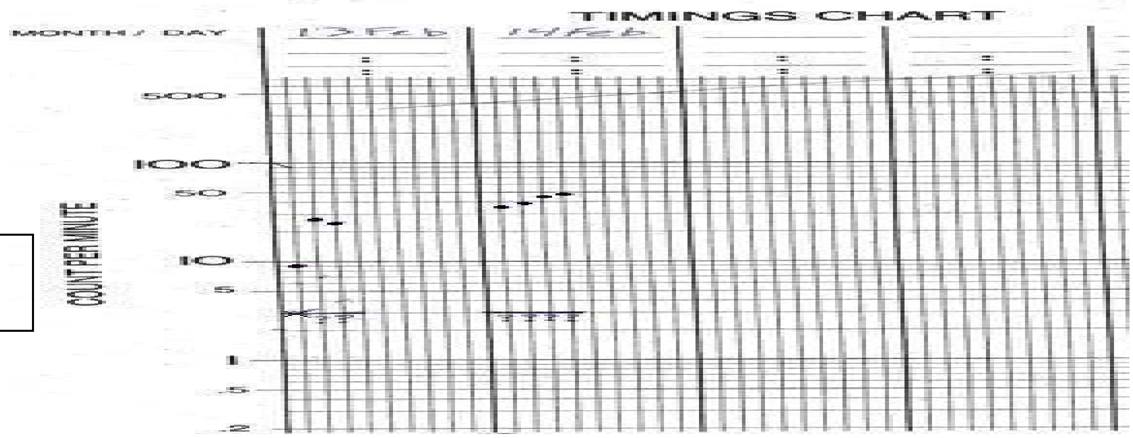
Figure 7. Top – Count/min of correct and incorrect responses in practice drills for Participant 2 during the first AR condition. Middle – Participant 2’s count/min of correct and incorrect responses during practice drills in the yoked AOR condition. Bottom – Participant 2’s count/min of correct and incorrect responses in practice drills during the second AR condition. (AR = accuracy+rate; AOR = accuracy+observing response)

Participant 3 Practice Drill Data

B



A



B′

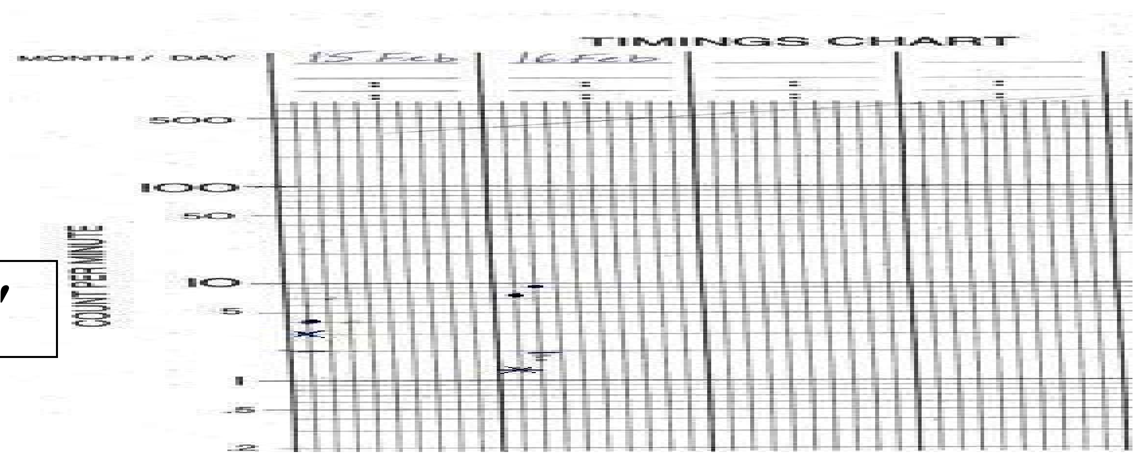


Figure 8. Top – Participant 3's per-minute rate of correct and incorrect responses during Practice drills in the initial AOR condition. Middle – Participant 3's per-minute rate of correct and incorrect responses in practice drills during the accuracy-only condition. Bottom – Participant 3's rate/min of correct and incorrect responses in practice drills during the second AOR condition. (AOR = accuracy+observing response)

