# THE EFFECTS OF "ERRORLESS" TRAINING AND TESTING ON THE PERFORMANCES OF TYPICALLY DEVELOPING CHILDREN DURING ACQUISITION AND RETENTION

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This study examines the effects of two teaching procedures and two testing procedures (“Skip” and “Guess”) on acquisition, retention and generalization of learning. Three typically developing females between the ages of 8 and 11 learned the 24 lower case letters of the Greek alphabet. Half of the letters were taught with the “Skip” procedure and the other half with the “Guess” procedure. The “Skip” procedure produced faster and more efficient learning than the “Guess” procedure. The “Skip” procedure also resulted in better initial retention (4 weeks), but this effect disappeared in subsequent retention tests. The training conditions did not have differential effects on generalization tests across learning channels, except for the Free/Say channel.

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# CHAPTER 1

## INTRODUCTION

For several decades, behavior analysts have been interested in the potential benefits of learning without errors. Training procedures designed to minimize errors became popular in the late fifties and early sixties when B. F. Skinner introduced programmed instruction (see Rilling, 1977). Skinner (1968) argued that errors were unnecessary for learning to occur. According to him, optimal learning is accomplished by maximizing the success of the learner. He pointed out that a high density of reinforcement increases motivation and facilitates learning while error responses are frequently accompanied with aversive consequences and generate escape behavior, avoidance, inaction and emotional responses that interfere with learning.

While behavior analysts have mostly been concerned with errors during acquisition (see Etzel, 1997; Goldiamond, 1966; Lancioni & Smeets, 1986; Rilling, 1977; Sidman & Stoddard, 1966; Terrace, 1963a, 1963b, 1966), recent literature indicates that errors may also have an undesirable effect on retention. This was noted first by Holland and Porter (1961) in a study that evaluated the effectiveness of a teaching-machine program. Their results suggest that retention is correlated with error rates: the greater the error rate, the poorer the retention. They concluded that eliminating errors not only helps retention, but also saves time that would have been spent correcting errors.

Recent studies in the field of cognitive neuropsychology and rehabilitation also indicate that errors may affect the acquisition and retention of knowledge by patients with memory impairments. For example, Hayman, Macdonald and Tulving (1993) evaluated the effects of

repeated learning trials and error responses on the acquisition and retention of words corresponding to definitions or descriptions. The participant was a patient with amnesia, and the experimental task was to supply a target word given a definition of the word (e.g. "a talkative featherbrain – PARAKEET"). The target words were randomly assigned to one of several conditions involving a combination of three variables: 1) error or no error during a pre-test, 2) error or no error during testing (answer provided or instructions to guess), and 3) presentation frequency (once or twice during a session). During the pre-test, errors were generated by instructing the participant to guess, and prevented by asking him not to guess. Errors during training were generated by giving the opportunity to guess, and were prevented by presenting the target word along with the definition. The results showed that the participant's performance on immediate and delayed tests depended on the conditions under which he learned the target words. During 3-day and 7-day retention tests, the participant produced 84% of the target words in conditions where guessing was prevented. However, when he was instructed to guess during pre-test and training, the participant's performance was only 29% correct. Delayed retention tests given 14 and 30 months later showed that retention was still better for learning conditions that minimized errors (46% vs. 17% and 29% vs. 4%).

Baddeley and Wilson (Baddeley & Wilson, 1994; Wilson, Baddeley, Evans & Shiel, 1994) found similar results. They compared "errorless" and "errorful" teaching procedures with three groups of subjects. The experimental group consisted of patients with amnesia, and the other two groups consisted of healthy control subjects (young and older). The participants learned two lists of words, one with each teaching method. In the "errorful" condition, participants were given the following instructions: "I'm thinking of a five letter word beginning with TR. Can you guess what the word might be?" Participants were allowed to guess the word up to four times before

hearing the correct answer and writing it on a piece of paper. Guessing was prevented in the "errorless" condition by the following instruction: "I'm thinking of a five letter word beginning with ST and the word is STORY. Please write that down." At the end of the training phase, participants were tested in nine test trials as follows: "One of the words you wrote down began with TR. Can you remember what the word was?" The investigators found that all 16 amnesic patients did better when prevented from guessing, with group performance ranging from 25-60% correct in the "errorful" condition, and 52-82% correct in the "errorless" condition.

Other research studies, using similar experimental tasks, have also shown the superiority of training procedures that minimize errors. For example, Hunkin, Squires, Parkin and Tidy (1998) replicated Baddeley and Wilson's (1994) study with patients suffering from various types of memory-impairments. The results indicated that group performance on immediate and delayed tests was significantly better following the "errorless" procedure, and that free recall was also better for those items. Similarly, O'Carroll, Rusell, Lawrie and Johnstone (1999) used a stem completion task (e.g. five letter word beginning with BR-BRING) to evaluate the effects of errors on a group of memory-impaired schizophrenic patients, and found that the "errorless" teaching procedure resulted in a significantly better outcome on post-tests. Finally, Squires, Hunkin and Parkin (1997) compared "errorless" and "errorful" teaching procedures in a study on associated words tasks with memory-impaired patients. Participants learned 20 pairs of remotely associated words (e.g. SALAD-COLD). Results indicated that "errorless" procedures provided better performance on immediate tests, but no overall difference was found between performance on delayed tests and during relearning. In the second part of the experiment, the authors used novel associations (unrelated word pairs) and found that "errorless learning" procedures

produced better performance on immediate tests, delayed tests, and across relearning (Squires, Hunkin & Parkin, 1997).

Participants in the studies discussed so far were taught to provide target words given other words or word-parts. However, "errorless" teaching procedures have also been extended to applied tasks, relevant to everyday life of memory impaired patients. Wilson, Baddeley, Evans and Shiel (1994) conducted a series of single subject experiments, comparing "errorful" and "errorless" procedures. Tasks included learning names, learning how to program an electronic aid, and learning new items of general knowledge. In each case, results showed that learning with few errors was superior to learning with many errors. Similarly, Clare, Wilson, Carter, Breen, Gosses and Hodges (2000) taught patients with dementia of Alzheimer type to name people and use memory aids, by means of individually tailored teaching procedures that minimize errors. Five out of six participants showed dramatic improvement and maintained the benefits up to six months. Parkin, Hunkin and Squires (1998) used "errorless" procedures to teach names of famous people and friends to a man with brain injuries. The participant was instructed not to guess during tests at the end of each session. The results showed that the participant successfully learned 80% of the names with minimal errors and retained the information across five weeks. Lastly, Squires, Hunkin and Parkin (1996) compared the benefits of "errorless" and "errorful" procedures when teaching a 60-year-old stroke victim to use a memory notebook. The participant was instructed to guess the correct answer for items assigned to the "errorful" condition. In contrast, correct answers were provided at the outset in the "errorless" condition. The results reliably showed that more items were recalled from the "errorless" condition during immediate tests, and delayed tests conducted 24 hours, one week and 10 weeks later.

Data from the research studies reviewed above indicate that errors interfere with acquisition and retention of information in various populations of memory impaired patients. These results have prompted experts in the field of rehabilitation and cognitive neuropsychology to reevaluate some general and well-established rehabilitation practices. Based on data from these studies, researchers have recommended that guessing should be eliminated, and errors minimized to the extent possible (see Baddeley & Wilson, 1994; Hayman, Macdonald & Tulving, 1993; Wilson, Baddeley, Evans & Shiel, 1994). This point was made very clear by O'Carroll, Russell, Lawrie, & Johnstone (1999):

> It is ironic that in traditional rehabilitation approaches "effortful" approaches have generally been advocated…adopting the traditional approach is extremely unhelpful, as making errors during learning leads to confusion during retrieval. (p. 111).

It has been suggested that results from studies on memory impaired patients might apply to other populations such as elderly, children with dyslexia, or patients with language disorders, and even healthy subjects (Baddeley & Wilson, 1994; Wilson, Baddeley, Evans & Shiel, 1994). Data from healthy control subjects suggest that errors might also interfere with their learning and retention. For instance, the results of Baddeley and Wilson's (1994) study showed that 10 of 16 elderly control subjects, and 11 of 16 young controls did better when prevented from guessing. The average scores of the young group ranged between 82-100% in the "errorful" condition, and between 97-100% in the "errorless" condition. The average scores of the older control group were 60-93% in the "errorful" condition, and 78-95% in the "errorless condition." Thus, both control groups performed better when errors were minimized, but the difference between the conditions was small. This is probably because accuracy of the control groups was close to

ceiling. Interestingly, the type of errors displayed by the healthy control subjects were similar to those displayed by amnesic patients.

Similarly, in the study by O'Carroll, Rusell, Lawrie and Johnstone (1999), healthy- control subjects made 82-100% correct responses in the "errorful" condition, and 94-100% correct in the "errorless" condition. Schizophrenic control subjects without memory impairments scored between 84-97% in the "errorful" condition, and 92-100% in the "errorless" condition. Again, it is difficult to account for these differences because group performances were close to ceiling.

Finally, although Hayman, Macdonald and Tulving (1993) reported that healthy control subjects were not affected by errors generated during training, other researchers have pointed out that their control data does show an effect under the most difficult learning conditions (see Hunkin, Squires, Parkin & Tidy, 1998). The control group made 72% correct responses on immediate tests when errors were generated during training, and 83% correct when errors were prevented.

The question of whether the interfering effects of errors are restricted to populations of memory-impaired patients is an important one. Current research suggests that the phenomenon is also seen in populations without memory impairments, but their effects are small and require further investigation.

In the studies above, all the researchers have been concerned with errors during training. However, data from Hayman, Macdonald & Tulving (1993) suggest that errors during testing can also be detrimental. Except for the pre-test procedures of Hayman et al. (1993), there are no specific procedures to prevent errors during testing. In their study, participants were instructed to guess if they could think of a word that fit the definition, but not to guess if a word didn't come to mind. Thus, the participant had the option to guess, be silent, or somehow indicate that he did

not know the answer. Apparently, saying nothing, or giving a fixed answer (e.g. “I don’t know”) when subjects don’t know a particular answer, does not affect the acquisition and retention the same way as making a guess**.** The addition of such a response would be advantageous for research and teaching purposes since it would allow researchers and teachers to conduct tests before, during, and after acquisition without affecting responding (i.e. without producing errors).

The purpose of this study was to examine whether errors, generated during training and testing, interfere with acquisition and retention of the Greek letter names in typically developing children.

# CHAPTER 2

# METHOD

## Participants

Three typically developing females of Hispanic ethnicity volunteered to participate in this study. The participants were between the ages of 8 and 11 years, and attended a neighborhood after-school program for Hispanic children living in low-income housing. They attended regular classrooms, spoke English as a second language, and were considered to be good students by their tutors. The children selected for participation did not know the lower case letters of the Greek alphabet. The experimenter made an agreement with the participants, allowing each one of them to select a prize after completing the acquisition phase of the study. The participants' legal guardians signed a consent form (Appendix A). Originally, six participants were selected to participate in the study, but three of them did not finish due to poor attendance to the after-school program.

## Settings

The study was conducted in the neighborhood after-school program facility. Each session took place in one of two rooms available for the study. Both rooms were furnished with chairs and tables. The experimenter sat at one side of the table and the participant sat across from her.

## Materials

Stimuli consisted of the 24 lower case letters of the Greek alphabet (Appendix B). Each letter was printed with black ink on a white background and attached to a blue 4" X 6" flashcard. Each card had a Greek letter on the front and the printed letter name on the back (Appendix C).

The stimuli were divided into two sets of 12 letters. The sets were equated for length of letter names, and for the similarity of the Greek letters to the letters of the Roman alphabet. A sheet of paper with the word "SKIP" on one side and the word "GUESS" on the other side was used in all sessions during the acquisition phase. The sheet either showed the word "SKIP" or the word "GUESS", depending upon the experimental condition. The sheet was placed on the table facing the participant.

Pre-training materials consisted of 24 blue 4" X 6" flashcards, showing black computer drawings on a white background. The drawings were prepared by the experimenter. Twelve drawings were unambiguous pictures of known objects such as a house, a cat and a car. The remaining twelve drawings were ambiguous and did not look identical to any known objects (Appendix C).

Other materials included sheets for data collection (Appendix D), a timer, a voice recorder, and a sharp pencil.

Measurements

Dependent variables. The dependent variables in this study were the rate of correct responses, incorrect responses, "skip" responses, and non-responses during acquisition and retention of the study. Another dependent variable was the number of correct responses, incorrect responses, "skip" responses, and non-responses during acquisition, retention and generalization tests. The final dependent variable was the total time spent training and testing each set during the acquisition phase.

A correct verbal response was defined as the participant saying the correct name of the presented letter. An incorrect verbal response was defined as the participant saying a name different from the correct letter name. A "skip" response was defined as saying "skip" upon any

stimulus presentation. A response was counted as a non-response when a participant did not say anything for 5s following the presentation of a letter.

Errors were analyzed in terms of their source as follows: Greek alphabet errors, Roman alphabet errors, correct approximations, incorrect approximations, and other errors. Greek alphabet errors were recorded when a participant said a name of a Greek letter other than the target letter. Greek alphabet errors were further scored as "within set" if the letter name came from the same set of letters, and "between sets" if the letter name came from the other set of letters. Roman alphabet errors were recorded when a participant said a letter name from the Roman alphabet. Correct approximations were scored when a participant said a letter name that had the correct number of syllables, but one syllable sound was incorrect. Incorrect approximations were defined as saying a letter name that approximates a Greek letter other than the target letter. Errors that were neither approximations nor related to the Greek or the Roman alphabet were scored as "other errors."

A correct drawing response was counted when a participant drew all major components of the vocally presented Greek letter. Responses were defined as approximations when the drawings had some but not all of the correct components, if the letters were reversed, or if components were not proportional (i.e. not in correct size, shape or position). Responses were counted as incorrect when a participant drew a letter or a symbol other than the presented letter. Responses were counted as "skips" when no attempts were made to draw a Greek symbol.

A correct marking response was counted when a participant drew a circle around a Greek letter corresponding to the vocally presented letter name. A marking response was counted as incorrect when a participant marked any letter other than the target letter.

Timing procedures. Total duration timings were conducted during all trials of training and testing. Right before timing the experimenter would say "one- two- three- go." The timing started when the participant made the first response, and ended when the last response was completed.

Observer agreement. Data on interobserver agreement were collected for correct responses, incorrect responses, "skip" responses, and non-responses in approximately 25% of sessions in the acquisition phase. Observer agreement data were also collected for all retention tests and generalization tests. Interobserver agreement was calculated by dividing agreements by agreements plus disagreements and multiplying by 100. Interobserver agreement for the acquisition phase ranged from 99-100% for participant 1, 96-100% for participant 2 and 99-100% for participant 3. Agreement for retention tests ranged from 92-100% for all participants. Interobserver agreement for the generalization tests ranged from 91-100% for participant 1, 94-100% for participant 2, and 92-100% for participant 3.

Independent variables. The independent variables in this study were two teaching procedures and two testing procedures: "Skip" and "Guess." These procedures differed in the amount of errors generated during training and testing.

During the "Skip" procedure, participants were presented with the Greek letter and the correct letter name at the same time, and were instructed to repeat the letter name. Thus, the probability of participants emitting correct verbal responses during training was maximized. During tests, participants were instructed to flip through a deck of 12 of cards, name all known letters and say "skip" if the letters were unknown. This was done to minimize the number of errors generated during testing.

