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## Position bias in matching-to-sample tasks

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**Position Bias in Matching-to-Sample Tasks: Is Counterbalancing  
Stimulus Positions Really Necessary?**

**A Thesis Presented**

**by**

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Running head: COUNTERBALANCING STIMULUS POSITIONS AND POSITION  
BIAS

Position Bias in Matching-to-Sample Tasks: Is Counterbalancing  
Stimulus Positions Really Necessary?

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### Abstract

Stimulus overselectivity, or restricted stimulus control, occurs when behavior comes under control of a restricted set of stimulus cues. Individuals with autism and other developmental disorders frequently display restricted stimulus control when, in the presence of multiple stimulus cues, behavior comes under control of only one component of a complex stimulus or other unintended variables such as stimulus position during visual discrimination tasks. In the present study, three different teaching procedures were used to teach relations between sample and comparison complex visual stimuli. Stimuli were counterbalanced across trials, across sessions, or not counterbalanced at all. All participants were able to learn the relations with relative ease, regardless of whether or not trials were counterbalanced. An error analysis indicated that participants showed a preference for one stimulus position over the others, but this preference did not appear to significantly impact learning. These findings suggest that in the context of a matching-to-sample task with typically developing adults, position bias as a result of a failure to counterbalance stimulus positions during training may not interfere with acquisition.

## Position Bias in Matching-to-Sample Tasks: Is Counterbalancing Stimulus Positions Really Necessary?

Stimulus control can be defined as “a situation in which the frequency, latency, duration or amplitude of a behavior is altered by the presence or absence of an antecedent stimulus” (Cooper, Heron & Heward, 2007). As behavior analysts, we work toward identifying variables that control behavior and manipulating these variables in such a way that learning is increased and problem behavior is decreased.

Stimulus overselectivity, commonly referred to as restricted stimulus control in recent literature (e.g. Sidman, 1992; Geren, Stromer & Mackay, 1997; Groskreutz, Karsina, Miguel & Groskreutz, 2010), can be described as a condition in which an individual is presented with multiple stimulus inputs and their behavior comes under control of a set of inputs that is too restricted (Lovaas, Koegel & Schreibman, 1979). In this review, Lovaas, Koegel and Schreibman provided an overview of research that investigated how stimulus overselectivity may interfere with learning in a variety of ways among individuals with Autism or other disabilities. First, stimulus overselectivity may occur when an individual is exposed to multiple stimulus cues. In a 1971 study by Lovaas et al., typical children and children with diagnoses of autism and mental retardation were taught to respond to a complex stimulus display with visual, auditory and tactile elements. Typically developing children were able to respond to each component in isolation while children with Autism responded to only one component cue. When this study was replicated with a two-component stimulus display, children with Autism demonstrated less difficulty responding to each cue in isolation. This suggests that stimulus overselectivity is more likely to occur when a larger number of

stimulus inputs are present. Because the natural environment contains a large number of stimuli, children with Autism may have difficulty learning without systematically reducing the stimulus display.

In a third study by Koegel and Schreibman (1977), two groups of children, one with diagnoses of Autism and the other typically developing, were taught to respond to visual and auditory stimuli in isolation. They were then exposed to each stimulus in isolation on some trials, and both stimuli combined on other trials. Reinforcement was given for responding to the complex, two-component stimulus while responses to each component in isolation were not reinforced. For typically developing children, responses to one-component stimuli were quickly extinguished, but children with autism had far more difficulty discriminating the complex stimulus from its visual and auditory components (Lovaas, Koegel & Schreibman, 1979).

In 1973, Koegel and Wilhelm investigated stimulus overselectivity with visual discrimination tasks. Typically developing children and children with autism were taught to discriminate between two cards, each containing two components. During testing sessions in which only one component of each card was presented, children with autism frequently responded to only one component of the original correct stimulus.

Another way that responding may come under control of a restricted set of stimulus inputs was investigated by Sidman (1982). The author found that, in a visual discrimination task, Rhesus monkeys' responding came under the control of key position in addition to relevant stimulus properties. A later review of these data (Sidman, 1992) suggested that, in a standard conditional discrimination procedure, controlling aspects of

stimuli may include both the experimenter-specified features and some other unintended feature, such as key position.

In the original 1982 study, Sidman attempted to prevent side bias by presenting comparison stimuli in varied positions with six possible key combinations. There were 300 trials per session and comparison stimulus positions were counterbalanced across trials to prevent restricted stimulus control from developing based on key position. See figure 1 for a schematic representation of the key positions. The sample stimulus always appeared in position 3, in the center of the screen. The comparison stimuli appeared on any two of the remaining keys (1, 2, 4 and 5) in a counterbalanced fashion, so that each stimulus pair appeared with equal frequency on each of the six possible key combinations (1-2, 1-4, 1-5, 2-4, 2-5 and 4-5). The purpose of this arrangement was to make key position an irrelevant feature of the stimuli, but, upon further analysis of the data described in his 1992 study, Sidman found that key position was indeed a controlling aspect of the stimuli despite efforts to prevent this. He described and demonstrated a signal-detection matrix which analyzes the extent to which the monkeys were responding to different features of the stimuli (see Figure 2).

Sidman (1992) found that, when monkeys were exposed to experimental procedures in which a sample stimulus appeared on a center key and comparison stimuli appeared in any two of five possible positions, the monkey's performance varied depending on key position. Though Sidman intended to teach the monkeys to complete an identity matching task, in actuality he taught monkeys six different conditional discriminations based on the positions in which the comparison stimuli appeared. In other words, when the monkeys were shown a vertical sample, they responded not

necessarily by identifying the identical vertical comparison stimulus, but instead by identifying a comparison stimulus based on the position of the choices.

Figure 3 illustrates how the signal-detection matrices may be graphically represented in a signal-detection space, so that performance based on stimulus preference may be analyzed based on accuracy, hit rate and false alarm rate simultaneously.

Matrices that appear outside of the ADEB square indicate that the intended stimulus properties are not involved in the conditional discrimination, but rather some other property, such as key position, is responsible for responding. A signal detection matrix that appears on point A would indicate a “perfect” performance, in which the subject always identifies the correct comparison stimulus given a specific sample stimulus.

