Olfactory Matching-To-Sample In Rats Using a Novel Apparatus

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ABSTRACT

The present study used a semi-automated device to test olfactory matching-to-sample in rats. The apparatus was a modified operant chamber with three nose ports that were covered with three independently-operating guillotine doors. The center door was opened to allow access to the sample scent and once the photo beam inside the nose port was broken for 2 s, the comparison doors were raised. In Experiment I, rats were trained on an identity matching-to-sample procedure using olfactory stimuli that were presented beneath the nose ports. This training continued until the performance criterion of 75% or higher accuracy over ten sessions was achieved. When the subject met the criterion, they were introduced to a novel set of five olfactory stimuli. In Experiment I, rats were exposed to the same set of stimuli throughout the entire experiment because the performance criteria were never met. In Experiment II, in which some procedural refinements were implemented, one subject (Z2) progressed through three MTS sets and showed some evidence of generalized matching, but the other two rats did not meet any of the matching criteria. These results suggest that response topography may be an important factor in conditional discrimination in rats.

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DEDICATION

I would like to dedicate this thesis to my parents, Ted and Camilla Thomas, whose continued support and encouragement throughout my educational career has meant the world to me. They are responsible for my love of wildlife and have nurtured my interest throughout the years. I would not be where I am today without their love and support.

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INTRODUCTION

The definition of a concept has long been debated by scientists and philosophers. From the perspective of behavioral psychology, Keller and Schoenfeld (1950) stated that instead of asking “What is a concept?” scientists should inquire “What type of behavior is it that we call conceptual” (p. 154). Keller and Schoenfeld proposed that “when a group of objects gets the same response, when they form a class the members of which are reacted to similarly, we speak of a concept” (p. 154). As an example of conceptual behavior in non-humans, consider a case in which a pigeon is taught to make one response to a set of stimuli consisting of circles and a different response to a set of square stimuli. Such a collection of objects, as pointed out by Zentall, Galizio and Critchfield (2002), is a group, or class, of stimuli that generate similar responses in a certain situation. A key point is that a stimulus class controls a common response and that there is differential responding between one class and another. As Keller and Schoenfeld put it: “Generalization *within* classes and discrimination *between* classes—this is the essence of concepts” (p.155). Cases of special interest, as pointed out by Delius (1994), are those in which class members are determined by their relation to other stimuli, for example, “the abstract twin concept of identity and oddity" (p.25), have been extensively studied in human and non-human subjects.

Identity matching-to-sample (MTS) is a conditional discrimination task that has been used to establish whether the physical relation between the sample stimulus and matching comparison stimulus can come to control the performance of the subject, (Dube, Mcilvane & Green, 1992). A MTS trial begins with the presentation of a sample stimulus. In most cases, an observing response is required to ensure that the subject has attended to the sample. Once the observing response, which can include a nose poke, key peck or touching an object, has been made, two or more comparison stimuli are presented. The reinforced, or correct, comparison stimulus is determined by the properties of the sample stimulus. In identity MTS, responses to the comparison stimulus that is physically identical to the sample stimulus are reinforced, (S+), while no reinforcement is provided if the subject responds to the physically different comparison stimulus, (S-).

When the subject appears to have learned MTS with a particular pair or set of stimuli, often defined in terms of some criterion performance level over time (e.g. 80% correct), the next step is to test for generalized matching-to-sample. This requires substitution of novel stimuli into the procedure. Schwartz, Wasserman, & Robbins (2002) suggest that the response transfer from “familiar to novel stimuli is considered by most theorists to be an empirical hallmark of conceptualization.” The idea of generalization is often used to determine whether a subject can transfer their responding from a set of familiar stimuli to a set of novel stimuli that have never been presented before. If the subject can generalize the matching relation to novel stimuli, then it may be claimed that physical identity between the sample stimulus and the comparison stimulus has come to control the subject’s responses, often referred to as generalized MTS.

One important question is whether non-human subjects can learn such concepts. Cumming and Berryman (1961) conducted a classic experiment with pigeons that demonstrates why it is important to test for generalized MTS. They used three white Carneaux pigeons in their experiment, maintaining the subjects at 80% of their free feeding weight. Cumming and Berryman first trained the pigeons to peck a key lit by a white light. After the key response was established, the pigeons were exposed to three keys, each lit by a red, green or blue light presented in a random sequence. Responses to the lit key were reinforced. When the pigeons were responding to the lit keys with no control by the color of the light, pre-training was concluded and the next session began the matching procedure.

During the matching procedure, Cumming and Berryman (1961) presented the pigeon with the sample stimulus on the center key, lit by either a red, blue or green light. Once an observing response was made to the center key, the comparison stimuli on the left and right keys were presented, with the center key remaining lit with the sample. If the pigeon responded to the center key again, nothing occurred, however, if it responded to the comparison key with the matching color light, the lights turned off and grain was presented for 3 s. If the pigeon responded to the incorrect comparison stimulus, the side key whose hue did not match the sample, the result was a timeout with all of the keys and overhead light turned off for a duration of 3 s. When the reinforcement or the timeout session ended, a 25 s inter-trial interval went into effect, with the keys remaining dark, but the overhead light on. Any responses during this time had no effect. The pigeons were exposed to 140 trials per day for 22 sessions with 12 stimulus arrangements that were randomly presented in which red, blue and green each served as a sample stimulus and as comparison stimuli. Examples of a trial arrangement would include the red hue presented as the sample on the center key with comparison stimuli red on the left and green on the right, (i.e. RRG) while on another trial, the sample might be a blue light with green on the left and blue on the right, (i.e. GBB). All 12 possible combinations were used: RRB, RRG, BRR, GRR, BBR, BBG, RBB, GBB, GGR, GGB, RGG, and BGG. In the first three days of testing, the pigeons' performance was at chance level, but matching behavior began to appear after this period of time with almost perfect performance emerging within eight to ten sessions.

On the 23rd and 24th sessions, Cumming and Berryman (1961) introduced a novel stimulus, which was defined as a stimulus that had not been presented to the subject before as a sample or as a comparison. For example, the novel stimulus was a yellow light that substituted for one of the hues that had been presented, the blue light. Thus, yellow might be presented as a sample and as the comparison stimulus on the left key with green being presented on the right key as the incorrect comparison. It was discovered that when the pigeons were presented with trials involving the novel stimulus, they performed at chance levels, which gave evidence that the pigeons had not learned generalized MTS. Cumming and Berryman suggested that the pigeons had learned to respond on the basis of configurations of stimuli. For example, they may have learned to peck the left key given a configuration of red light, red light, green light. Alternatively, they may have learned to peck the right key given a green light, red light, red light configuration. They concluded that the pigeons' MTS behavior was more likely under the control of the pattern or configuration of hues than the identity relation. Generalized matching would have required the pigeons to transfer the matching concept to the novel stimulus of the yellow light, even though this created configurations the pigeon had not encountered before. Birds eventually did show an increase in performance on trials involving the yellow light. However, this probably occurred because of reinforced training with configurations involving the new stimulus.

Carter and Werner (1978) described a multiple-rule model of conditional discrimination learning that appeared to occur in pigeons, suggesting that the subjects might follow “if…then…” rules, rather than the configuration learning proposed by Cumming and Berryman (1961). With the multiple-rule model, the subject learns to respond to a certain color only when it is presented with a certain sample. Carter and Warner noted that two types of rules may be derived from the multiple-rule model: 1) the rule that designates the correct choice and 2) the rules that determine the incorrect choice. An example of the multiple-rule model would be if the sample is red, respond red. Otherwise, if the sample is green, respond green. To eliminate the possibility that a subject is following the multiple-rule model, once again the experimenter should introduce a novel stimulus, this time as the sample. The subject should show chance performance with the novel sample stimulus given the multiple-rule model. If the subject is using true identity matching, then the performance would not change that of a trial using familiar stimuli. Carter and Werner state that from the reviewed studies, there is evidence that pigeons form rules based on the sample stimuli and respond accordingly.

It is in the best interest of the researcher to introduce several novel stimuli to test for generalized MTS, in order to assess the likelihood that performances are due to chance. It is also imperative that when using novel stimuli, the very first presentations should be recorded and examined to determine if the subject transferred the concept of identity matching or if learning occurred during the first trial presentations. It can be said that generalized MTS occurred only when the subject transfers the relation of matching to novel stimuli in the initial presentation. Even though Cumming and Berryman (1961) and Carter and Werner (1978) were unable to determine that pigeons could perform generalized MTS, other researchers have had more success with non-humans.

Matching-To-Sample in Non-Humans

Pigeons

Zentall and Hogan (1978) used sixteen pigeons that were kept at 75-80% of their free-feeding weight. After magazine training, the pigeons were placed into an operant chamber with three square response keys that were lit from the rear with one of four different hues, red, green, yellow or blue. The keys could also have one of two shapes: a white circle or a plus that was on a black background. In Training Phase I, the pigeons were divided into two groups which received either matching or oddity training. The pigeons in both groups were presented with the sample stimulus on the center key, either the circle or plus. Forty key pecks were required to turn on the two side comparison keys. A single response to a comparison key initiated a 5 s inter-trial interval. A session contained 96 trials with the shapes and reinforced side keys balanced.

After the last day of training, the pigeons began Transfer Phase I in which the birds were switched from the shape stimuli, (plus or circle) to hues of red and green. The oddity group was split with half of the pigeons continuing on an oddity task while the other four pigeons were shifted to a matching contingency. With the matching pigeons, three remained on a matching task and two pigeons were placed on the oddity task. The pigeons were studied for nine sessions on the first transfer phase.

Zentall and Hogan (1978) did not find a significant effect based on the type of task, most likely due to the large performance range. However, they did find evidence of faster learning and better first-session transfer for non-shifted birds, pigeons that had the same training and transfer tasks, i.e. all matching or all oddity tasks.

Shifted pigeons had different tasks for training and transfer tasks, i.e., the subjects were moved from identity to oddity or the reverse. In Transfer Phase I, a significant difference was found between shifted and non-shifted pigeons when the performance was combined over the nine sessions. When examined, the performance on the first transfer session was somewhat better for shifted subjects, though this could be accounted for by one of the subjects' excellent performance. Yet, over the phase sessions, two of three shifted birds took more time to learn than the slowest non-shifted bird. No significance was found on the last five sessions of Transfer Phase I, which the authors suggest might be due to the high within group variability.

After Training Phase II, all of the subjects were moved from shapes to colors. There was better first-session transfer for the three pigeons that were not shifted from shapes to colors as well as quicker learning when compared to the birds that had been shifted. It took two of the three pigeons that had been shifted longer to learn than the slowest of the non-shifted pigeons. While on Transfer Phase III, one group of pigeons remained on the same procedure as Transfer Phase II, while the other group was presented with blue and yellow stimuli in 36 single-stimulus trials that were randomly mixed into the session. One response to the stimuli on these trials resulted in the key light turning off and 2 s exposure to reinforcement. The pigeons that were in the second group, when exposed to blue and yellow adaptation stimuli, promptly responded to the single stimuli trial after the first session of being exposed to the new stimuli. The effect of exposing the second group of pigeons to the novel stimuli prior to Transfer Phase IV had only a minor effect on the transfer task.

Transfer Phase IV involved splitting the birds into two groups based on the task that was learned during Transfer Phase I, i.e. whether the subjects received adaptation training and training task. Seven pigeons were switched to a matching task and six pigeons were placed on an oddity task to evaluate the transfer to hues of yellow and blue. The trials in Transfer Phase IV were similar to the trials in Transfer Phase I with the exception of the change in stimuli that were used.

Large transfer effects were visible during Transfer Phase IV when the birds were moved from red and green stimuli to yellow and blue stimuli. Subjects shifted from one contingency to another performed very poorly on the first transfer session (30-52%), while the subjects that were not shifted performed above chance (71-95%). The differences between shift and non-shifted pigeon data were statistically significant. There was evidence that the oddity concept was better learned than the "identity" concept when on the first transfer session, non-shifted matching birds averaged 78.5% correct while the non-shifted oddity birds averaged 86.7%.

Overall, Zentall and Hogan (1978) concluded that non-shifted subjects showed evidence of faster learning and better first-session transfer performance than those subjects who were shifted from oddity to identity or vice versa. Thus, this study is often taken as providing support that some control by stimulus identity may transfer to novel stimuli in pigeons.

A follow up study by Wright (1997) required pigeons to respond to the sample stimulus with a set number of key pecks to determine whether their performance would vary based on the required observing response. Wright (1997) trained 16 pigeons divided into four groups on a matching-to-sample task that used color cartoons that were generated and presented to the subjects by a computer that was angled upward from the floor of operant chamber. The pigeons pecked downward at the stimuli, imitating normal feeding behavior. The sample was the center cartoon that was presented on the screen with the comparison stimuli presented on either side of the sample. The number of pecks required for the observing response varied between the four groups: 0, 1, 10 or 20 pecks. Once the pigeon responded to the sample stimulus, the comparison stimuli were presented. If the pigeon pecked the matching comparison stimulus, five wheat seeds were placed on top of the correct comparison stimulus. If the non-matching comparison stimulus was chosen, no reinforcement was delivered and during the training procedure, was followed with a timeout that lasted 8 s before the trial was repeated.

With Group 0, no sample pecks were required and the comparison stimuli were presented simultaneously with the sample stimulus. Groups 10 and 20 had intermediate training to raise their fixed ratios from one response to the final level of 10 or 20 required responses. When the subjects reached 70% performance criteria for two successive sessions, they progressed to a test of the “if-then” hypothesis. As noted by Carter and Werner (1978), the if-then hypothesis proposes that subjects learn rules like: “If sample ‘Blue,’ then select comparison ‘Blue,’” or “If sample ‘Pear,’ then select comparison ‘Pear.’” Rather than testing the if-then hypothesis with the presentation of novel stimuli, Wright (1997) first chose to use the same stimuli that had been presented during training to the pigeons. The familiar stimuli were presented in different displays during the testing procedure. Wright hypothesized that the pigeons’ performance would be similar between the training and testing procedures due to if-then rules formed with the stimuli. Yet, if subjects did not have accurate performance, it would not be due to a disruption of performance because of the presentation of novel stimuli.

If the pigeons were learning by if-then rules, then those in Groups 0 and 1 should display accuracy similar to those shown in training displays. Instead, the pigeons were at chance levels, performing at 55%-56% correct, giving support that the pigeons did not learn MTS by forming if-then rules.

Following the if-then test, the pigeons were exposed to a novel stimulus test where the pigeons were presented with novel drawings. The novel stimuli were presented only once to prevent learning from occurring with five consecutive sessions per day, each containing 10 novel trials for a total of 50 novel trials and 100 novel stimuli presented. The performance of concept learning increased with the number of required sample responses. Pigeons in Group 0 demonstrated no performance transfer to the novel stimuli, while the pigeons in Groups 1 and 10 showed some transference of performance to the novel stimuli. The subjects in Group 20 had performance transfer of 80% to the novel stimuli, demonstrating that the concept learning increased with the number of responses to the sample that were required. Wright (1997) stated that groups that were required to make the most responses to the sample learned more than responses that were "item-specific." The concept learning increased in relation to the number of sample responses that were required.

In summary, a wide range of results have been shown when pigeons are presented with a MTS task. Cumming and Berryman

(1961) suggested that pigeons learned to respond to configurations of stimuli in MTS training while Carter and Werner (1978) found evidence for sample specific if-then rules. Neither found support for generalized matching. In contrast, Zentall and Hogan (1978) did find evidence of generalized matching in a transfer task experiment, and Wright (1997) provided evidence that when a pigeon is required to make more sample responses they are more likely to develop generalized MTS. After extensive training with varied results, it appears that pigeons can meet the criterion for generalized matching in certain types of experimental arrangements.