During the "Guess" procedure, the participants were instructed to make a guess in every training trial if the letter was unknown. As a result, errors were generated during training. During tests, participants were instructed to flip through the deck of 12 cards, name the known letters and guess if the letter was unknown. This was done to maximize the number of errors generated during testing.

## Design

A multiple-treatment design was used to compare the effects of the two procedures used to teach the Greek letter names. Each participant learned one set of 12 lower case letters with the "Skip" procedure, and the other set of 12 with the "Guess" procedure. The sets were counterbalanced between subjects (see Table 1).

## Procedures

Sessions were conducted in the afternoon Monday through Friday, starting around 4 p.m. The experimenter entered a participant's classroom and asked the student to accompany her to one of the experimental rooms. Sessions lasted for approximately 10 min.

Selection-test. The experimenter presented the 24 lower case letters of the Greek alphabet one at a time in a random order. Participants were instructed to name the Greek letter or say "skip" if it was unfamiliar to them. The experimenter presented each letter, asked "what is this?" and waited for a response. When participant responded, the experimenter immediately presented the next letter.

Pre-training. Pre-training was conducted to gain instructional control and to practice "guess" and "skip" responses in the presence of unknown stimuli. Participants were taught to give the correct answer when presented with drawings of known objects, and to either guess or to say

"skip" in the presence of unknown drawings, depending on the instructional sheet with the written words "SKIP" and "GUESS."

The experimenter presented participants with the unknown picture cards and asked them to select two cards. Then she introduced the instructional sheet with the word "GUESS" printed on one side and "SKIP " on the other side. It was explained that when the "GUESS" side of the sheet was facing up, they would have to guess what was in the picture, but when the "SKIP" side was facing up they would say "skip." The experimenter modeled correct "guess" and "skip" responses.

First, the word "GUESS" was facing up. The participants were instructed to guess what was in the pictures, one card at a time, and to put each card on the table when a guess had been made. Next, the "SKIP" side faced up, and the participants were instructed to "skip" each card. When participants had successfully made both "skip" and "guess" responses with unknown pictures, they were allowed to select one known picture and add to the deck. It was explained that when they knew for sure what was in the picture, they should say what it is, but if they were not sure, they should either guess or say "skip" depending on the word on the instructional sheet. If all responses were correct, the experimenter gave praise and allowed the participant to add a card to the deck. If any errors occurred, the experimenter reviewed the instructions and modeled correct responding. The number of cards with known and unknown pictures was gradually increased until participants could flip through a deck of 12 cards (6 known pictures and 6 unknown pictures), guessing or "skipping" depending on the instruction sheet. The experimenter started timing the participants once they had advanced to 6 pictures in a deck. Pre-training ended when a participant complied with the instructions to "guess" or "skip" 3 times in a row over two consecutive days.

Pre-test. The purpose of the pre-test was to give a baseline of performance using the same test procedures as used in the acquisition and retention phases of the study. The participants were given a deck of cards and instructed to go through it as fast as possible. Participants were instructed to name the letters that they knew and to say "skip" if the letters were unfamiliar. The experimenter said "one-two-three go" and started timing when participants gave the first response. If participants stopped responding for 5s, they were instructed to "go to the next one." The test ended when a participant had flipped through all cards in the set.

Acquisition of Greek letter names. One set of 12 letters was taught using the "Skip" procedure and the other set of 12 was taught using the "Guess" procedure. The sequence of the sets was alternated between sessions. Training in each set consisted of two consecutive training trials followed by a test.

During the "Skip" procedure, the experimenter gave the following instructions: "I will hold up the cards, one at a time, and say the name of the Greek letters. Please repeat after me." Then she said "one-two-three-go" and started timing. Each letter name was presented along with the corresponding Greek symbol, and the participant repeated the letter name. The experimenter praised the participant for correct pronunciation. If the participant mispronounced a letter name, the experimenter would repeat the correct letter name until it was correctly articulated by the participant. The training phase ended when all cards had been presented and correctly named by the participant (see Appendix E). Next, the experimenter randomized the cards and started a second training phase. When all 12 letters had been presented for the second time, the experimenter tested the participant. During testing the participant was given a deck of cards and was instructed to go through it as fast as possible. Participants were instructed to name the letters that they knew and to say "skip" if the letters were unfamiliar. The experimenter said "one-two-

three-go" and started timing as soon as the participant started responding. If participants stopped responding for 5s, they were instructed to "go to the next one." The test ended when a participant had flipped through all cards in the set (see Appendix E).

In the very first session of the guess procedure, training was identical to the "Skip" procedure. In every session after that, participants were instructed to give the correct answer if they knew it, or to make a guess if the letter was unfamiliar. The experimenter gave the following instructions: "I will hold up the cards, one at a time, and you will say the name of the Greek letters. If you don't know the name of the letter you should guess." Then she said "one-two-three-go" and started timing. The experimenter presented each letter in the set and asked, "What is it?" The experimenter gave praise for correct answers as well as guesses, and gave corrective feedback when incorrect guesses were made. If a participant did not give any answer within 5s, she was reminded to "guess." If no answer was given within 5s after that, a non-response was scored and the correct answer was provided. The training trial ended when all letters in the set had been presented (see Appendix E). Next, the experimenter randomized the cards and started another training phase. When all letters had been presented for the second time, the experimenter tested the participant. During testing the participant was given a deck of cards and instructed to go through it as fast as possible. Participants were instructed to name the letters that they knew and to guess if the letters were unfamiliar. The experimenter said "one-two-three-go" and started timing as soon as the participant started responding. If a participant stopped responding for 5s, she would be instructed to "go to the next one." The test ended when the participant had flipped through all cards in the set (see Appendix E).

The acquisition phase ended when a participant correctly named all letters in each set during three consecutive sessions; two sessions of training and testing, and one session with a test only.

Retention test. The retention interval began when both sets of the Greek lower case letters had been mastered. The first retention tests were conducted 4 weeks and 8 weeks after the acquisition phase ended, and a third test was conducted after 11 weeks for participants 2 and 3, and 13 weeks for participant 1. Retention tests were similar to the tests conducted throughout the acquisition phase. The only difference was that participants were now asked to go through each set twice, first "skipping" unknown letters and then guessing unknown letters. This was done to compare the number and types of errors made in each set.

A sheet of paper showing the word "SKIP" was placed on the table in front of the participant. The experimenter gave the participant a shuffled deck of cards and instructed her to go through the cards as fast as possible. The participant was asked to name the known letters and to say "SKIP" if the letters were unfamiliar. The experimenter said "one-two-three-go" and started timing as soon as the participant started responding. If a participant stopped responding for 5s, she was instructed to "go to the next one." The test ended when a participant had flipped through all cards in the set. This was repeated with the other deck of cards. Next a sheet of paper showing the word "GUESS" was placed on the table. The experimenter shuffled the first deck of cards, and again instructed the participant to go through it as fast as possible. The participant was instructed to name the known letters and to make a guess if the letters were unknown. The experimenter said "one-two-three-go" and started timing as soon as the participant started responding. If a participant stopped responding for 5s, she was instructed to "go to the next one."

The test ended when the participant had flipped through all cards in the set. This was repeated with the other deck of cards. Total duration was recorded.

Generalization tests.

On the day following the day of the retention tests, additional tests were conducted to assess generalization of the Greek lower case letters. Tests were conducted in the Free/Say, Hear/Draw and Hear/Mark channels in the following sequence:

1) During the Free/Say, participants were asked to name as many Greek letters as possible without any visual or auditory prompts. The student was told the following instructions: "Please say as many Greek letter names as you can, and I will write them down. Please say stop when you are finished." (See Appendix D for the data sheet). Total duration was recorded.
2) During the Hear/Draw, participants were provided with a sheet with 12 squares on it (Appendix D). They were told the following instructions: "I will say the names of the Greek letters, one at a time. Please listen carefully and draw the letters in the blank squares as well as you can. When you are done drawing a letter, please say "next" and I will say the next letter." The test was repeated with the other set of 12 letters. Total duration was recorded.
3) During Hear/Mark, participants were provided with eight sheets, each containing three frames with 12 letters from the Greek alphabet. The following instructions were given: "I will say the names of 12 Greek letters one at a time. Please listen carefully and mark the letter in the first frame as fast as you can. After you mark a letter, please move your pencil to the next frame, and I will immediately say the next letter. If you don't want to

mark, you can say “skip.” The test was repeated for the other set of 12 Greek letters (see Appendix D). Total duration was recorded.

# CHAPTER 3

# RESULTS

Figures 1, 2 and 3 show the speed and accuracy of responding during the first training trials (top graphs), second training trials (middle graphs), and tests (bottom graphs) of the acquisition phase. The graphs on the left side show performance in the "Skip" condition, while the graphs of the right demonstrate performance in the "Guess" condition. Black data points represent correct responses, open circles represent "skip" responses, and Xs represent error responses. Horizontal lines stand for record floors (i.e. time of training or testing trials), and question marks below the record floors signify that no errors occurred during that timing. Gray lines drawn through data points represent acceleration and deceleration of responding, and their values are shown to the right of the lines. Celeration lines were drawn according to the Trend-Following strategy, in which a new celeration line is drawn any time that the trend changes. Celeration lines were drawn by visually determining the slope and direction of the data path, and drawing a line through the data path that best describes the trend (See Graf & Lindsley, 2002).

Figure 1 shows the frequencies of responses during the acquisition phase for participant 1. In the "Skip" condition, correct responses accelerated at X1.1 per week during the first and second training trials and no errors occurred. During tests, correct responses initially accelerated at X5 and then at X1.1 per week, and "skip" responses decelerated at /2.6. During the first and second training trials of the "Guess" condition, correct responses initially accelerated at X5, and then at X1.1 per week. Errors decelerated at /1.4 in the first training trials, and /1.5 in the second training

trials. During the tests of the “Guess” condition, correct responses first accelerated at X3.5 and then at X1.1 per week. Errors decelerated at /2 per week.

Figure 2 displays the frequencies of responses during the acquisition phase for participant 2. In the “Skip” condition, correct responses accelerated at X1.1 per week during the first and second training trials and no errors occurred. During tests, correct responses initially accelerated at X6 and then at X1.3 per week, and “skip” responses decelerated at /2.2 per week. During the first training trials of the “Guess” condition, correct responses initially accelerated at X2, and then at X1.4 per week, and errors decelerated at /1.1 per week. In the second training trials, correct responses accelerated at X6 and then at X1.3 per week, and errors decelerated at /1.3 per week. During the tests of the “Guess” condition, correct responses first accelerated at X4.5 and then at X1.3 per week. Errors decelerated at /1.5 per week.

Figure 3 shows the frequencies of responses during the acquisition phase for participant 3. In the “Skip” condition, correct responses accelerated at X1.15 during the first and second training trials and no errors occurred. During tests, correct responses initially accelerated at X2.3 and then at X1.3 per week, and “skip” responses decelerated at /1.5 per week. During the first training trials of the “Guess” condition, correct responses initially accelerated at X2.3, and then at X1.4 per week. Errors initially accelerated at X1.05 and then decelerated at /1.2 per week. In the second training trials, correct responses accelerated at X.2.3 and then at X1.4 per week, and errors decelerated at /1.16 per week. During the tests of the “Guess” condition, correct responses first accelerated at X2 and then at X1.35 per week, and incorrect responses decelerated at /1.3 per week.

Figure 4 shows a frequency distribution of the initial celerations during tests of the acquisition phase for all participants. Data are displayed on a base 10 multiply scale with X1 in

the center. One cycle of multiply factors goes above the X1 line (X10), and 1 cycle of dividing factors goes below the line (/10). Black data points represent correct responses for each participant, open circles are used for "skip" responses, and Xs for incorrect responses. In the "Skip" condition, the median acceleration for correct responses was X5 per week, and the median deceleration for "Skip" responses was /2.2 per week. In the "Guess" condition, the median acceleration for correct responses was X3.5 per week and the median deceleration for error responses was /1.5 per week.

Figure 5 shows the frequency distribution of correct responding during the last test in the "Skip" and "Guess" conditions of the acquisition phase for all participants. No errors or "skip" responses occurred during these tests since both sets were trained to 100% accuracy. The median frequencies of correct responding were 60 per min during the "Skip" and 60 per min during the "Guess" condition.

Tables 2, 3 and 4 show the total number of correct responses, "skip" responses, non-responses and errors in each condition during training and testing of the acquisition phase. The tables also include an error analysis, showing the types of errors made by the students. Table 2 shows that participant 1 made a total of 672 responses in each condition. In the "Skip condition" she made 618 correct responses, 49 "skip" responses and 5 incorrect responses. Errors during the "Skip" condition consisted of 2 Roman alphabet errors and 3 Greek alphabet errors. In the "Guess" condition, she made 454 correct responses, 12 "skip" responses and 206 errors. Errors during the "Guess" condition consisted of 187 Roman alphabet errors, 16 Greek alphabet errors and 3 other errors.

Table 3 shows that participant 2 made a total of 1,044 responses in each condition. In the "Skip condition" she made 947 correct responses, 93 "skip" responses and 4 incorrect responses.

All errors in the “Skip” condition were Greek alphabet errors. In the “Guess” condition, she made 743 correct responses, 12 “skip” responses and 289 errors. Errors during the “Guess” condition consisted of 172 Roman alphabet errors, 92 Greek alphabet errors, 17 correct approximations, 7 incorrect approximations, and 1 “other” error.

Table 4 shows that participant 3 made a total of 960 responses in each condition. In the “Skip” condition she made 858 correct responses, 93 “skip” responses and 9 incorrect responses. All errors during the “Skip” condition were Greek alphabet errors. In the “Guess” condition, she made 681 correct responses, 12 “skip” responses and 264 errors. Errors in the “Guess” condition were 148 Roman alphabet errors, 112 Greek alphabet errors, 1 incorrect approximation and 3 “other” errors.

Figure 6 shows the results from timed training and testing trials during acquisition. Participant 1 reached mastery after 20 training sessions. The total time of all training trials was 22 min in the “Skip” condition, and 23 min in the “Guess” condition. The total time of all tests was 4 min 54 s in the “Skip” condition and 5 min 36 s in the “Guess” condition. Participant 2 reached mastery after 31 training sessions. The total time of all training trials was 29 min 36 s in the “Skip” condition, and 35 min 36s in the “Guess” condition. The total time of all tests was 6 min 54 in the “Skip” condition and 8 min 18 s in the “Guess” condition. Participant 3 reached mastery after 28 training sessions. The total time of all training trials was 29 min 6 s in the “Skip” condition, and 39 min 36 s in the “Guess” condition. The total time of all tests was 9 min 30 s in the “Skip” condition and 12 min 12 s in the “Guess” condition.

Figure 7 shows a frequency distribution of the results from the retention tests for the “Skip” condition (top graph) and the “Guess” condition (bottom graph) for all participants. Each graph consists of six boxes, displaying data from the three retention tests under two different test

conditions (skip and guess). The effects on retention were determined by comparing the last correct, incorrect, and "skip "frequencies from the test conditions of the acquisition phase, to the frequency of corrects, "skips" and incorrect responses in the retention test. To calculate the effect, the higher frequency was divided by the lower frequency. When retention frequencies were higher than the comparison frequencies, the data points were placed above the X1 line and a multiply sign was used. When retention frequencies were lower, the data points were placed below the X1 line.