Participant 4 Practice Drill Data

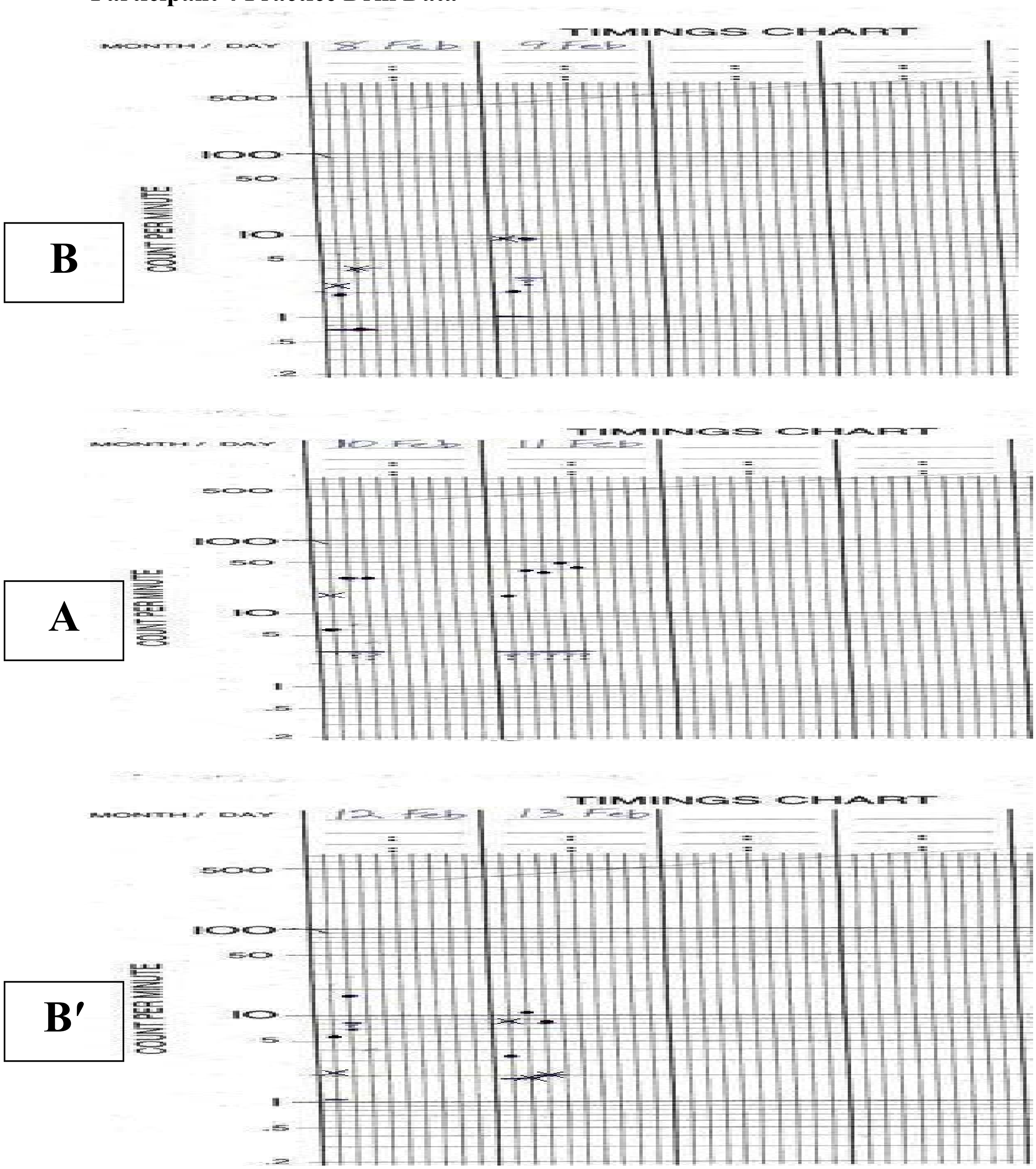


Figure 9. Top – Participant 4's per-minute rate of correct and incorrect responses during Practice drills in the initial AOR condition. Middle – Participant 4's per-minute rate of correct and incorrect responses in practice drills during the AR condition. Bottom – Participant 4's rate/min of correct and incorrect responses in practice drills during the second AOR condition. (AR = accuracy+rate; AOR = accuracy+observing response)