Primates

Studies with non-human primate subjects have also shown mixed results, but several have demonstrated generalized MTS. Jackson and Pegram (1970) trained 11 rhesus monkeys in a MTS procedure. The sample stimulus key was approximately 1 inch above the two comparison keys. The hues that Jackson and Pegram used included: red, blue, yellow, white, and green. During the simultaneous hue matching task, the sample key was lit. When the rhesus monkey responded to the lit sample key, the two comparison keys would illuminate, one hue matching the sample key. A correct response to the matching hue comparison key ended with a reinforcement and an inter-trial interval of 2 s while an incorrect response was not reinforced and the inter-trial interval was 10 s. The primates experienced 200 trials per session with 20 matching-to-sample configurations each presented ten times with the order varying across ten different session sequences. When the primates had reached criterion of 90% for three consecutive days, they were moved to the next task of transfer-to-form matching. The stimuli used in the form matching were novel forms that included a triangle, a square, an X and a horizontal line. On the 15th day, the primates were returned to the hue-matching task again where they were tested until they reached 90% correct for three days consecutively.

Jackson and Pegram (1970) found that subjects were transferred from color matching to novel form matching, only two of the eleven monkeys performed above chance the first day, though the majority of the animals performed above chance on the second session, giving evidence that it was difficult for the primates to generalize matching across stimulus dimensions.

The only novel stimuli used in the Jackson and Pegram (1970) experiment were the form stimuli that the primates were shifted to after the hue matching task. When the primates were shifted back to the hue matching, the stimuli were the same as before. To determine if the primates could meet the criterion of generalized matching, Jackson and Pegram (1970) should have introduced either novel colors to the primates after the hue matching task or novel forms after the form matching task.

D'Amato, Salmon and Colombo (1985) also used color and form stimuli with New World primates to determine if they could meet the criterion for generalized MTS. They studied nine *Cebus paella*, or tufted capuchin monkeys, to determine how New World primates would perform on a MTS procedure. Two monkey test chambers were used, with the front wall with four inline projectors positioned at the four corners of a 12-cm square and a fifth projector located in the center of the square. Each projector had a transparent key that, when pressed, had the potential to deliver a banana pellet as reinforcement. Three colored disks, (red, blue and yellow) were the color stimuli used, along with eight form stimuli, (circle, square, dot, upright triangle, inverted triangle, vertical line, plus and a complex form created by placing the plus on the square).

After preliminary shaping trials, the primates were moved on to the second phase of shaping that was modified matching trials. Eight monkeys were trained on identity matching, all with two-sample sets with four sets used overall. One observing response on the center key resulted in the presentation of the two comparison stimuli on two of the four outer projectors. The sample remained on the center key throughout the entire trial. Reinforcement was given after presses on the matching stimulus. An incorrect response was followed immediately by a time-out that lasted between 30 and 60 s, indicated by dimming the house light. The performance criterion was two sessions of 48 trials with 90% or higher of correct responses.

For the first identity matching task, acquisition rates differed greatly, with four monkeys that had been previously exposed to hues meeting criterion after fewer trials (750) than the monkeys that had not had color in their sample set (1616). It was determined that the characteristics of the sample stimuli played an important role and that possibly differentiating between a color and form might be easier than between two forms.

The transfer tests were four 48-trial sessions with half of the trials based on the old sample set and half on novel samples. Transfer-of-matching criterion was set at 17 correct responses on 24 trials during Sessions 2, 3 and 4.

In the first transfer test, four of the eight primates met criterion which was to have their correct responses be a minimum of 70.8% or higher during Sessions 2, 3 and 4. Two of the four monkeys performed at 75% during their first session. Three of four of the primates that did not meet criteria did learn to match the novel stimuli faster than their earlier performance.

In regards to second and third transfer tests, two primates met the transfer criteria on the second transfer test, above 70.8% on the first transfer session and both had a high performance on the novel stimuli.

One monkey failed to meet the criterion, but after she was trained on the second transfer test stimuli to criterion, she was presented with a third test of novel stimuli. The primate transferred with high success, 91.7% correct on Session 1 with novel stimuli and 100% on Sessions 2, 3 and 4.

The subjects had no prior experimental encounters with the presented visual stimuli and five of the seven subjects met criterion with 70.8% or higher on the first test session with a novel sample set. By being able to transfer the identity matching to novel stimuli, the primates demonstrated evidence of generalized matching.

In Experiment Two, four monkeys from the prior study and two control subjects were used. The same apparatus from Experiment 1 was used. A green disk was chosen for the steady stimulus and the same stimulus with a flicker rate was designated as the flashing stimulus. The same procedures from Experiment 1 were conducted with the first four transfer sessions having 24 trials with the old stimulus pair and 24 with the steady and flashing stimulus pair. The two control subjects were trained on a simple discrimination task between the steady and flashing stimuli.

None of the subjects reached transfer criterion that they had previously met on the final test in Experiment 1 with the conventional visual stimuli. There were occasional high performances, but D’Amato et al. (1985) argue that these may have been based on a property of the stimulus other than hue, i.e. brightness. The subjects then discarded this approach due to increased experience with the novel stimuli that led to a correspondence between the steady and flashing stimuli, especially when the flashing stimuli was in the ‘on’ stage. The evidence suggests that the experienced primates were unable to transfer generalized matching to the steady and flashing stimuli. The control animals were able to discriminate between the flashing and steady stimuli in just a few trials, so the lack of transfer was not due to the difficulty in distinguishing between the two stimuli.

Even though the primates failed to show a transfer of matching to the flashing and steady stimuli, D’Amato et al. (1985) stress that this does not mean primates are not capable of forming generalize MTS using dynamic visual stimuli. Upon testing the four experimental primates on transfer of matching to several sets of flashing and steady stimuli, it was found that the primates could do a nearly complete transfer to flashing and steady white or amber disks. Yet, this might have been the generalization of stimuli instead of transfer. It still took a great deal of matching training with dynamic sample sets in order to find evidence that transfer could occur to novel stimuli. D’Amato et al. suggested that perhaps the monkeys had to re-learn the matching concept for the new stimuli.

This study does provide evidence that primates can demonstrate some degree of generalized identity matching using a small set of visual stimuli, based on the findings of Experiment I where the primates were able to transfer identity matching to novel stimuli. Yet, in Experiment II, the primates failed to transfer to steady versus flashing stimuli in spite of the established ability to discriminate between the two stimuli. As D'Amato et al. (1985) determined in Experiment II, the concept of matching does not appear to be an "all-or-none affair." Identity matching stimulus control transferred across hues in Experiment I, but did not extend to other dimensions of stimuli, such as the steady light and flashing light used as stimuli in Experiment II.

Even stronger evidence for generalized matching has been found in chimpanzees. Oden, Thompson and Premack (1988) demonstrated that it is possible for chimps to transfer the ability to match from trained stimuli to novel stimuli with different physical properties. They examined four infant chimpanzees' ability to learn a matching-to-sample task using only two stimuli in training. The subjects' were exposed to morning and afternoon sessions and were tested in pairs in a modified baby crib. The crib was divided by a piece of clear

Plexiglas so that the primates could see each other during the session. The front of the crib was composed of metal bars with a gap between the bars and the crib floor to allow access to the objects by the subject and experimenter. The two stimuli used during training included stainless steel 1/4-cup measuring cups and brass-plated sliding bolt locks. The chimpanzees were allowed to interact with the objects and two baking tins in a neutral play area prior to MTS training. An experimenter modeled placing the locks and cups into the baking tins. When chimpanzees placed either a lock or cup into the baking tin reinforcement was presented. Once the subjects performed this task at the encouragement of the experimenter, they were moved to the MTS training task in the crib.

A MTS training trial began when the experimenter presented the sample to the primate. As soon as the primate made a response, defined as placing the sample object into the baking tin, the experimenter placed two comparison objects into the crib. If the chimpanzee made a correct response, defined as placing the matching object into the pan with the sample, reinforcement was delivered. If the primate placed the incorrect, or non-matching, object into the pan with the sample, the experimenter removed the incorrect stimulus and replaced it with the matching stimulus.

It took the primates a mean of 816 trials to reach criterion of a minimum of 10 out of 12 correct responses. Once a primate reached the performance criterion, the subject was moved to the transfer tests.

In a transfer test session, two novel stimuli were used equally during a 12-trial session. Both correct and incorrect responses were reinforced on transfer trials. Three types of transfer tests were presented to the subjects and included two sessions each of objects, fabrics and food. A total of 12 novel stimuli were used during the transfer tests, i.e. four objects, four fabrics and four food items. The food items that were used consisted of bite-sized pieces of ‘low-preference’ foods, i.e. potato or monkey chow.

The mean percent correct for the object transfer task was 85.4%, for the fabrics task was 84.4% and the food transfer task was 67.7%. All percentages were above chance, supporting the notion that the chimpanzee’s behavior reflected generalized matching. Oden, Thompson and Premack (1988) attribute the lower performance percentage in the food transfer task to certain preferences exhibited by some subjects. Two primates, specifically, had .84 probability of choosing the same food object regardless of its matching property. The food items would have been chosen equally had the primates failed to transfer, yet the primates showed above chance performance with the food transfer items. Thus, the decline would appear to be related to the individual preference of the subject instead.

Oden, Thompson and Premack (1988) examined the first trial of each transfer task with a novel pair of stimuli. Two chimpanzees performed correctly on all six transfer sessions on Trial 1. One primate responded correctly on three transfer tasks on Trial 1, one of each category. The final subject performed correctly on Trial 1 in both fabric transfer tasks and in one session each of objects and food. When Oden et al. compared the first half of a transfer task to the second half of a transfer task; there was no indication of possible practice effects in the subjects' performances.

Oden, Thompson and Premack (1988) demonstrated that when chimpanzee infants are trained a MTS task with only two stimuli, they transferred their performance to novel stimuli. Oden et al. found no decline in performance when the subjects were moved to the transfer tasks. This study provides strong evidence that chimps can generalize MTS to novel objects that are physically different from the objects used during the training task, i.e. metal locks and cups to fabric pieces.

Jackson and Pegram (1970) and D'Amato, Salmon and Colombo (1985) had limited success in demonstrating that primates could meet the criterion for generalized MTS with rhesus or Cebus paella monkeys. However, Oden, Thompson and Premak (1988) provided strong evidence that chimpanzees do have the capacity to transfer the concept of matching to novel stimuli with no decline in performance. In summary, there is some evidence that non-human primates can demonstrate generalized MTS.

Sea Lions

Kastak and Schusterman (1994) used visual matching-to-sample tasks to assess generalized MTS in California sea lions. Two female California sea lions with previous experience with arbitrary MTS tasks were used in the study.

The apparatus used for the study consisted of a set of hinged wooden panels with three boxes that had the front panel constructed of windows. The center box held the sample object while the two side boxes contained the comparative stimuli. The stimuli were black shapes against a white background in Experiment 1 and three-dimensional objects made of black wood, steel and/or plastic and displayed on a white background. The sample was presented for 4 s before the comparison stimuli were presented. Responses were defined as a nose poke through a plane in front of the stimulus box. Pieces of fish were used as reinforcement after correct responses. Kastak and Schusterman classify a problem as two sets of matching stimuli in their experiment.

The baseline trials consisted of familiar stimuli that served as the sample and correct comparison stimuli. When the familiar stimuli served as the incorrect comparison stimuli, it was considered an exclusion trial. It was expected that the subject would most likely respond based on the elimination of the familiar stimuli that was non-matching instead of a relation of identity between the sample and reinforced matching comparison. Rio, but not Rocky, was exposed to exclusion trials that were included in the initial training problem with sessions consisting of 20 baseline trials and 40 exclusion trials.

Rio was trained on 14 additional training problems that were taught using trial and error. Once the criterion of 90% for two consecutive sessions was met, the stimuli that were presented in training were placed into the baseline of previously learned stimuli. Thus, the baseline increased by two stimuli after the acquisition of a problem. All of Rocky's 15 problems were trained in this manner.

Before the reshuffling phase, the training problem stimuli were paired so that both were presented as sample and comparisons. The pairs were split up during reshuffling and a stimulus could be presented with any of the other stimuli during a trial.

Rio's test pool contained 15 problems with 30 paired novel stimuli. Three test sessions contained ten unique test trials and 50 baseline trials. Rio's second test had 15 new problems with 30 novel stimuli. For Rocky, both tests followed the structure of Rio’s Test 2. No decrement in performance was seen in either Rocky or Rio during the reshuffling phase, which provided evidence that the subjects were either responding due to an identity relationship or had formed “if-then” rules, as suggested by Carter & Werner (1978).

Rio performed on Test 1 at chance levels for the first two trials, but for Trials 3-6, her performance rose above 90%, which provided evidence of rapid learning or possibly concept formation. The stimuli used in the first test session were a combination of novel stimuli as well as previously trained stimuli. The experimenters note that Rio was reacting to the novel stimuli differently by behavioral signals, such as vocalization or touching the stimuli. Rocky performed at 87% on the first trial of Test 1, but her performance dropped in later trials.

For the second test, the experimental trials were placed into groups of four consecutive trials that belonged to the same problem. Rio performed significantly above chance on the first trial of Test 2 with a performance of 80% correct. There was an improvement in performance for the following trials with 93.3% on Trials 2-4 and 95% on Trials 5-8. These performance scores give a demonstration of successful generalized MTS by Rio. Rocky had a performance of 46.7% on the first trial of Test 2, with an improvement for Trials 2-4 to 93.3%. Yet, on Trials 5 and 6, the sea lion’s performance dropped to just above chance.

Rocky was given a third test that increased the ratio of test trials to baseline trials with random presentation throughout the session. The baseline consisted of the stimuli from the prior two tests and training. The sea lion’s first trial performance was not significantly better than chance, but high at 73.3%. On the following trials, Rocky’s performance on test stimuli increases above baseline performance for Trials 2-4. In Trials 5-8, the subject performed at the same level for both novel and baseline stimuli.

In a second experiment, both sea lions were presented with stimuli that had not been used in identity matching training. Both sea lions displayed high first-trial performance levels, Rio having a performance of 80% and Rocky demonstrating a performance of 70%, thus providing further evidence of generalized matching. The sea lions increased their levels to above 80%, even though this level was not sustained consistently. In summary, both sea lions showed evidence of generalized identity MTS with stimuli novel in the identity MTS context.

Dolphins

Matching-to-sample has also been successfully demonstrated in dolphins, (Herman & Gordon, 1974). Herman and Gordon examined the capability of a female bottlenose dolphin to perform delayed matching-to-sample tasks using auditory stimuli. A channel was created in the tank using ropes to define the boundaries. A start paddle was in the center of the channel that was located 1.0 meters passed the channel exit. The area between the start paddle and the channel exit was designated as the ‘listening area’ and all of the speakers were directed towards this area. Two stimulus speakers were mounted at 45 degrees on either side of the start paddle which were used to play the sample and the comparison stimuli sounds with response paddles the animal would use to respond with positioned in front of the speakers. A control speaker was also used to signal entry and exit in the listening area as well as sound reinforcement for correct responses on the paddles.

Herman and Gordon used 17 sound-pair types. Training involved presenting two sounds for a simple discrimination problem with a response to one of the sounds being reinforced. There was no correction procedure or reinforcement for selecting the non-reinforced sound. The sample sound and delay period were introduced over several trials with the length of the sample sound increasing from .2 to 2.5 s within the first 12 sessions and the delay interval increasing from .2 to 1.5 s across the first three sessions and remained at 1.5 for sessions

4 through 12. Various delay lengths were then presented in the following sessions, the longest delay being 18 s.