During the first retention tests (4 weeks) for the "Skip" condition, the median change was /1.51 for correct responses, X1 for incorrect responses, and X1 for "skip" responses in the skip test. In the guess test, the median change was X1.06 for correct responses, and X1 for incorrect responses. For the "Guess" condition, the median change was /1.36 for correct responses, X2.31 for incorrect responses, and X4 for "skip" responses in the skip test. In the guess test, the median change was /1.45 for correct responses, and X6 for incorrect responses.

During the second retention tests (8 weeks) for the "Skip" condition, the median change was /1.98 for correct responses, X4.29 for incorrect responses, and X1 for "skip" responses in the skip test. In the guess test, the median change was /1.80 for correct responses, and X4.29 for incorrect responses. For the "Guess" condition, the median change was /2.11 for correct responses, X1 for incorrect responses, and X6.67 for "skip" responses in the skip test. In the Guess test, the median change was /1.55 for correct responses, and X3.53 for incorrect responses.

During the third retention tests (11/13 weeks) for the "Skip" condition, the median change was /1.57 for correct responses, X1 for incorrect responses, and X4.62 for "skip" responses in the skip test. In the guess test, the median change was /0.52 for correct responses,

and X7.5 for incorrect responses. For the “Guess” condition, the median change was /1.63 for correct responses, X1 for incorrect responses, and X6 for “skip” responses in the skip test. In the guess test, the median change was /1.69 for correct responses, and X4 for incorrect responses.

Table 5 is an analysis of responses during acquisition and during retention tests for participant 1 (top tables), 2 (middle tables), and 3 (bottom tables). The tables on the left side display performance for the set learned in the “Skip” condition, while the tables on the right show performance for the set learned in the “Guess” condition. Both conditions show the number of “skip” responses, non-responses and incorrect responses during acquisition, and an error analysis for the retention tests. Results for participant 1 show that during the first retention tests, she made 1 error and 3 “skip” responses in the “Skip” set and 1 error and 1 “skip” response in the “Guess” set. During the second tests, she made 2 errors and 4 “skip” responses in the “Skip” set, and 1 error and 3 “skip” responses in the “Guess” set. During the third retention test, she made 3 errors and 3 “skip” responses in the “skip” set, and 1 error and 2 “skip” responses in the “Guess” set. During retention tests, all errors except for one were Roman alphabet errors. Participant 1 was more likely to forget letters with higher number of “skip” responses during acquisition (e.g. stimuli # 3, 6 and 9 in the “Skip” condition), and higher number of errors during acquisition (e.g. stimulus #6 in the “Guess” condition).

Results for participant 2 show that during the first retention tests, she made 0 errors and 0 “skip” responses in the “Skip” set, and 6 errors and 1 “skip” response in the “Guess” set. During the second tests, she made 1 error and 0 “skip” responses in the “Skip” set, and 2 errors and 3 “skip” responses in the “Guess” set. During the third retention test, she made 3 errors and 1 “skip” response in the “skip” set, and 3 errors and 4 “skip” responses in the “Guess” set. During retention tests, all errors except for one were Greek alphabet errors. The number of “skip”

responses during acquisition was not associated with accuracy during retention tests, but participant 2 was more likely to forget letters with higher number of errors during acquisition (e.g. stimuli # 2, 3, 6 and 10 in the "Guess" condition).

Results for participant 3 show that during the first retention tests, she made 1 error and 0 "skip" responses in the "Skip" set, and 3 errors and 0 "skip" response in the "Guess" set. During the second tests, she made 4 errors and 0 "skip" responses in the "Skip" set, and 5 errors and 1 "skip" responses in the "Guess" set. During the third retention test, she made 0 errors and 0 "skip" response in the "skip" set, and 4 errors and 0 "skip" responses in the "Guess" set. During retention tests, all errors in the "Skip" set and the "Guess" set were Greek alphabet errors. The number of "skip" responses during acquisition is not associated with accuracy during retention tests, but participant 3 was more likely to forget letters with higher number of errors during acquisition (e.g. stimuli # 3, 6 and 10 in the "Guess" condition).

Figure 8 shows the relations between "skip" responses (top graph) and errors (bottom graph) during acquisition, and errors during retention tests. The graphs indicate that there is no overall correlation between "skip" responses during acquisition and errors during retention (except for participant 1), but a strong relation between errors during acquisition and errors during retention tests.

Table 6 shows the letter names recalled during the Free/Say generalization tests for participant 1 (top), 2 (middle), and 3 (bottom). From the set of letters learned in the "Skip" condition, participant 1 recalled 5 letters in the first retention test, 5 in the second test, and 2 in the third test. Only two letter names were consistently remembered throughout the testing. From the "Guess" set, she recalled 6 letters in the first test, 5 in the second test, and 7 in the third test. Three letters were consistently remembered. From the "Skip" set, participant 2 recalled 8 letters

in the first test, 4 in the second test, and 4 in the third test. Only two letter names were consistently remembered throughout the testing. From the "Guess" set, she recalled 9 letters, 8 letters, and 7 letters respectively. Six letter names were consistently remembered. From the "Skip" set, participant 3 recalled 8 letters in the first test, 4 in the second test, and 10 in the third test. Four letters were consistently remembered throughout the testing. From the "Guess" set, she recalled 5 letters, 7 letters, and 6 letters respectively. Five letter names were consistently remembered.

The bar graphs in Figure 9 show the number of correct responses during all generalization tests for each participant at 4 weeks (top), 8 weeks (middle), and 11/13 weeks (bottom). The results show no systematic differences in generalization. Overall, performance was best in the Hear/Mark channel and poorest the Hear/Draw channel, regardless of the condition.

# CHAPTER 4

# DISCUSSION

The results show that more errors were produced during acquisition when participants were instructed to guess than when they were prevented from guessing. This led to faster acquisition of the material learned with the "Skip" procedure than the material learned with the "Guess" procedure. With respect to retention, the "Skip" procedure produced better performance during the first retention tests, as measured by both the speed and accuracy of performance, but these differences disappeared by the third retention tests. The rate of errors and "skip" responses for the skip set increased to frequencies similar to the guess set. In terms of the number of errors made during the first retention tests, the "Skip" condition generated fewer errors for participants 2 and 3, and participant 1 made an equal number of errors in each condition. Subsequent tests increased the number of errors for the skip set for all participants, although participant 3 made no errors on the third test. No such trend was seen for the guess set. Overall, the higher the number of errors made on a particular letter during acquisition, the more likely that the letter would be answered incorrectly during the retention tests. Such a correlation was not found for the number of "skip" responses during acquisition, except for participant 1. The training conditions did not have any differential effect on generalization tests across learning channels, except for the Free/Say test, which produced better performances for the guess set.

The results of this study are consistent with other research (e.g. Baddeley & Wilson, 1994; Hayman, Macdonald & Tulving, 1993; Squires, Hunkin & Parkin, 1997) showing that participants learn better, and are more likely to retain material when errors generated by guessing

are prevented. With respect to acquisition, previous research demonstrated that patients with memory impairments learned more items when errors were prevented, but training was completed after a fixed number of trials was reached rather than using an accuracy criterion. The present research shows that acquisition is also better when errors are prevented, in situations where all stimuli are trained to 100% accuracy and similar fluency levels. In this study, initial celerations of correct responses were consistently faster for the "Skip" condition than the "Guess" condition, and "skip" responses decelerated faster than errors. Also, learning in the "Skip" condition was more efficient than learning in the "Guess" condition, as training and testing for all three participants took less time when guessing was prevented.

With respect to retention, the results are not as dramatic as the ones found for participants with memory impairments, but are similar to the ones found with healthy participants (e.g. Baddeley & Wilson, 1994; O'Carroll, Rusell, Lawrie and Johnstone, 1999). When both the speed and accuracy of performance are taken into account, the "Skip" condition shows better performances during the first retention tests. However, the results of the second and third retention tests showed no overall difference in performances between the learning conditions. It is unclear why these differences disappeared with repeated testing. One possible reason could be that each stimulus set was tested under both conditions (skip and guess). Thus, it might be that the skip set was affected by errors generated in the guess tests during retention. In future studies, it would be interesting to keep test conditions the same throughout all retention tests. Another possible reason why performances became similar is that the generalization tests, conducted after each retention test, might have influenced the retention performances of the original task. The Hear/Mark test is especially likely to influence retention because the student can learn through

exclusion. This could be prevented by assessing generalization after all retention tests are finished.

The differences in accuracy-only results seemed less clear than the differences in accuracy-and-speed results. In general, all participants remembered the stimuli quite well, and usually remembered between 9-12 letters. This is similar to the results found with healthy control participants in previous studies (e.g. Baddeley & Wilson, 1994; O'Carroll, Rusell, Lawrie and Johnstone, 1999). Part of the reason why these results seem small is that an accuracy-only measure makes it difficult to evaluate the results because of the ceiling effects encountered with healthy control subjects. That is, there are fewer errors to evaluate the effects. This suggests that in order to fully see the effects of guessing, a greater number of items and more complex material (e.g. Squires, Hunkin & Parkin, 1997) should be used. Also, longer retention intervals may be required. The differences in results between the speed-and-accuracy and accuracy-only may be because the accuracy-and-speed does not impose a ceiling on performance. It has been shown that accuracy measures that include time are more sensitive than accuracy alone. For example, Binder (2003) collected data on various skills from groups of normal adults with graduate degrees, children, and students with brain damage and genetic defects. He found that accuracy alone could not distinguish between the skill levels of these groups, but time-based measurement revealed very clear differences.

One way to get around the ceiling effects is to analyze responses to individual stimuli independently of overall accuracy, and see if forgotten items are correlated with more errors during acquisition. The results of this study show that this is the case; invariably the items with the highest errors were forgotten. Of the nine items that were named incorrectly more than once during retention tests, eight had 40 or more errors during acquisition. In contrast, letters with the

highest numbers of "skip" responses were not more likely to be forgotten, except in the case of participant 1. However, this analysis is incomplete because the number of errors is confounded with the number of times that the correct responses were reinforced. That is, the items with the highest errors were learnt last, and therefore the correct responses to these items were reinforced less. Thus, it might be that the number of errors is not the relevant variable that affects retention. Further research should control for the number of correct responses that are reinforced.

The results for participant 1 were somewhat different from the other two participants. It is not clear why this happened. It might be because the assignment of stimulus sets to the "Guess" and the "Skip" condition was different for this participant. However, participant 1 behaved differently from the other two subjects. This participant had a consistent response from the Roman alphabet for almost all letters in the "Guess" condition, and her Greek alphabet errors were minimal. Thus, it cannot be said that she was guessing during the "Guess" condition, rather she was responding consistently with letter names learned for the Roman alphabet. Another difference between participant 1 and the other participants was that training and testing during the "Guess" condition did not take much longer than training and testing in the "Skip" condition. In contrast, training and testing in the "Guess" condition took considerably longer for participants 2 and 3. These variables may have been relevant for the retention performances of participant 1. It is also possible that other variables during the retention interval or at the time of testing were in effect (see, Ebbinghaus, 1964; Palmer, 1991; Wheeler, 1995).

An interesting effect is that the See/Say and Free/Say tests did not produce the same results. More letters from the guess set were remembered during the Free/Say tests. However, it did not even seem that the responses on both tests were under the control of the Greek letters. During the Free/Say task, participants often recalled sequences of letters that rhyme or sound

similar (e.g. Nu and Mu, or Omega and Omicron). This suggests that in the absence of the Greek letters, auditory aspects of the task and verbal chains are more relevant. Although, the Free/Say and the See/Say tests might be considered somewhat similar tests of retention (e.g., free recall and cued recall), they measured different things in this case.

The addition of the "skip" response was a useful procedure for the error prevention condition. It allowed for the administration of a pre-test and made it possible to continuously track the course of acquisition without the interfering effects produced by guessing. Thus, it insures that the experimenters only include items that the participant does not know before training, and makes it possible to train the stimulus materials to any mastery criterion before going into the retention phase. In addition, teaching a "skip" response can reveal stimulus control that is not obvious when using the guessing procedure. That is, it can be used to distinguish between stimuli that evoke particular responses (e.g. saying PSY in the presence of the letter PHI), and stimuli that are not associated with any particular responses (saying SKIP). In addition, teaching students to "skip" may prevent emotional responses produced by errors. However, it is important to keep in mind that the "skip" response needs to be carefully taught during pre-training, using both known and unknown stimulus items.

Overall, the data suggest that the unfavorable effects of guessing are not necessarily restricted to populations of patients with memory impairments and brain injuries, although they may be less obvious. The results of this study show that teaching procedures which generate errors, can affect learning and retention in typically developing children. Thus, in general it can be said that retention is not only affected by interfering variables occurring after learning, but also by variables related to the teaching procedures (Hayman, Macdonald & Tulving, 1993). This calls for further inspection of general education procedures that promote guessing. One example

is the method of Invented Spelling, which originates from the developmental view and involves instructing children to think about sounds and invent their own spellings of words (see Chomsky, 1976; Rhea, 1976; Gettinger, 1993; Ivernizzi, Abourzeid, & Gill, 1994). Despite very limited research on the effectiveness of Invented Spelling, this approach has been increasingly popular in many schools (Gettinger, 1993). It may be that such teaching procedures also affect retention, but additional research is needed to further examine this possibility. In any case, even if Invented Spelling and other education procedures that promote guessing prove not to be detrimental to retention in typically developing children, instructional time could be spent more efficiently by preventing errors.

# APPENDIX A

# CONSENT FORMS

Estimados padres de _____

Mi nombre es Iris Arnadottir. Soy una estudiante en el Departamento de Análisis de la Conducta en la Universidad del Norte de Texas. Soy una voluntaria que trabaja en el programa "Después de la Escuela" de los departamentos de la comunidad Phoenix. Esta carta es para solicitar su ayuda con mi tesis de Maestría.

Su hijo(a) ha sido seleccionado para participar en mi estudio. Me gustaría obtener su permiso para que su hijo(a) pudiera participar en mi estudio. Mi estudio esta interesado en estudiar el efecto de dos métodos de enseñanza en la retención del material estudiado. En ninguna forma su hijo va estar expuesto a situaciones que pudieran ser molestas a su hijo. Los beneficios incluyen el conocimiento de material académico avanzado (el alfabeto Griego). Si usted permite la participación de su hijo(a), la participación consistirá en aproximadamente 15 minutos de trabajo individual conmigo de Lunes a Viernes. Después de que su hijo(a) aprenda el material. Voy a ser tres pruebas durante el semestre para evaluar la retención del material aprendido.

La participación de su hijo(a) es voluntaria. Usted o el pueden interrumpir la participación en cualquier punto del estudio. Sin embargo, es importante de que su hijo(a) atienda a todas las sesiones. Toda la información con respecto a la participación de su hijo se mantendrá confidencial. Sin embargo, los resultados de este estudio pueden proveer información que pueda mejorar la enseflanza de otros niños. Por lo cual también solicitamos permiso de presentar los datos. En caso dado, ningún dato que pueda identificar as hijo sera presentado en publico. Gracias por su tiempo y cooperación. Si usted tiene alguna pregunta, por favor llame a mi asesor Jesús Rosales-Ruiz en el Departamento de Análisis de la Conducta al (940) 565-2559. Por favor firme para dar su consentimiento.