Participant 1 Test Performance

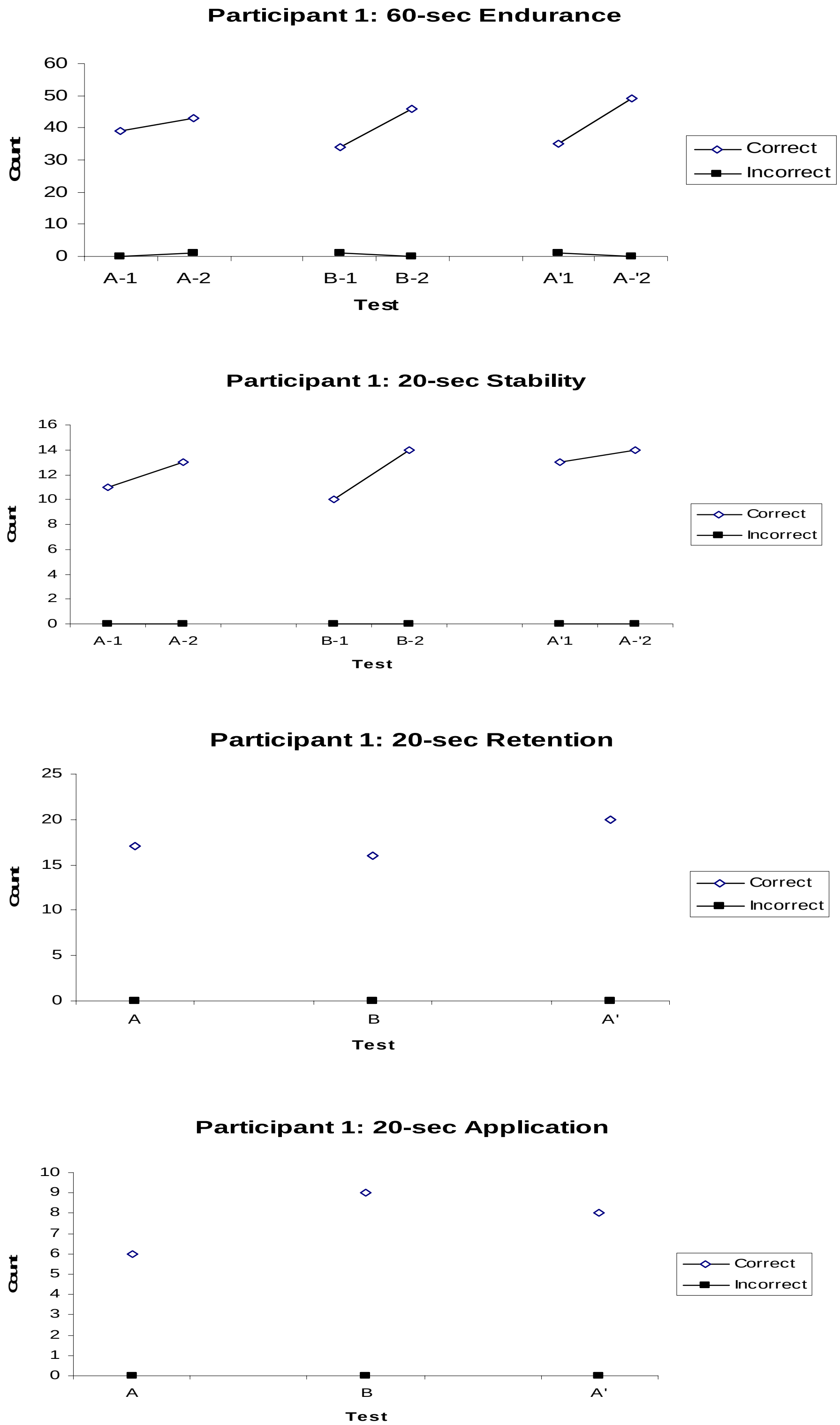


Figure 10. Participant 1's number of correct and incorrect responses during endurance, stability, application, and retention tests for all three conditions.