A total of 21 trials with unique sounds were presented in a nine day period with two or three problems being presented per day. A trial began with the presentation of a tone that lasted a maximum of 10 s from the control speaker, which could be turned off once the dolphin entered the listening area and pressed the start paddle. The two stimulus speakers then presented the sample sound at the same time 1.5 s after the control tone had been sounded. When the delay interval passed, the comparison sounds were presented successively for 2.5 s with a silent interval that was .5 s with the presentation of the comparison sounds order randomly assigned. After the sounds were presented, a sound was presented from the control speaker to signal the dolphin to leave the listening area and respond to one of the response paddles. When a response was made, the pressing of one of the paddles, the control tone ended and 2.5 s of the test tone that the dolphin responded to was played. If it was the correct comparison stimulus, S+, another tone was played from the control speaker for .5 s along with food reinforcement and a 7 s inter-trial interval. If the incorrect stimulus was selected, S-, only the inter-trial interval occurred.

The dolphin was presented with 346 delayed matching-to-sample trials during four weeks of testing with 20 trials with duration of 5 to 10 minutes between the trials. During the later testing blocks of trials, Herman and Gordon changed the procedure so that the longest delay of the trial set, which was either 90 or 180 s, was at the beginning of the session during the first trial to reduce the subject’s emotional displays.

The dolphin showed improvements in performance across sessions and showed above chance accuracy on novel trials. The dolphin’s matching performance continued to increase over the first 150 to 170 trials. The dolphin responded without error during the delays of 30, 40, 60 and 90 s with one Trial 1 error on the 120 s delays. Overall, there was strong evidence that the dolphin generalized matching to novel stimuli since new sounds were used for each trial presented.

Matching-to-Sample in Rats

Historically, rats have done poorly on matching-to-sample tasks, particularly with visual stimuli, and it takes a great deal of training for rats to perform accurately, (Iverson, 1993; 1997). Iverson (1993) used three female Long Evans hooded rats that were kept at 85% of their free-feeding weight. The stimuli used were either a steady light or a blinking light presented on keys within an operant chamber. The sample was presented first on the center key, either a steady or blinking light, followed by the comparison stimuli on either side. Accuracy improved to approximately 60% in four to six sessions. At the beginning of the testing, the rats often responded on the key that was most recently reinforced. A correction procedure was implemented that prevented these “repeat errors” from being reinforced and these errors dropped out gradually.

A preference for the steady light emerged within the first six sessions. Over sessions, preferences for a particular stimulus or position were common. When Rat 1 displayed a position preference for Key 3, the researchers altered the distribution of reinforcement for three sessions so that Key 1 was reinforced more often than Key 3. With this change, the preference quickly shifted to Key 1. Two more sessions occurred before the position preference returned. Another alteration of trials was initiated for two more sessions. After this was completed, no key preference was apparent for 13 sessions. Then, a Key 3 preference occurred for several sessions until another alteration of trials was initiated, after which any position preference was less obvious. Iverson found that briefly presenting trials that reinforced responding the opposite the exhibited preference effectively, if temporarily, resolved the preference of stimulus or position. The percentage of correct responses increased when position or stimulus preferences were corrected with modified allocation of trials.

Iverson used four stimulus configurations: BBS, SBB, SSB, and BSS, (B=Blinking, S=Steady) which appeared from left to right on one of the three keys. Despite the difficulties noted above, all three subjects eventually performed at 90% or better. Within the first 25 sessions, all of the subjects had an accuracy of approximately 80%. The subjects maintained 95% correct or better on the last three sessions prior to the 0 s delay session. When a subject made a response to the sample in a 0 s delay session, the sample was turned off and the comparison stimuli were presented, rather than the sample remaining present as in the other procedure. While Rat 1 shifted control of the sample to the new delay condition, the same was not true for the other two subjects. In the cases of Rats 2 and 3, their performances were linked to the steady sample light. Still, even when Rats 2 and 3 did acquire high accuracy, response biases occasionally reappeared.

Iverson (1993) successfully demonstrated matching-to-sample with visual stimuli in rats. Within 25 sessions, Iverson demonstrated that rats were able to obtain 80% correct with the subjects attaining 90% performance accuracy after 50 sessions. However, acquisition was complicated by the development of position and stimulus biases, and these studies involved just two stimuli, steady and blinking lights. Thus, there was no attempt to assess generalized matching in this study.

Iverson (1997) conducted follow-up experiments immediately after the training presented in Iverson (1993). In this study, the sample was displayed on any of the three keys and the comparison stimuli were on the remaining two keys with equal probability in order to examine potential sources of stimulus control that might have occurred with the sample and comparison stimuli appearing in fixed locations.

The same three female Long Evans hooded rats were used once more, along with the same apparatus in Iverson (1993). The rats received between 54 and 64 100-trial sessions of matching-to-sample training with the sample always appearing on the center key. When accuracy was 90% or higher, the next training stage was introduced.

In this stage, the sample appeared equally frequently on any one of the three keys. A response to the sample produced the comparison stimuli on the remaining two keys, so that all three keys were lit. A response on the matching comparison stimulus resulted in the delivery of a food pellet and the key lights were extinguished. A response to the non-matching key resulted in all key lights turned off without reinforcement. Twelve configurations of stimuli were used: SSB, BBS, BSS, SBB; while the remaining had the sample displayed on either right or left sides: i.e. SSB with the first position being the sample. When the rats were tested on the moving sample procedure, their performance dropped from 90% to around 60% and stayed in that region. Iverson (1997) separated the correct responses by sample location in his analysis. The middle sample location resulted in baseline levels for Rats 1 and 2 and approximately 80% for Rat 3. When the sample was presented on either side key, it lost control over the responses to the comparison stimuli with all three of the subjects' accuracy dropping to around chance performance. The 60% accuracy was due to high middle sample performance and near chance performance on the side sample presentations.

The control of the sample that was established in baseline training did not shift to the new positions of the sample. That is, sample control did not occur when the same two stimuli were presented in different positions. Iverson presumed that the first phase of training using the fixed location of the sample did not set up control by the relation of identity, but rather a compound involving the spatial location and physical properties of the stimulus. Iverson (1997) conducted Experiment 2 in order to train the rats from Experiment 1 to each location of the sample individually to set up high matching-to-sample performance with the moving sample procedure. In Experiment 2, the subjects received between 21 and 65 sessions with the left key always presenting the sample. Then, for 13 to 22 sessions, the sample was alternated between the middle and the left keys.

The subjects were then reintroduced to the moving sample procedure. In one session, the sample alternated between the left and middle key randomly. In the following two sessions, the sample appeared on any of the three keys equally. Rat 3 was the only subject to be exposed to the right side sample training since Rats 1 and 2 had problems with the left key sample even after repeated training.

Rats 1 and 2 had difficulty performing the matching-to-sample task when the sample was presented on the left key. During the first three sessions, both rats, after pressing the sample on the left key, pressed the center, or comparison, key on almost all the trials and the accuracy of the subjects dropped to chance levels. In order to avoid reinforcing the position bias on an intermittent schedule, the correct comparison stimulus appeared solely on the right key. Results show that sample control did not develop for all three key locations even with additional sample training on the left key and that the control over the left key sample was not preserved when trials with all three sample locations were mixed together.

Iverson (1997) showed with Experiment 2 that after extensive training, control could be created for a sample presented on a side key. Yet, the control did not transfer to samples presented on the right key, weakened for left key samples for Rats 1 and 2, and dropped for Rat 3 when trained samples on the right key were assorted with samples on the left and middle keys. These results provide evidence that each sample location must be trained individually in order to produce an effective discrimination. Iverson demonstrated that when the comparison and sample stimuli were repositioned after training rats with fixed locations, the control of the sample did not shift to untrained spatial locations.

Iverson's result might lead one to the conclusion that rats are not capable of generalized identity MTS, yet results from procedures using olfactory stimuli have yielded different outcomes.

Olfactory Identity Matching in Rats

Lu, Slotnick and Silberberg (1993) used a variation of matching-to-sample task with a go/no-go procedure and olfactory stimuli were presented to the rats using an olfactometer. A sampling tube was fixed on one end of the operant chamber where the stimuli were pumped into the area. An exhaust fan was mounted at the top of the sampling tube with a valve controlling delivery of the stimuli was mounted below the sampling tube. A reinforcement tube delivering water was positioned within the sampling tube. Water was used as reinforcement in quantities of .05 milliliters. Three male rats on a water deprivation schedule were used in the experiment. A two odor procedure used only two odors during a session. In the three odor go/no-go procedure, three odors were presented throughout a session. Thirty different odors were divided into 10 sets of three odor conditional go/no-go discrimination problems and 10 additional novel odors were grouped into five pairs for two odor conditional go/no-go discrimination problems.

The sample stimulus was presented for 1 s by the olfactometer releasing the scent where it was directed into a sampling tube. After 1 s had passed, the sample was drawn out by the exhaust fan and then a second odor was presented for 1 s. The presentation of the comparison odor was followed by a 2 s response window. If the subject made a response, defined as licking the reinforcement tube that was measured by a lickometer circuit, during the response window when the comparison stimulus matched the sample, the .05 milliliters of water was delivered and the trial was scored as a ‘hit.’ If the rat failed to respond, it was marked as a miss while making a response on an S- trial was scored as a false alarm. Failure to respond on an S- trial was treated as a correct rejection. The inter-trial interval was 5 s and was signaled by a house light.

Using amyl acetate as the S+ and air for the S-, rats were trained to respond to the odor. After one or two sessions, the subjects were progressed to one session with butanol as the S+ and air as the S-. In Phase I, the rats were trained by exposing them to only S+ trials with amyl acetate as both the sample and comparison. S- trials were then introduced over time using amyl acetate as the sample and butanol as the comparison. In the following session, butanol was presented in the S+ trials and butanol was presented as the sample in S- trials with the comparison being amyl acetate. During Phase II, the same two stimuli were presented in a randomized order. Additional trials were presented with a correction procedure following false alarm responses. On an S- trial, if a subject responded, the stimulus configuration was repeated until the subject responded correctly or three trials occurred. After 200-300 trials with the correction procedure implemented, 400 more trials were conducted with no correction. In Phase III, training continued with two new odors, (linalyl acetate and geraniol) and the subjects were trained on this procedure until reaching 80% performance.

Before the correction procedure was implemented, every subject was at chance performance in the Phase II of two odor matching-to-sample. During the trials when correction was introduced, performance went up and maintained at a high level even when the correction was removed. Thus, the rats were responding during the S+ trials and withholding responses during S- trials with accuracy between 80%-91% on the first session. Two of three subjects continued to maintain accuracy when a novel odor was substituted for one already in the trial, but the third subject did not. By the second session, all three subjects had a performance of 82%-96%.

In the last phase of training, the subjects were presented with two novel odors with no shaping or punishment procedures. The rats made a response to nearly all S+ trials and the majority of the task included the rats learning to not respond to S- trials.

The odors used in the first three-odor problem set were the same odors used in initial training, amyl acetate, butanol and geraniol, while the rest of the problems were comprised of novel odors. Ninety percent correct was attained by the subjects within the first or second session, displaying that the rats were able to quickly attain the go/no-go problems. As with the two-odor sessions, the rats performed on nearly all S+ trials and had to learn to not respond on S- trials. Thus, performance on S+ trials was high, while S- performance was inconsistent. Some S- trials had few errors while other configurations had several errors. Yet, there was no one combination of stimuli that resulted in low performance and instead based on differences that varied by individual subjects.

With this study, Lu, Slotnick and Silberberg (1993) provide evidence that rats have the ability to attain high performance with an olfactory go/no-go procedure. They were able to establish that rats have the ability to discriminate between odors with a high rate of accuracy. It is difficult to determine if the rats were able to respond on the basis of the identity concept because the first novel trial was not analyzed separately to determine the rats’ performance when first presented with novel stimuli. It does provide further support that rats, when presented with olfactory stimuli, are capable of displaying excellent learning of discrimination tasks.

Peña, Pitts and Galizio (2006) attempted to extend the procedures of Lu, Slotnick and Silberberg (1993) by developing a simple matching-to-sample procedure for rats with olfactory cues. Four Sprague-Dawley male rats that were placed on food restrictions were used in the experiment. The testing chamber had the front wall constructed of clear Plexiglas that permitted the experimenter to observe the rat during the sessions. The olfactory stimuli used consisted of kitchen spices or concentrated oils that were mixed in proportion with sterilized playground sand. Two plastic trays were used in the procedure, one with three holes drilled into the top and one tray with four holes drilled into the top. Each tray had one sample hole that was positioned in such a way that when the tray was pushed partway into the operant chamber, the rat could only access the sample cup. When the tray was pushed the rest of the way into the chamber, the rat could access all of the stimuli cups.

Digging was reinforced by a sugar pellet that was concealed in the scented sand.

A response was operationally defined as a paw or nose placement in such a way that the sand was displaced. When the rat responded to the sample, the comparison stimuli were presented. The comparison stimulus cup that matched the sample (S+) had a sugar pellet buried 1 cm beneath the sand, while the non-matching cup (S-) was usually not baited. If the rat responded to the incorrect comparison cup, the trial continued until the subject responded in the S+ and retrieved the pellet or when 3 minutes had passed.

The matching comparison cup was the only cup reinforced in most trials, with the exception of two random trials in sessions in the initial Novel Stimuli Phase in order to determine that the behavior was not under control of the scent of the food pellet.

During the beginning sessions of matching-to-sample training, the rats were only presented two stimuli with the sample always reinforced. When a subject reached 75% or higher criterion, the reinforcement of the sample cup was dropped to 75%. When the subject reached 90% correct for two or more sessions, the reinforcement of the sample was dropped to 50%, where it remained for the rest of the experiment. Two rats met this criterion within 5 to 6 sessions while the remaining two rats took between 13 to 16 sessions.

In the Novel Probe Phase I, the experimenters introduced stimuli that had not been experienced by the subjects before. During the first session, a novel scent was presented as the sample with one of the familiar scents from the baseline as the S- comparison, designated a Novel Probe trial. Once the novel scent was introduced, it became a permanent part of the stimulus set used through the experiment. After this point, each time the subject met the criterion of 90% correct or higher for two consecutive sessions, two novel stimuli were introduced. High performance accuracy on baseline trials and trials with novel stimuli introduced were seen from all four rats by the end of this phase. Three of four rats also performed correctly on five of the last six Novel Probe trials, thus providing evidence of generalized matching.

It became a concern that during Novel Probe trials, the novel sample cup was always baited and that the rats' responses might have been based on the last reinforced scent. In Novel Probe Phase II, the initial novel stimuli were presented without sample reinforcement. The sample reinforcement stayed at 50% for the trials, but the novel probe trials did not have the sample reinforced, while both comparison cups, S+ and S-, had sugar pellets in the sand to make certain the subjects were not tracking the scent of the pellet. If the session had no new scents being used, two trials were randomly selected to bait both comparison cups. One rat met the 90% criterion in the minimum number of sessions while another rat only needed four sessions to meet criteria. The same two rats also made correct responses to all six of the Novel Probes introduced during this phase and maintained high performance levels on baseline and novel trials. One rat maintained high levels of performance on baseline trials, but needed more sessions in order to meet the generalized matching criteria. The last rat met generalized matching criteria, but his baseline performance dropped and after not meeting the two consecutive sessions at 90%, the rat was removed from the study.