Matrices that appear above the line AB indicate a preference for one stimulus, and matrices that appear below the line AB indicate a preference for the other stimulus.

Matrices on the line AB indicate no preference for one stimulus over the other.

In sum, the data from each of the six possible comparison key combinations produced a different learning curve when represented in the signal detection space plots. This indicates that the subjects were not performing a true identity matching task, but were instead responding in a particular manner depending on the position of the keys in the comparison array (see figure 4). In other words, the subjects learned relations between sample and comparison stimuli differently when the comparison stimuli appeared in different positions.

It is common practice for researchers in the field of applied behavior analysis to randomize or counterbalance stimulus position across trials (Stromer, Mackay, Howell, McVay & Flusser, 1996; Green, Stromer & Mackay, 1997; Clark & Green, 2004;

Clevenger & Graff, 2005; Groskreutz, Karsina, Miguel, & Groskreutz, 2010). In the context of research, these procedures are necessary to strengthen experimental control and to improve the likelihood that responding comes under control of the intended discriminative stimuli and not some other variable. In the context of service delivery, however, it is unclear whether these procedures are necessary to prevent position bias from interfering with learning in all cases.

The purpose of current research is to examine whether counterbalancing trials within or across teaching sessions affects acquisition rates among typically developing adults and to determine whether, among a population of typical adults, restricted stimulus control occurs as a result of a failure to counterbalance trials.

## **Method**

### **Participants, setting and materials**

Two women and one man participated. Michelle was a 28 year old environmental safety specialist. Steve was 28 years old and worked in the stock room at a local department store. Stacy was 25 years old and worked in retail at an independent bookstore. Participants were selected based on their availability and interest in participating, and none of the participants had any prior experience with Applied Behavior Analysis or any familiarity with the materials used. Sessions took place in a quiet room, free from distractions, in either the participant's home (Michelle and Steve) or the home of the experimenter (Stacy) depending on availability. Participants sat at a table with a Dell laptop computer, and the experimenter sat next to the participant so that both the participant and the experimenter were able to view the computer monitor. The experimenter used a pen, an answer key and a data recording form to record correct or

incorrect responses. Prior to beginning, participants were asked to read and sign a one-page description of the experimental procedures (see appendix). Participants were given the option to request clarification before proceeding, though this was not necessary for any participants.

Hieroglyphic symbols were used as arbitrary complex visual stimuli throughout the study (see Figures 5-7). Images were approximately 1.5 inches square and they were spaced approximately .5 inches apart on PowerPoint slides.

### **Procedure**

Participants were exposed in order to each of three stimulus sets (AB, CD and EF). Stimulus sets A, C and E were used as sample stimuli and sets B, D and F respectively were used as comparison stimuli (see figures 5-7). Each stimulus set was associated with one of three teaching procedures (described below). The order in which participants were exposed to different teaching procedures varied by participant (see table 1).

Materials were presented in a PowerPoint Presentation format in which odd-numbered slides contained a single sample stimulus from set A, C or D and even-numbered slides contained an array of three comparison stimuli from sets B, D or E arranged horizontally. Participants were asked to use the touchpad mouse on the laptop computer to click on the sample stimulus and move it to the top of the slide. The purpose of this was to ensure that an observing response was taking place. They were then asked to move on to the next slide, which contained three stimuli, arranged horizontally, approximately .5 inches apart. The participant was asked to click on whichever stimulus they believed 'matched' the sample stimulus from the previous slide, and to move the

stimulus to the top of the slide. The purpose of this was twofold: first, this allowed the experimenter to check for discrepancies between actual participant responses (permanent product) and reinforcer delivery (data collection forms). Second, this allowed the experimenter to conduct an error analysis to determine whether position bias occurred during training as a result of a failure to counterbalance stimulus positions. Next, the experimenter delivered verbal feedback to the participant, indicating whether they had selected the correct or the incorrect stimulus, and recorded data on a separate recording form out of the participants' view. Participants were not allowed to review previous slides or to correct themselves following an incorrect response. Trials continued in this manner until all trials had been completed. Pretest sessions consisted of nine trials and training and post-test sessions consisted of eighteen trials. When participants achieved 100% accuracy during a training session, they were given an eighteen-trial post test in which all trials were perfectly counterbalanced. Trials were arranged so that each of the three sample stimuli appeared the same number of times and each of the three comparison stimuli appeared in each of three possible positions (i.e. left, center or right) the same number of times. No comparison stimulus appeared in the same position on more than two consecutive trials, and no sample stimulus was presented on more than two consecutive trials.

*Pretest.* Prior to beginning training on a new stimulus set, participants completed a nine-trial pretest during which no performance feedback was given. Training on the stimulus set began if the participant scored 89% or lower accuracy, or eight out of nine trials correct on the pretest.

*Training.* Following the pretest for stimulus set AB, participants began training. Participant 1 was exposed to teaching procedure 1, participant 2 was exposed to teaching procedure 2 and participant 3 was exposed to teaching procedure 3 (see table 1). When each participant scored 100% accuracy in training, they were given an 18-trial post-test during which no performance feedback was given. If the participant scored 100% accuracy with the post test, then sessions using stimulus set AB were terminated and a pretest for stimulus set CD began. If the participant made any errors during the post test then training sessions would resume until 100% accuracy was reached. It was not necessary to return to training for any participant or stimulus set. Sessions continued in this manner until all three teaching procedures (described below) had been used to teach the participants to match sample stimulus sets A, C and D to their designated comparison stimulus sets B, D and F.

*Procedure 1: Fully counterbalanced.* Trials were arranged so that each of the three sample stimuli appeared the same number of times and each of the three comparison stimuli appeared in each of three possible positions (i.e. left, center or right) the same number of times. No comparison stimulus appeared in the same position on more than two consecutive trials, and no sample stimulus was presented on more than two consecutive trials.

*Procedure 2: Counterbalanced across sessions.* Comparison stimuli appeared in the same position for the entire session, but their positions varied from session to session. No sample stimulus was presented on more than two consecutive trials.

*Procedure 3: Not counterbalanced.* Comparison stimuli appeared in the same position for the entire session and their position did not vary from session to session. No sample stimulus was presented on more than two consecutive trials.