Yo, _____doy permiso de que mi hijo(a)

_____ participe en este estudio. Fecha: _____

Dear Parents of _____

My name is Iris Arnadottir and I am a graduate student in the Department of Behavior Analysis at the University of North Texas. I volunteer at the Phoenix After-School Program and will be conducting my Masters project there.

Your child has been selected to participate in my study, and I am asking your permission for your child's participation. My study involves evaluating the effects of two teaching strategies on learning and retention. Your child will not be exposed to any harm during her participation. The benefits of participation include learning advanced academic material (the Greek Alphabet). If you allow for your child's participation, I will be working individually with your child for approximately 15 minutes every day Monday through Friday. After that, I will be conducting retention tests three times this semester. The participation of your child is voluntary and she may withdraw from this study at any time. However, it is important that your child attends all sessions.

All information will be strictly confidential. However, the results of this study may provide information that will benefit other students in the future. For this reason, I also ask for your permission to present the data to professional communities. In any event, your child cannot be identified by any data shown. Thank you for your time and cooperation. If you have any questions, please contact my advisor, Dr. Jesús Rosales-Ruiz at the Department of Behavior Analysis at (940) 565-2559. Please sign and date below to give consent for you child's participation.

I _____give permission for my child

_____to participate in this study. Date_____

# APPENDIX B

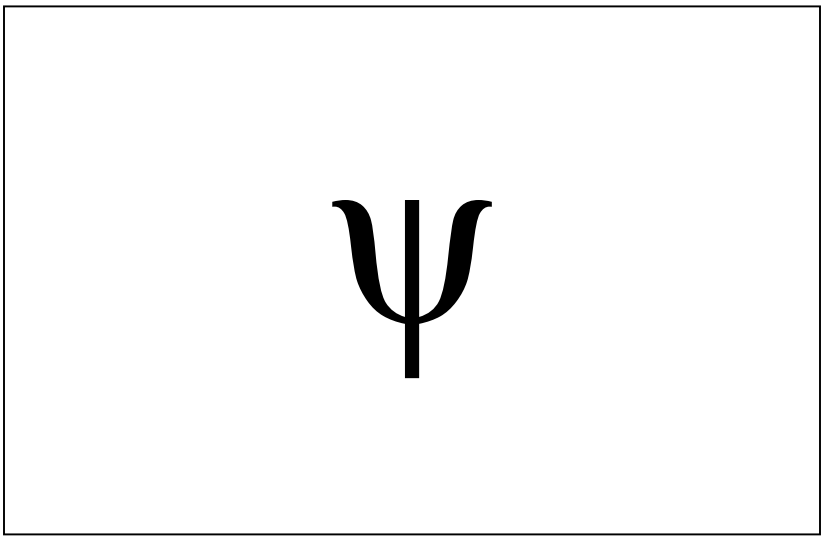
# STIMULUS SETS

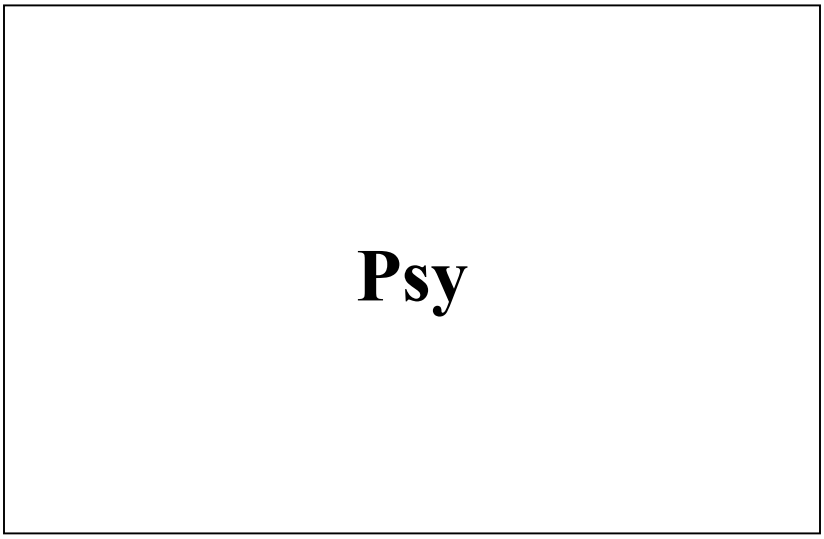
| Set A | | Set B | |
|---|---|---|---|
| **Symbol** | **Name** | **Symbol** | **Name** |
| μ | Mu | ν | Nu |
| ξ | Xi | π | Pi |
| ψ | Psi | η | Eta |
| τ | Tau | ρ | Rho |
| ι | lota | ζ | Zeta |
| ϕ | P'hi | χ | K'hi |
| β | Beta | δ | Delta |
| α | Alpha | κ | Kappa |
| γ | Gamma | ω | Omega |
| θ | Theta | σ | Sigma |
| λ | Lambda | ε | Epsilon |
| υ | Upsilon | ο | Omikron |
| Letters: | **49** | Letters: | **51** |
| Syllables: | **20** | Syllables: | **23** |

# APPENDIX C

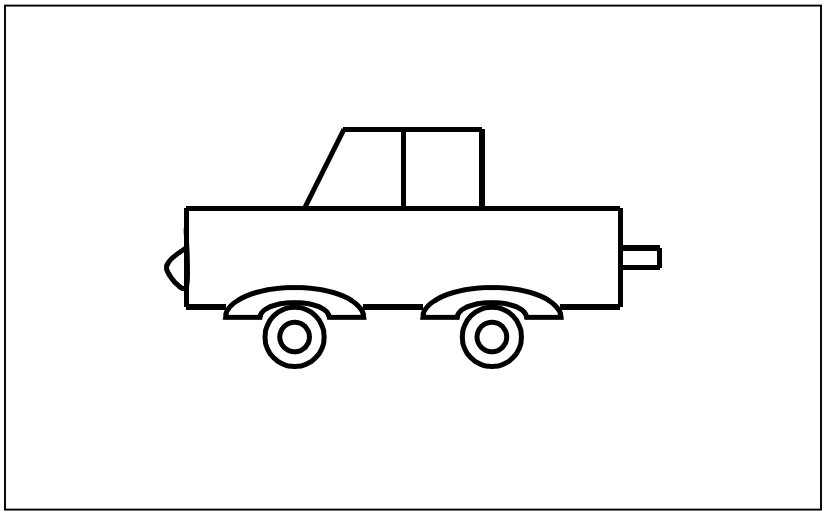
# SAMPLE TRAINING CARDS

SAMPLE TRAINING CARD

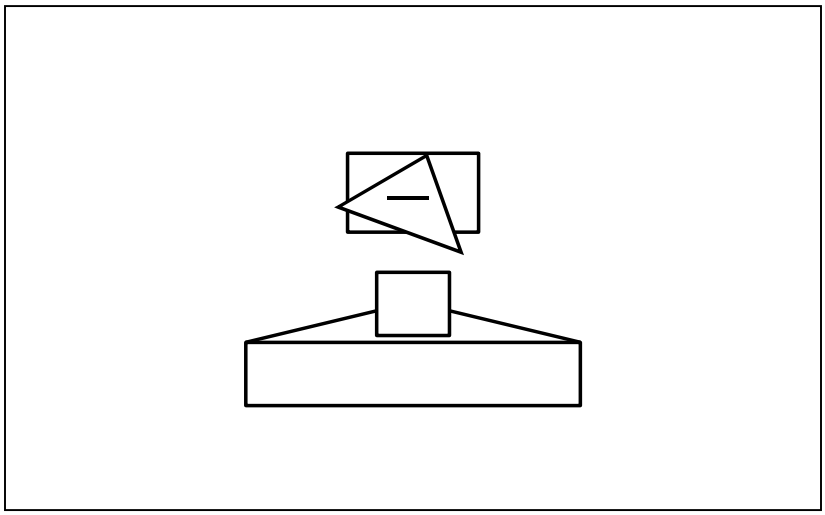


SAMPLE PRE-TRAINING CARD (unambiguous)



SAMPLE PRE-TRAINING CARD (ambiguous)



# APPENDIX D

# DATASHEETS

# Pre-Training Datasheet

**Name:**_____ **Age:**_____

| # of pictures in deck | # known | # unknown | Date | GUESS (+ / -) | Duration (s) | SKIP (+ / -) | Duration (s) |
|---|---|---|---|---|---|---|---|
| 2 | 0 | 2 | | | | | |
| 3 | 1 | 2 | | | | | |
| 4 | 2 | 2 | | | | | |
| 5 | 2 | 3 | | | | | |
| 6 | 3 | 3 | | | | | |
| 7 | 3 | 4 | | | | | |
| 8 | 3 | 5 | | | | | |
| 9 | 4 | 5 | | | | | |
| 10 | 5 | 5 | | | | | |
| 11 | 5 | 6 | | | | | |
| 12 | 6 | 6 | | | | | |
| 12 | 6 | 6 | | | | | |
| 12 | 6 | 6 | | | | | |

**Notes:**

GUESS: Score + if participant named all known pictures and guessed all unknown pictures

SKIP: Score + if participant named all known pictures and "skipped" all unknow pictures

Duration: Time participants when they advance to a deck of six cards

# Training Datasheet

**Name: _____**

**Date:_____**

**SKIP set#_____**
**GUESS Set#_____**

**Session #: _____**

**Start with set_____ then set_____**

**Skip** ☐ **Guess** ☐

**Set A**

| | | TR1 | | | | TR2 | | | | TE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RND | Ans | +/-/S | Err type | RND | Ans | +/-/S | Err type | RND | Ans | +/-/S | Err type |
| 1 | μ | | | | | | | | | | | | |
| 2 | ξ | | | | | | | | | | | | |
| 3 | ψ | | | | | | | | | | | | |
| 4 | τ | | | | | | | | | | | | |
| 5 | ι | | | | | | | | | | | | |
| 6 | ϕ | | | | | | | | | | | | |
| 7 | β | | | | | | | | | | | | |
| 8 | α | | | | | | | | | | | | |
| 9 | γ | | | | | | | | | | | | |
| 10 | θ | | | | | | | | | | | | |
| 11 | λ | | | | | | | | | | | | |
| 12 | υ | | | | | | | | | | | | |

TOTAL correct:_____ TOTAL correct:_____ TOTAL correct:_____

TOTAL duration:_____ TOTAL duration:_____ TOTAL duration:_____

---

**Skip** ☐ **Guess** ☐

**Set B**

| | | TR1 | | | | TR2 | | | | TE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RND | Ans | +/-/S | Err type | RND | Ans | +/-/S | Err type | RND | Ans | +/-/S | Err type |
| 1 | ν | | | | | | | | | | | | |
| 2 | π | | | | | | | | | | | | |
| 3 | η | | | | | | | | | | | | |
| 4 | ρ | | | | | | | | | | | | |
| 5 | ζ | | | | | | | | | | | | |
| 6 | χ | | | | | | | | | | | | |
| 7 | δ | | | | | | | | | | | | |
| 8 | κ | | | | | | | | | | | | |
| 9 | ω | | | | | | | | | | | | |
| 10 | σ | | | | | | | | | | | | |
| 11 | ε | | | | | | | | | | | | |
| 12 | ο | | | | | | | | | | | | |

TOTAL correct:_____ TOTAL correct:_____ TOTAL correct:_____

TOTAL duration:_____ TOTAL duration:_____ TOTAL duration:_____

---

RND: number of card in the randomized sequence
Ans: student's answer
+/-/S: correct / incorrect / incorrect

Err type: error analysis
TR 1: training one
TR 2: training two

TE: testing

# Generalization test: Free/Say

**Name: _____** **Date: _____**

| **Letter Names:** | **Set:** |
|---|---|
| 1 _____ | _____ |
| 2 _____ | _____ |
| 3 _____ | _____ |
| 4 _____ | _____ |
| 5 _____ | _____ |
| 6 _____ | _____ |
| 7 _____ | _____ |
| 8 _____ | _____ |
| 9 _____ | _____ |
| 10_____ | _____ |
| 11_____ | _____ |
| 12_____ | _____ |
| 13_____ | _____ |
| 14_____ | _____ |
| 15_____ | _____ |
| 16_____ | _____ |
| 17_____ | _____ |
| 18_____ | _____ |
| 19_____ | _____ |
| 20_____ | _____ |
| 21_____ | _____ |
| 22_____ | _____ |
| 23_____ | _____ |
| 24_____ | _____ |

**Total Correct:_____** **Total duration: _____**

**Total Incorrect: _____**

# Generalization test: Hear/Draw

**Name: _____** **Set: A B**

**Date: _____** **Total Duration: _____**

| | | | |
|---|---|---|---|
| **1** | **2** | **3** | **4** |
| **5** | **6** | **7** | **8** |
| **9** | **10** | **11** | **12** |

**Correct:_____** **Approximations:_____**

**Incorrect: _____**

**Skips: _____**

# Generalization test: Hear/Mark (A)

Hear/Mark
Set A

| | | | |
|---|---|---|---|
| μ | ξ | β | α |
| ψ | τ | γ | θ |
| ι | ϕ | λ | υ |
| ψ | γ | ι | λ |
| ξ | β | α | ϕ |
| θ | υ | τ | μ |
| λ | β | ξ | ι |
| γ | ψ | υ | μ |
| α | τ | θ | ϕ |

