

THE EFFECTS OF CAPTURING AND SEARCHING ON THE
ACQUISITION OF A SIMPLE ARM POSITION

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The present experiment compared two methods of training a simple arm position using auditory feedback: capture and search. The participants were four right-handed female college students. During capture, auditory feedback was delivered by the experimenter after the participant moved along a single axis into the target position. During search, auditory feedback was produced by the computer after the participant left clicked a mouse inside the target location.

The results of a multi-element design showed that participants performed more accurately during capture training than search training. Pre-training and post-training probes, during which no auditory feedback was provided, showed similar fluctuations in accuracy across probe types. A retention check, performed seven days after the final training session, showed higher accuracy scores for search than capture, across all four participants. These findings suggest that TAGteach should incorporate an approach similar to search training to improve training outcomes.

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INTRODUCTION

Traditional sports training methods primarily use error correction that generally consists of punishment and negative reinforcement: verbal feedback (reprimands), time-outs, and overcorrection (Allison and Ayllon, 1980) along with a combination of physical guidance, modeling, cues, instruction, performance feedback, and praise (Allison & Ayllon, 1980; Jones, Wells, Peters, & Johnson, 1988). Error correction occurs after the learner has already made an error - thus increasing the total number of responses required for skill mastery. Traditional sports training procedures generally take months or years to produce competitive athletes. This can be frustrating for the athlete, and places him or her at increased risk of injury. Studies have demonstrated that gymnasts average 0.5 to 3.6 injuries per 1000 hours of training, with inexperienced gymnasts typically experiencing a higher rate of injury than experienced gymnasts. (Canie, Caine, & Zemper, 1989; Cupisti et al., 2007; & Lindner & Caine, 1990).

Although effective at reducing undesired behaviors (Allison & Ayllon, 1980), aversive control strategies may lead to unwanted side-effects. According to Sidman (1989), punishment and negative reinforcement may cause escape and avoidance behaviors such as skipping practice or dropping a sport completely. Other side-effects of aversive control procedures include increased aggression and counter-control directed at the agent associated with the procedures. An athlete may be less likely to follow instructions or be friendly with trainers who frequently use aversive methods to control behavior.

Sports training programs based on behavior analytic principles offer an effective alternative to the traditional approach. These programs greatly reduce or eliminate the use of aversive consequences, while increasing accurate responding across a wide variety of sports behaviors (Allison & Ayllon, 1980; Anderson & Kirkpatrick, 2002; Fogel, Weil, & Burris, 2010;

Scott, Scott, & Goldwater, 1997). When compared to traditional training methods, behavior analytic approaches resulted in better performance in a shorter period of time and are less aversive to the learner (Allison & Ayllon, 1980, Sidman, 1985). Sidman (1985) suggested that the best method for training a desired performance without errors is to first train prerequisite skills. Once each skill component has been learned the final composite behavior will emerge without error. Unfortunately, even component skills may be difficult to train.

Skinner (1959) described a method for training component skills using conditioned reinforcers. Skinner explained that food and other primary reinforcers are difficult to deliver quickly, which may inadvertently select undesirable behaviors occurring after the target behavior. Conditioned reinforcers can be delivered instantly, thus avoiding the problem. When conditioning a stimulus, the first step is selecting the best stimulus for the job. The ideal stimulus is one that can be delivered immediately and is easily noticed by the animal. Next, the stimulus should be repeatedly paired with a primary reinforcer. After several pairings, the stimulus takes on a discriminative function, evoking movement towards the spot where food was previously delivered. Movement to where food has been delivered in response to the stimulus also signifies that the stimulus has been conditioned as a reinforcer.

Instead of waiting for the animal to emit the complete performance a trainer should reinforce approximations towards the desired behavior. The first behaviors selected with a conditioned reinforcer should be those most closely resembling the final desired performance that already exist in the animal's repertoire (Skinner, 1959). In order to isolate the first steps in a training sequence, complex behaviors must be broken down into smaller units. After the first step in the sequence has been strengthened, that behavior must be placed on extinction and reinforcer delivery made contingent on a closer approximation towards the target performance.

This process of differentially reinforcing successive approximations towards a target behavior continues until the animal reliably emits the target behavior.

Animal training programs based on the method described in Skinner (1959), have become increasingly popular (Pryor, 1999) and have the advantage of being faster and less aversive than traditional animal training procedures (Ferguson & Rosales-Ruiz, 2001).

Adaptations of Skinner's approach have recently been applied to train complex motor skills to humans. Some of these skills include tennis, ballet, and golf (TAGteach International, n.d.).

TAGteach International (n.d.), is an organization devoted to training a wide variety of human behaviors using methods similar to those described in Skinner (1959). TAG stands for *teaching with acoustical guidance* and refers to the use of auditory feedback during training. Differences between the TAGteach approach and Skinner's include the use of instructions, verbal feedback, and a post-training discussion of progress. Instead of pairing the auditory stimulus with food, TAGteachers verbally describes the contingency between a correct response and stimulus delivery (Fogel, Weil, and Burris, 2010).

The website for TAGteach International (n.d.) states that, "The TAG refers to the distinctive sound made to mark or 'TAG' a moment in time. This sound becomes an acoustical binary message, a sort of 'snapshot' that is quickly processed by the brain." TAGteach practitioners have indicated that auditory feedback, used as part of their training package, helps students to correctly reproduce whatever response or body posture occurred during stimulus onset. These claims have yet to be proven experimentally.

Fogel et al. (2010) evaluated the effectiveness of the TAGteach training package in teaching a golf swing to a novice golfer. The golf swing was broken down into five skill sets: grip, address position, alignment, pivot, and arm positions. Each skill set was further broken

down into component responses, which were trained individually. The authors provided one example of how an early training trial for a component response in the grip skill set was conducted. The experimenter physically prompted the hand and finger positions and delivered auditory feedback. After six consecutive correct component responses were performed independently by the participant the experimenter asked her if she was ready to move forward in the teaching sequence. If three consecutive incorrect responses were performed the participant was redirected to an earlier step in the sequence.

Fogel et al. (2010) found that after training, the participant showed significant improvement in four out of five composite skill sets. These findings are limited, however, due to the failure to train the fifth skill set (arm postures). No description was provided for how physical prompts were faded to allow independent response performance. Also, the combined effects of the training package obscured the effects of individual procedures. In particular, the effects of auditory stimulus delivery on skill acquisition were unclear. Additional research is needed to clarify the relation.

Fogel et al. (2010) provided the click immediately after moving the participant into the desired position using physical guidance. In order to perform the target response independently the participant would also have had to learn to find the position without prompts. One way that people may learn to find a particular body position is using proprioception. Proprioception is the ability to sense stimuli arising within the body (Sherrington, 1907). After being physically guided into a desired position a person may learn to return to that same position by feel. He or she must learn to correctly discriminate the feel of the target position from the feel of other body positions. Additional stimulation in the form of the click may aid in training the discrimination and improve shaping a desired performance.