Participant 2 Test Performance

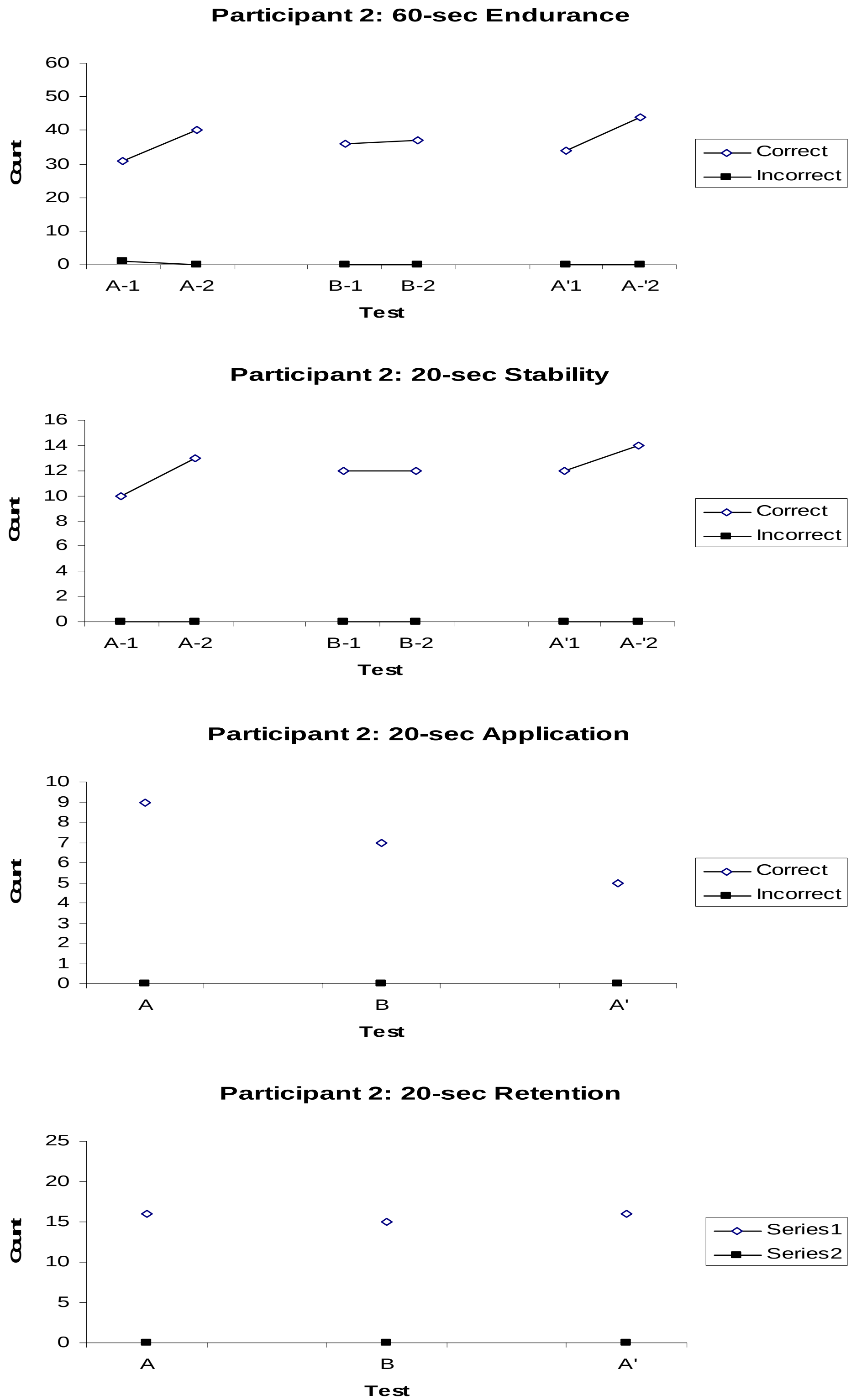


Figure 11. Participant 2's number of correct and incorrect responses during endurance, stability, application, and retention tests for all three conditions.