Three of the four subjects progressed to Novel Probe Phase 3. Two different configurations were used in this phase that had not been used in earlier phases. One type was designated as Novel-Familiar and involved a novel sample with S- being a previously encountered odor. The Familiar-Novel trials included a previously encountered odor as the sample and a novel scent as the S-. As in earlier phases, the samples of novel trials were never reinforced and both comparisons contained sugar pellets. In the minimum sessions required, one rat performed correctly on all six tests and kept a baseline performance of almost 100%. Another rat also had 100% performance on the novel probe trials and maintained 90% performance for his baseline and novel trials.

A Three Comparison Phase was used to determine if one stimulus could have a stronger scent that was controlling the subjects' responses. In the two comparison task, there are two cups of one spice, the sample and matching comparison and one cup of the non-matching comparison. The experimenters designed this phase to rule out the possibility that the intensity of the odor was controlling the subjects' responses. Three comparison stimuli were presented to the rats, one that matched the sample, S+, and two that did not match, S-. Half of the trials were designed so that the two non-matching comparison stimuli were identical so that each scent would be the same intensity in comparison to the sample and matching comparison stimulus. It should also be noted that the Three Comparison phase also created a different spatial configuration of the sample and comparison stimuli. Thus, this phase also helped rule out the possibility of the subjects' learning by stimulus configurations. The performance accuracy of both rats decreased to some extent but remained well above chance and was similar to those achieved when two of the non-matching comparison stimuli were the same. These findings provide evidence that the rats' performance was not based on the stimulus configurations in the two-comparison phase and that the intensity of the stimulus odor did not control responding.

In Peña, Pitts and Galizio’s (2006) study, all rats met criterion of two sessions at 75% or better after 15 to 24 sessions, and between 25 and 30 sessions, the subjects reached 90% accuracy on the discrimination between two stimuli. The high levels of performance continued through Phases 1 and 2, averaging between 80%-95% correct. Accuracy on novel trials in both phases remained above 80%, giving evidence that the rats were not rapidly learning configurations. Three subjects performed at above chance levels on the novel probe trials providing evidence for generalized matching. Peña, Pitts and Galizio’s (2006) study demonstrated generalized MTS in rats, however, their procedures involved manual stimulus presentation and data recording. The present study was an attempt to replicate the Pena et al study with the refinement of a semi-automated MTS procedure using olfactory stimuli. It was anticipated that this type of procedure would assist in eliminating possible experimenter effects, decreasing experimenter effort, making the response recording more accurate and eliminate the need for pellet detection control tests.

EXPERIMENT I METHODS

Subjects

Three male Sprague Dawley albino rats, all experimentally naïve, were housed individually in wire mesh cages. The subjects were placed on a reverse 12 hour light/dark cycle. Rats were given 1 hr free feeding approximately 15 minutes after each daily session. After the 1 hr time frame, any remaining food was removed from the cage. The animals were provided water ad lib. The rats in Group Y were Y1, Y3 and Y5.

Apparatus

A modified operant chamber was used in this procedure (Figure 1 and 2). The olfactory discrimination apparatus for rats (ODAR) had outside dimensions of 30.8 cm in length, 34.3 cm in height and 27.9 cm in width. The inside dimensions for the chamber was 27.9 cm in length, 29 cm in height and 26.7 cm in width. The apparatus had three ports that served for stimulus presentation and delivery of reinforcement (Figure 3). Each port was 3.8 cm length by 3.8 cm width. The doors in Experiment 1 were constructed of heavy cardboard that could be raised or lowered by a computer. The two comparison doors were constructed of one piece of cardboard while the sample door was a single piece of cardboard that was operated independently of the side doors by a separate motor. The ports permitted access to the olfactory stimulus as well as reinforcement, which was controlled by a computer program. Photocells situated inside each port detected the presence of the rat’s head inside the port. The response was operationally defined as a nose poke sufficient to activate the photocell for 2 s, and was recorded by the computer with Med Associates software.

Olfactory stimuli were delivered by placing odorants (spices or aromatic oils) into a stimulus presentation tray that slid beneath the nose ports (Figure 4) under a piece of wire grid that prevented the subject from touching the olfactory stimuli, yet allowed the subject to smell the spice. The grid also caught the sucrose pellets that were delivered by the pellet dispensers. The stimulus presentation tray was 24.8 cm by 6.4 cm (Figure 5). Sucrose pellets were delivered to the port by one of three 8.9 cm diameter pellet dispensers, connected by a clear plastic tube to the rear of the appropriate nose port (Figure 6 and 7).

The scents were placed into a clear plastic tray that was attached to a small condiment cup. This procedure positioned the scent in close proximity to the nose ports. Two forms of olfactory stimuli were used. The majority of scents were in the form of powdered spices. The other form of olfactory stimuli that was used in the study was concentrated oils. The powdered spice was placed onto the tray with just enough spice to cover the bottom of the tray. When the concentrated oils were used, two drops were placed on the tray. The olfactory scents were standard kitchen spices and concentrated oils that were obtained from the Great American Spice Company (Table 2). Sucrose pellets (45 mg) were used for reinforcement.

Eight stimulus sequences were used throughout the testing procedure. A stimulus set contained five spices that were inserted into the stimulus sequence to create eight sessions using those stimuli. A total of six stimulus sets were created for Experiment I and II (Table 1). In a session, neither comparison side was reinforced more than three times consecutively. Each spice was designed to appear six times as the sample and reinforced comparison, while also appearing 12 times as a non-reinforced comparison. The reinforced stimuli were balanced with three appearing on the left side and three on the right side for each stimulus. Non-reinforced comparison stimuli also were balanced across the sessions. An arrangement of stimuli was used once per session and would not appear again until the next session.

Pre-training

Sessions were generally conducted five days per week, Monday through Friday. Pre-training involved placing the rats in the ODAR chamber to allow habituation to the new environment for duration of five minutes on the first day. White noise was projected at 70 db to mask outside noise. Rats were also trained to eat sucrose pellets by providing access to some pellets in their home cage on the first day of training.

Following two days of acclimation to the chamber, nose port training began. The experimenter opened the three doors to allow the subject access to the nose ports and a pellet was delivered immediately after the photo beam was broken. When responding was consistent, the required response time was extended to 2 s and after the subject responded to a nose port, the door would close to prevent access until the rat had received reinforcement in all of the ports by responding. When the rat was responding regularly, a faux MTS program with no olfactory stimuli present was initiated. Trials began by raising the sample door and when the rat responded for 2 s, the side doors raised to allow side port responses. The rat could respond in either the left or right side to produce reinforcement. After 1 s, the doors were lowered and an approximately 20 s inter-trial interval began during which the experimenter prepared for the next trial. The inter-trial interval was not shorter than 12 s or longer than 30 s. After the inter-trial interval was over, the experimenter began a new trial. In an effort to avoid creating a side bias, reinforcement was delivered if the rat responded to one port exclusively for three consecutive trials. For example, if the rat responded to the right side port three times consecutively, only left side responses would be reinforced on the next trial. After the rat had two sessions with this procedure, the MTS training program began.

MTS Training

MTS Training involved the procedure just described with olfactory stimuli included in the trials. After the experimenter had placed the spices into position, the trial began by raising the sample door. After the rat responded to the sample stimulus, the side doors were opened to allow access to the two comparison stimuli. If the rat responded to the non-matching stimulus, no reinforcement was delivered and the doors remained open until the rat responded to the matching stimulus. Responses to the matching comparison stimulus were reinforced with the delivery of a sugar pellet into the corresponding nose port. After 5 s, the doors closed and the inter-trial interval began. The inter-trial interval was controlled manually, based upon how quickly the experimenter could set up the next trial, but ranged from 10 s to 30 s.

Rats Y3 and Y5 were tested with Stimulus Set A, while Y1 was tested under Set B, (see Table 1). Table 2 lists the stimulus sets each subject was exposed to during the experiment. Rats began MTS testing with a 2 s response requirement for all ports. After the first week of testing, the rats began to show signs of side bias, with responses mainly on either the left or right port. In an attempt to correct the side bias, the rat was placed on a program that reinforced one side only, i.e. if the subject was responding mainly on the left side, the program was set to reinforce the right side only, which was used with a special assortment of stimuli so that the correct comparison corresponded with the reinforced side. On the charts, these special side bias correction sessions are distinguished with a gray circle.

At the beginning of the testing, the ODAR box had vinyl-covered cardboard doors that were mechanically lifted by two motors affixed to the back of the box. One motor controlled the single door that covered the center, or sample, port while the other motor controlled the larger piece of cardboard that covered both sides of the side ports. The piece of cardboard that covered the sample door measured approximately 28 cm high by 4 cm wide while the larger piece of cardboard was approximately 26 cm in width by 27 cm in height.

The rats were tested for 10 to 11 sessions with the cardboard doors. Several difficulties arose with the doors, including the doors jamming, the motors unable to raise the weight of the doors, and the doors not closing properly. Testing was stopped to remove the cardboard doors and install new guillotine doors. The two motors were removed that controlled the old doors and three motors were installed, each one able to control one guillotine door over each port. A house light was also installed into the ODAR box that was lit during a session.

In addition to the new guillotine doors and the house light, this phase of the study also changed the response requirement from 2 s to 3 s. The time requirement was lengthened in an effort to make certain that the subject had an appropriate amount of time to attend to the stimuli. The wire grid that was installed below the nose ports was replaced six test days later due to some of the subjects biting and tearing through the grid. A thin strip of Plexiglas with multiple holes drilled into it replaced the wire grid above the stimuli.

At Session 21, the response requirement for the comparison ports was changed to 4 s. Y1 and Y5 showed a slight improvement in performance scores, but still remained at chance. It was decided four sessions later to switch all of the subjects to a 4 s requirement on all ports, so that the subject had to break the photo beam for a minimum of 4 s to progress the trial.

To explore the basis of the poor matching-to-sample performance with these rats, it was decided that the subjects Y3 and Y5 would be placed on a simple discrimination task. At Session 46, Y3 was placed on the task; while Y5 was moved at Session 48 to the simple discrimination task. The task involved two stimuli, one designated as S+, or reinforced, and the other as S-, not reinforced. In this scenario, Nutmeg was S+ and Sage was S-. The two comparison doors were used to present the stimuli. The trial began with both side doors rising to allow the subject to access the S+ and S-. The location of the S+ was alternated to prevent side biases from reoccurring. The 10 s correction procedure, where the subject was placed on a 10 s interval after an incorrect response where the house light was turned off and all of the nose port doors were closed, was kept the same as it had been during the matching-to-sample program with the exception that the response requirement was reduced to 1.5 s. At Session 55 for both subjects, the response requirement was increased to 2 s to allow the subjects’ a longer interval to distinguish between stimuli.

EXPERIMENT I RESULTS

The results for subject Y1 can be viewed in Figure 8. Session 1 in Panel A for Y1 was terminated when there was no response from the subject for five minutes. When calculating the terminated sessions, the number correct was divided by the number of trials actually presented to the subject, rather than the total number of trials, (i.e. Y1 was presented 17 trials, and responded correctly on 7 of those trials. 7/17 = 41.2%). These sessions are designated on the graphs as yellow circles, such as Y1’s Session 1 in Figure 8. On the second session, Y1’s performance was directly at chance with 50% performance.

Sessions 3, 4 and 5 fluctuated at near chance performance with a left side bias developing. The subject was put on a side bias prevention (SB) session that reinforced only left port responses in Sessions 6 through 11. Y1’s performance was as low as 17% on Session 6 but climbed steadily to 63% by Session 9. Both Sessions 10 and 11, both were terminated early due to low rates of responding. In Session 10, Y1 had a performance of 19% but in Session 11, even though the session was terminated prematurely due to lack of responding, Y1 had made correct responses on all trials presented.

The new guillotine doors, as described above, were installed and in place for Y1’s Session 12 and Panel B. The subject performed below chance (43%) on Session 12 while also showing signs of left side bias, so Y1 was placed on SB prevention for Session 13. Y1 demonstrated high performance for Session 13 but dropped back to chance levels for Sessions 14 and 15 when returned to the MTS program and began to show a right side bias again. Once again, for Session 16, Y1 was placed on a SB prevention session which resulted in a highly accurate performance of 93%, but dropped back to chance when the subject was placed back onto MTS. For Sessions 17 through 20, performances continued to hover at near chance levels once again.

On Session 21 in Panel C, a new response requirement was introduced that required a 3 s response time in the sample port and 4 duration in the comparison ports in an effort to allow the subject more time to differentiate between the odors. While Sessions 21 and 22 were terminated prematurely due to the subject's lack of responding, Y1 performed at chance on Session 21 and at 75% on Session 22. Y1 also had above chance performances on Session 23 and 24. However, the right side bias returned and Y1 was placed on SB prevention for Session 25 with chance performance.

On Session 26 in Panel D, the sample response requirement was also extended to 4 s so that all of the ports had the same response requirement and Y1's performance dropped to below chance during that session. The subject performed slightly above chance for Sessions 27 and 28 before being placed on SB prevention session once more for a right side bias. No more SB prevention sessions were used for the remainder of the experiment after Session 29 as they did not appear to be producing enduring effects. As one can see, Y1 performed above chance in Sessions 30 and even better in Session 31, but dropped dramatically to 40% for Session 32. Y1's performance continued to hover near chance levels until the end of testing.

Percent correct across sessions for Rat Y3 is shown in Figure 9. Rat Y3 was studied with Stimulus Set A with a 2-s response requirement on all ports. In Panel A, the subject had below chance performance on Session 1 and accuracy fluctuated at near chance levels for Sessions 2 through 6. Y3 demonstrated a right side bias and was placed on a SB prevention session for Sessions 7 and 8. Y3’s performance dropped dramatically on Session 7 to 23% and climbed to 47% on Session 8. Y3 was placed back on the MTS program for Session 9 and performed at above chance levels for Sessions 9 and 10.

In Panel B, the new doors and house light were installed for Session 11, and a 3 s response requirement was initiated, but Y3 performed at chance during this session. Y3 was placed on SB prevention session once more for Session 12 and the subject showed above chance accuracy for this session, though performance dropped below chance for Session 13 when Y3 was placed back on the MTS program. Performance climbed above chance for Sessions 14 and 15, though the new screens were installed above the spices for Session 16 and performance dropped below chance. Performance fluctuated above and below chance levels over Sessions 17 through 20. The response requirement was changed from 3 s to 4 s on the comparison ports and remained at 3 s on the sample port on Session 21 and performance was at chance for this session. Performance rose above chance on Session 22 (57%), but dropped below chance for Session 23 (47%). For Session 24, the session was terminated prematurely due to lack of responding from Y3 and the subject performed at 33%. Y3 performed at 70% when placed on left side bias prevention (LSB) where all of the reinforced matching comparison stimuli were on the right side for Session 25. Y3 was moved back to the MTS program for Session 26 in Panel D and the sample port response requirement was changed to 4 s, though performance remained at chance. Session 27 was another SB prevention session for Y3 for a right side bias, though performance remained at chance for that session and only rose slightly above chance for Session 28 when placed back on MTS. Session 29 was the last SB prevention session for a left side bias, on which Y3 performed slightly below chance. From Session 30 through 35, performance for Y3 was at chance levels. On Session 36, the beginning of Panel E, the correction procedure was implemented (incorrect responses produced a 10 s correction period). Y3's performance on the first session with the correction procedure, Session 36, was at 27%. Performance slowly climbed back to chance levels over the next three sessions. Session 39 showed an above chance performance of 57% that continued to climb up to Session 42 with a performance of 67%. On Session 43, however, performance dropped down to 40%. Sessions 44 and 45 had above chance performances of 57%.