Some evidence suggests that physical forces, such as angular momentum acting on a moving limb, could result in systematic changes in how the click affects learning. Research by Dassonville (1995) suggested that proprioception may be distorted by movement. He provided a tactile stimulus during a movement and then asked participants to indicate the physical position of their limb at the time of stimulus delivery. All participants indicated a position that was further along the line of motion than they had been at the time of stimulus delivery. The author concluded that the tactile feedback did not capture the desired arm position as the arm traveled from a starting point towards a resting point. This type of capture procedure may differ from a search procedure in which feedback is provided contingent on participants locating the target position. In light of this finding the effects of clicking during movement should be compared to the effects of clicking for a stationary position.

The present experiment sought to address these issues by comparing two procedures for training a simple arm movement using auditory feedback. Both procedures took place in a restrictive environment that reduced the chances of erroneous responding. Similar to Fogel et al. (2010), the click was thought to function as an additional stimulus that aids in discriminating the correct body position. One procedure, called capture, involved auditory feedback delivered directly by the experimenter using a handheld clicker tool. The audible stimulus was delivered when the participant's arm reached the desired position. capture allowed examination of how movement affects the learning of a specific arm position. capture also prevented errors from occurring by guiding the learner to the desired position. Another procedure, called search, allowed freedom of movement and required the participant to come to a full stop and left click a computer mouse to produce auditory feedback. The search procedure allowed errors to occur and provides a counterpoint to the more guided capture procedure.

METHOD

Participants

Four undergraduate students, referred to in this experiment as Helen, Marla, Sue, and Tilly, participated in this study. These students were between the ages of 19 and 31 years of age, and all were females of Caucasian descent. Each participant was given a short interview by the experimenter to rule out physical conditions. None of the participants reported any impairment that could interfere with experimental training. Participants were required to have some history using a computer mouse and be between five and six feet tall. Participants were exposed to some behavior analytic concepts prior to their involvement in this research.

Setting and Materials

All experimental sessions were conducted in a 5x5 square foot room containing a 3x3 foot table. The participants sat on a chair on the experimenter's right side, and facing either forwards or backwards, depending on the experimental condition in effect. In addition, the position of the participant's chair with respect to the table was held constant so as to minimize topographical differences in responding across sessions. Stickers, placed on the ground, marked the exact location of the chair across training conditions. The experimenter sat on a chair at the front of the table with experimental materials on the table within the experimenter's reach. A yardstick was fixed on the table 23.5 cm away from the edge facing the participant. This distance allowed participants just enough room to operate a computer mouse, while restricting mouse movements along a vertical axis parallel to the edge of the table. Two pieces of cardboard were fixed to the yardstick using tape. These cardboard pieces were positioned so as to stop the mouse if participants tried to move out of a prescribed range. The bottom edge of one cardboard bumper was 46.4 cm from the top edge of the other bumper. The distance from either

bumper to the nearest target was 11.1 cm. The length of the target from top to bottom was 1.9 cm. A Toshiba Satellite® laptop computer was positioned on the side of the yardstick opposite from where participants would be moving the mouse. From the computer a Logitech G3® laser mouse extended from its power cord to rest with the top of the mouse flush with one of the cardboard squares. The power cord had to be draped over the edge of the table in such a way as to avoid influencing participant movements. In front of the computer's keyboard sat a notebook, pencil, stickers and a clicker tool (see Figure 1).

Independent Variables

The independent variables manipulated in this study were two procedures for teaching a simple arm position using sound. These procedures were called capture and search.

Capture. The capture procedure consisted of a discrete trial teaching format, which allowed participants to find the correct arm position in one movement cycle. After the experimenter said a word always associated with this procedure the participant began moving her arm holding a computer mouse along a single axis towards a target position. A sound was delivered immediately after the participant arrived at this target position and the participant was told to immediately stop all movement along the axis and left click the mouse before returning to the start position.

Search. The search procedure consisted of a discrete trial teaching format, which did allow participants to make either correct or incorrect responses while attempting to find the correct arm position. After the experimenter said a word always associated with this procedure,



Figure 1. Setting and materials.

the participant began moving her arm along a single axis towards a target position. After moving to their best estimate of the target position the participant was to freeze in place and press a button, which produced auditory feedback if their arm position was correct. If the response produced this sound they were to immediately return to the start position. If the response did not produce a sound they were to move to a new location along the axis and try again. This process would continue until auditory feedback was finally delivered, at which point the participant would immediately return to the start position.

Dependent Variables

The dependent variables measured in this study were the location of the mouse cursor on a computer screen and the percentage of mouse clicks in a target location. The location of mouse clicks was measured in terms of the pixel coordinates on the laptop's LCD screen using a computer program (Microsoft Visual Studio 2008®, see Figure 2). The screen resolution was set to 1366x768. Measureable onscreen area consisted of 1366x700. This left 34 pixels above and below the measureable on-screen area. The start position for the cursor was set at 50 vertical pixels from the top of the measureable area. Only data related to the vertical pixel location of the on-screen cursor were used for this experiment.

The band of responding defined as the target stretched from pixels 300 to 350 along the vertical axis (see Figure 2). The distance from the cursor's start position to the edge of the target was 250 pixels. This represents the mouse traveling 11.1cm from the start position to the target. The 50 pixel target area was 1.9 cm of vertical distance along the yardstick. Using the location numbers produced during sessions, a graph of the relative position of the mouse could be made for all session conditions. Percent accuracy was calculated by looking at the data for pre-



Figure 2. Screen-shot of measurement program (created using Microsoft Visual Studio 2008®).

treatment probes (10 trials each) and looking at left mouse click location numbers that were within the target band divided by the total number of responses and multiplied by 100.

Procedures

At the beginning of the session participants were positioned by the experimenter as follows:

1. The experimenter asked the participant to sit down on the chair with either her left or right arm alongside the table.
2. Experimenter adjusted participant's position such that whichever arm was being used for the experiment was parallel to the upright torso with elbow on the table and hand on the mouse in a fully forward position (the mouse was touching the bumper). This arrangement was explained to participants.
3. The participant's chair position was adjusted as needed to facilitate correct posture and positioning: The experimenter asked the participant to move their arm to their lap, and from their lap to the mouse to determine if the chair was the proper distance from the table. If they had to lean or strain to reach the mouse, the chair was considered too far away from the table. If the participant could not easily move their arm from their lap to the top of the table, the chair was considered too close to the table.
4. Participants were asked to move their arm from the mouse to their lap before beginning the experiment.

After the participants were placed in the proper start position they were asked to put on a sleep mask to block learning by sight (Figure 3).



Figure 3. Participant start position.

Probe trials. First the experimenter read the following instructions:

For the next ten trials I'm going to say the word (*vai* or *ora*) and I want you to put your (specify hand) on the mouse and move to where you think the (*vai* or *ora*) position is.

When you feel you have reached this position I want you to stop, left click, move the mouse to the top and put your hand back on your lap. Do you have any questions?

A probe trial consisted of the experimenter giving the vocal cue associated with either the search or capture procedure. The participant responded to this cue by placing a hand on the mouse and pulling it back to her estimation of the target. The participant then stopped, left clicked, pushed the mouse back up to the starting position, and put her hand back on her lap.

Pre-training and post-training probes consisted of 10 trials that occurred before and after both of the training procedures and did not include any feedback. Pre-session probe trials occurred 24 hours from the end of the last session, while post-training probes occurred immediately after training. For this reason, improved performance during pre-session probe trials was used as the criterion for mastery. The master criterion required participants to make five or more responses within the target band (i.e., 50% accuracy) for three consecutive pre-training probes. Participants were then told to return in a week's time.