# Generalization test: Hear/Mark (B)

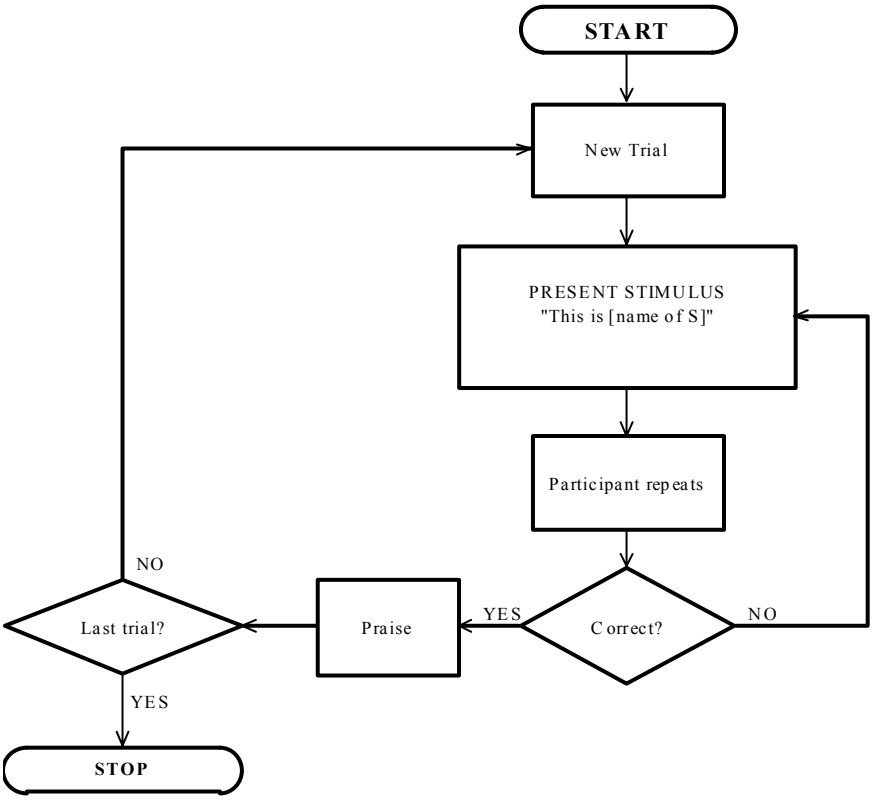
Hear/Mark
Set B

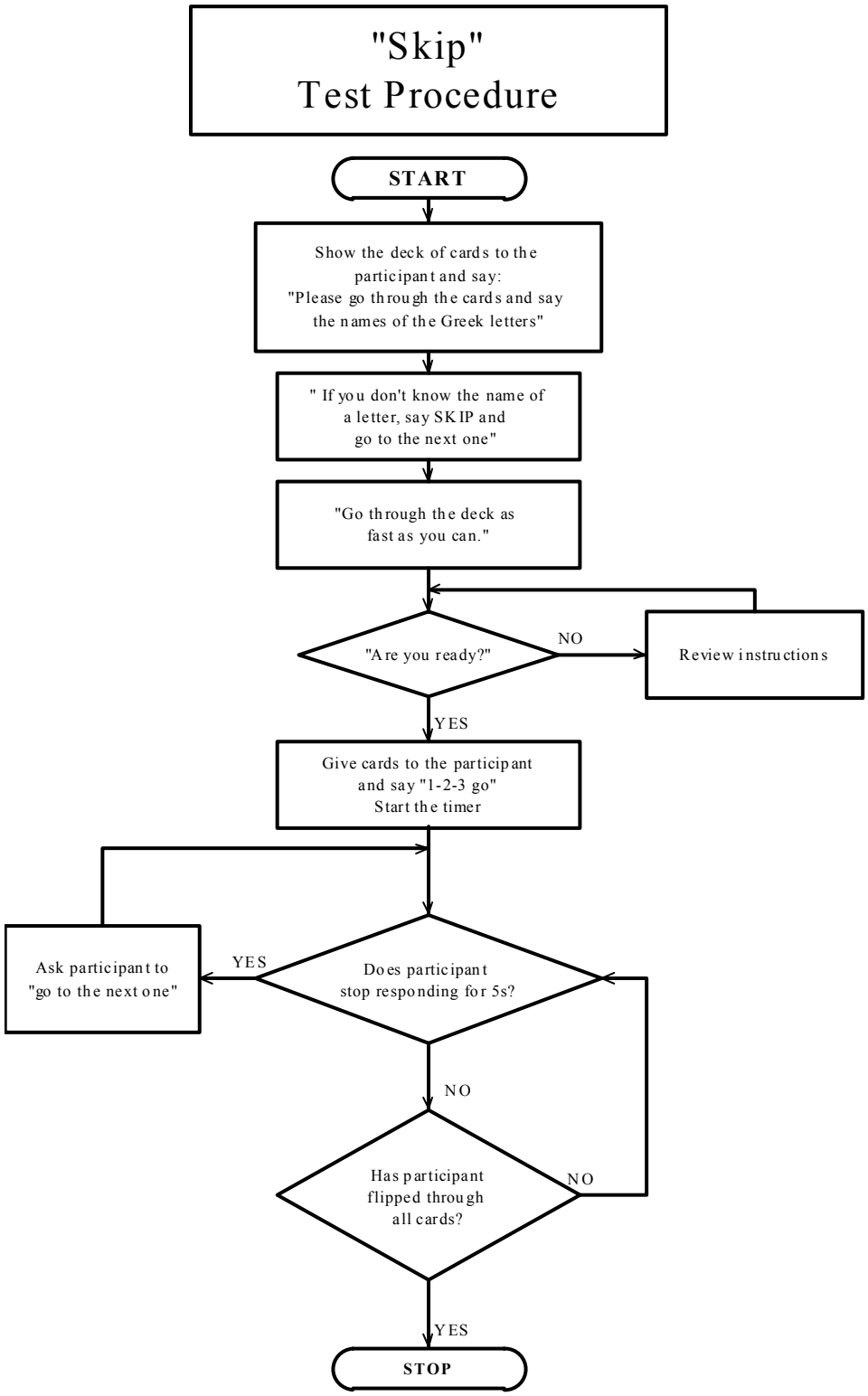
| | | | |
|---|---|---|---|
| ν | π | δ | κ |
| η | ρ | ω | σ |
| ζ | χ | ε | ο |
| η | ω | ζ | χ |
| ο | ν | ρ | κ |
| π | ε | δ | σ |
| ο | ε | σ | η |
| π | ζ | χ | δ |
| ρ | ω | ν | κ |

# APPENDIX E

# FLOWCHARTS OF PROCEDURES

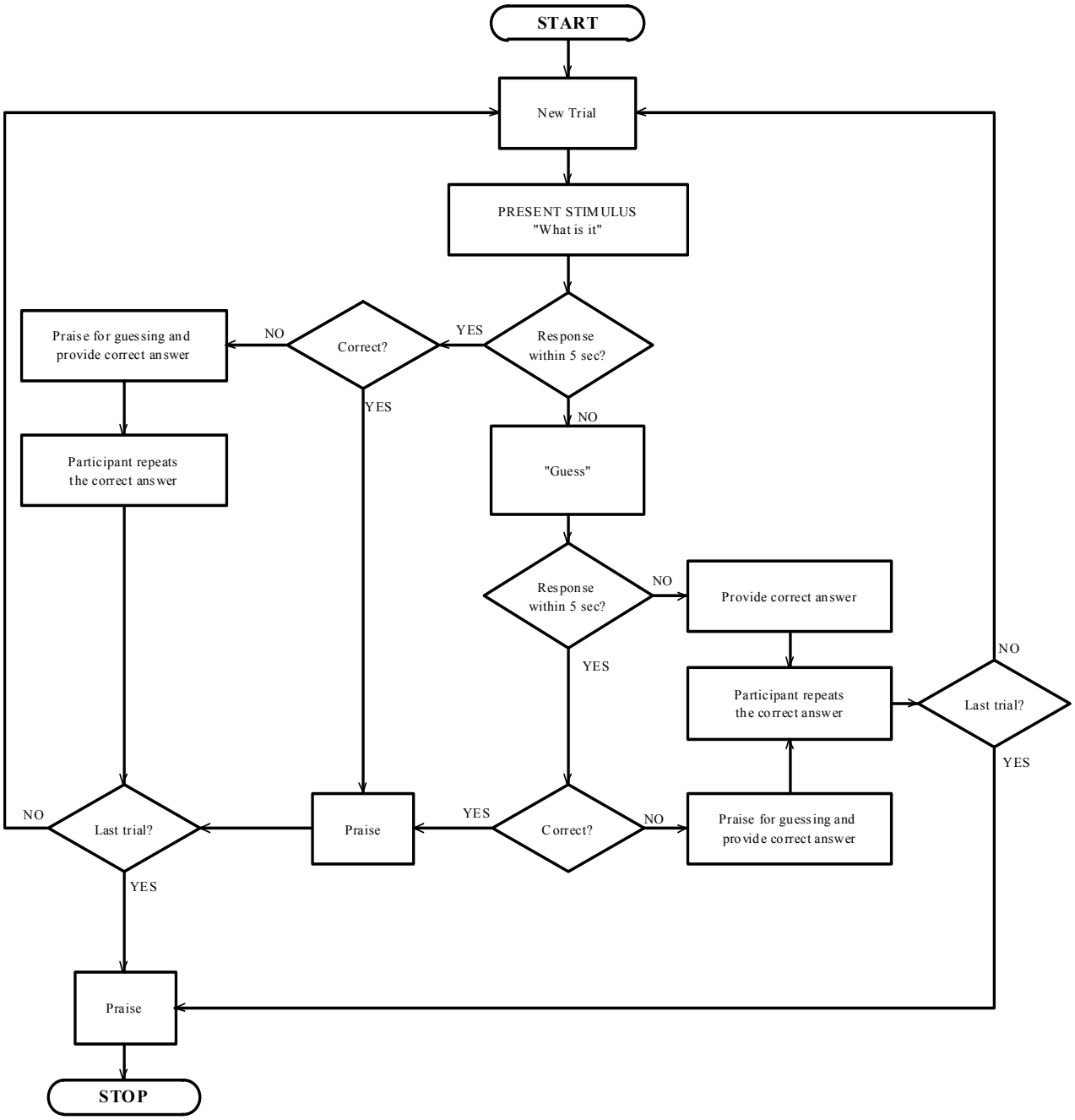
"Skip"
Training Procedure




"Skip"
Test Procedure
START
Show the deck of cards to the participant and say: "Please go through the cards and say the names of the Greek letters"
" If you don't know the name of a letter, say SKIP and go to the next one"
"Go through the deck as fast as you can."
"Are you ready?"
NO
Review instructions
YES
Give cards to the participant and say "1-2-3 go" Start the timer
Ask participant to "go to the next one"
YES
Does participant stop responding for 5s?
NO
Has participant flipped through all cards?
NO
YES
STOP

# "Guess" Training Procedure

First session: model correct answers like in training procedure 1.



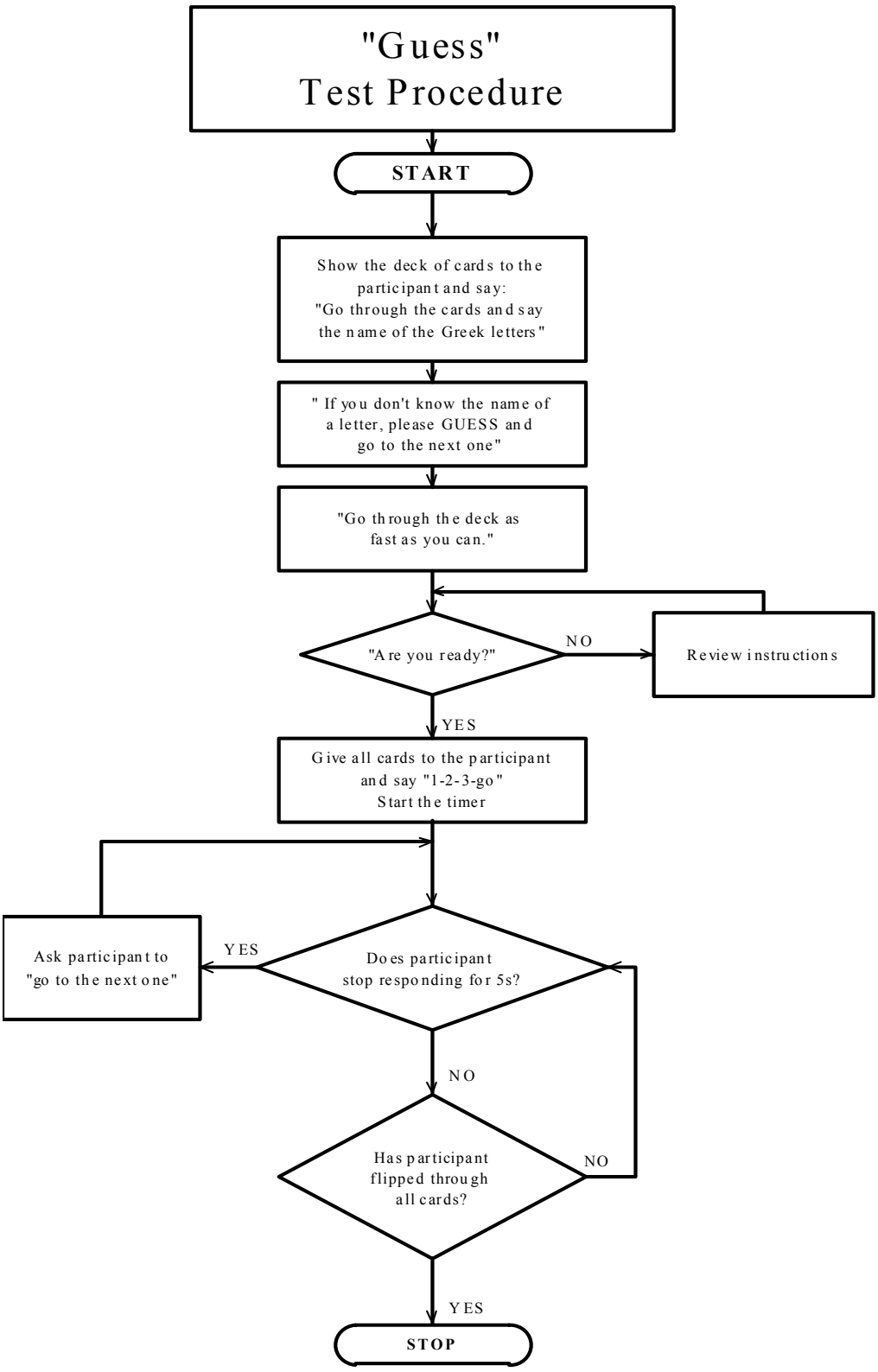

"Guess"
Test Procedure
START
Show the deck of cards to the participant and say: "Go through the cards and say the name of the Greek letters"
" If you don't know the name of a letter, please GUESS and go to the next one"
"Go through the deck as fast as you can."
"Are you ready?"
NO
Review instructions
YES
Give all cards to the participant and say "1-2-3-go" Start the timer
Ask participant to "go to the next one"
YES
Does participant stop responding for 5s?
NO
Has participant flipped through all cards?
NO
YES
STOP

**Table 1**. Participants, conditions and stimulus sets.

| | **Skip condition** | **Guess condition** |
|---|---|---|
| **Participant 1** | Set A | Set B |
| **Participants 2 and 3** | Set B | Set A |

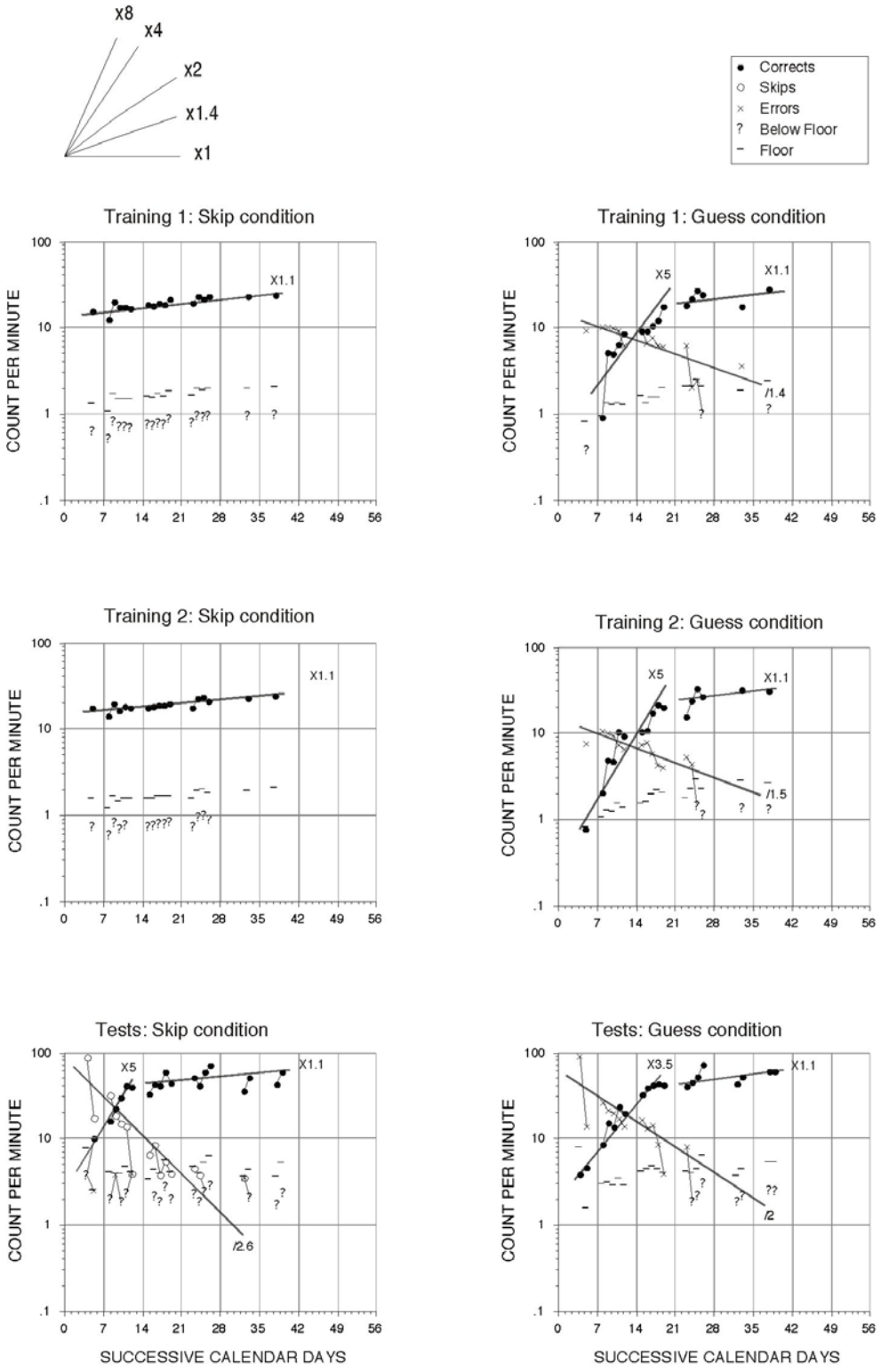



**Figure 1.** Correct-, incorrect-, and "skip" responses during the first training trials (top graphs), second training trials (middle graphs), and tests (bottom graphs) for participant 1 during the "Skip" condition (left column) and the "Guess" condition (right column).