### **Results**

Results are presented in figures 8 (Michelle), 9 (Steve) and 10 (Stacy). All participants scored less than 89% accuracy on all pretests, indicating that they were not familiar with the materials prior to the study. During the first training session, participants showed a significant improvement in performance, which indicates that learning occurred as a result of the feedback that was provided following each response. There is one exception worth noting. Stacy scored the same during the first training session as she did on the pretest for stimulus set CD. Regardless of which teaching procedures were used, all participants were able to learn the relations between sample and comparison stimuli in six or fewer sessions. For all participants, the final stimulus set (EF) was completed in only 4 sessions.

To determine whether or not a position bias had occurred, an error analysis was conducted to determine which position was chosen most frequently during errors for all participants. Results for Michelle, presented in figures 11 and 12, indicate a clear preference for the stimulus in the right position with 7 errors in which the left stimulus was chosen, 9 in which the center stimulus was chosen and 17 in which the right stimulus was chosen. Results for Steve, presented in figures 13 and 14, are less clear. In the context of errors, Steve chose the center position most infrequently (12 times), but stimuli in the left and right positions were chosen with approximately equal frequency, on 18 and

17 trials respectively. Similarly, Stacy chose both the center and right stimuli 17 times during errors, but she chose the left stimulus only 10 times (see figures 15 and 16).

Figures 12, 14 and 16 show a breakdown of all errors for each participant by stimulus set and teaching procedure. All participants had the most errors during training for stimulus set AB regardless of which training procedure was used, but Michelle, who was taught stimulus set AB with teaching procedure 1, had only 7 errors compared Steve and Stacy who had 22 and 13 errors respectively. It is possible that counterbalancing stimulus positions early in the study enhanced skill acquisition for Madeline.

### **Discussion**

The data suggest that position bias may occur during matching-to-sample tasks when stimulus positions are not counterbalanced across trials or sessions, but it appears that position bias did not interfere with participants' ability to learn the materials. In other words, participants were able to learn relations between sample and comparison stimuli with relative ease, regardless of whether or not stimuli were systematically assigned to specific positions in the array. However, Michelle showed overall fewer errors than Steve and Stacy, which may suggest that counterbalancing trials during the early stages of the study enhanced learning. It is possible that counterbalancing procedures are the most useful when the matching-to-sample procedures are novel to the participant, and that they may be faded out without interfering with acquisition of new stimulus sets.

These findings are significant to the field of Applied Behavior Analysis because in many classrooms teachers are required to randomize materials in a specific manner in order to prevent their students from acquiring inadvertent side biases. This process can be

cumbersome for teachers, and it can interrupt the flow of teaching sessions by increasing inter-trial intervals and decreasing treatment integrity as teachers make errors. These results suggest that counterbalancing trials within sessions may not significantly improve an individual's ability to learn relations between sample and comparison stimuli in all cases.

It is interesting to note that all three participants stated that they had named the stimuli during the course of the study, and that they felt that this helped them to learn. During debriefing, the experimenter asked each participant to report on any naming that occurred during the course of the study. It is possible that naming the stimuli may have enhanced skill acquisition more than a lack of counterbalanced trials hindered it. Michelle's performance on the first stimulus set improved more significantly during the first training session than the performance of both Steve and Stacy. This may be explained by the fact that she was exposed to teaching procedure 1 first. Unlike Steve and Stacy, who were exposed to teaching procedures 2 and 3 first respectively, she did not rely on the position of the comparison stimuli. It is interesting to note that Stacy stated during the first training session using stimulus set CD and teaching procedure 1, "this one switches up a lot more".

There are several limitations to the present research that are worth noting. First, it is possible that this result is unique to the population of typical adults. Second, all participants were exposed to the same stimulus sets in the same order (i.e. stimulus set AB was taught first, followed by stimulus set CD and EF). It is possible that stimulus set EF was not as difficult as the other stimulus sets, which may explain the participants' improved performance on stimulus set EF. However, it is likely that participants

performed better on the last stimulus set simply because they had more experience with the experimental procedures at the end of the study.

Third, participants were asked to move the sample and comparison stimuli to the top of the slide on each trial in order to establish an observing response. It is possible that process was responsible for the participants' success with this task.

Future research should replicate this study with other populations in which ceiling effects are less likely to occur such as individuals with disabilities, and examine whether students with diagnoses of Autism or other developmental disabilities demonstrate a significant difference in performance depending on whether or not trials are counterbalanced within or across teaching sessions. Future research should also assess the extent to which the use of counterbalanced trials can impact treatment integrity. It is possible that, in the context of non-automated classroom teaching, the counterbalancing requirement may compromise the integrity of related teaching procedures (e.g. intertrial interval, reinforcement delivery, prompting integrity, etc). It would also be worthwhile investigating whether performance on visual matching-to-sample tasks are influenced by the presence, absence, or duration of an observing response and whether counterbalancing procedures may be faded without decreasing acquisition rates.

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disabilities: transfer of stimulus control to writing tasks. *Journal of Applied Behavior Analysis*, 29, 25-42.

Participant	Stimulus set AB	Stimulus set CD	Stimulus set EF
1	Procedure 1	Procedure 2	Procedure 3
2	Procedure 2	Procedure 3	Procedure 1
3	Procedure 3	Procedure 1	Procedure 2

Table 1

Order of teaching procedures by participant

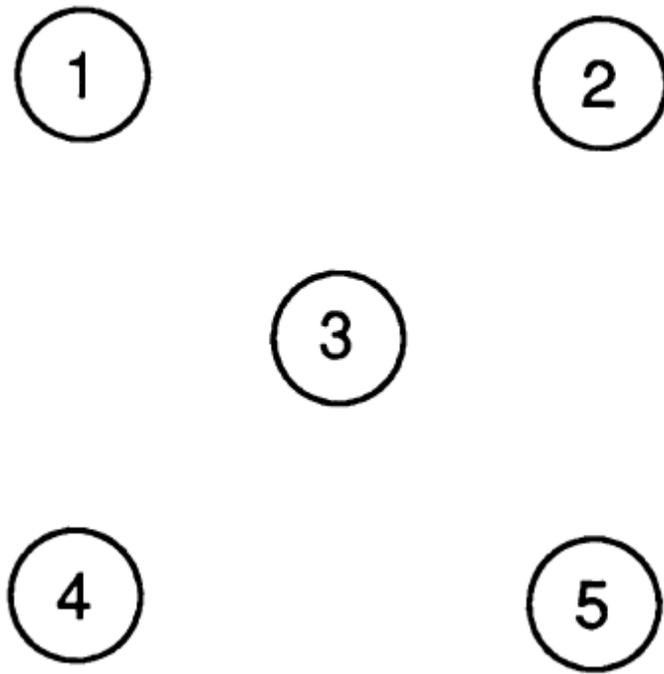


Figure 1

Schematic representation of key locations (Sidman, M. 1992)