A retention probe was conducted after a week with no training. Procedures used during the final session were similar to procedures used in pre- and post-training probes, except that probes were now run in blocks of 30 trials and no training or follow-up probes were administered. Participants completed a block of 30 trials, responding to a cue associated with a specific training procedure. Then participants were repositioned by the experimenter to respond with their other arm, and completed a second block of 30 trials, responding to a cue associated with the second training procedure.

Capture. First the experimenter read the following instructions:

Now I'm going to teach you how to find the *vai* position. When I say the word *vai* I want you to put your (specify hand) on the mouse and pull it down along the yard stick until you hear the click of the clicker tool. As soon as you hear that sound I want you to stop, left click, move the mouse back up to the top, and put your (left or right) hand back on your lap. Do you have any questions?

The experimenter then said the word *vai* to begin the trial. The participant responded by putting her hand on the mouse and pulling it backwards until she heard the "click" from the clicker tool. As soon as she heard that sound she left clicked, pushed the mouse back up to the starting position, and put her hand back in her lap. Trials continued until 30 clicks from the clicker tool had been delivered.

Clicks from the clicker tool were sounded by the experimenter immediately before or within the target location. The timing of the click with respect to the participant's location was determined by the speed with which the participant moved towards the target. Slow movement produced clicks within the target, while fast movement produced clicks above the target. Clicks above the target location allowed participants time to decelerate before coming to a stop in the target band. This also prevented late click delivery due to slow experimenter reaction time.

Search. During the first search procedure, after the experimenter said the word *ora*, which was always associated with this procedure, participants were instructed to place their hands on the mouse at the start position and slowly pull the mouse down along the yardstick while continuously left clicking until they clicked within a target band and produced a computer generated click sound. This part of the Search procedure only occurred during the very first trial

of the first session for the search procedure and was not repeated across sessions. Next the experimenter read the following instructions:

Now I'm going to teach you how to find the *ora* position. When I say the word *ora* I want you to put your (specify hand) on the mouse and pull it down along the yardstick until you think you're at the *ora* position. As soon as you reach this position I want you to stop, left click, and listen for a click sound. If you hear this sound, move the mouse back up to the top and put your (left or right hand) back on your lap. If you do not hear this sound move the mouse either up or down along the yardstick and click until you hear the click sound. Do you have any questions?

The experimenter then said the word *ora* to begin the trial. The participant responded by putting her hand on the mouse and pulling it back to her estimation of the target. She then stopped and left clicked the mouse. If the click produced a sound from the computer, she moved the mouse back to the start position and put her hand back on her lap. If she clicked the mouse and no sound was produced she moved the mouse either up or down along the yard stick and clicked until a click sound was produced by the computer, followed by returning her hand to her lap. This process continued until the participants had completed 30 trials in which they successfully produced the click sound.

Training assignment. Training procedures were assigned so that two participants (Helen and Sue) were taught the left arm position using capture and the right arm position using search. The other two participants (Marla and Tilly) learned the left arm position with search and the right arm position with capture. The purpose of alternating the assignment of training across arms in this manner was to control for the effects of arm dominance on skill acquisition.

Trouble shooting. In order for participant data to be measured consistently the experimenter had to occasionally adjust the participant's position or make minor adjustments to the position of the mouse (e.g., trouble shooting). Occasionally, the actions of the participant on the computer mouse resulted in a slight discordance between the mouse's start position and the location of the cursor on the screen. The mouse cursor on the computer screen needed to be properly aligned with a line at the top of the screen corresponding with the 50 pixel mark during the start of all trials. In these instances, it was necessary for the experimenter to pick up the mouse and place it in such a way that the cursor was once again aligned with the 50 pixel line while the mouse was simultaneously at the start position. These actions took place after the participant had moved the mouse to the start position and had moved their hand back to their lap.

The experimenter was required to verbally prompt the participant to return to the start position if the onscreen cursor was moved to a position below the point where the cursor location could be measured. First, the experimenter would say, "Please return the mouse to the start position and place your hand back on your lap." After the participant had followed these instructions, the experimenter would make the necessary adjustments and give the cue to begin the next trial.

Experimental Design

A multi-element design was used to compare the effects of capture and search on the acquisition of both left and right arm positions taught to the same participant. Pre-training and post-training probes allowed performance to be assessed in the absence of training. The training sequence alternated across sessions to control for order effects. A probe conducted seven days after the end of training tested participants' retention of the trained arm positions.

RESULTS

Figure 4 shows an example of raw data collected across sessions four, five, and six for Helen. Each session day has been divided by a vertical line. For each session there are six clusters of data points. The three sets of black data points represent performance during the search phase and the three sets of grey data points represent her performance during the capture phase. Each phase shows three clusters representing pre-training, training, and post-training data points. The y-axis represents the range of allowable movement during procedures. Data during search training showed more overall variability than was seen for capture training. The range for search training (50-443 pixels) was greater than for capture training (273-398 pixels).

Figures 5-8 show the performance for all participants in terms of the percentage of correct responses within the target band. Each column shows three experimental phases. These phases from top to bottom are pre-training probe, training procedure, and post-training probe. Columns on the left show the search conditions and columns on the right show the capture conditions. Helen's data showed that, in general, search was better than capture, except during training. Marla's data showed better performance during capture pre-training and training and better performance during search post-training. Sue's data showed better performance during capture pre-training and training, and similar performance for both search and capture post-training probes. Tilly's data showed better performance during capture training and similar performance across search and capture pre- and post- training probes.

Figure 9 shows the errors and correct responses for all four participants during search training. The graphs are arranged in a two by two format showing participants who reached mastery for search on the left (Helen and Tilly) and those who mastered capture on the right