In Panel F on Session 46, Y3 was placed on the Simple Discrimination program where the response requirement was lowered to 1.5 s and a 10 s correction procedure was maintained. Y3’s performance was 65% on the first session with the Simple Discrimination program. Over Sessions 47, 48 and 49, performances dropped steadily to 60%, 40% and 35%, respectively. Y3 had a performance accuracy of 40% on Session 50 while the subject’s performance was 70% for Sessions 51 and 52 and 75% for Session 53. Y3’s performance dropped to 65% for Session 54.

The response requirement was extended to 2 s in Session 55 in Panel G, where performance dropped to 40% as the subject acclimated to the new response requirement. Y3’s performance was 80% in Session 56, and remained above chance through Sessions 57 to 59, though the subject’s performance dropped to below chance on Session 60.

Figure 10 shows Y5 responded at chance with 50% performance on the first session in Panel A. Sessions 2 and 3 were terminated prematurely due to lack of responding from Y5 with accuracy at 63% and 57% respectively. Y5 responded at chance performances for Sessions 4 and 5 while demonstrating a right side bias. To counter this, Y5 was placed on SB prevention sessions for Sessions 6 and 7. There was an obvious drop in performance for Session 6 with Y5 performing at 27%, yet on Session 7, Y5 had an accuracy of 80%. Y5 was moved back to the MTS program for Session 8 but demonstrated the right side bias and was placed on SB prevention for Session 9.

The new doors and house light were in place for Y5's Session 10, along with the 3 s response requirement, (Panel B). Y5's performance was at chance (53%) for Session 10 and declined to 43% for Session 11 with beginning signs of a left side bias. Session 12 was aborted due to a lack of responding from the subject and Y5 was placed on SB prevention for Session 13, where the subject performed at 70%. Y5 was placed back on the MTS program for Session 14 and performed at chance levels for Sessions 14 through 18. The subject's performance increased slightly to 57% for Session 19, but then dropped to 40% for Session 20.

When the 4 s response requirement for the comparison doors and the 3 s response requirement for the sample door was put into effect for Session 21 (Panel C), Y5's performance dropped to 33% for Session 21 and slowly improved on Session 22 at 40% and at chance for Session 23. Y5 had a performance of 57% for Session 24 but showed signs of side bias and was placed on Therapy for Session 25 where the subject's performance was 60%.

Y5 was placed back on the MTS program (Panel D) for Session 26 with a 4 s response requirement now in place for all of the nose ports and responded at 60%. The subject's performance dropped slightly for Session 27 and Y5 was placed back on SB prevention for Session 28 with 60% performance. Y5's performance dropped to 53% when moved off of Therapy for Session

29 and still showed signs of a side bias, thus was placed on SB prevention for the last time on Session 30, demonstrating a 63% performance. It was decided that no more SB prevention sessions would be used for this subject after Session 30. Y5 performed at 53% for Session 31, but the subject's performance slowly declined to 43% in Session 32 and 47% in Session 33. Session 34 and 35 had performances of 40% and 37%, respectively.

A correction procedure was implemented for Session 36 with a 4 s response requirement of all ports and a 10 s timeout for any incorrect responses with the missed trial repeated, as shown in Panel E of Figure 10. Y5 performed at 37% for Session 36 and increased to 57% for Session 37. Y5 had chance performance for Session 38 and 39, with his performance dropping to 43% for Sessions 40 and 41. For Session 42, Y5's performance increased to 53% and to 60% for Session 43, but dropped down to 43% for Session 44. Y5 had 63% performance for Sessions 45 and 46, but once more dropped to chance for Session 47.

Y5 was placed on the Simple Discrimination task for Session 48, beginning in Panel F, where Nutmeg was the reinforced stimulus and Sage was the non-reinforced stimulus. The response requirement for the stimulus ports was 1.5 s with a 10 s correction for any incorrect responses that resulted in a repeated presentation of the missed trial. Y5 performed at 55% for Session 48 and climbed to 65% in Session 49 before dropping back to 55% in Session 50. The subject performed at 70% for Session 51 before dropping to 60% in Session 52 and to 35% for Session 53. In Sessions 54 and 55, Y5 performed at 60% while the response requirement was lengthened to 2 s beginning in Session 55. Y5's performance increased to 75% in Session 56, indicated in Panel G, but then dropped back to chance levels in his final session at 55% performance.

EXPERIMENT I DISCUSSION

Despite the various manipulations through the experiments, performances continued to hover at chance levels on MTS. Even when Y3 and Y5 were studied under a simple discrimination task, performances were erratic, although above chance levels. These results suggested that some aspect of the procedure had interfered with acquisition of stimulus control. It was hypothesized that perhaps the many alterations in procedure had resulted in acquisition of stimulus control by irrelevant environment cues (e.g., position bias) and that these may have prevented more appropriate responding from developing.

In Experiment 2, three new rats began their training in the rebuilt apparatus and were studied with the 2 s response requirement in the hopes that the steady requirement would produce better stimulus control.

EXPERIMENT II METHODS

Subjects

Three male Sprague Dawley albino rats, all experimentally naïve, were housed individually in wire mesh cages as in Experiment I. The subjects were placed on a reverse 12 hour light/dark cycle. Rats were given 1 hr free feeding approximately fifteen min after each daily session. After the 1 hr time frame, any remaining food was removed from the cage. The animals were provided water *ad lib*. The rats in Group Z were Z2, Z6, and Z12, also designated as the Z Group.

Apparatus

The same olfactory chamber that was used in Experiment I was used in Experiment II, though Experiment II started with the plastic guillotine doors already in place. Three motors were installed, each one able to control one guillotine door over each port. A house light was also installed into the ODAR box that was lit during a session. The olfactory box used in Experiment II contained a thin strip of Plexiglas with multiple holes drilled into it which replaced the wire grid used at the beginning of Experiment I.

A second apparatus, designated as the non-automated procedure, was used in Experiment II with subjects Z6 and Z12. These two subjects were placed in the operant chamber design that was originally discussed in Peña, Galizio and Pitts with the same olfactory stimuli that they had been exposed to in the olfactory chamber. The manual apparatus was constructed of Plexiglas on the front and back side of the structure to allow observation of the subject during testing, while the sides of the chamber were constructed of metal. The overall dimensions were 12 in. by 11 in. by 13.5 in. with interior dimensions being 11 in. by 11 in. by 10.5 in. The front Plexiglas of the sandbox had a rectangle area that was 12 in. by 1.75 in. cut out to allow an 8.25 in. by 10.25 in. plastic tray that contained the stimuli to be inserted into the sandbox. The tray had three 2 in. diameter holes drilled into it that held the stimulus cups, one hole in the front of the tray and two in the back, (Figure 11).

Pre-training

Sessions were once more conducted five days per week, Monday through Friday. Pre-training involved placing the rats in the ODAR chamber to allow habituation to the new environment for a duration of 5 min on the first day. White noise was again projected at 70 db to mask outside noise. Rats were also trained to eat sucrose pellets by providing access to some pellets in their home cage on the first day of training.

Group Z was given the same training as Group Y had encountered in Experiment I. Following two days of acclimation to the chamber, port training began. The experimenter opened the three doors to allow the subject access to the nose ports and a pellet was delivered immediately after the photo beam was broken. When the subject's responding was consistent, the response time was extended to 2 s and after the subject made a 2 s response to a nose port, the door would close to prevent access until the rat had received reinforcement in all of the ports by responding. When the rat was responding consistently, a faux MTS program with no olfactory stimuli present was initiated. Trials began by raising the sample door and when the rat responded for 2 s, the side doors raised to allow side-port responses. The rat could respond in either the left or right side to produce reinforcement. After 1 s, the doors lowered and an approximately 20 s inter-trial interval began during which the experimenter prepared the next trial. The inter-trial interval was never shorter than 12 s or longer than 30 s. After the inter-trial interval, the experimenter began a new trial. In an effort to avoid creating a side bias, reinforcement was not delivered after the rat responded to one port exclusively for three consecutive trials. For example, if the rat responded to the right-side port three times consecutively, only left-side responses would be reinforced on the next trial.

Subjects Z6 and Z12 were placed on a light contingency program during the last part of Experiment II. A light was installed above the nose ports on the outside of the chamber.

When the rat was breaking the photo beam, the light would blink steadily to provide a visual stimulus to the subjects.

Simple Discrimination Training

All three rats went through the same training procedures as Experiment I, though instead of progressing directly to a matching-to-sample task after training, all three rats were placed on the Simple Discrimination program where responses to Nutmeg were reinforced, (S+), and responses to Sage were not reinforced, (S-). This program was used to determine if the subjects could detect the stimuli and distinguish between the odors. The response requirement for the Group Z rats was set at 2 s. A correction procedure was implemented such that if an incorrect response was made, the doors would close and the house light would be turned off for 10 s. After the interval, the light would be turned back on and the sample door would rise to restart the missed trial with the stimuli in the same positions.

After the subject had demonstrated two consecutive sessions with 90% or better accuracy, the MTS training procedure began.

MTS Training

All three rats progressed to the MTS training program after 6 to 12 sessions of the Simple Discrimination procedure. The MTS training program was similar to the one described in Experiment I with the exception that a 2 s response requirement was in place for Group Z along with the 10 s correction contingency. Once the subject had an average of 80% or better accuracy over ten sessions with the initial set of stimuli (see Table 2), the next set of stimuli was introduced.

After repeated failures under these conditions, two rats, Z6 and Z12, were placed into the manual apparatus chamber for 10 minutes to allow them to become acclimated to the environment. The subjects were then presented with a sugar pellet in a cup in the sample position. Once the rat had retrieved that pellet, the tray was pushed further into the sandbox to allow the rat to access a second sugar pellet in a cup in one of the two comparison sides. The cup that contained reinforcement was rotated on each trial to prevent spatial bias. The next part of training consisted of the pellet being placed on top of unscented sand. When the subject retrieved the pellet quickly, the next pellet was pushed a little further into the sand to cause the rat to dig in the sand for the pellet. This training continued until the pellet was buried a 1/4 inch into the sand. Once the rat was digging consistently for the pellets, the olfactory stimuli were introduced. The scented sand was created by mixing sterilized playground sand with powdered spices. Ten grams of spice were mixed to 1000 grams of sand to create a scented sand mixture. The same stimulus set that had been presented to Z6 and Z12 for approximately 80 sessions in the ODAR box was used in the manual apparatus.

EXPERIMENT II RESULTS

Figure 12 shows performance accuracy of Rat Z2 across Experiment II. Panel A shows the beginning of simple discrimination training for Z2 with Nutmeg designated as S+ and Sage as S-. Session 1 was terminated prematurely due to lack of responding from the subject, who had a chance performance on the trials completed. When calculating the terminated sessions, the number correct was divided by the number of trials actually presented to the subject, rather than the total number of trials, (i.e., Z1 was presented four trials, and responded correctly on two of those trials. 2/4 = 50%). These sessions are represented on the graphs with yellow circles, such as Z2's Session 1 in Figure 12.

On Session 2, Z2 had an accuracy of 35%, yet in Session 3, the subject's performance was 70%. Z2's performance dropped to 60% for Session 4 but climbed to 85% in Session 5 and 95% in Sessions 6 and 7. Z2 had a perfect performance of 100% in Session 8 to meet criterion and then began MTS training (Stimulus Set B, Table 2). For the first session of the MTS program, Session 9, Z2 had chance accuracy levels (Panel B). Little evidence of conditional discrimination was observed over the first 30 sessions of MTS training (Sessions 9-38), as seen in Panel B. Z2 had an accuracy of 37% in Session 39 and was placed on a side bias prevention session for the left-side bias in Session 40 and had an accuracy of 60%. Z2's performance accuracy increased to 70% in Session 41 on the side bias prevention session, yet when placed back on the MTS testing, accuracy decreased to chance levels for Session 42. Sessions 43 and 44, Z2 had an accuracy of 73% and 67% for Sessions 45 through 47. Z2 had a decreased accuracy of 57% in Session 48, but then increased to 80% accuracy for Session 49. Z2 remained above chance for the majority of the rest of the experiment.

Rat Z2 met the criterion of 80% over ten sessions after Session 71 and novel stimuli were introduced (Stimulus Set C-Panel C) on Session 72. The novel spices were introduced in the first five trials as samples. Z2 was correct on four out of five of the novel spices, providing some evidence of transfer from the old stimuli to the novel stimuli. Z2 had a performance accuracy of 73% in Sessions 72 and 73 before increasing to 80% performance in Sessions 74 and 75. Z2 generally maintained accurate, but variable performances, and never dropped below chance during this phase. However, it required 50 sessions before the criterion was met and Z2 was moved to the next stimulus set, (Stimulus Set D-Panel D). Z2 was correct on four out of five novel spices once more, providing further evidence of some transfer from old stimuli to novel stimuli. Z2 then met the criterion in the minimum requirement of ten sessions before being moved to the next novel stimulus set (Stimulus Set E-Panel

E). Z2 was correct on three out of five novel stimuli presented in Stimulus Set E.

After 25 sessions of performances hovering between 60% and 80%, it was decided to remove Savory from the spice set and insert Anise in its place, as seen in Panel F of Figure 12. Z2's performance increased and met criterion after six sessions with the substitution.

In the Panel G, Z2 was moved from the MTS program to a Reversal procedure and presented with Stimulus Set F. In the Reversal procedure, responses to the non-matching comparison stimuli were reinforced, rather than the stimuli that matched the sample stimuli. If a subject had been demonstrating generalized MTS, when placed on a Reversal procedure, the subject's performance would drop to very low levels. This was seen with Z2 in the first session of the Reversal procedure, Session 162. Z2 performed correctly on one out of five of the novel stimuli presented and at chance for the entire session. Z2's performance continued to drop for Sessions 163 through 166. From Sessions 167 to 176, Z2's performance varied and showed some signs of adjusting to the non-MTS procedure. In summary, Rat Z2 showed strong evidence of generalized MTS.

Rat Z6 began on the simple discrimination task with Nutmeg as S+ and Sage as S-. After six sessions, the subject met the criterion of two consecutive sessions of 90% or better accuracy and was placed on the MTS task, (Stimulus Set B-Panel B). The MTS task had a 2 s response requirement and a 10 s correction procedure if an incorrect response was made by the subject.

On the first session of the MTS task, Session 7, Z6 had an accuracy of zero due to lack of responding. The subject was only presented with three trials during this session and incorrectly responded on all three. On the last trial, the subject had his head caught by the door and after the timeout procedure of 10 s, did not approach the front of the apparatus again and did not respond. The session was aborted after 10 minutes of no response. On Session 8, Z6 completed the session with an accuracy of 43% and of 67% on Session 9. Between Sessions 10 to 22, Z6’s response rate fluctuated around chance levels, never dropping below 40% nor passing 60% during that time frame. On Session 23, Z6 had a SB prevention session for a left side bias, so all correct responses were placed on the right side only and reinforced. Z6 had an accuracy of 63% on the SB session and was placed back on the regular MTS session for Session 24. Between Sessions 24 and 33, Z6 continued to perform around chance levels, ranging from 33% to as high as 67%. Z6 began developing a left side bias once more and was placed on a SB session for Session 34, where the subject’s performance was once again 63%. Z6 was placed back on the MTS program for Session 35 and performed at 43% for that session.