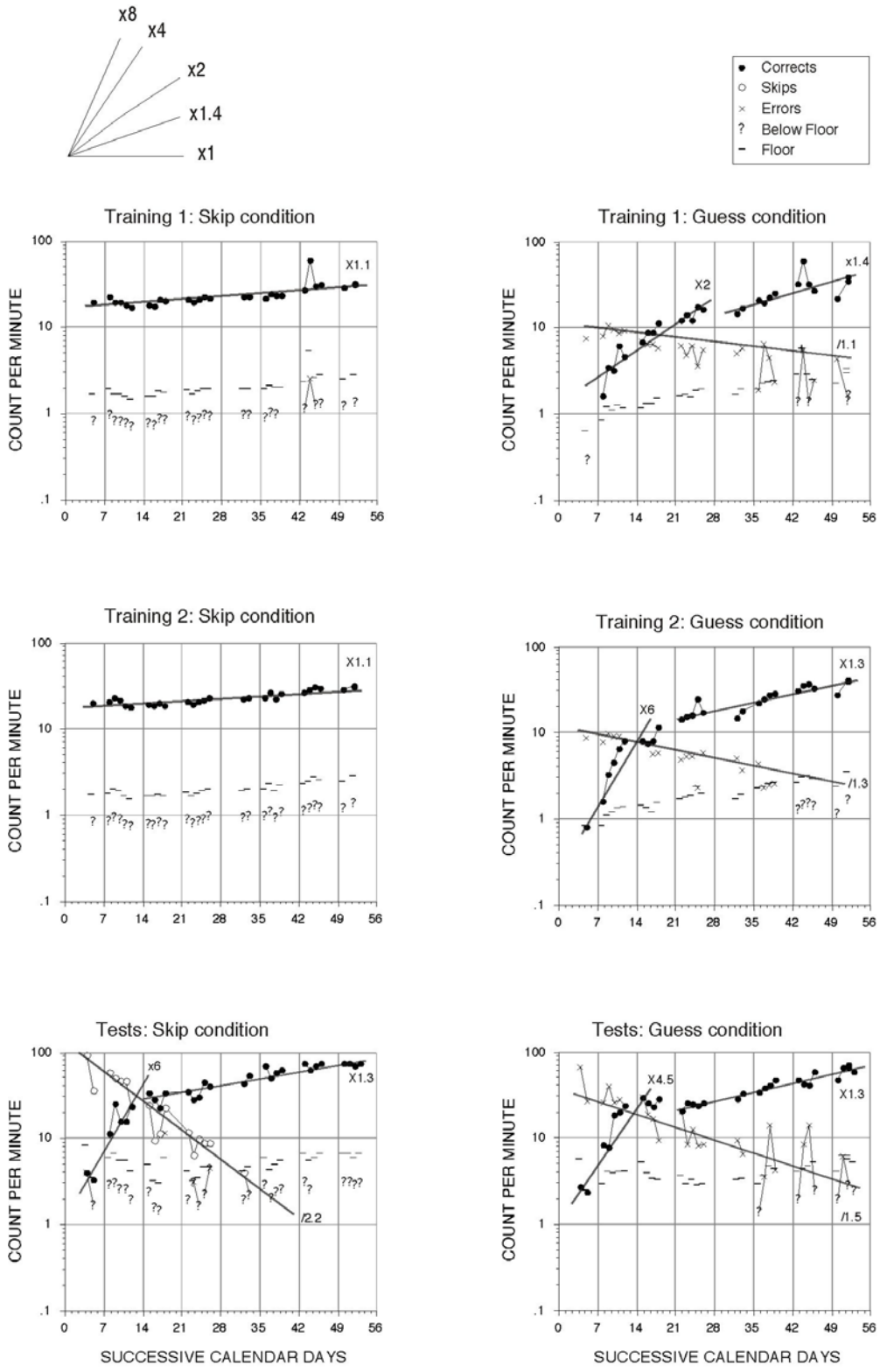



**Figure 2.** Correct-, incorrect-, and "skip" responses during the first training trials (top graphs), second training trials (middle graphs), and tests (bottom graphs) for participant 2 during the "Skip" condition (left column) and the "Guess" condition (right column).

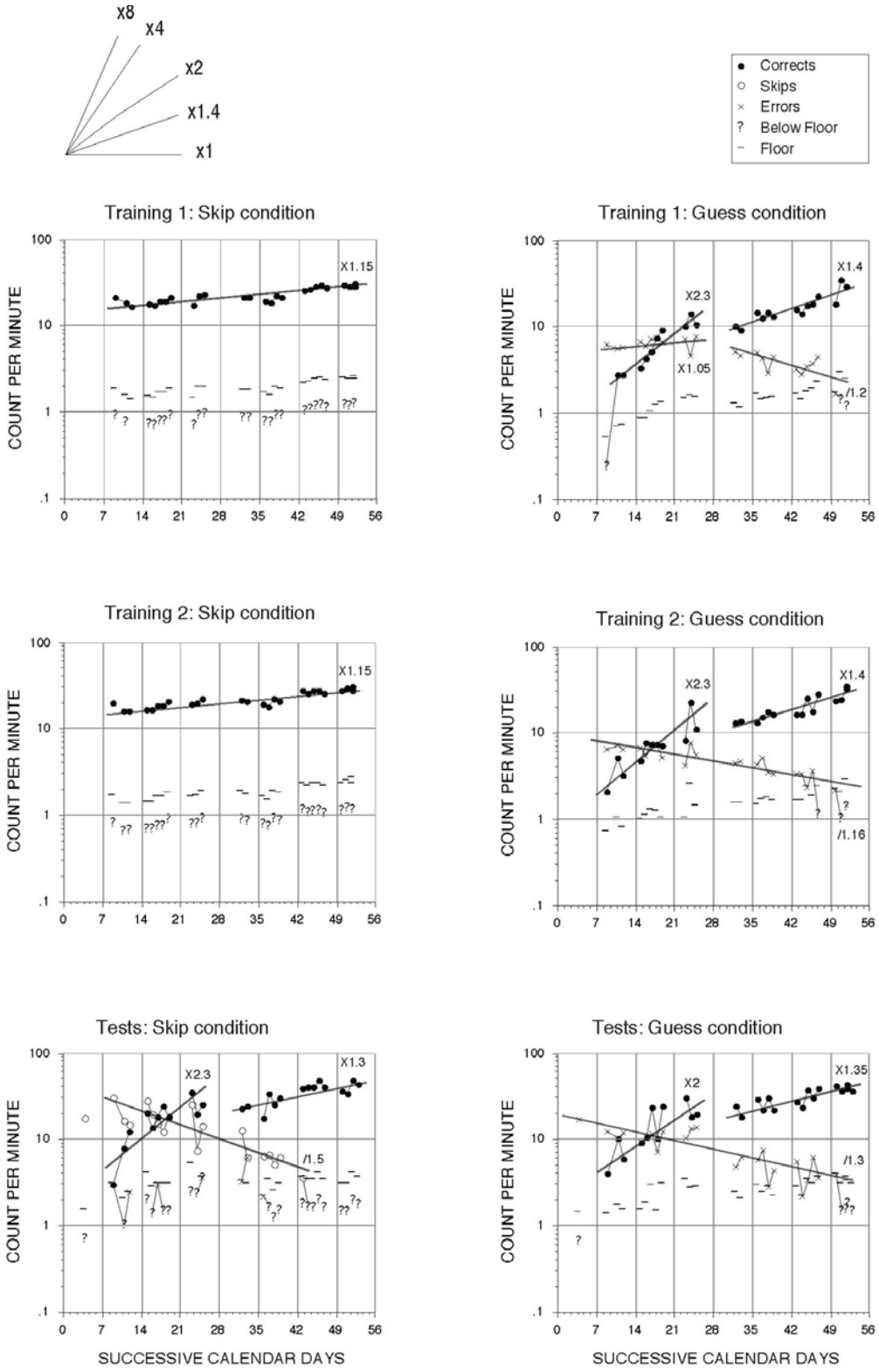



**Figure 3.** Correct-, incorrect-, and "skip" responses during the first training trials (top graphs), second training trials (middle graphs), and tests (bottom graphs) for participant 3 during the "Skip" condition (left column) and the "Guess" condition (right column).

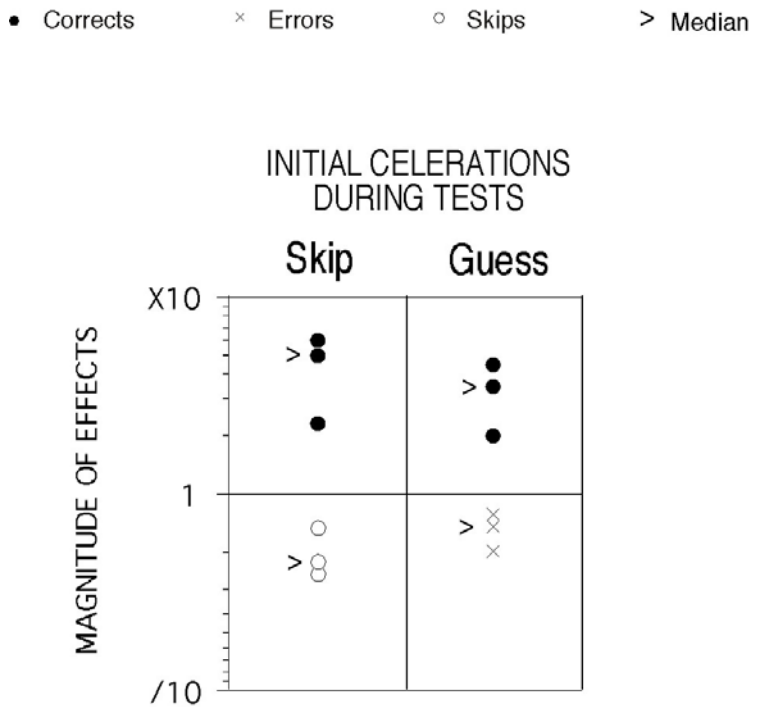



**Figure 4.** Frequency distribution showing initial celerations of correct responses, "skip" responses, and errors during acquisition in the "Skip" and "Guess" conditions.

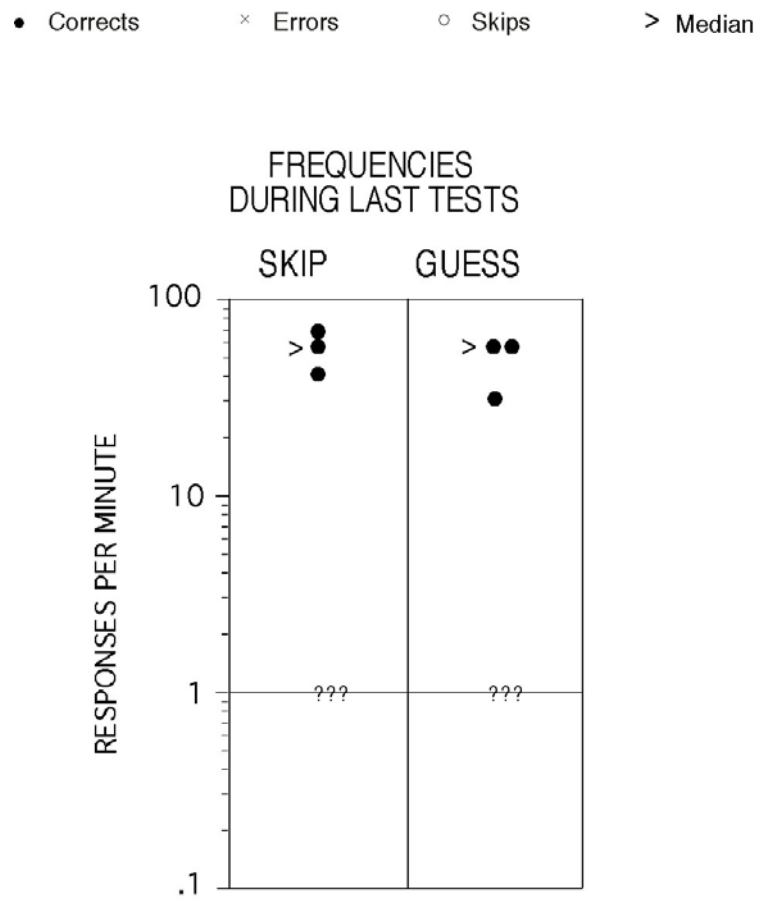



**Figure 5.** Frequency distribution showing last frequencies of correct responses of the tests in the "Skip" and "Guess" conditions.

**Table 2.** Analysis of correct responses, "skip" responses and errors for participant 1 in the "Skip" condition (top), and "Guess" condition (bottom) during the acquisition phase.