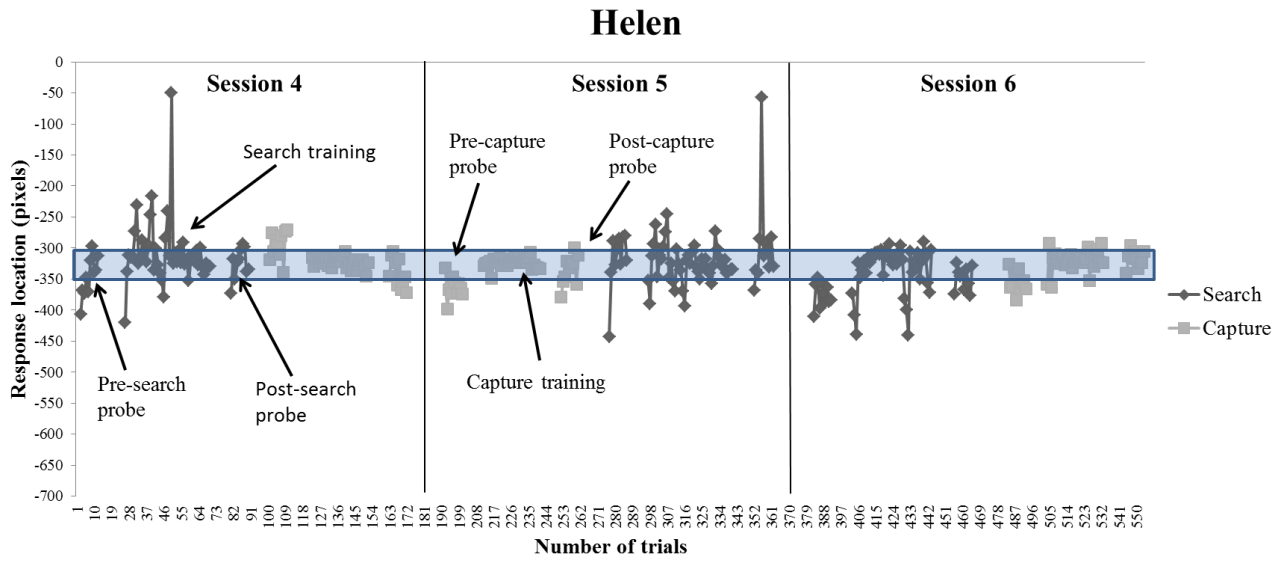
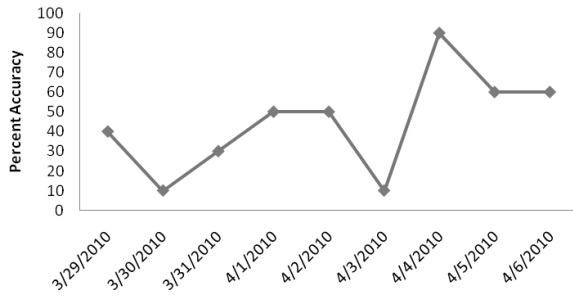


Figure 4. Helen's performance across three sessions. The shaded region shows the target location.

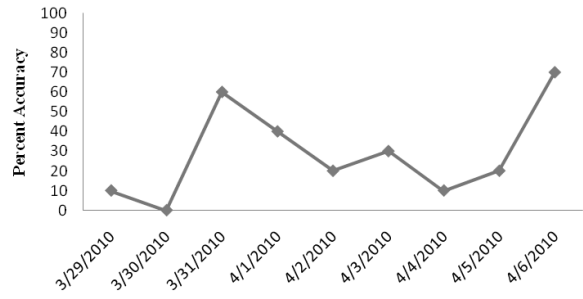
Search Condition (Right-arm)

Capture Condition (Left-arm)

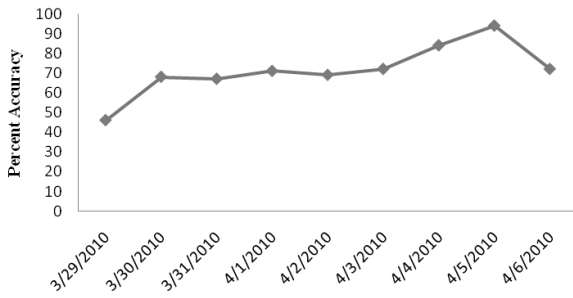
a Pre-training probe



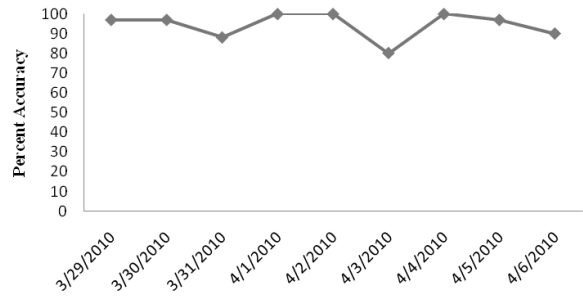
b Pre-training probe



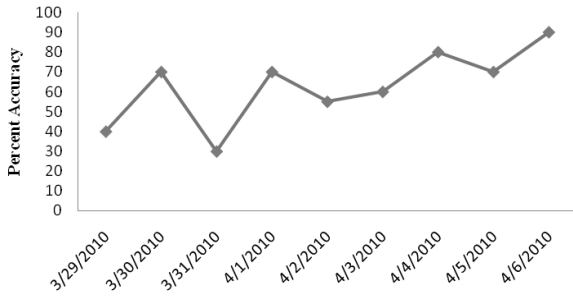
c Search procedure



d Capture procedure



e Post-training probe



f Post-training probe

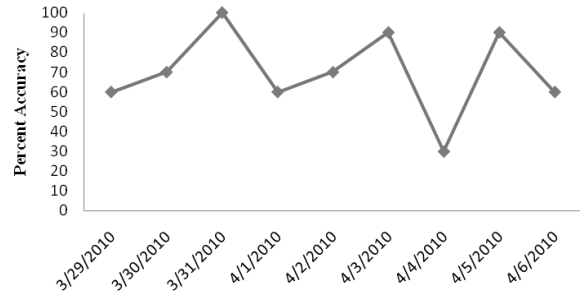
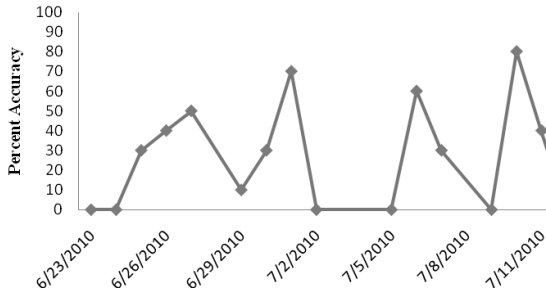


Figure 5. Helen's performance during each of the treatment conditions.

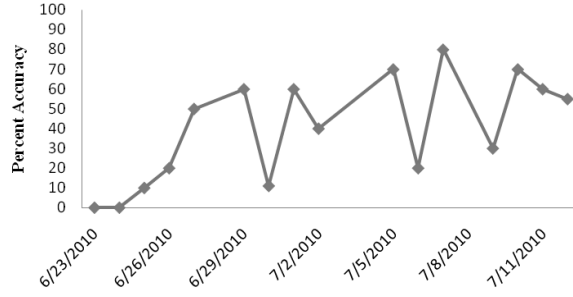
Search Condition (Left-arm)

Capture Condition (Right-arm)