		SELECTIONS OF COMPARISON STIMULI	
		VERTICAL	HORIZONTAL
CONDITIONAL STIMULI (SAMPLES)	VERTICAL	V/V  HIT	H/V  MISS
	HORIZONTAL	V/H  FALSE ALARM	H/H  CORRECT REJECTION

Figure 2

Signal Detection Matrix (Sidman, M. 1992)

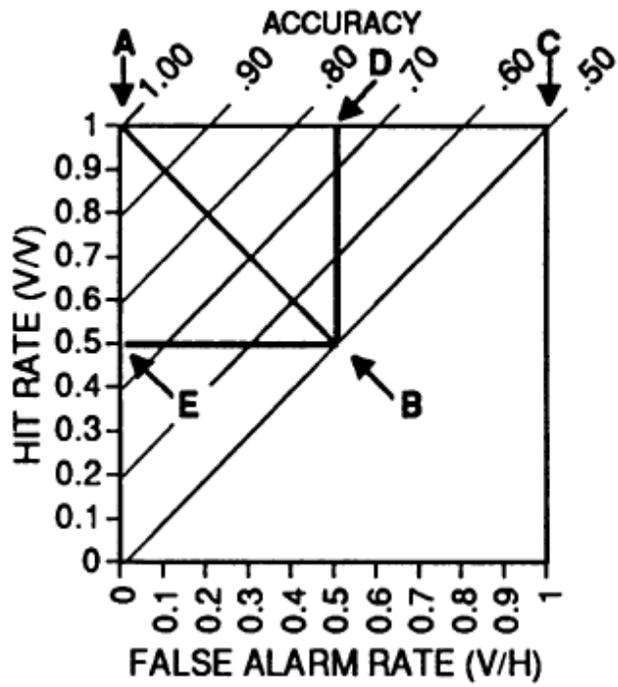


Figure 3

Signal detection space (Sidman, M. 1992)

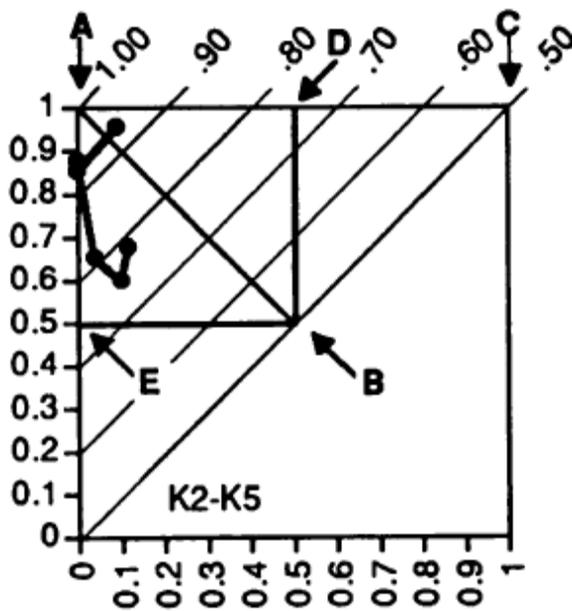
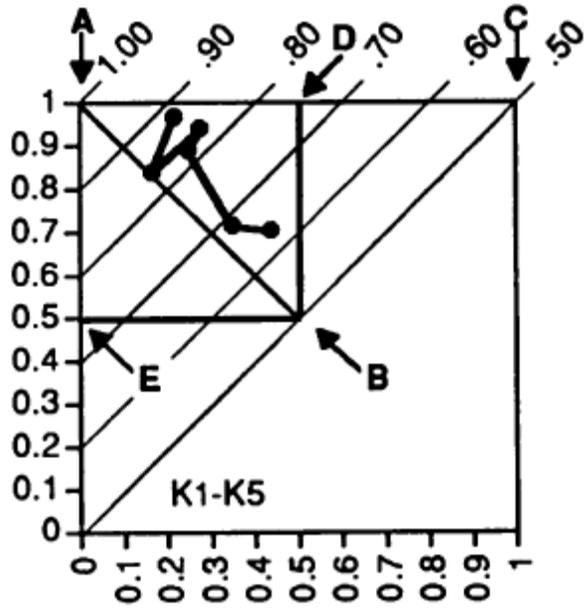


Figure 4

Signal detection spaces indicating restricted stimulus control

Stimulus set	Sample Stimulus	Comparison Stimulus
AB 1		
AB 2		
AB 3		

Figure 5

Stimulus set AB

Stimulus set	Sample Stimulus	Comparison Stimulus
CD 1		
CD 2		
CD 3		

Figure 6

Stimulus set CD

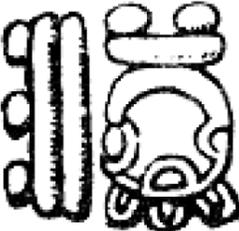
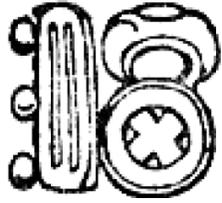
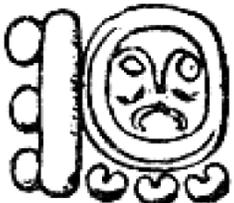
Stimulus set	Sample Stimulus	Comparison Stimulus
EF 1		
EF 2		
EF 3		