For Session 36 and 37, Z6 performed at 67% and 57% respectively. There was a 12 day period between Session 37 and Session 38 during which Z6 was not tested due to a holiday break. On Session 38, Z6 maintained the same accuracy of 57% that he had demonstrated in Session 37 before the break. Z6 performed at chance in Session 39 and once more showed signs of a left side bias, and was placed on a SB session for Session 40, where the subject performed at 60%. Z6 was placed back on the MTS program for Sessions 41 and 42 for performance accuracy of 43% and 53% respectively before showing signs of a recurring left side bias and was placed back onto the side bias prevention program in Session 43 (77%). Z6 was placed back on the MTS program for Sessions 44 through 46 with performances slightly better than chance, but still showed signs of left side bias and was once more placed on the SB prevention program for Session 47 (77%). Z6 was placed back on the MTS program in Session 48, and performed at 67% before dropping to 43% in Session 49 and 47% in Session 50. Z6 was placed back on the SB prevention program for Sessions 51 and 52 when the subject demonstrated left side bias once more. Z6 performed at 80% in Session 51 and 90% in Session 52 before being placed back on the MTS program for Session 53. Between Sessions 53 through 56, Z6’s performance fluctuated from as low as 40% to 60%. In Session 57, another SB prevention program was presented for the left side bias, with Z6 performing at 77%. Yet, when he was placed back on a normal MTS program in Session 58, he developed the left side bias once more. Z6 performed at 97% when placed on the SB prevention program in Session 59. From Session 60 to 64, Z6 was back on the MTS program with performances from 50% to 63%. In Session 65, Z6 performed at 80% for a SB prevention session but dropped to 57% in Session 66 when placed back on the MTS program. Z6 performed at 67% and 63% in Sessions 67 and 68 respectively before returning to SB prevention program for Session 69, when the subject performed at 97%. Once more, Z6 was placed back on the MTS program for Session 70 (60%). On Session 71, Z6 performed at 40% and then increased to 70% performance in Session 72, before dropping down to chance levels in Session 73. For Sessions 74 through 77, Z6 performed at 57% for every session, before increasing to 60% for Sessions 78 and 79.

Session 80, Panel B, marks the beginning of the non-automated procedure. Z6 remained on the same stimulus set (Stimulus Set B-Panel B) when transferred to the non-automated procedure. The non-automated procedure, as described earlier, consisted of the olfactory stimuli mixed with sterilized playground sand and the reinforcement consisted of a sugar pellet buried in the comparison stimulus that matched the sample stimulus. In Sessions 80 and 81, Z6 was only presented with six trials due to lack of responding and time. For both trials, the subject’s accuracy was 33%. In Session 82, Z6 had an accuracy at chance levels, responding correctly on six out of 12 trials that were presented with the session terminated due to lack of responding after the 12 trial. A similar scenario occurred in Session 83, with only 12 trials presented to Z6 due to a time constraint that occurred from lack of responding from Z6. The subject had a performance of 75% out of these 12 trials. It should be noted that beginning in Session 83, dill was removed from the stimulus set and replaced with clove. For the rest of the non-automated procedure that occurs in Panel B, 25 trials are presented in a session rather than the 30 that are presented in the MTS program. In Session 84, Garlic was removed from the stimulus set and replaced with Sage. Both of the odor substitutions that occurred in Session 83 and 84 continue throughout the rest of the experiment for Z6 and were due to an apparent aversion that the subject had developed for the two spices. This was deduced when the rat would not respond to the cups that held those specific stimuli. From Session 84 through 88, Z6’s performance hovered around chance levels, from 40% to 60%. Due to a right side bias that developed in the sandbox, Z6 was placed on a side bias prevention session for Sessions 89 and 90 that had all reinforced matching comparison stimuli on the left side. Z6 had a performance of 44% in Session 89 and 56% in Session 90. Z6 was placed back on the normal MTS procedure in

Session 91 with a performance of 76%. The subject’s performance rose to 84% in Session 92, dipped to 64% in Session 93 before rising to above 80% in Sessions 94 through 97. In Session 98, Z6 had an accuracy of 92% while demonstrating an accuracy of 84% in Session 99 and 88% in Session 100. Z6’s accuracy was 84% in Session 101 before climbing to 96% in Session 102. In Session 103, Z6 dropped slightly to 88% before increasing to 96% in Session 104.

Z6 was transferred back to the olfactory apparatus, beginning with Session 105 with the same stimulus set still being used, (Stimulus Set B-Panel C). On Session 105, only seven trials were presented due to a lack of responding and Z6 had an accuracy of 57%. Z6’s performance for these same spices, now being presented in the semi-automated olfactory apparatus, drops to around chance levels with the occasional spikes in performance.

The light contingency program went into effect on Session 135, where a light was installed on the outside of the chamber above the nose ports and would blink when the photo beam was being broken by the subject’s response. Z6 remained on Stimulus Set B during these phase of testing, (Stimulus Set B-Panel D). Z6’s performance dropped to chance on Session 135, but increases and hovers between 57% to as high as 77% from Sessions 136 to 145. Due to evidence of a left side bias occurring, Z6 was placed on a side bias prevention session and reinforcement programmed solely on the right side for Session 146 with a performance accuracy of 47%. From Sessions 147 to 159, Z6's performance hovered between 60% and 70% with only two sessions below 60% (156 and 157). Z6 demonstrated chance performances during the olfactory apparatus MTS program, but when placed in the non-automated procedure with the same stimuli, demonstrated above chance MTS performance after 12 sessions. Yet, when transferred back to the olfactory apparatus, accuracy dropped to chance levels for the remainder of the sessions (though slightly better during Panel D when the light contingency was introduced).

Z12 began the simple discrimination task with S+ designated as Nutmeg and Sage as S-, (Figure 14, Panel A). On the first session, Z12 had a performance of 75%. Z12 had a performance of 59% on Session 2, with only 17 trials presented due to lack of responding. In Session 3, Z12 had a performance of 70% and of 40% in Session 4, though only 10 trials were presented in Session 4, due to lack of responding. Z12 had a performance of 30% in Session 5 and 55% in Session 6. Between Sessions 7 and 12, Z12 had a steady increase in performance from 65% to 95%.

The MTS procedure began in Session 13, (Stimulus Set C-Panel B). For the duration of the experiment, Z12 received reinforcement 50% of the time after the sample. Z12 had a performance of 60% in Session 13 and dropped to chance in Session 14. Between Sessions 15 and 26, Z12 had a performance that fluctuated as low as 37% to 67%, though the majority hovered slightly above chance levels. In Session 27, 22 trials were presented due to a malfunction of the odor tray that prevented the rest of the session to continue, though Z12 had a 59% performance of the 22 trials. Z12 had accuracy around chance levels between Sessions 28 and 32 that steadily increased from 43% to 70%. Between Sessions 33 and 36, Z12’s performance declines from 67% to 50% and the subject was placed on a side bias prevention program in Session 37 and had a performance of 57%. The subject was placed back on the MTS program in Session 38 with a performance of 43% and 40% in Session 39. Between Sessions 40 and 43, Z12’s performance fluctuated between 47% and 63% before Z12 was placed back on a side bias prevention program for a right side bias in Session 44 with a performance of 57%. Z12 was placed back on the MTS program for Sessions 45 and 46 with performances of 57% and 53%, respectively before being placed back on a side bias prevention program for Session 47 due to evidence of a right side bias emerging once again. Z12 had a performance of 77% in Session 47 on the SB prevention program before being placed back on the MTS program in Session 48 with a performance of 53%. In Session 49, Z12 had a performance of 47% and 60% in Session 50. Between Sessions 51 and 55, Z12 had a performance between 67% and 57%, with a session down to 40% in Session 53. Z12's performance hovered around chance between Sessions 55 and 64, ranging from 40% to 63%. Evidence of a right side bias arose once more and Z12 was placed on the SB prevention program for Sessions 65 and 66, with performances of 50% and 77% respectively. For Sessions 67 and 68, Z12 was placed back on the MTS program with performances of 50% and 67% before placed back on the SB session in Session 69 with an accuracy of 73%. Z12 had a performance ranging from 43% to 60% in Sessions 70 to 76. The subject was placed back on the SB program for a right side bias in Session 77 and had a performance of 70%. Session 78 was a normal MTS program with Z12 performing at 60%.

Beginning with Session 79, Z12 was transferred to the second operant chamber that involved presenting the subject the olfactory stimuli mixed with sterilized sand and the reinforcement buried within the matching comparison stimuli, (Stimulus Set C-Panel C). In Sessions 79 and 80, only eight trials were presented due to lack of responding. Z12 had a performance of 75% and 0% respectively in these two sessions. Ten trials were presented in Sessions 81 and 82 due to lack of responding and Z12 performed at 40% and 30% in these two sessions. In Session 83, 100% of the samples were reinforced and Z12 had an accuracy of 52%. Z12 had a performance accuracy of 52% in Session 84, where 75% of the samples were reinforced. In Session 85, Z12 was placed on a SB session due to a right side bias, though only 21 trials were presented because of a lack of responding. Two additional SB sessions resulted in zero correct responses. The sample reinforcement was increased back to 100% for SB prevention in Session 87 (4%). For Sessions 88 and 89, Z12 had a performance of 32% and 40% respectively. In Session 90, Z12 returned to the MTS procedure, though only eight trials were presented due to lack of responding from the subject. Z12 had a performance accuracy of 50% in Session 90 and 56% in Session 91, where all of the trials were presented. The sample reinforcement was dropped down to 75% once more for Sessions 92 and 93, where Z12 had a 64% performance for both trials. In Session 94, the sample reinforcement was dropped to 50% where it was maintained for the rest of the experiment. Z12 had a performance of 84% for Session 94. Only 10 trials were presented in Session 95 due to lack of responding with Z12 having a performance of 40%. In Session 96, Z12 had a performance of 72% before being placed on a SB procedure for a right side bias. Z12’s performance decreased slightly between MTS Sessions 99 and 101 from 80% to 72%. Z12 was put on a SB procedure for Session 102 to correct a right side bias and had a performance of 48%. Between Sessions 103 and 109, Z12’s performance increased from 68% to 92%.

Z12 met criterion on Session 109 for a grand mean of 80% or greater over the prior 10 sessions and was transferred back to the ODAR box. Z12 remained on the same stimulus set, (Stimulus Set C-Panel D) but was placed on the light contingency program with no sample reinforcement. The light contingency program, as described earlier, consisted of a light installed above the nose ports outside of the apparatus that would blink when the photo beam was being broken by the subject. In the first session back in the ODA-R box, Z12 had a performance of 43%. Z12's performance drops and hovers around chance levels from Session 111 to the end of the experiment of Session 129.

Even after demonstrating high accuracy in the sandbox, Z12's performance dropped to chance levels when placed back into the ODA-R box even though the stimuli were essentially the same.

EXPERIMENT II DISCUSSION

All three subjects in the Z group started on the simple discrimination task as a means of introducing them to the apparatus and testing procedures. All three subjects met the criterion of two consecutive sessions of 90% performance or greater within six to 12 sessions of the simple discrimination task. Z2 met all criteria for generalized MTS with high rates of accuracy on baseline trials, above chance performances on novel trials, and below chance performances when contingencies were reversed. Z6 and Z12 both remained longer on the first phase of the experiment, 73 and 66 sessions, respectively, before being transferred into the second apparatus while remaining on the same stimulus set. Both Z6 and Z12 demonstrated high accuracy on their stimulus set while being tested in the second apparatus. Yet, when the two subjects were transferred back to the olfactory apparatus, their performances dropped to chance levels once more, despite remaining on the same stimulus set.

CONCLUSIONS

The subjects in Y Group in Experiment I hovered at chance performances throughout the entire experiment. None of the rats progressed past their original MTS stimulus set throughout the entire experiment and showed no evidence of mastering the MTS procedure. However, Y3 and Y5 did demonstrate above chance performances during the simple discrimination task, (Figure 9-Panel F, G; Figure 10-Panel F, G). These results led experimenters to hypothesize that the subjects were able to discriminate between the olfactory stimuli in the apparatus.

The subjects in Experiment I had several disturbances throughout their testing that could have been responsible for the fluctuations in their performance accuracy. The first doors were flawed, which resulted in frequent contact with the animal. The replacement of the doors in Experiment I resulted in a break in the testing sessions while the apparatus was rebuilt with the new guillotine doors. Disturbances caused by nearby construction may also have been a factor.

In Experiment II, new subjects were placed on the simple discrimination task for the beginning phase of testing. All three rats in Group Z demonstrated high performance accuracy in between 6 and 12 sessions, again providing support that the subjects were able to discriminate between the olfactory stimuli. However, Z2 was the only subject of Experiment II to reach criterion with the conditional discrimination task and progress to the next novel stimuli set. Z2 demonstrated high accuracy on the novel stimuli that were presented in Figure 12-Panels C, D and E. In the first trial presented on the novel stimuli sets (see Panel C and D), Z2 correctly matched four out of the five novel stimuli presented as samples for the first time, thus having 80% correct on the novel stimuli. Z2 correctly matched three of the five novel stimuli on their first presentation for an above chance performance of 60% (See Panel E-Set E). These results (11/15 correct overall) provide evidence that Z2 was performing generalized MTS by maintaining high accuracy on novel sets and matching correctly when the novel stimuli were first presented instead of following other possible learning methods, such as configurations. To truly test whether Z2 was performing generalized MTS, the subject was exposed to a reversal design (see Panel G-Set F) that required the subject to respond to the non-matching comparison stimuli in order to receive reinforcement. The hypothesis was that if Z2 was indeed performing generalized MTS, the subject’s performance would drop to chance levels or lower. On the first session, Z2 correctly responded to one of the five novel stimuli when it was first presented, giving a performance accuracy of 20% for those five trials. Z2’s performance was below and around chance levels during the rest of the experiment on the reversal design.

After exposure to 78-79 sessions of MTS training without acquisition, Z6 and Z12 were placed in the non-automated apparatus, and demonstrated high accuracy on the MTS stimuli set. However, when the subjects were transferred back to the semi-automated olfactory apparatus, their performance accuracy dropped back to chance levels immediately with no evidence of having transferred the higher, steadier performances that had been seen in the other apparatus. Clearly, the semi-automated apparatus limited the success of these two rats.

As stated earlier, the semi-automated apparatus was designed in an attempt to reduce the possibilities of experimenter bias and error that existed in the manual apparatus. The design of the semi-automated apparatus was based on the manual one with an effort to preserve its basic components while automating them. Access to the stimuli was changed from a sliding tray to automated doors. The stimuli used in the manual apparatus were a proportion of sand and spice, while powdered spice or concentrated oils were used in the semi-automated apparatus. Reinforcement was not hidden in the stimuli in the semi-automated apparatus, but delivered into the nose port from a tube at the top of the port.

One possible account of the difficulties exhibited by the subjects may involve a combination of factors including response topography, the way reinforcement was delivered, and how the stimuli were presented to the subjects. In the manual apparatus, the reinforcement pellet was hidden in the sand and spice mixture and required the subject to dig in the mixture to locate the reinforcement. However, in the automated apparatus, no digging was necessary and the subject was required to break the photo beam with their head in the port located above the matching comparison stimuli in order to have reinforcement delivered. It is possible that the semi-automated MTS task was more difficult because rats were not required to dig in the stimuli. The motor response might be more important to the rat than once thought and play a major role in identifying a scent. Perhaps the lingering odors and taste of the spice on the rat’s muzzle and paws after digging are important to the MTS procedure. Consider that the semi-automated procedure is, of necessity, a delayed MTS task because the rat must leave the sample-port odor in order to respond to one of the comparison stimuli. In the digging procedure, lingering scents may help bridge the temporal gap.

In the manual apparatus, the period of time before reinforcement was delivered was based on the subject’s ability to locate it. This led to displays of anxious behavior as the comparison stimuli were presented into the chamber and immediate responding to the olfactory stimuli. In the semi-automated apparatus, only after meeting the time requirement for the response would reinforcement be delivered to the subject. Sometimes, the rat would leave the nose port milliseconds before reinforcement was to be delivered. This would reset the computer timer and would require the subject to remain in the nose port the determined amount of time before the reinforcement would be delivered.