**Participant 1**

**Set A (Skip)**

| | | | | | | | Error Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
| 1 | μ | 56 | 55 | 1 | | 0 | | | | | | |
| 2 | ξ | 56 | 53 | 3 | | 0 | | | | | | |
| 3 | ψ | 56 | 45 | 9 | | 2 | | 1 | 1 | | | |
| 4 | τ | 56 | 53 | 2 | | 1 | 1 | | | | | |
| 5 | ι | 56 | 55 | 1 | | 0 | | | | | | |
| 6 | ϕ | 56 | 46 | 10 | | 0 | | | | | | |
| 7 | β | 56 | 54 | 2 | | 0 | | | | | | |
| 8 | α | 56 | 55 | 0 | | 1 | 1 | | | | | |
| 9 | γ | 56 | 47 | 8 | | 1 | | 1 | | | | |
| 10 | θ | 56 | 51 | 5 | | 0 | | | | | | |
| 11 | λ | 56 | 52 | 4 | | 0 | | | | | | |
| 12 | υ | 56 | 52 | 4 | | 0 | | | | | | |
| | TOTAL: | 672 | 618 | 49 | 0 | 5 | 2 | 2 | 1 | 0 | 0 | 0 |

**Set B (Guess)**

| | | | | | | | Error Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
| 1 | ν | 56 | 21 | 1 | | 34 | 33 | 1 | | | | |
| 2 | π | 56 | 51 | 1 | | 4 | 2 | | | | | 2 |
| 3 | η | 56 | 31 | 1 | | 24 | 19 | 4 | 1 | | | |
| 4 | ρ | 56 | 44 | 1 | | 11 | 8 | 3 | | | | |
| 5 | ζ | 56 | 54 | 1 | | 1 | 1 | | | | | |
| 6 | χ | 56 | 15 | 1 | | 40 | 39 | | | | | 1 |
| 7 | δ | 56 | 48 | 1 | | 7 | 6 | | 1 | | | |
| 8 | κ | 56 | 52 | 1 | | 3 | 3 | | | | | |
| 9 | ω | 56 | 30 | 1 | | 25 | 25 | | | | | |
| 10 | σ | 56 | 23 | 1 | | 32 | 28 | 3 | 1 | | | |
| 11 | ε | 56 | 43 | 1 | | 12 | 12 | | | | | |
| 12 | ο | 56 | 42 | 1 | | 13 | 11 | 2 | | | | |
| | TOTAL: | 672 | 454 | 12 | 0 | 206 | 187 | 13 | 3 | 0 | 0 | 3 |

**Table 3.** Analysis of correct responses, "skip" responses and errors for participant 2 in the "Skip" condition (top), and "Guess" condition (bottom) during the acquisition phase.

**Participant 2**

**Set B (Skip)**

| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Error Analysis: Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ν | 87 | 80 | 7 | | 0 | | | | | | |
| 2 | π | 87 | 84 | 3 | | 0 | | | | | | |
| 3 | η | 87 | 71 | 13 | | 3 | | 3 | | | | |
| 4 | ρ | 87 | 73 | 14 | | 0 | | | | | | |
| 5 | ζ | 87 | 86 | 1 | | 0 | | | | | | |
| 6 | χ | 87 | 76 | 11 | | 0 | | | | | | |
| 7 | δ | 87 | 81 | 6 | | 0 | | | | | | |
| 8 | κ | 87 | 85 | 2 | | 0 | | | | | | |
| 9 | ω | 87 | 78 | 8 | | 1 | | 1 | | | | |
| 10 | σ | 87 | 71 | 16 | | 0 | | | | | | |
| 11 | ε | 87 | 81 | 6 | | 0 | | | | | | |
| 12 | ο | 87 | 81 | 6 | | 0 | | | | | | |
| TOTAL: | | 1044 | 947 | 93 | 0 | 4 | 0 | 4 | 0 | 0 | 0 | 0 |

**Set A (Guess)**

| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Error Analysis: Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | μ | 87 | 82 | 1 | | 4 | 2 | 1 | | 1 | | |
| 2 | ξ | 87 | 45 | 1 | | 41 | 12 | 9 | 17 | 1 | 1 | 1 |
| 3 | ψ | 87 | 32 | 1 | | 54 | 29 | 23 | 1 | 1 | | |
| 4 | τ | 87 | 82 | 1 | | 4 | 4 | | | | | |
| 5 | ι | 87 | 83 | 1 | | 3 | 1 | | 1 | 1 | | |
| 6 | φ | 87 | 27 | 1 | | 59 | 30 | 20 | 4 | | 5 | |
| 7 | β | 87 | 81 | 1 | | 5 | 5 | | | | | |
| 8 | α | 87 | 76 | 1 | | 10 | 9 | | | | 1 | |
| 9 | γ | 87 | 74 | 1 | | 12 | 8 | 1 | 1 | 2 | | |
| 10 | θ | 87 | 41 | 1 | | 45 | 29 | 3 | 2 | 11 | | |
| 11 | λ | 87 | 61 | 1 | | 25 | 24 | 1 | | | | |
| 12 | υ | 87 | 59 | 1 | | 27 | 19 | 1 | 7 | | | |
| TOTAL: | | 1044 | 743 | 12 | 0 | 289 | 172 | 59 | 33 | 17 | 7 | 1 |

**Table 4.** Analysis of correct responses, "skip" responses and errors for participant 3 in the "Skip" condition (top), and "Guess" condition (bottom) during the acquisition phase.

**Participant 3**

**Set B (Skip)**

| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Error Analysis: Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ν | 80 | 78 | 2 | | 0 | | | | | | |
| 2 | π | 80 | 77 | 3 | | 0 | | | | | | |
| 3 | η | 80 | 72 | 8 | | 0 | | | | | | |
| 4 | ρ | 80 | 78 | 2 | | 0 | | | | | | |
| 5 | ζ | 80 | 79 | 1 | | 0 | | | | | | |
| 6 | χ | 80 | 70 | 10 | | 0 | | | | | | |
| 7 | δ | 80 | 61 | 18 | | 1 | | 1 | | | | |
| 8 | κ | 80 | 78 | 2 | | 0 | | | | | | |
| 9 | ω | 80 | 63 | 12 | | 5 | | 5 | | | | |
| 10 | σ | 80 | 65 | 13 | | 2 | | 2 | | | | |
| 11 | ε | 80 | 69 | 11 | | 0 | | | | | | |
| 12 | ο | 80 | 68 | 11 | | 1 | | 1 | | | | |
| TOTAL: | | 960 | 858 | 93 | 0 | 9 | 0 | 9 | 0 | 0 | 0 | 0 |

**Set A (Guess)**

| # of Greek letter | Greek Letter | Total # of responses | Correct | Skips | Non-responses | Incorrect | Error Analysis: Roman | Greek (within set) | Greek (between sets) | Correct Approxi-mation | Incorrect Approxi-mation | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | μ | 80 | 78 | 1 | | 1 | 1 | | | | | |
| 2 | ξ | 80 | 74 | 1 | | 5 | 1 | 3 | 1 | | | |
| 3 | ψ | 80 | 27 | 1 | | 52 | 27 | 9 | 16 | | | |
| 4 | τ | 80 | 52 | 1 | 1 | 26 | 20 | 3 | 1 | | 1 | 1 |
| 5 | ι | 80 | 77 | 1 | | 2 | | 1 | | | | 1 |
| 6 | φ | 80 | 17 | 1 | | 62 | 27 | 9 | 25 | | | 1 |
| 7 | β | 80 | 78 | 1 | | 1 | 1 | | | | | |
| 8 | α | 80 | 70 | 1 | | 9 | 5 | 1 | 3 | | | |
| 9 | γ | 80 | 56 | 1 | | 23 | 12 | 10 | 1 | | | |
| 10 | θ | 80 | 30 | 1 | 1 | 48 | 29 | 4 | 15 | | | |
| 11 | λ | 80 | 68 | 1 | 1 | 10 | 9 | 1 | | | | |
| 12 | υ | 80 | 54 | 1 | | 25 | 16 | 4 | 5 | | | |
| TOTAL: | | 960 | 681 | 12 | 3 | 264 | 148 | 45 | 67 | 0 | 1 | 3 |

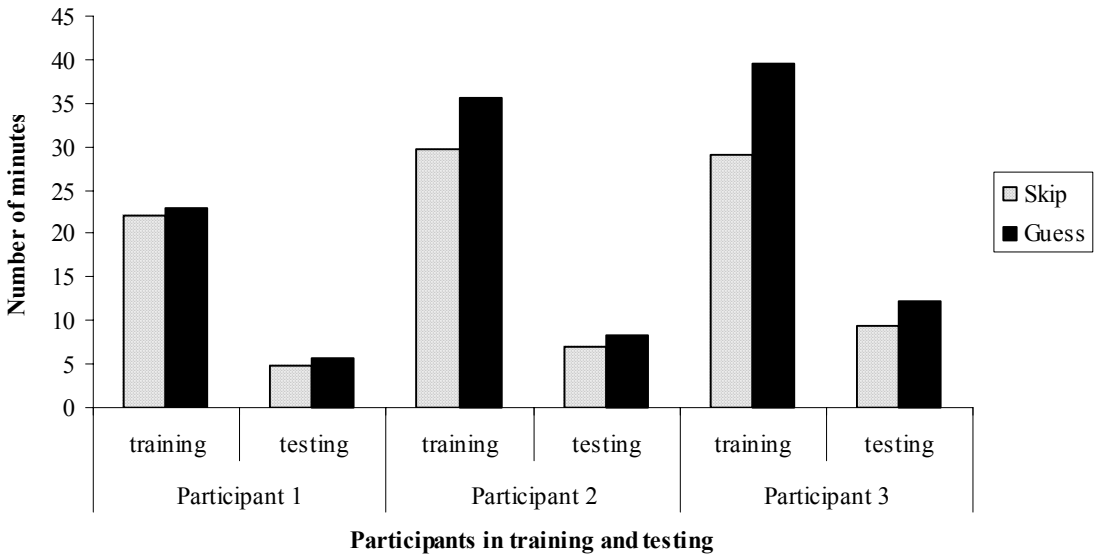



**Figure 6.** Total time (min) spent training and testing for each participant in the "Skip" and the "Guess" conditions

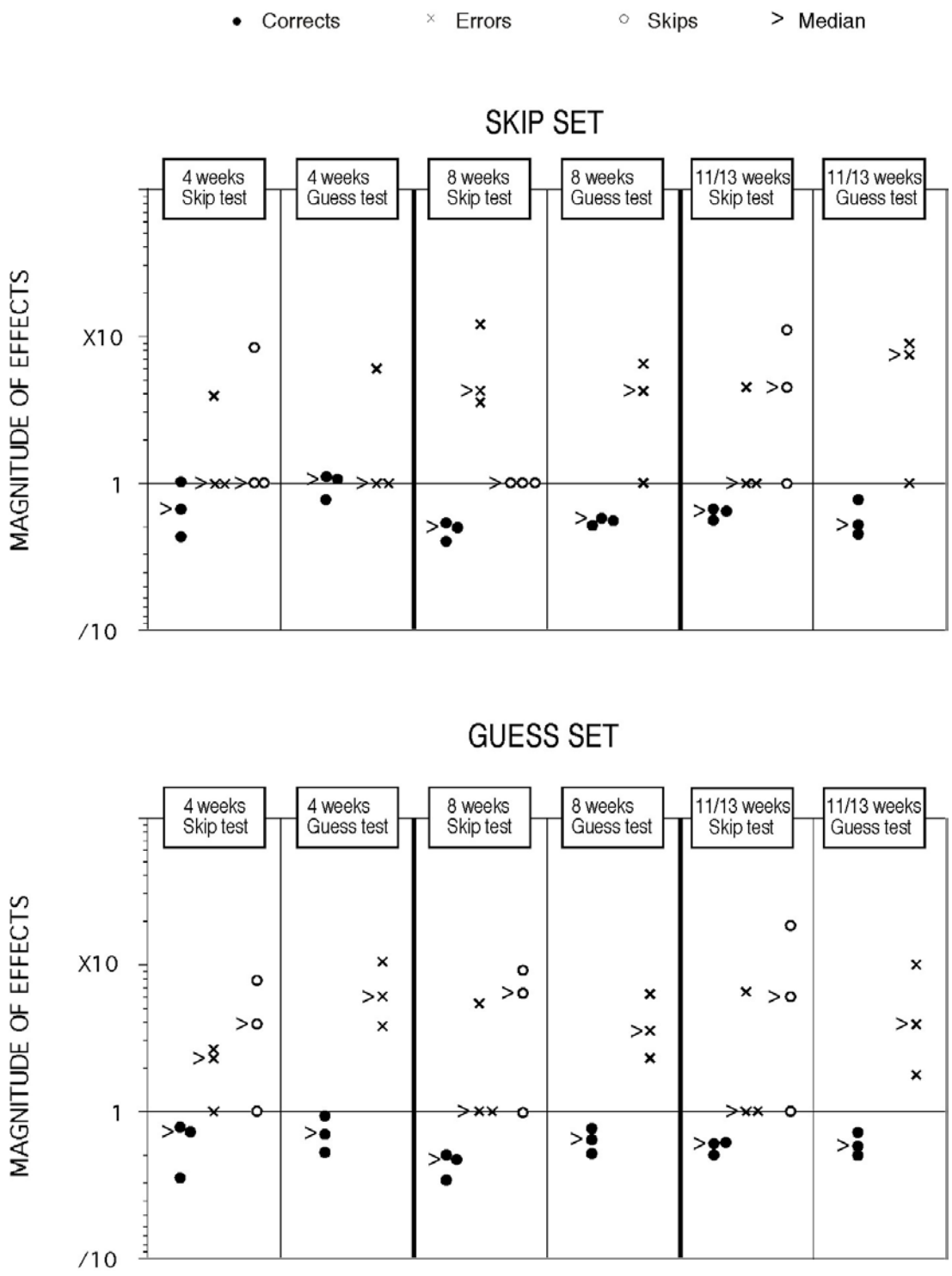



**Figure 7.** Frequency distribution showing results of retention tests for the "Skip" condition (top graph) and the "Guess" condition (bottom graph).