Figure 7

Stimulus set EF

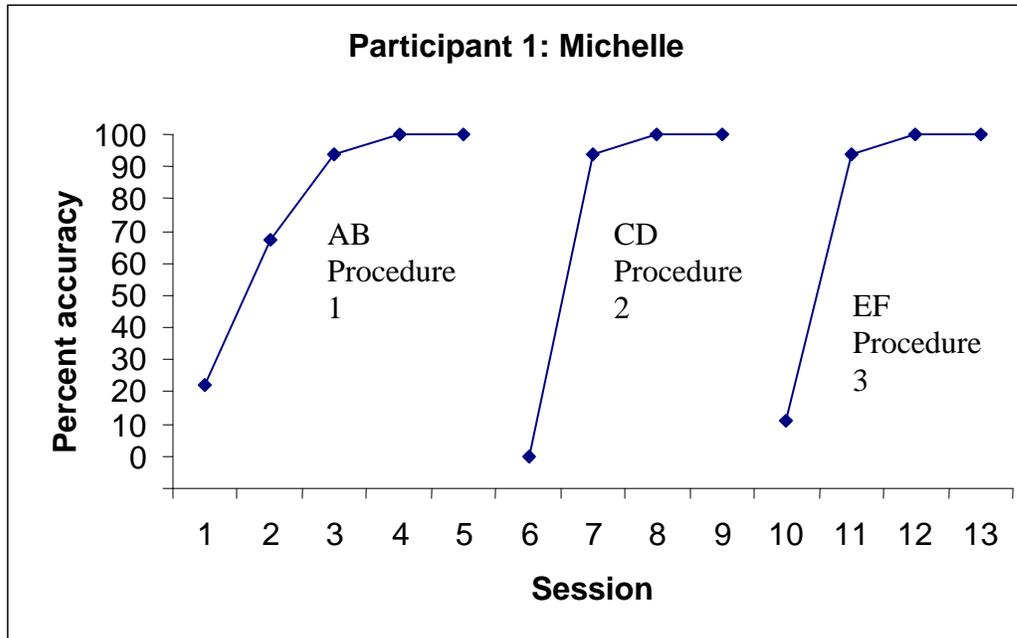


Figure 8

Results for Participant 1

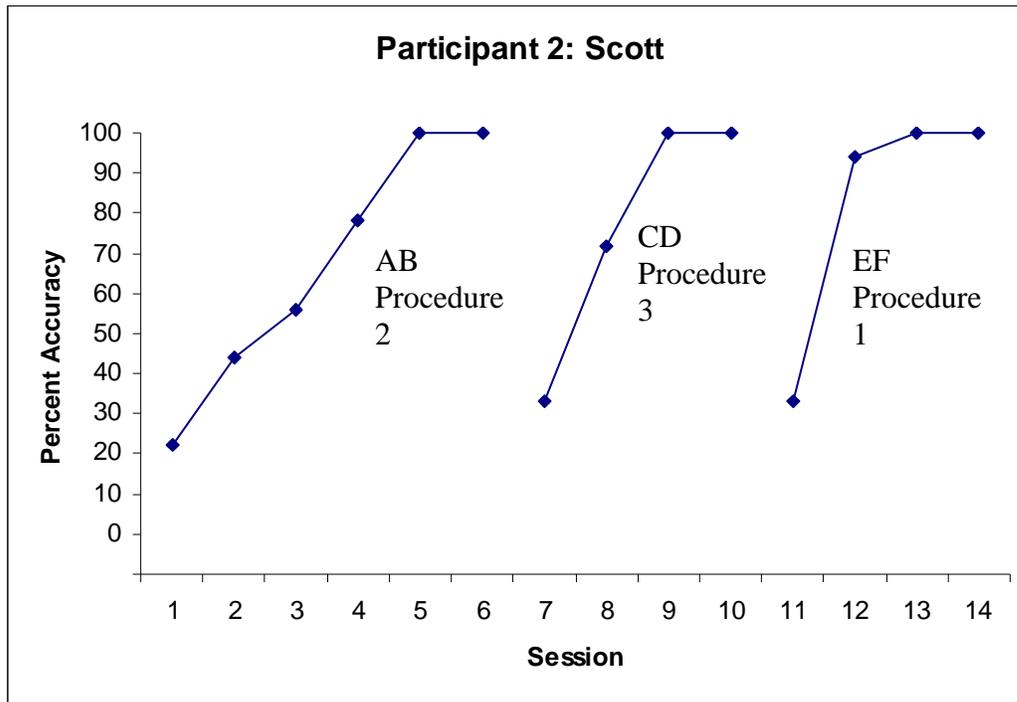


Figure 9

Results for participant 2

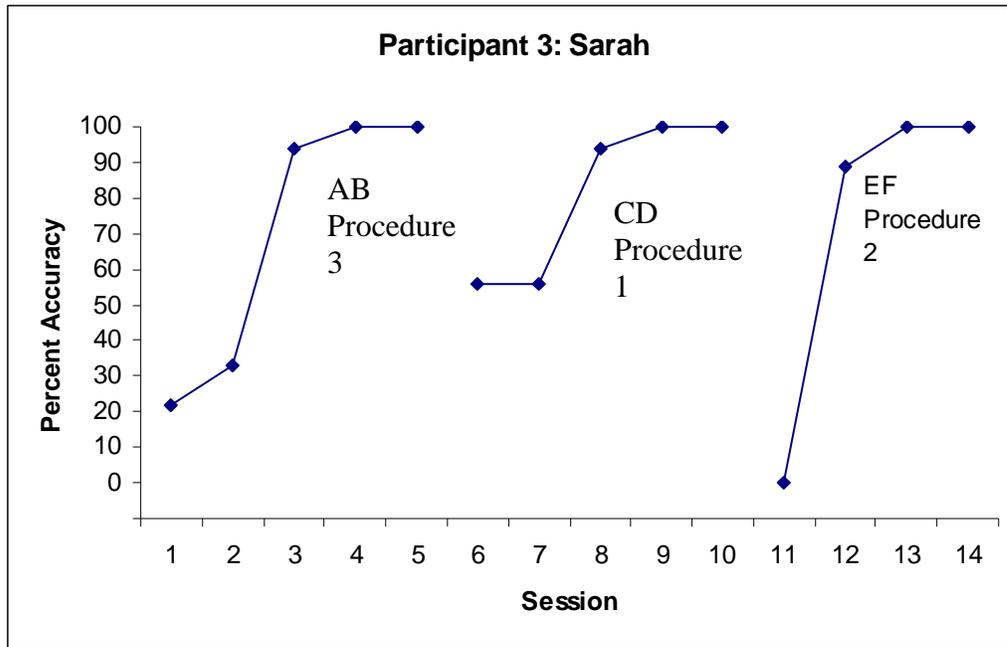


Figure 10

Results for participant 3

Figure 11

Stimulus positions selected during errors for participant 1

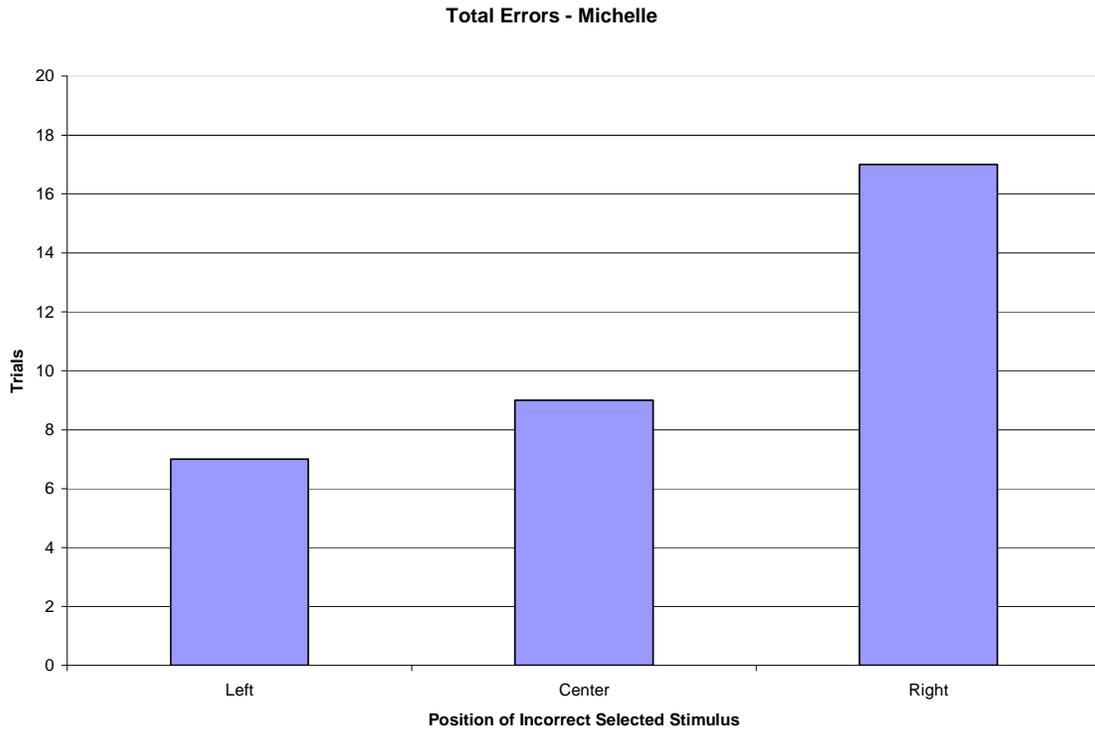


Figure 12

Position of selected incorrect stimulus by session type for participant 1

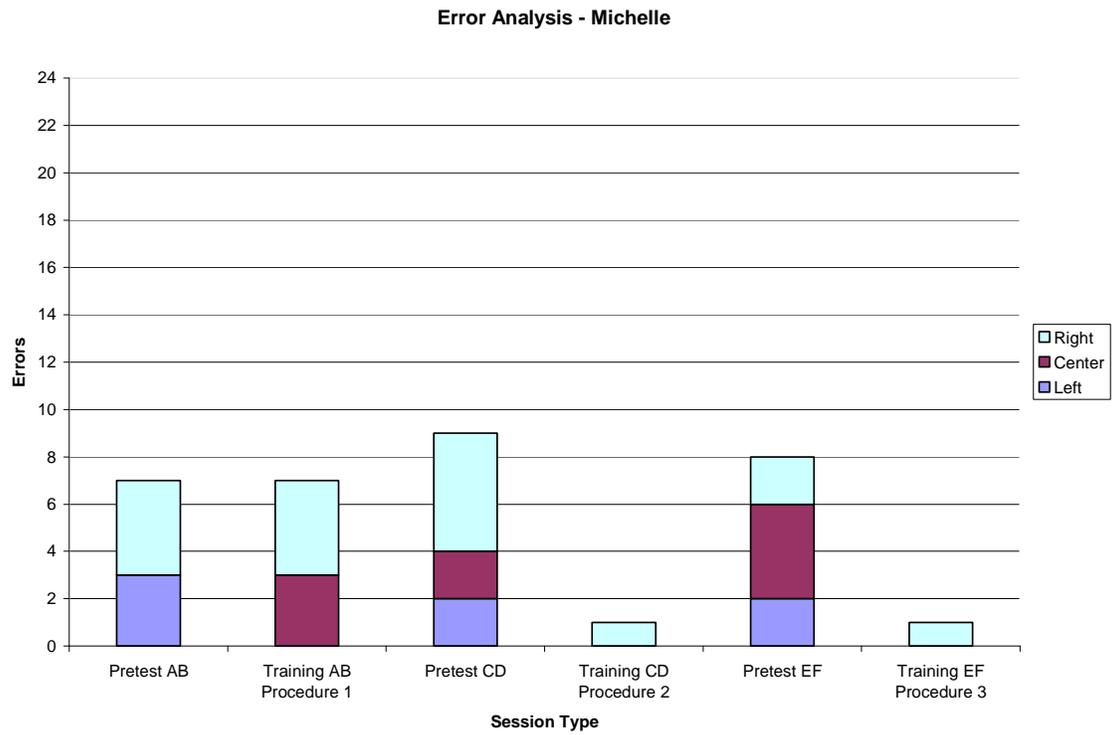


Figure 13

Stimulus positions selected during errors for participant 2

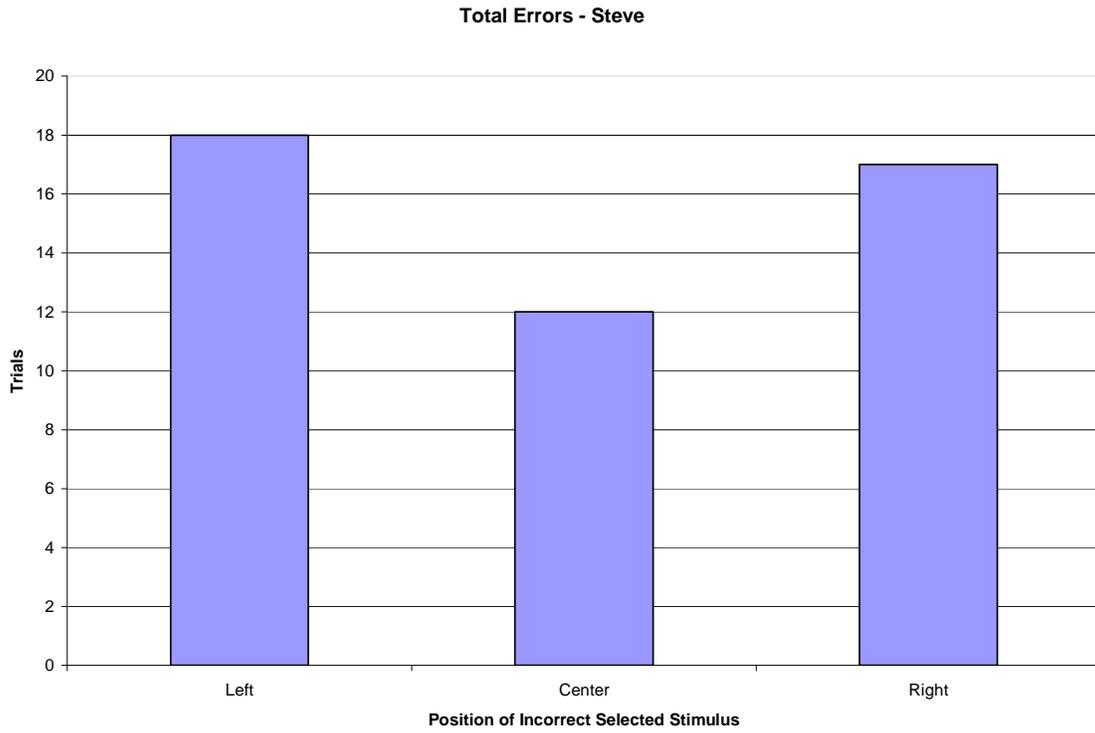


Figure 14

Position of selected incorrect stimulus by session type for participant 2

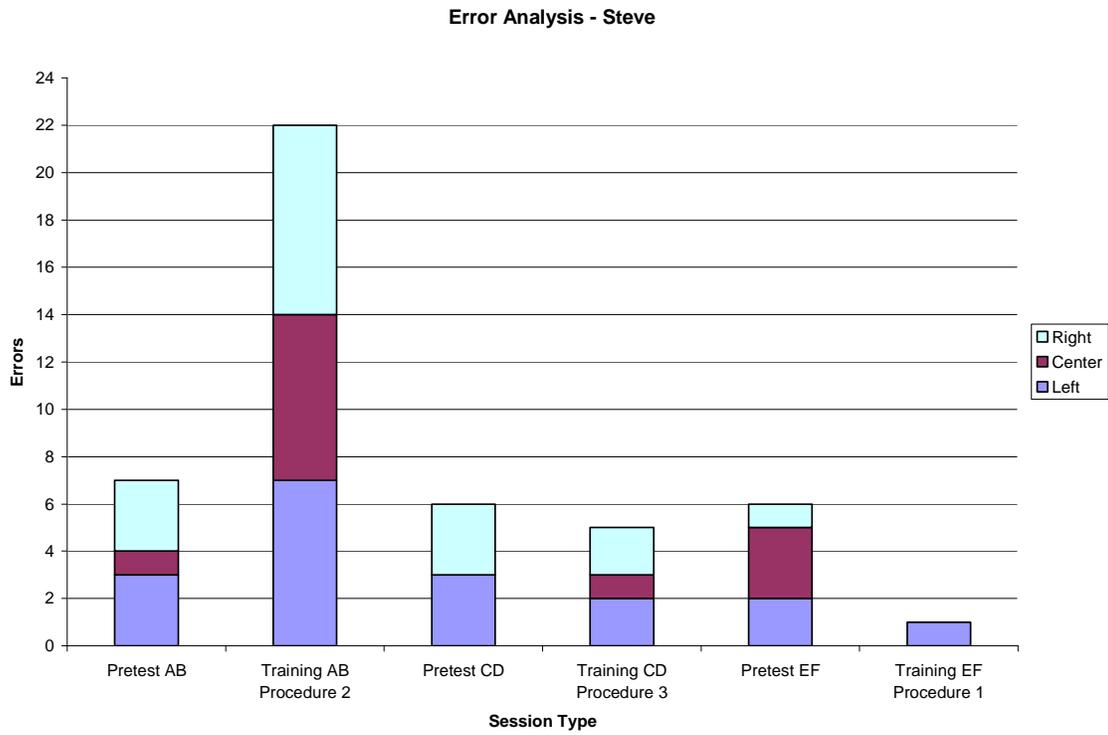


Figure 15