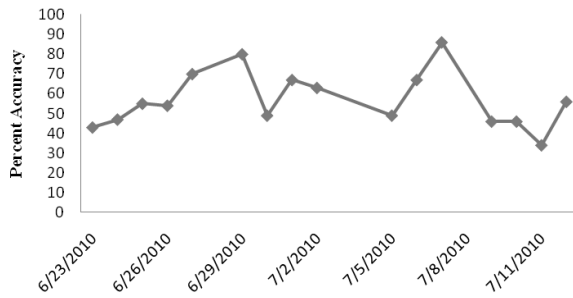
a Pre-training probe



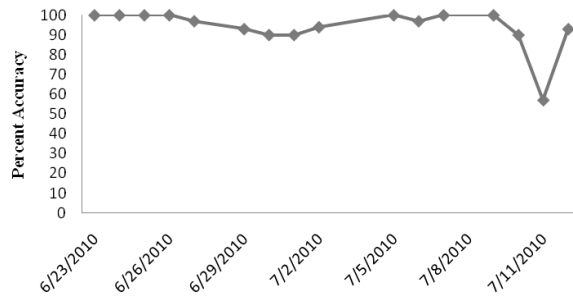
b Pre-training probe



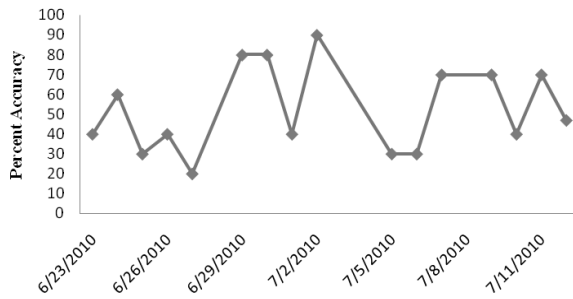
c Search Procedure



d Capture Procedure



e Post-training probe



f Post-training probe

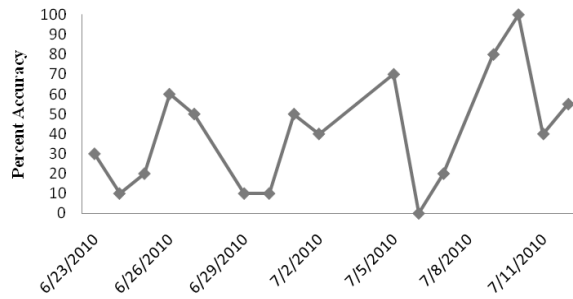


Figure 6. Marla's performance during each of the treatment conditions.

Search Condition (Right-arm)

Capture Condition (Left-arm)

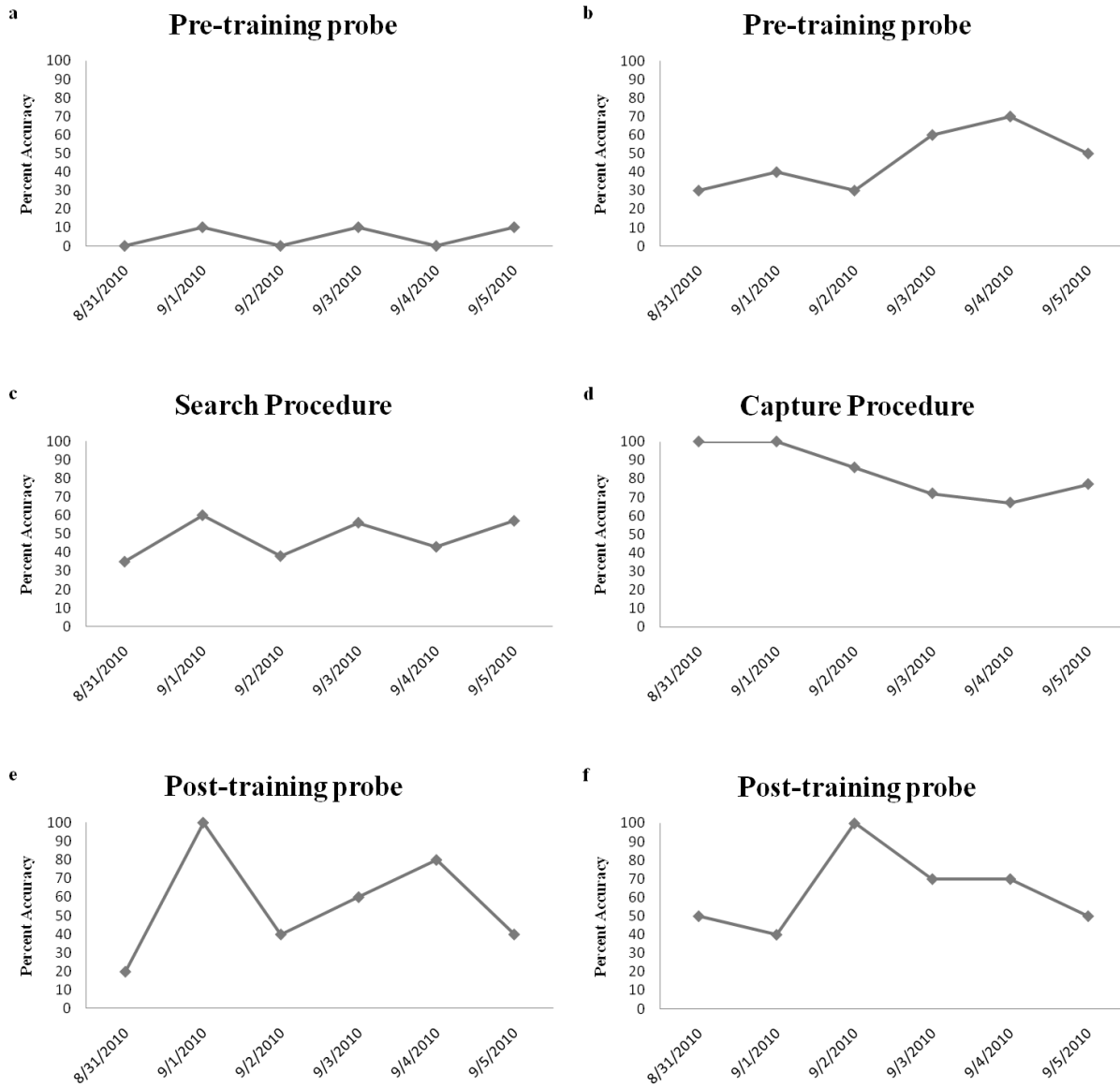


Figure 7. Sue's performance for all treatment conditions.

Search condition (Left-arm)

Capture condition (Right-arm)