Participant 3 Test Performance

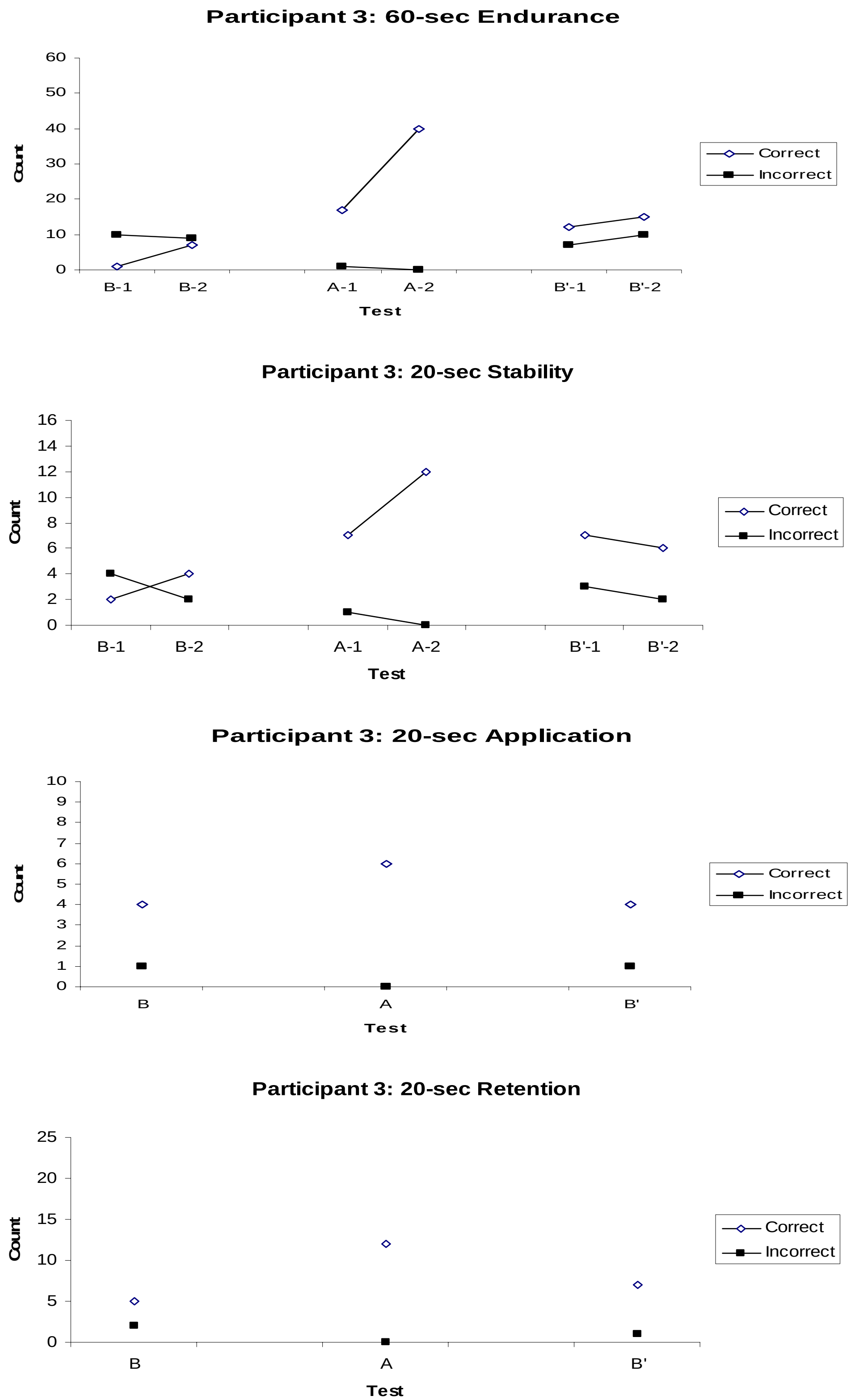


Figure 12. Participant 3's number of correct and incorrect responses during endurance, stability, application, and retention tests for all three conditions.