The subject had more control over when reinforcement could be delivered in the manual apparatus. If the rat was able to dig quickly enough in the matching comparison stimuli, then reinforcement was only delayed a few milliseconds.

The response requirement in the automated apparatus was as low as 1.5 s in Experiment I when Y3 and Y5 were placed on the simple discrimination task. The response requirements were extended to up to 4 s in an effort to make certain the subject had an appropriate amount of time for discrimination between the stimuli. It is unknown how the subjects might have responded on a 1 s response requirement, but response duration may be an important factor.

While the semi-automated apparatus resulted in successful matching in two of the rats, Z2 did demonstrate generalized MTS. Z2 was the only subject to replicate the findings of the Peña et al study by meeting criterion and progressing to multiple sets of novel stimuli where he demonstrated generalized MTS with high accuracy with the novel stimuli in the MTS procedure. Also consistent with generalized MTS was the finding of below chance responding when Z2 was exposed to a reversed contingency. However, even though Z2 replicated the generalized MTS success of the Peña, et al. (2006) study, considerably more training was required for Z2. In Peña et al, the subjects met criterion in fewer sessions and with higher accuracy than any of the subjects in this study.

Wright (1997) noted that the pigeons imitated normal feeding behavior in their responses by pecking downward at the stimuli. It is possible that the subjects in the non-automated procedure demonstrated high accuracy because the digging response in the stimulus cups was comparable to their natural foraging behavior. Also, the digging response may force more contact with the sample stimulus like Wright's FR 20 schedule. Yet, when Z6 and Z12 were placed back in the ODAR box, their accuracy dropped once more to chance levels, despite the same set of stimuli being presented throughout the experiment.

The ODAR box relied solely on the rat's ability to discriminate between stimuli using olfactory senses, while the non-automated apparatus allowed the subject the ability to dig in the stimuli as well as smell and taste the stimuli. It is very possible that the subjects performed at a lower accuracy because they were unable to perform these natural behaviors in the ODAR box.

In summary, the present study showed that procedural factors may be very critical in determining whether non-human subjects can demonstrate identity MTS. Our findings that procedural factors are important in rats are not surprising, given the results from studies in other non-human species. For example, pigeons demonstrate generalized MTS when multiple sample responses are required, but not when a single response is required, (Wright, 1997).

In future research, it would be beneficial to design an olfactory apparatus that would eliminate the possibility of experimenter bias, as the ODAR box did, but also allow the subject the ability to have more interaction with the stimuli. Requiring the subject to make more than one response to the sample, as Wright (1997) required of the pigeons might increase performance accuracy in rats. Another possibility, besides increasing the number of sample responses, is to introduce another form of response, such as a lever press after a nose poke response has occurred. It may also be important to begin with the simple discrimination task as a method of determining if the subject can discriminate between stimuli in the apparatus, as was conducted in Experiment II. Hopefully, by addressing the issues that arose from the ODAR box and examining the key differences between it and the non-automated apparatus, it will be possible to construct a procedure that would allow rats to show the high performance accuracy that were seen in the non-automated procedure with the more automated convenience and low experimenter interaction that occurred in the ODAR box.

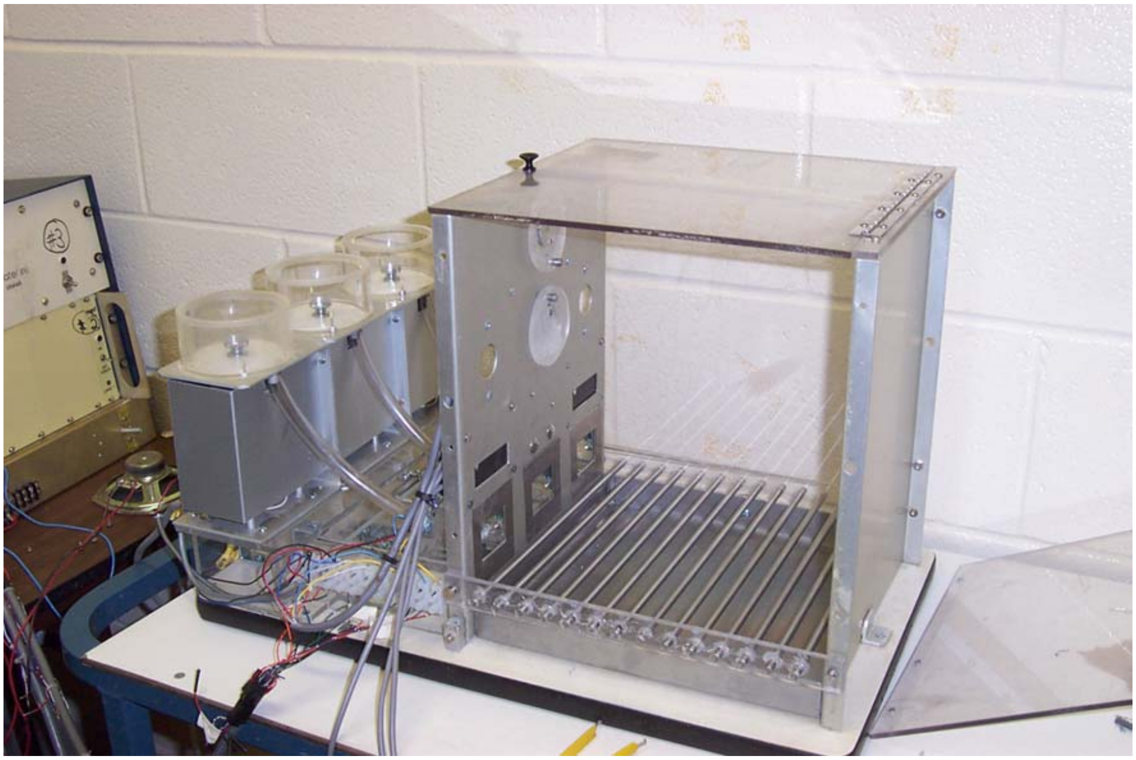


Figure 1: The olfactory discrimination apparatus for rats, ODAR.

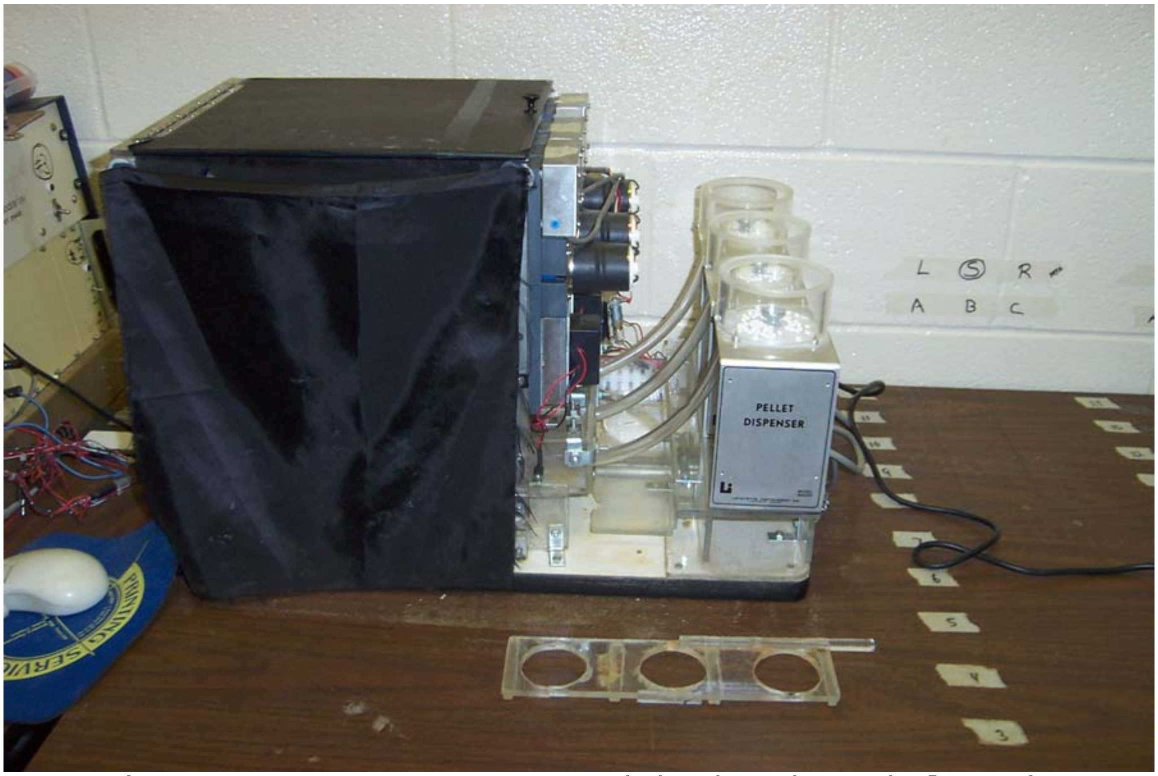


Figure 2: ODAR apparatus with the three-hole spice stimulus tray.

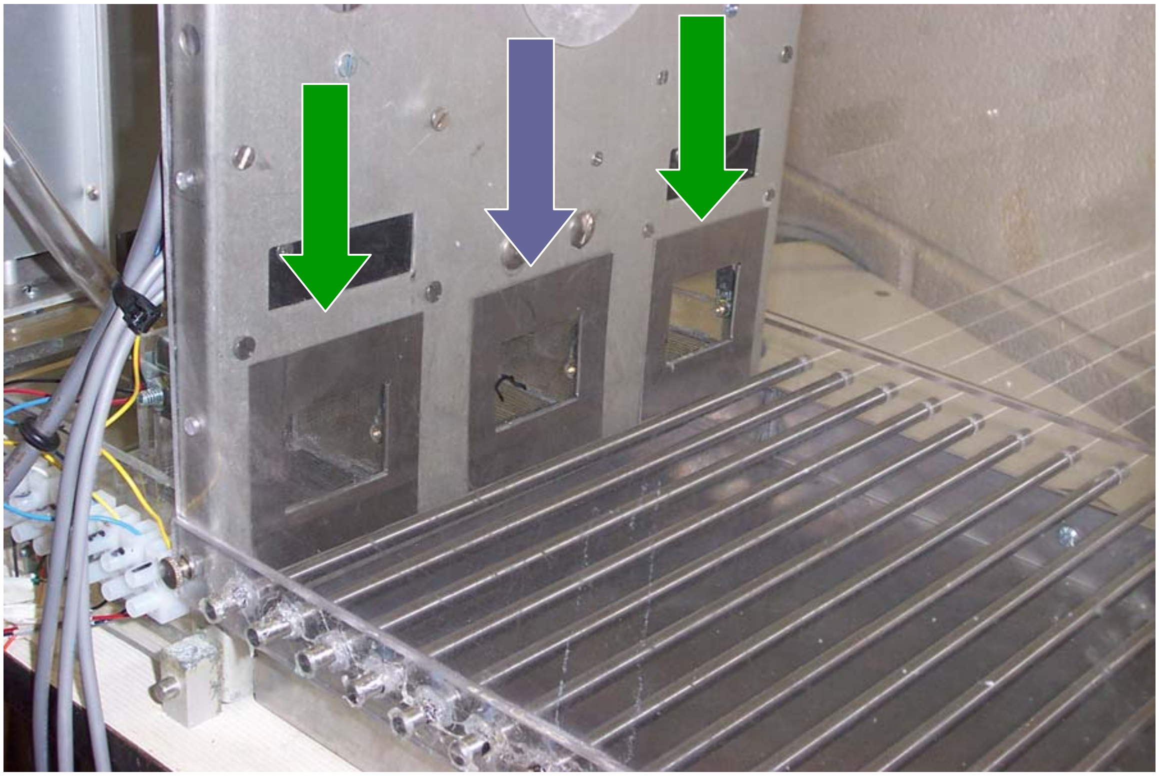


Figure 3: Positions of the nose ports in the ODAR apparatus. The center square, indicated by the blue arrow, is the sample stimulus position. The other two squares, specified by the green arrows, are the comparison stimuli positions. The subject placed its nose in each nose port for 2 s in order to make a response and receive reinforcement.

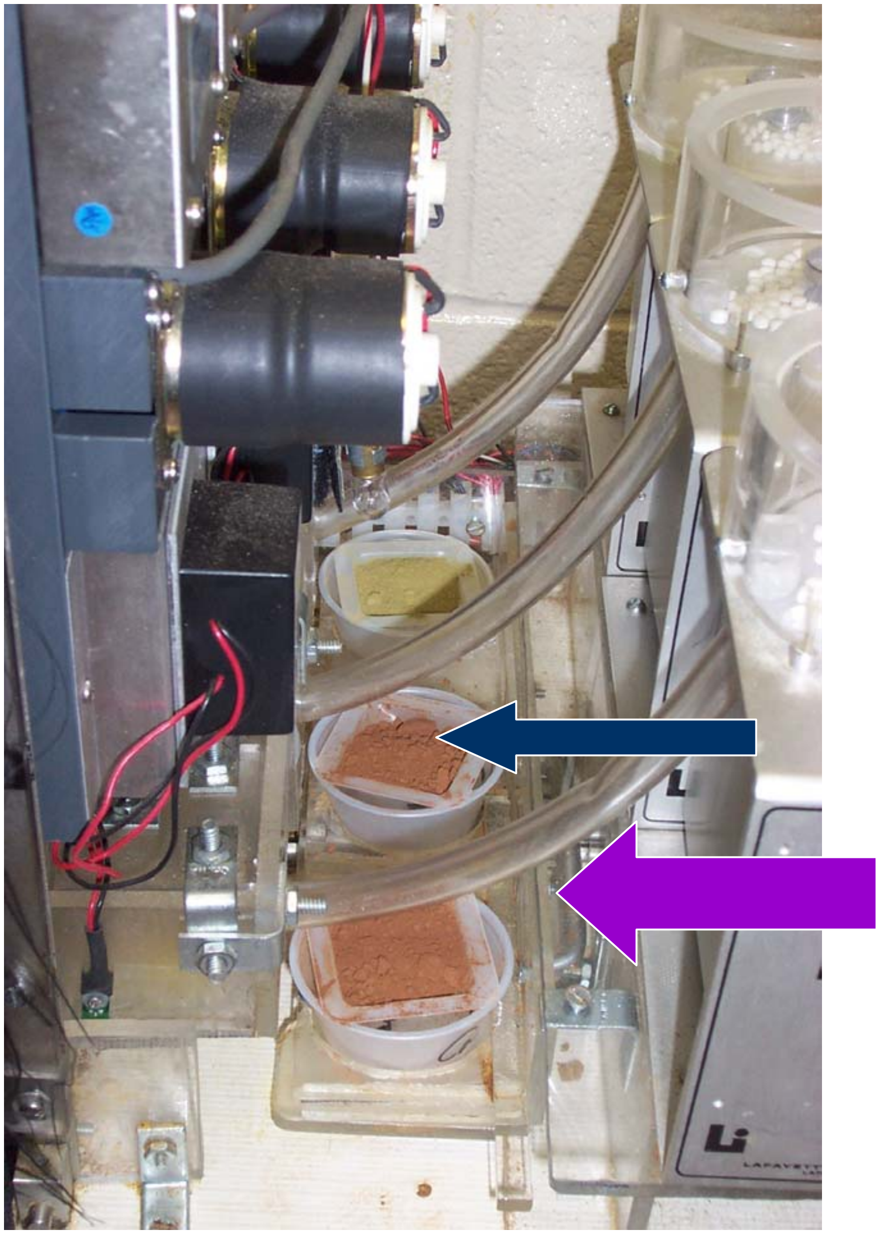


Figure 4: Stimulus presentation drawer. The purple arrow indicates the handle to the stimulus presentation drawer, while the thin dark blue arrow points to the sample stimulus cup.