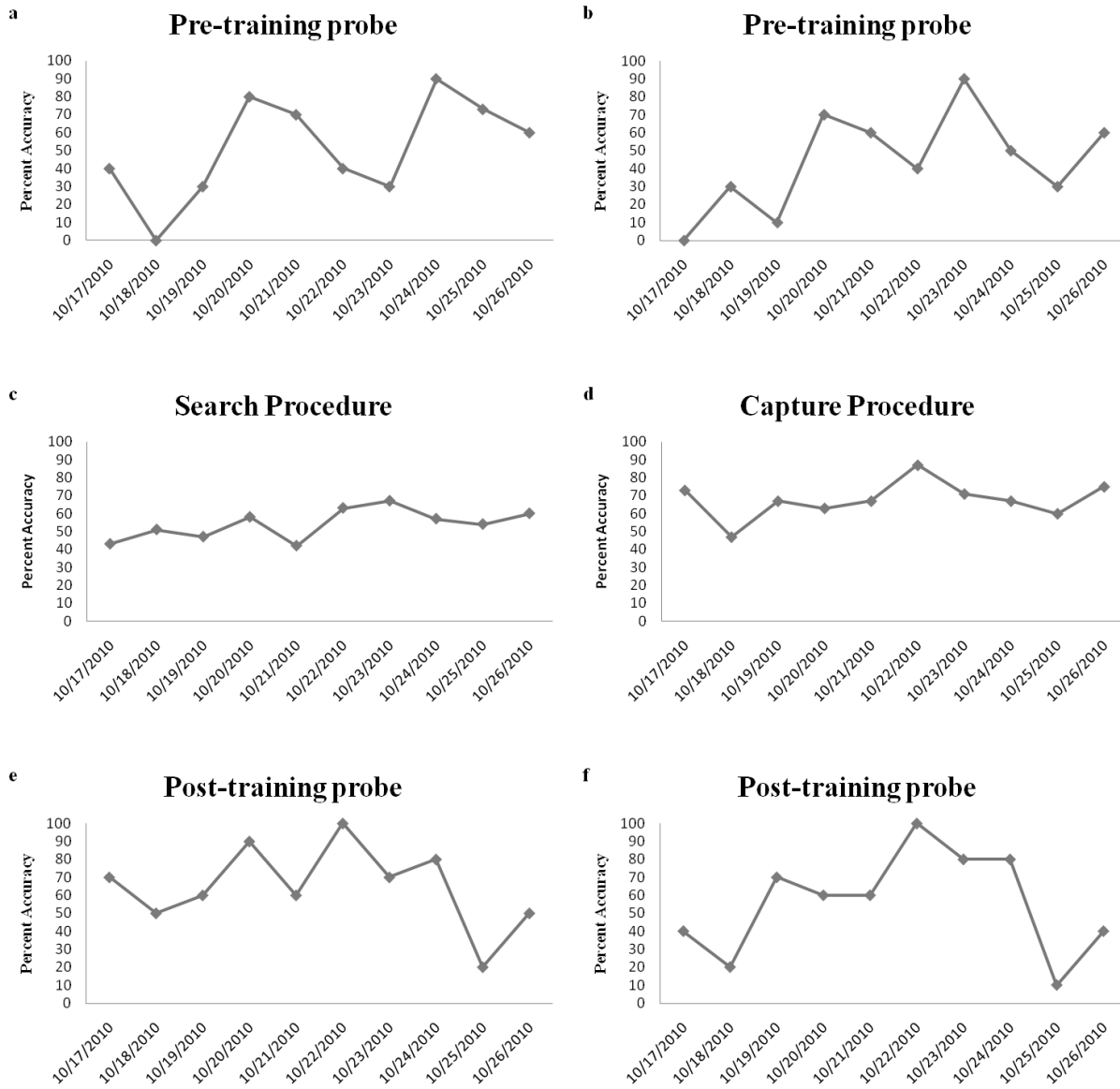


Figure 8. Tilly's performance for all treatment conditions.

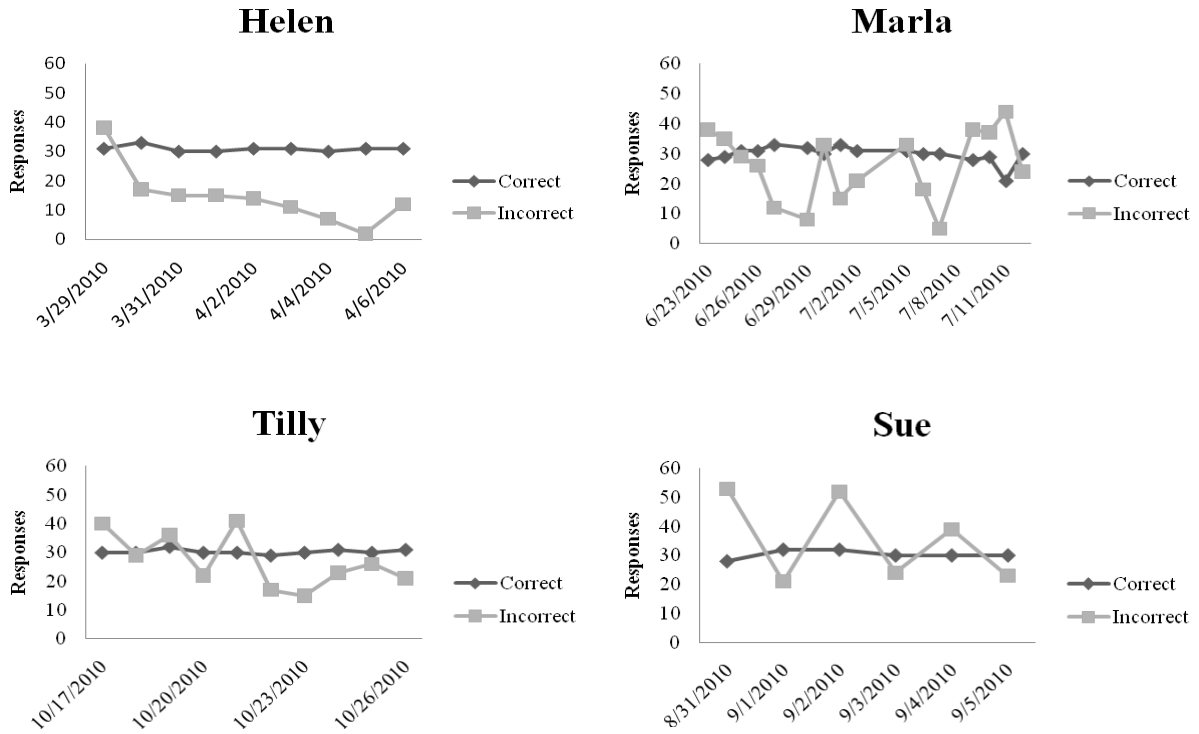


Figure 9. Correct and incorrect responses for all four participants during search training.

Participants in the left column reached mastery criteria for the search procedure and participants in the right column reached mastery for the capture procedure.

(Marla and Sue). Helen and Tilly's data show a decrease in the number of errors over time. Helen's data show a clear decrease in errors from 40 at the beginning to 12 errors at the end of training. Tilly's data show more variability than Helen's, but her rate of errors remains lower than her rate of correct responses for the last five sessions. In contrast to Helen and Tilly's data, Marla and Sue's data show higher rates of error. Marla's error rate was initially seen to decrease from 38 to 8 over the course of six sessions, but later fluctuated above her rate of correct responding. Sue's range of errors was between 53 and 21 per session. Although her data show a decrease in variability, Sue achieved mastery criteria for capture before her search data could reach stability. Fluctuations in the rate of correct responses per session were the result of experimenter error.

Figure 10 shows a summary of the accuracy scores for the one-week retention check for all participants. The bar-graph shows that all participants responded more accurately during the search condition than the capture condition after seven days without training. Two of the participants (Tilly and Helen) showed very low accuracy for the capture condition and two participants (Sue and Marla) showed capture accuracies only slightly lower than their search accuracies. Tilly and Helen met mastery criteria for search and Sue and Marla met mastery criteria for capture.