Participant 4 Test Performance

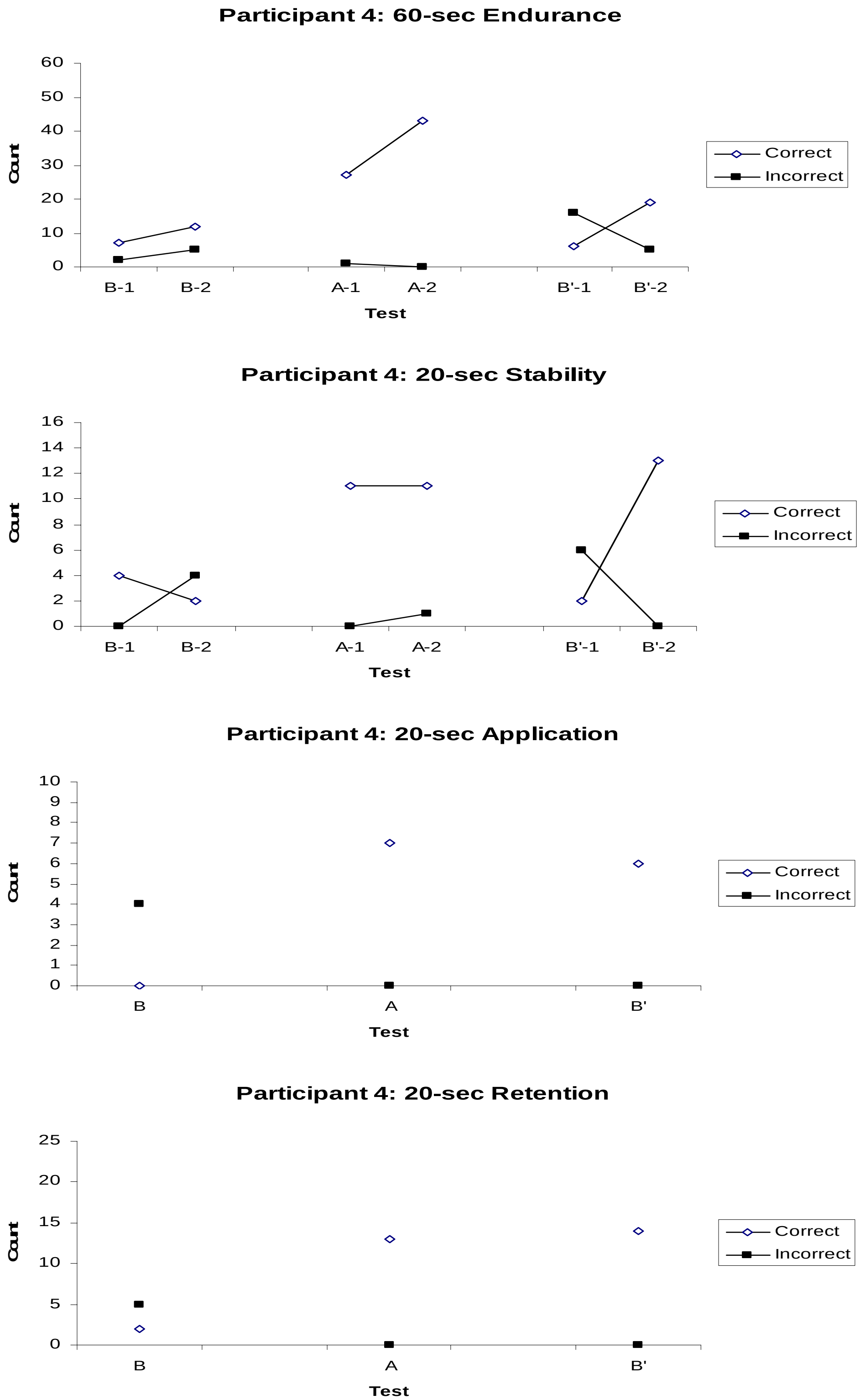


Figure 13. Participant 4's number of correct and incorrect responses during endurance, stability, application, and retention tests for all three conditions.

APPENDIX

POST-EXPERIMENT QUESTIONNAIRE

Post Experiment Questions Subject #:______

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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