**Table 5.** Number of "skip" responses, non-responses, and errors during acquisition, and an analysis of responses during the retention tests for the "Skip" and "Guess" condition.

| | | | |
|---|---|---|---|
| | Correct letter name | | Roman alphabet error, e.g. A |
| | Skip | | Greek alphabet error, e.g. ε |
| / | Correct approximation | * | Other error |
| # | Incorrect approximation | -- | Non response |

a = skip condition b = guess condition

**Participant 1**

| # | Acquisition Set A Skips | Non-responses | Incorrect |
|---|---|---|---|
| 1 | 1 | | 0 |
| 2 | 3 | | 0 |
| 3 | 9 | | 2 |
| 4 | 2 | | 1 |
| 5 | 1 | | 0 |
| 6 | 10 | | 0 |
| 7 | 2 | | 0 |
| 8 | 0 | | 1 |
| 9 | 8 | | 1 |
| 10 | 5 | | 0 |
| 11 | 4 | | 0 |
| 12 | 4 | | 0 |

| Retention Set A SKIP condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| μ | | | | | | |
| ξ | | | | | | |
| ψ | | | | Y | | Y |
| τ | | | | | | |
| ι | | | | | | |
| ϕ | | | | | | Q |
| β | | | | | | |
| α | | | | | | |
| γ | | | | V | | V |
| θ | | | | | | |
| λ | | γ | | | | |
| υ | | | | | | |

| Acquisition SET B Skips | Non-responses | Incorrect |
|---|---|---|
| 1 | | 34 |
| 1 | | 4 |
| 1 | | 24 |
| 1 | | 11 |
| 1 | | 1 |
| 1 | | 40 |
| 1 | | 7 |
| 1 | | 3 |
| 1 | | 25 |
| 1 | | 32 |
| 1 | | 12 |
| 1 | | 13 |

| Retention SET B GUESS condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| ν | | | | | | |
| π | | | | | | |
| η | | | | | | |
| ρ | | | | | | |
| ζ | | | | | | |
| χ | | X | | X | | X |
| δ | | | | | | |
| κ | | | | | | |
| ω | | | | | | |
| σ | | | | | | |
| ε | | | | | | |
| ο | | | | | | |

**Participant 2**

| # | Acquisition SET B Skips | Non-responses | Incorrect |
|---|---|---|---|
| 1 | 7 | | 0 |
| 2 | 3 | | 0 |
| 3 | 13 | | 3 |
| 4 | 14 | | 0 |
| 5 | 1 | | 0 |
| 6 | 11 | | 0 |
| 7 | 6 | | 0 |
| 8 | 2 | | 0 |
| 9 | 8 | | 1 |
| 10 | 16 | | 0 |
| 11 | 6 | | 0 |
| 12 | 6 | | 0 |

| Retention SET B SKIP condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| ν | | | η | | | |
| π | | | | | | |
| η | | | | | | |
| ρ | | | | | η | η |
| ζ | | | | | | |
| χ | | | | | | |
| δ | | | | | | |
| κ | | | | | | |
| ω | | | | | | |
| σ | | | | | | |
| ε | | | | | | π |
| ο | | | | | | |

| Acquisition SET A Skips | Non-responses | Incorrect |
|---|---|---|
| 1 | | 4 |
| 1 | | 41 |
| 1 | | 54 |
| 1 | | 4 |
| 1 | | 3 |
| 1 | | 59 |
| 1 | | 5 |
| 1 | | 10 |
| 1 | | 12 |
| 1 | | 45 |
| 1 | | 25 |
| 1 | | 27 |

| Retention SET A GUESS condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| μ | | | | | | |
| ξ | ε | ϕ | | | | ψ |
| ψ | ξ | ξ | | | | Y |
| τ | | | | | | |
| ι | | | | | | |
| ϕ | # | ψ | | ψ | | |
| β | | | | | | |
| α | | | | | | |
| γ | | | | | | |
| θ | | | | ϕ | | ϕ |
| λ | | | | | | |
| υ | | | | | | |

**Participant 3**

| # | Acquisition SET B Skips | Non-responses | Incorrect |
|---|---|---|---|
| 1 | 2 | | 0 |
| 2 | 3 | | 0 |
| 3 | 8 | | 0 |
| 4 | 2 | | 0 |
| 5 | 1 | | 0 |
| 6 | 10 | | 0 |
| 7 | 18 | | 1 |
| 8 | 2 | | 0 |
| 9 | 12 | | 5 |
| 10 | 13 | | 2 |
| 11 | 11 | | 0 |
| 12 | 11 | | 1 |

| Retention SET B SKIP condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| ν | | | | | | |
| π | | | τ | τ | | |
| η | | | | | | |
| ρ | | | | | | |
| ζ | | | | | | |
| χ | | | | | | |
| δ | | | θ | θ | | |
| κ | | | | | | |
| ω | | | | | | |
| σ | | | | | | |
| ε | | | | | | |
| ο | ω | | | | | |

| Acquisition SET A Skips | Non-responses | Incorrect |
|---|---|---|
| 1 | | 1 |
| 1 | | 5 |
| 1 | | 52 |
| 1 | 1 | 26 |
| 1 | | 2 |
| 1 | | 62 |
| 1 | | 1 |
| 1 | | 9 |
| 1 | | 23 |
| 1 | 1 | 48 |
| 1 | 1 | 10 |
| 1 | | 25 |

| Retention SET A GUESS condition Letter | 1a | 1b | 2a | 2b | 3a | 3b |
|---|---|---|---|---|---|---|
| μ | | | | | | |
| ξ | | | ϕ | ψ | | |
| ψ | ϕ | ϕ | | ϕ | ϕ | |
| τ | | | | | ι | |
| ι | | | | | | |
| ϕ | | ψ | | | ξ | |
| β | | | | | | |
| α | | | | | | |
| γ | | | | | | |
| θ | | | | ϕ | | δ |
| λ | | | | | | |
| υ | | | ε | | | |

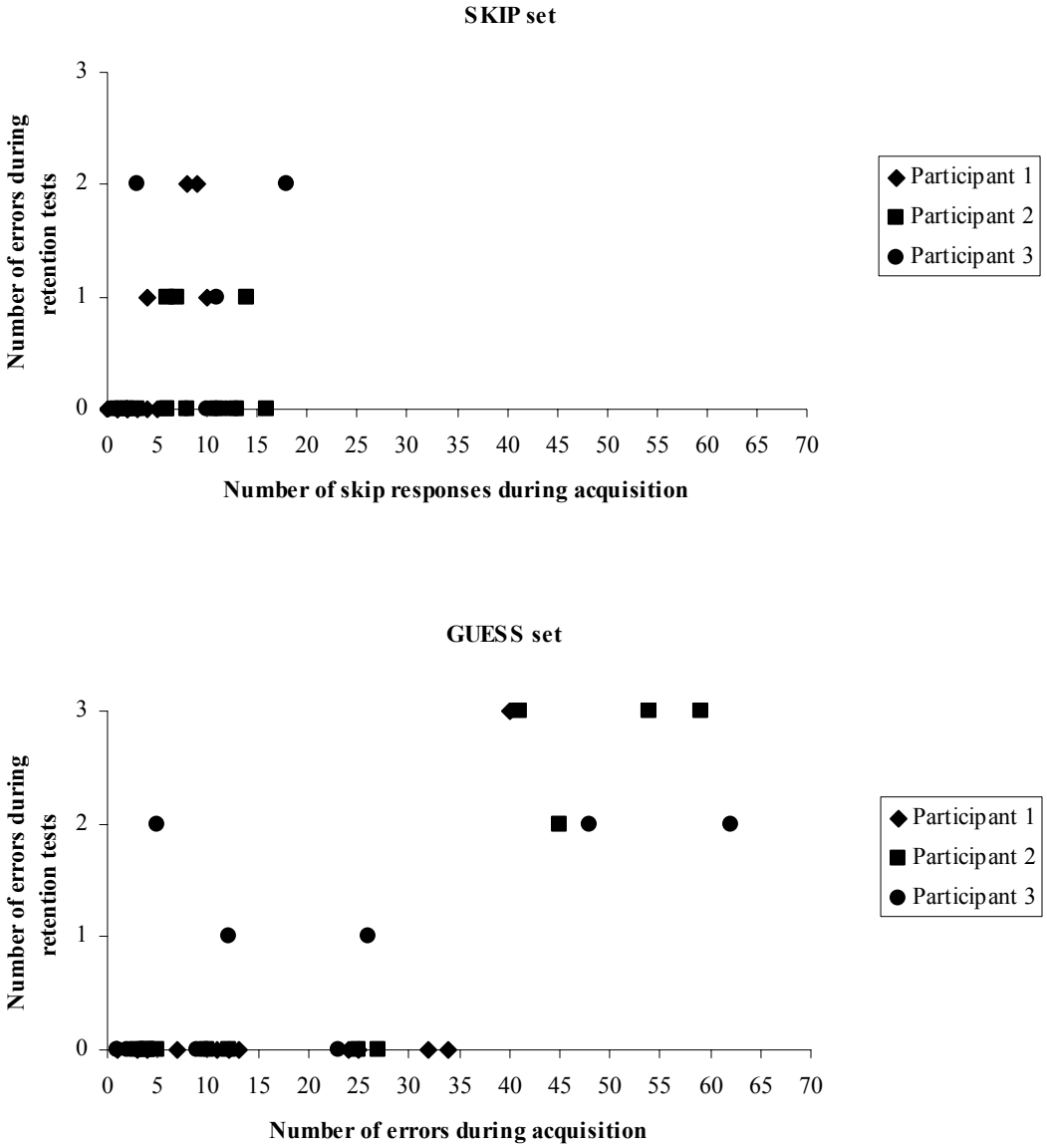



**Figure 8.** Scatter plot showing the relations between "skip" responses (top graph) and errors (bottom graph) during acquisition, and errors during retention tests.

**Table 6.** Letter names recalled during the Free/Say generalization tests.

| | Correct letter name | - - | Non response |
|---|---|---|---|

**Participant 1**

| Set A - SKIP | | | | | Set B - GUESS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| # of Greek letter | Greek Letter | test 1 | test 2 | test 3 | # of Greek letter | Greek Letter | test 1 | test 2 | test 3 |
| 1 | μ | | | | 1 | ν | | - - | - - |
| 2 | ξ | | | - - | 2 | π | - - | | |
| 3 | ψ | | | - - | 3 | η | - - | - - | |
| 4 | τ | - - | - - | - - | 4 | ρ | - - | | |
| 5 | ι | - - | - - | - - | 5 | ζ | | - - | - - |
| 6 | ϕ | - - | - - | - - | 6 | χ | - - | - - | - - |
| 7 | β | | - - | - - | 7 | δ | | | |
| 8 | α | - - | - - | - - | 8 | κ | - - | - - | |
| 9 | γ | - - | - - | - - | 9 | ω | - - | - - | - - |
| 10 | θ | - - | | - - | 10 | σ | | - - | - - |
| 11 | λ | - - | - - | - - | 11 | ε | | | |
| 12 | υ | | | | 12 | ο | | | |
| Correct | | 5 | 5 | 2 | | | 6 | 5 | 7 |

**Participant 2**

| Set B - SKIP | | | | | Set A - GUESS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| # of Greek letter | Greek Letter | test 1 | test 2 | test 3 | # of Greek letter | Greek Letter | test 1 | test 2 | test 3 |
| 1 | ν | | - - | - - | 1 | μ | | | |
| 2 | π | | | | 2 | ξ | | | |
| 3 | η | - - | - - | - - | 3 | ψ | | | - - |
| 4 | ρ | - - | - - | - - | 4 | τ | - - | - - | - - |
| 5 | ζ | - - | - - | | 5 | ι | - - | - - | |
| 6 | χ | | - - | - - | 6 | ϕ | | | |
| 7 | δ | - - | - - | - - | 7 | β | | | |
| 8 | κ | | - - | | 8 | α | | | |
| 9 | ω | | | - - | 9 | γ | - - | - - | - - |
| 10 | σ | | - - | - - | 10 | θ | | - - | - - |
| 11 | ε | | | | 11 | λ | | | |
| 12 | ο | | | - - | 12 | υ | | | - - |
| Correct | | 8 | 4 | 4 | | | 9 | 8 | 7 |

**Participant 3**

| Set B - SKIP | | | | | Set A - GUESS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| # of Greek letter | Greek Letter | test 1 | test 2 | test 3 | # of Greek letter | Greek Letter | test 1 | test 2 | test 3 |
| 1 | ν | | - - | | 1 | μ | - - | - - | - - |
| 2 | π | - - | - - | | 2 | ξ | | | |
| 3 | η | | | | 3 | ψ | | | |
| 4 | ρ | - - | - - | | 4 | τ | | | |
| 5 | ζ | | | | 5 | ι | | | |
| 6 | χ | | - - | | 6 | ϕ | | | |
| 7 | δ | - - | - - | | 7 | β | - - | | - - |
| 8 | κ | | - - | | 8 | α | - - | - - | - - |
| 9 | ω | | | | 9 | γ | - - | - - | - - |
| 10 | σ | | - - | - - | 10 | θ | - - | | |
| 11 | ε | - - | - - | - - | 11 | λ | - - | - - | - - |
| 12 | ο | | | | 12 | υ | - - | - - | - - |
| Correct | | 8 | 4 | 10 | | | 5 | 7 | 6 |

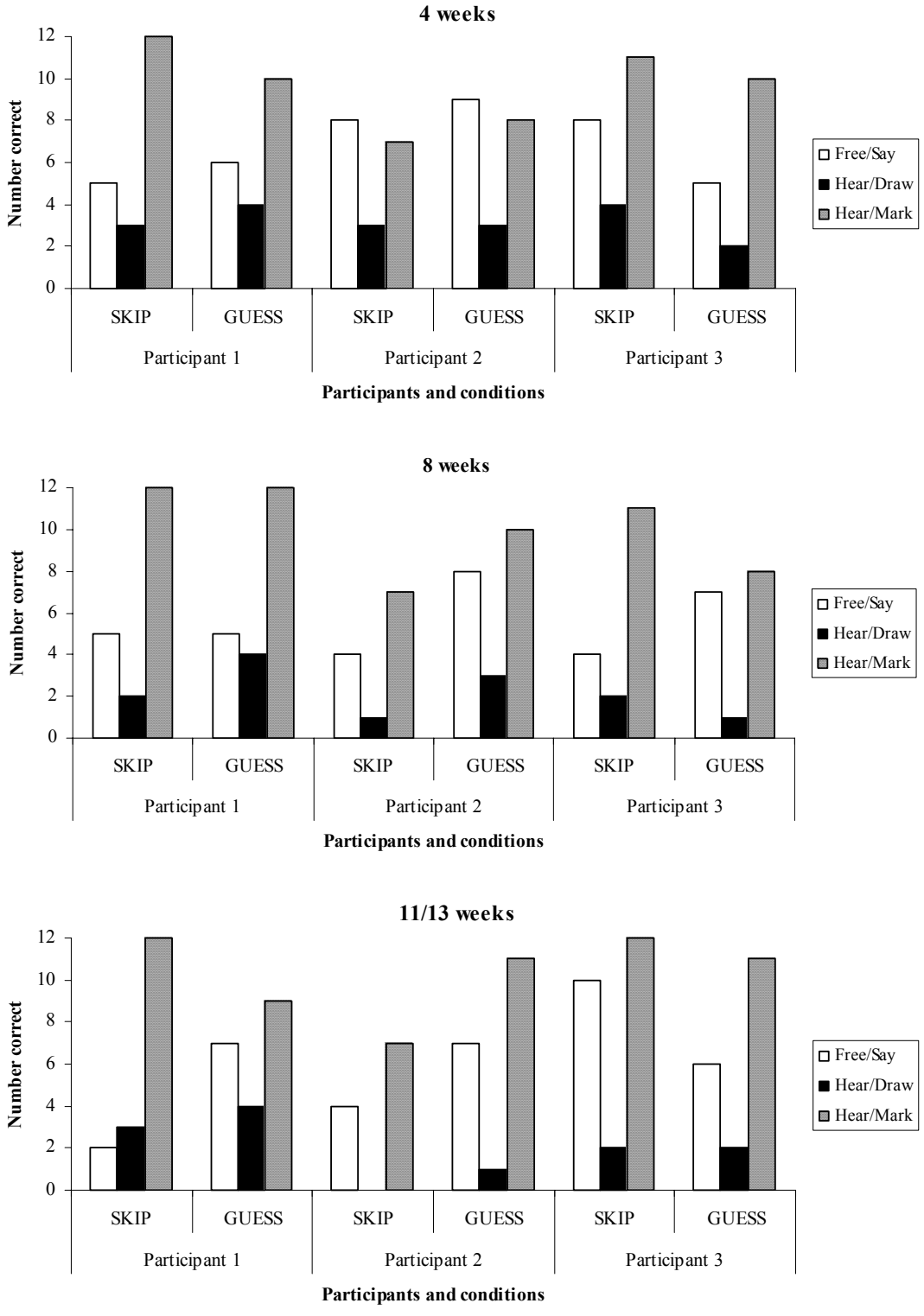



**Figure 9.** Number of correct responses during generalization tests across the Free/Say, Hear/Draw, and Hear/Mark channels.

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