Figure 11 shows two frequency distribution graphs. The top graph shows the frequency distribution for the retention check during the capture phase and the bottom graph shows the frequency distribution for the retention check during the search phase. For the capture phase three participants (Helen, Marla, and Tilly) distributed the majority of their responses above the target location (250-299 pixels) and one participant (Sue) distributed the majority of her

Retention Check

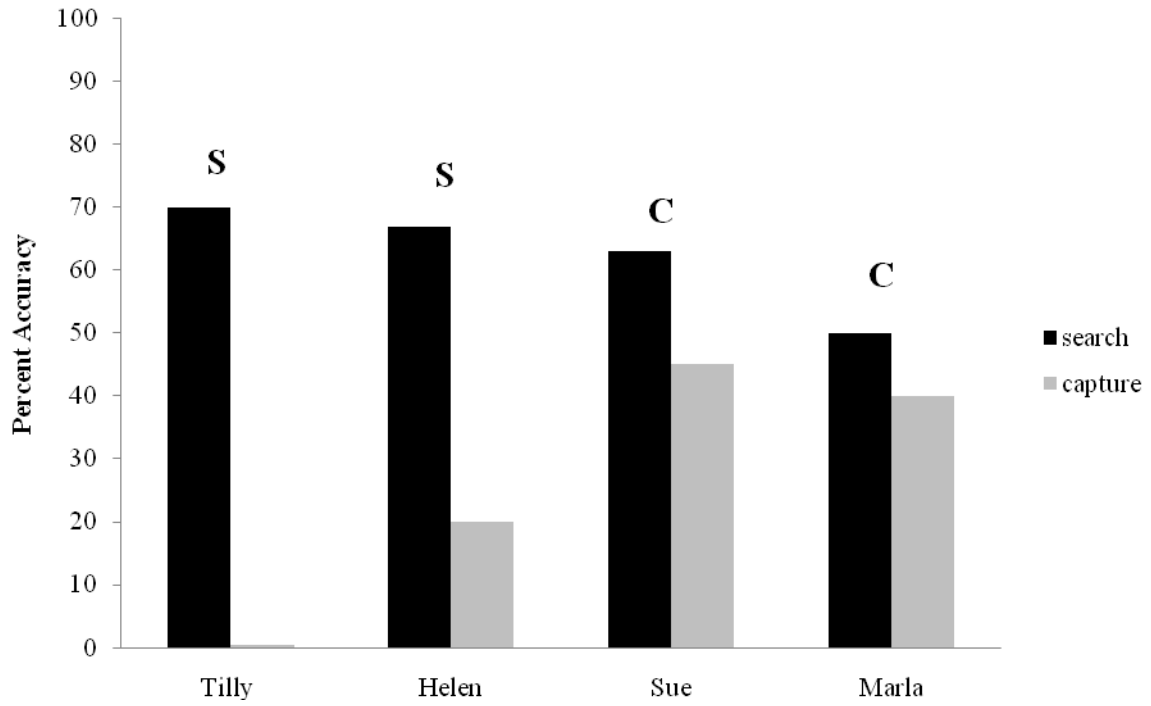
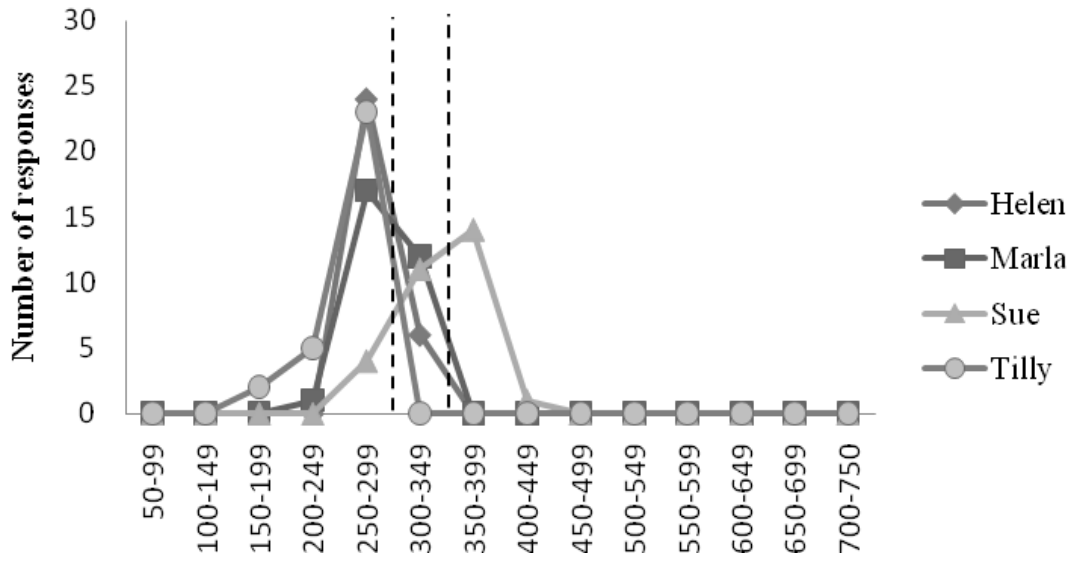


Figure 10. Retention performance data for all participants. Participants had previously met mastery criteria for either Search (S) or Capture (C).

Capture retention



Search retention

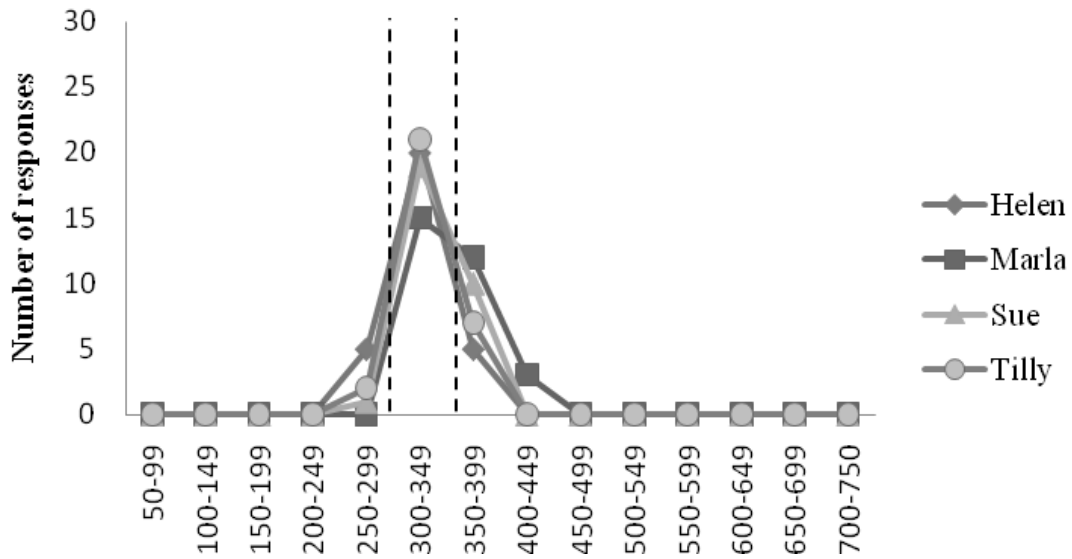


Figure 11. Frequency distribution of responses for all participants. Space between the dotted lines represents the target location.

responses below the target location (350-399 pixels). For the search phase all four participants distributed the majority of their responses within the target band (300-350 pixels).

Table 1 shows the results of the exit interview. All four participants reported that the procedures were enjoyable. Two participants stated that they preferred learning with the search procedure (Helen and Tilly), and two reported that the capture procedure was more enjoyable (Marla and Sue). All four participants reported that the search procedure helped them learn the arm position more effectively than the capture procedure. Helen reported using self-generated rhythm to find the target with her right arm, and visualized the correct position for her left arm. Marla reported singing a song and using rhythm to find both arm positions. Sue stated that she tried to remember where her arm muscles were in space when attempted to find either arm position. Tilly reported that she tried to remember where her arm was positioned in space to find the target.