Stimulus positions selected during errors for participant 3

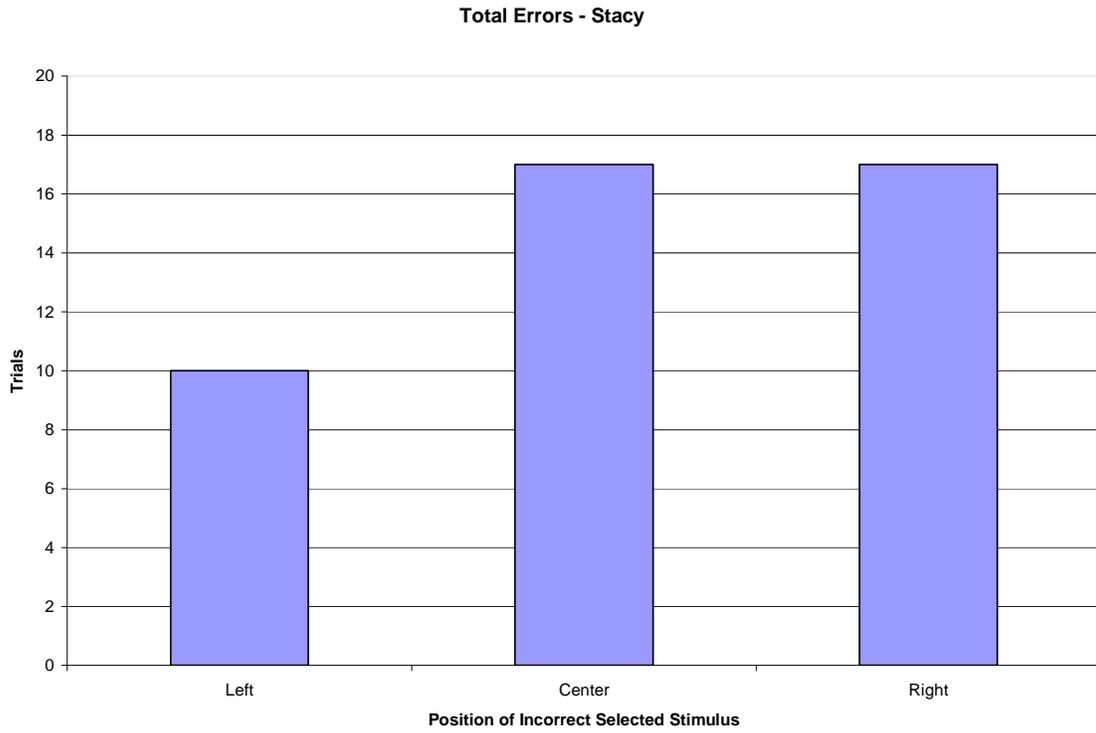
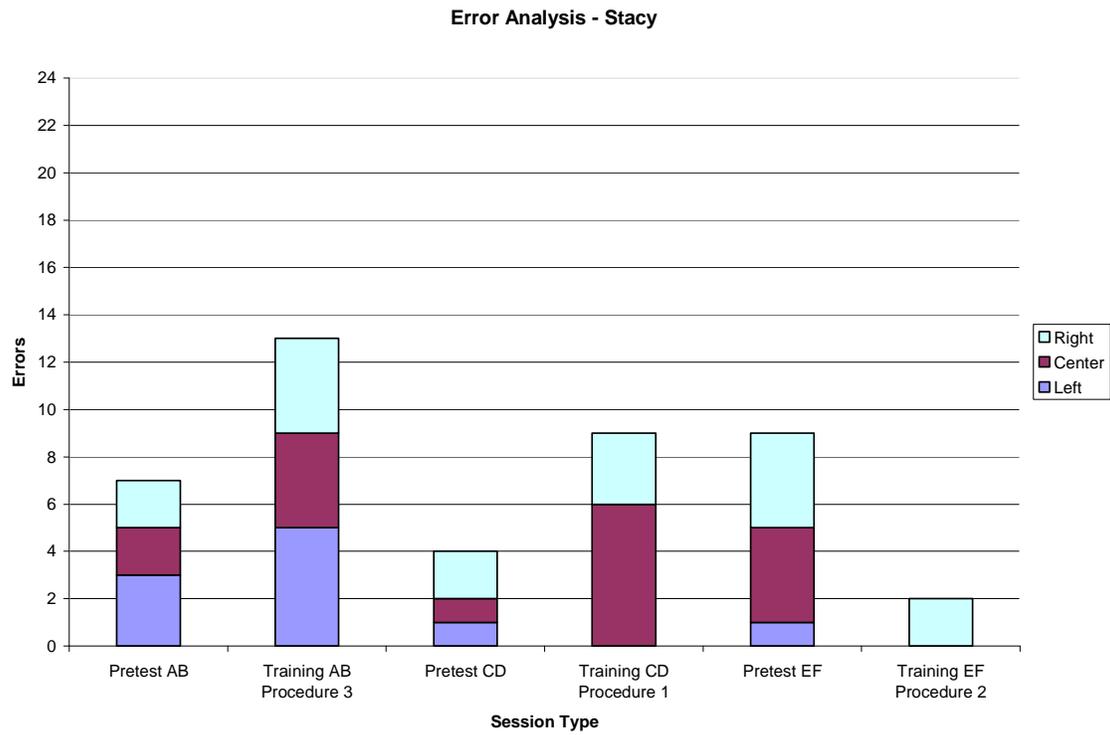


Figure 16

Position of selected incorrect stimulus by session type for participant 3



Appendix

Thank you for volunteering to participate in this study! Please carefully read the instructions below. If you have questions about the procedures, please ask now! I will answer your questions if I am able to do so without compromising the validity of this study.

You will be presented with several Power Point documents. On each slide, you will see one or three unfamiliar, arbitrary symbols. Don't worry, you are not expected to have any knowledge of the "meaning" of these symbols.

On the first slide, you will see a single symbol. You will click on the symbol and move it to the top of the page. You will then go to the next slide, which will contain an array of three symbols. You will select the symbol that you think "matches" the symbol from the previous page and move the symbol to the top of the page. I will tell you if you are right or wrong, but if you are wrong I will not tell you the correct answer. You will then go to the next slide, which contains a single symbol. You will move the symbol to the top of the slide, go to the next slide, and move the symbol from the array that you think "matches". We will continue in this manner until all of the trials have been completed.

Note: the purpose of moving the symbols is to indicate which symbol you have chosen and to prevent unnecessary ink and paper waste – the precise location where you place the symbol does not matter.

At times, you will be given "tests". During the tests, you will follow the same procedures, but I will not tell you whether you are right or wrong.

Pay close attention and try to work quickly. You will be given the option to take breaks between booklets.

Please note: The purpose of this study is to examine the effectiveness of different teaching techniques. This will not be in any way considered a test of intelligence. When all sessions are complete, I will explain the purpose of this study in more detail.

Please sign and date below to indicate that you have read and understand these instructions, and that you consent to participating in this study.

Print name

Signature

Date

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