Table 1

Participant Information and the Results of the Exit Interview

Name	Helen	Marla	Sue	Tilly
Procedure used for Left Hand	Capture	Search	Capture	Search
Overall was this experience enjoyable?	Yes	Yes	Yes	Yes
Did you prefer the clicker training or the computer feedback?	Search	Capture	Capture	Search
Which teaching procedure helped you learn the movement the best?	Search	Search	Search	Search
What strategies did you use to find the mouse position?	For my left arm I tried to visualize where it was. For my right arm I used beats like a meter (like a musical rhythm).	Singing a song in my head and counting. Listening to the sound of the mouse sliding with a somewhat steady speed.	I tried not to think about it. The more I would think the more I was wrong. I tried to remember how my muscles felt when my arm was in the right position.	I tried to remember where my arm was placed at the position where I heard the sound.

DISCUSSION

In this experiment, data collected during search training were found to be higher in accuracy than data collected during capture training. Search pre-training and capture pre-training probe data show similar fluctuations in accuracy for three out of the four participants, with one participant consistently responding less accurately during pre-search probes than she did during pre-capture probes. In general, data collected during post-training probes were similar, regardless of training condition. Two participants (Helen and Tilly) reached mastery for search, and the other two (Marla and Sue) reached mastery for capture. The retention check, conducted one week after training, showed that all four participants responded more accurately during the search rather than the capture. Several variables are thought to account for these findings.

Data collected during capture training were found to be higher than data from search training. The timing of auditory feedback delivery was a likely cause for these findings. During capture training, participants responded to a spoken cue by pulling the mouse downward in a straight line towards the target until auditory feedback was delivered in the form of a click from the clicker tool. Once they heard that sound, participants were to immediately come to a stop. The use of the click as a guide for when to stop moving explains why the majority of data points are near the target.

In contrast, during search training, participants moved the mouse to their best estimate of the target and left clicked the mouse. If the onscreen cursor had been moved within the target band, then the computer produced a click sound. Otherwise, participants kept moving the mouse and clicking until they found the correct location. Under these conditions, participants were observed to respond above and below the correct location before finding the target and producing the click sound. In the context of search training, the click confirmed the location of the target.

This confirmation could guide future responding, but occurred too late to guide participants to the target during the current trial. This explains why participants made more errors during search rather than capture training. Interestingly, neither search nor capture training data predicted performance during probe trials.

Pre-search and pre-capture probe data, taken 24 hours after the previous session, showed similar fluctuations in accuracy for three out of four participants, with one participant showing more accurate responses during the pre-capture than pre-search probes. For the most part response accuracy was found to be lower during pre-training probe trials than during training conditions. Similarly, post-search and post-capture probe data, taken immediately after training, revealed similar fluctuations in accuracy across all four participants. The data collected during post-training probes was found to be less accurate than during training conditions. In general, data collected during probe trials were less accurate than data collected during training. This suggests that the experimental feedback delivered during training was successful in guiding accurate performance. Without feedback, however, the participants experienced difficulty finding the target. This fails to validate the claims made by TAGteach International (n.d.), that the click produced a “snapshot” of the behavior, which allows the learner to easily return to that position in the future. On the contrary, none of the participants learned to consistently find the target outside of training conditions. These findings explain why Fogel et al. (2010), failed to train the arm position, even after a follow-up training session. Their participant was unable to find the arm position without auditory feedback.

In the absence of experimental feedback, participants had to find different cues to guide their performance. To investigate this further, a brief interview was conducted at the end of the last session. During the interview, two participants (Sue and Tilly) reported using only

proprioception to find both arm positions. One participant (Helen) reported using a proprioceptive strategy for one arm and “beats like a meter,” to guide the other. The last participant (Marla) used a strategy based on, “singing a song,” and “listening to the sound of the mouse sliding with a somewhat steady speed.” These reports suggest that individuals who have been placed in a state of visual deprivation may resort to creating their own cues to aid in responding. Studies found in the physical therapy literature may provide clues about how covert cueing strategies affect behavior. Physical therapy researchers have reported that individuals with Parkinson’s disease may use self-produced cues to aid in walking. These strategies are thought to develop as compensation for damaged brain structures, which typically play a role in motor functioning (Rochester, Hetherington, Jones, Nieuwboer, Willems, Kwakkel, and van Wegen, 2005; Nieuwboer, Kwakkel, Rochester, Jones, van Wegen, Willems, Chavret, Hetherington, Baker, and Lim, 2007).

Future research should investigate the nature of these covert cueing strategies and their effects on behavior. If these strategies provide a signal for when to stop moving, then it is likely that differences between capture and search training have some effect on covert cueing. Specifically, during capture training the click signals the participant to stop, while auditory feedback during search training occurs after the participant has already stopped moving. It seems that a covert cueing strategy would be most effective during search training, since no external cues signal the correct stopping position.

Two participants (Helen and Tilly) achieved mastery for search, while the other two (Marla and Sue) achieved mastery for capture. An analysis of the ratio of errors to corrects, observed during search training, revealed that those who mastered search had error rates that fell to a steady state below the rate of correct responses. Error rates for participants who mastered

capture, on the other hand, did not reach a steady state below the rate of correct responses. These data show that the ratio of errors to correct responses during search training may predict response accuracy during pre-training probes.

During the retention check, all four participants responded more accurately during the search rather than capture. An analysis of response location shows that during the search, participant responding forms a bell curve, with the majority of responses falling within the target and some responses above and below the target. Responding during the capture, for three out of the four participants, was found to be primarily located in the 50 pixel band immediately above the target location, with the other participant responding primarily within the 50 pixel band immediately below the target location.

The differences in responding observed during capture and search reflects different contingencies of reinforcement during the two procedures. capture training failed to produce responding within the target band during the retention check. During the capture training procedure, participants were guided to a stop with the click sound, whereas during search training participants received no guidance from the experimenter. In the absence of guidance, participants were more likely to respond outside of the target band. Since no feedback was provided for these responses, extinction was allowed to occur. The greater accuracy in performance observed during the search retention check suggests that errorless training procedures may be less effective than procedures that allow errors to contact extinction contingencies. These findings differ from Sidman (1985), which asserted that errorless learning leads to better results than trial and error learning. Future research is needed to further investigate the role of errors in the acquisition of motor behavior.

A limitation to these findings was the lack of a consistent location for click delivery during capture training. The inconsistency of click delivery makes it difficult to interpret the data observed for the capture retention check. During capture training, fast participant movements resulted in feedback delivery above the target. It is tempting to suggest that by sounding the clicker above the target, the experimenter inadvertently trained participants to respond above the target. Without data showing the time of click delivery in relation to the participants' location, however, this hypothesis cannot be ascertained. Future research using a method similar to capture training may wish to automate click delivery in a similar manner as Scott et al. (1997), where movement through the target location immediately produced a sound.

This experiment represents a first attempt at isolating the effects of contingent auditory feedback on human movement topography. While initially producing more errors, the search procedure eventually resulted in more accurate performance than capture training. These findings may be important to Sports trainers seeking to reinforce a desired performance. The automated sound delivery system, used during search training, provided consistent feedback to participants. Sports trainers may wish to incorporate an automated feedback system into their normal training routines. search training resulted in participants finding an exact arm position to within a few centimeters in a matter of weeks. A similar method may be useful for shaping ballet, gymnastic, and diving postures in less time than traditional sports training methods.

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