Figure 5: ODAR apparatus stimulus tray. The Plexiglas stimulus tray held the three cups of olfactory stimuli.

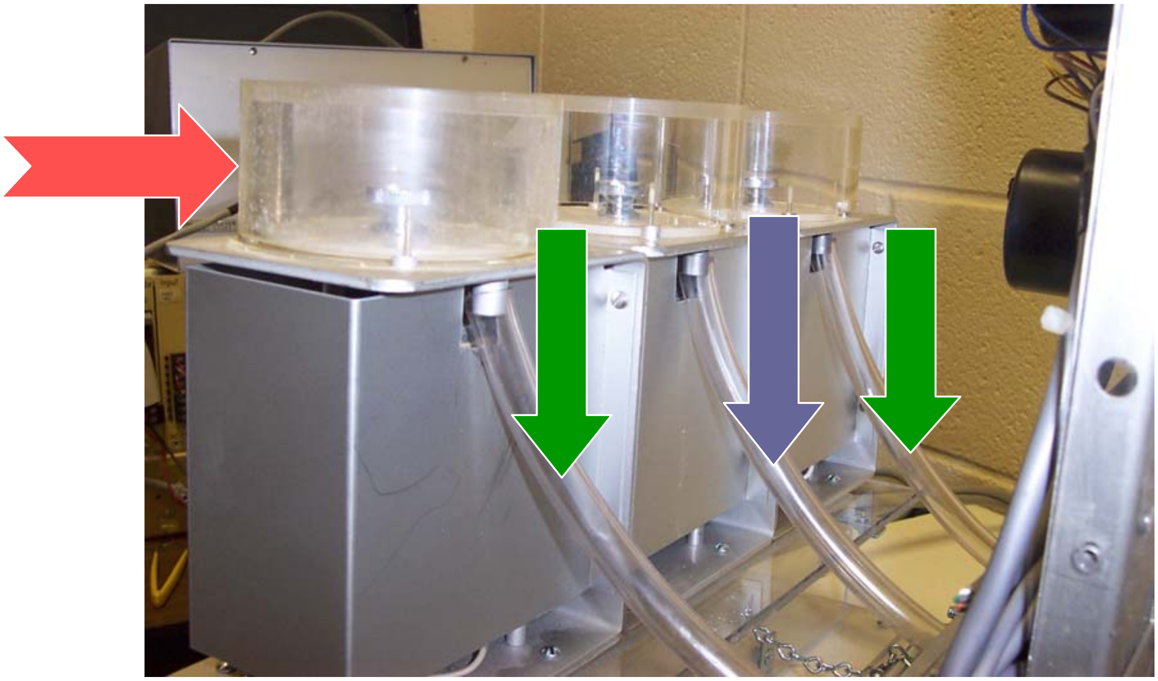


Figure 6: ODAR apparatus pellet dispensers. The red arrow indicates the one of the three pellet dispensers, while the blue arrow points to the center pellet dispenser tube that delivered reinforcement to the sample stimulus center nose port. The two green arrows point to the comparison stimuli plastic tubes.

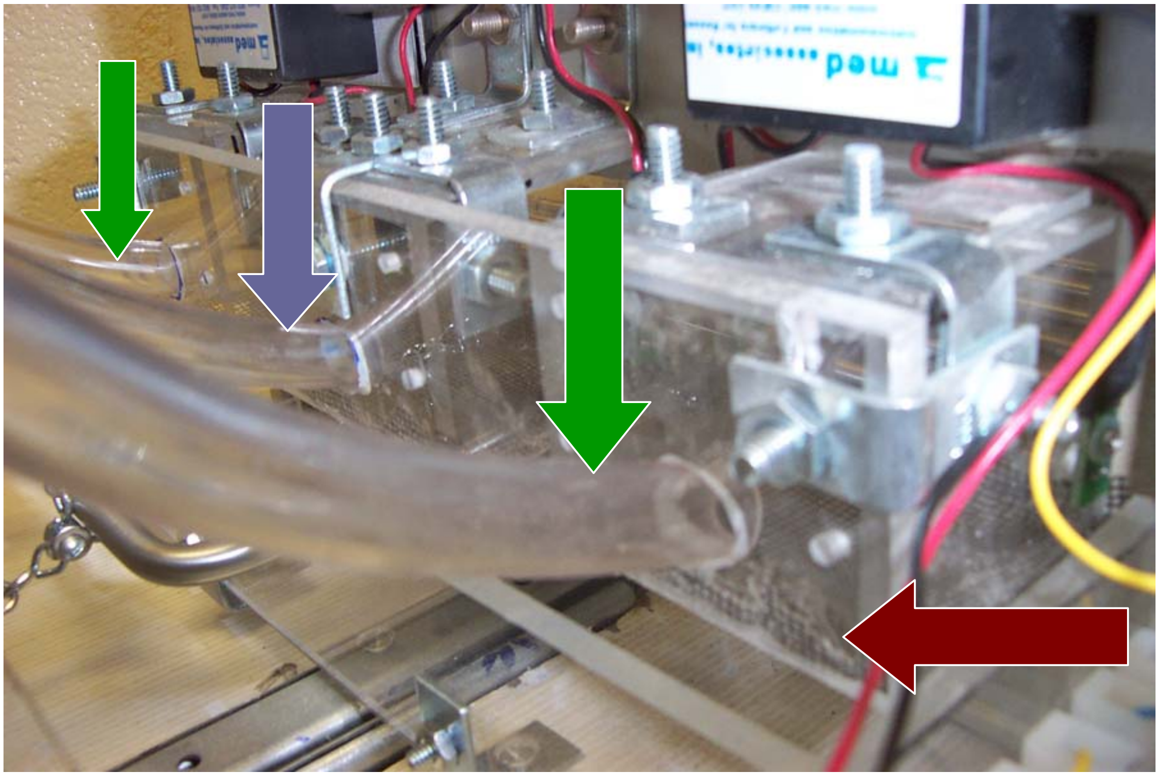


Figure 7: Tubes that deliver reinforcement in the ODAR apparatus. The blue arrow indicates the plastic tube that extends from the center pellet dispenser to the sample stimulus nose port. The two green arrows point to the comparison stimuli pellet dispenser tubes. The wire grid that runs beneath the nose ports can be seen in this photograph and indicated by the red arrow. It catches the sucrose pellet that is delivered from the pellet dispensers.

Table 1: Spice sets used in Experiment I and II

Spice Set A	**Spice Set B**	**Spice Set C**
Banana (Oil)	Coriander	Caraway
Cherry (Oil)	Cumin	Celery
Onion	Dill	Cinnamon
Oregano	Garlic	Thyme
Paprika	Mustard	Turmeric
Spice Set D	**Spice Set E**	**Spice Set F**
Banana (Oil)	Allspice	Bay
Fennel	Blackberry (Oil)	Carob
Onion	Fenugreek	Cloves
Oregano	Marjoram	Rosemary
Paprika	Savory	Tangerine (Oil)

Table 2: List of spice sets used for each subject. Aromatic oils are listed in italics. For Z6, the parenthesis indicates what spices were used in substitution.

Y1	**Y3**	**Y5**	**Z2**	**Z6**	**Z12**
Coriander Cumin Dill Garlic Mustard	*Banana* *Cherry* Onion Oregano Paprika	*Banana* *Cherry* Onion Oregano Paprika	Nutmeg Sage (Simple Disc)	Nutmeg Sage (Simple Disc)	Nutmeg Sage (Simple Disc)
	Nutmeg Sage (Simple Disc)	Nutmeg Sage (Simple Disc)	Coriander Cumin Dill Garlic Mustard	Coriander Cumin Dill(Cloves) Garlic(Sage) Mustard	Caraway Celery Cinnamon Thyme Turmeric
			Caraway Celery Cinnamon Thyme Turmeric		
			Banana Fennel Onion Oregano Paprika		
			Allspice *Blackberry* Fenugreek Marjoram Savory		
			Bay Carob Cloves Rosemary *Tangerine*		

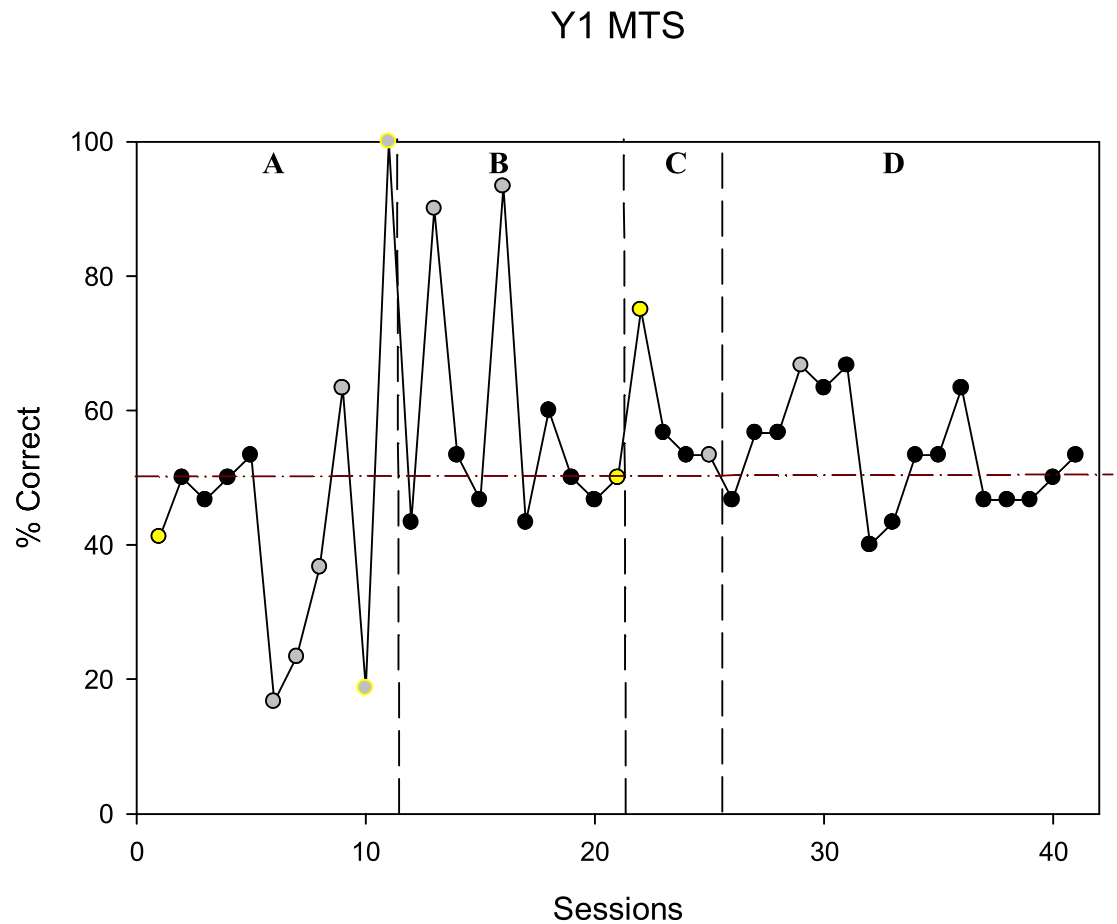


Figure 8: Experiment I graph for Y1. Gray circles represent SB prevention Sessions while yellow circles represent a session that did not have the total number of trials presented. Gray circles with yellow outlines represent SB prevention Sessions that did not have the total number of trials presented. Panel A represents the sessions where the old doors were in place. Panel B represents when the new doors and light were installed. Panel C shows when the 3 s sample response requirement and the 4 s response requirement for the comparisons began. Panel D represents when the sample response requirement was changed to 4 s.

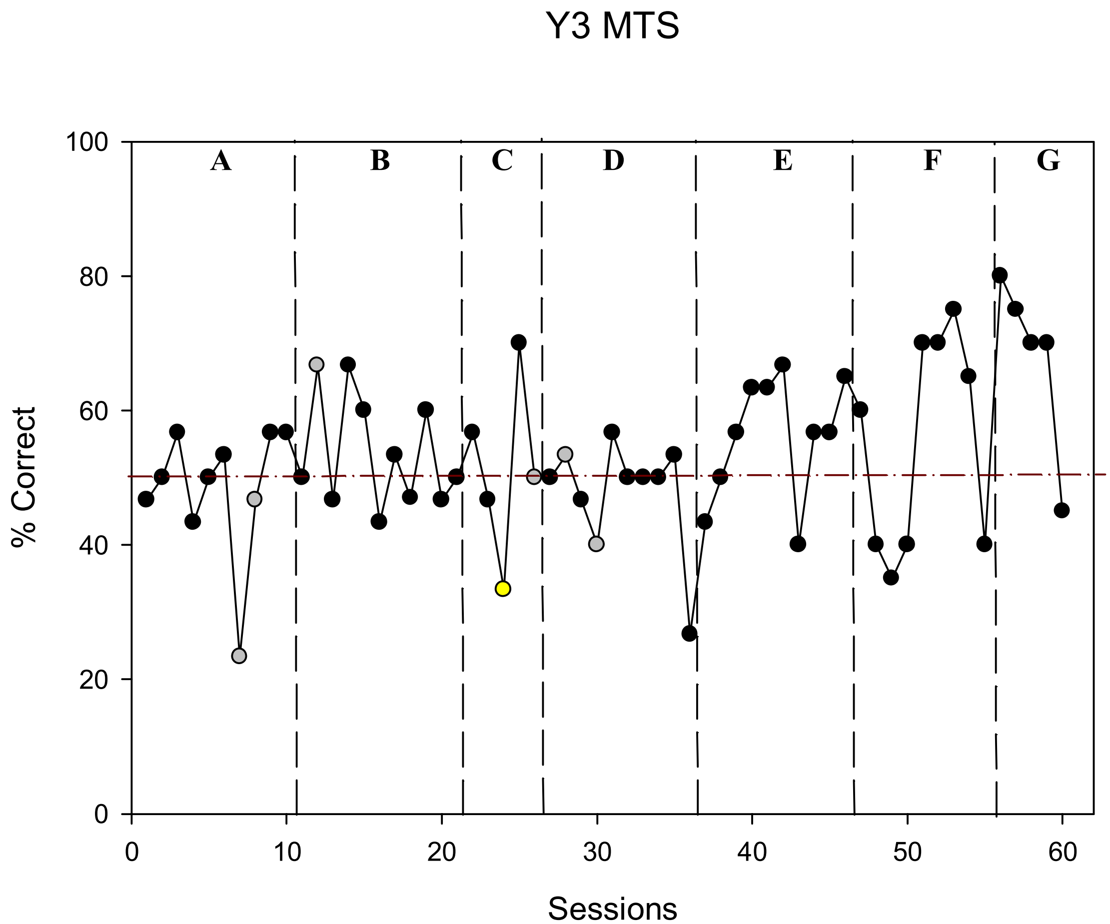


Figure 9: Experiment I graph for Y3. Gray circles represent SB prevention Sessions while yellow circles represent a session that did not have the total number of trials presented. Panel A represents the sessions where the cardboard doors were being used. Panel B represents when the new doors and light were installed. Panel C represents when the 3 s sample response requirement and the 4 s response requirement for the comparisons began. Panel D represents when the sample response requirement was changed to 4 s. Panel E is when the 10 s correction procedure was implemented. Panel F represents when the subject was placed on the Simple Discrimination task with a 1.5 s response requirement and the 10 s correction procedure. Panel G is when the response requirement was changed to 2 s in duration.

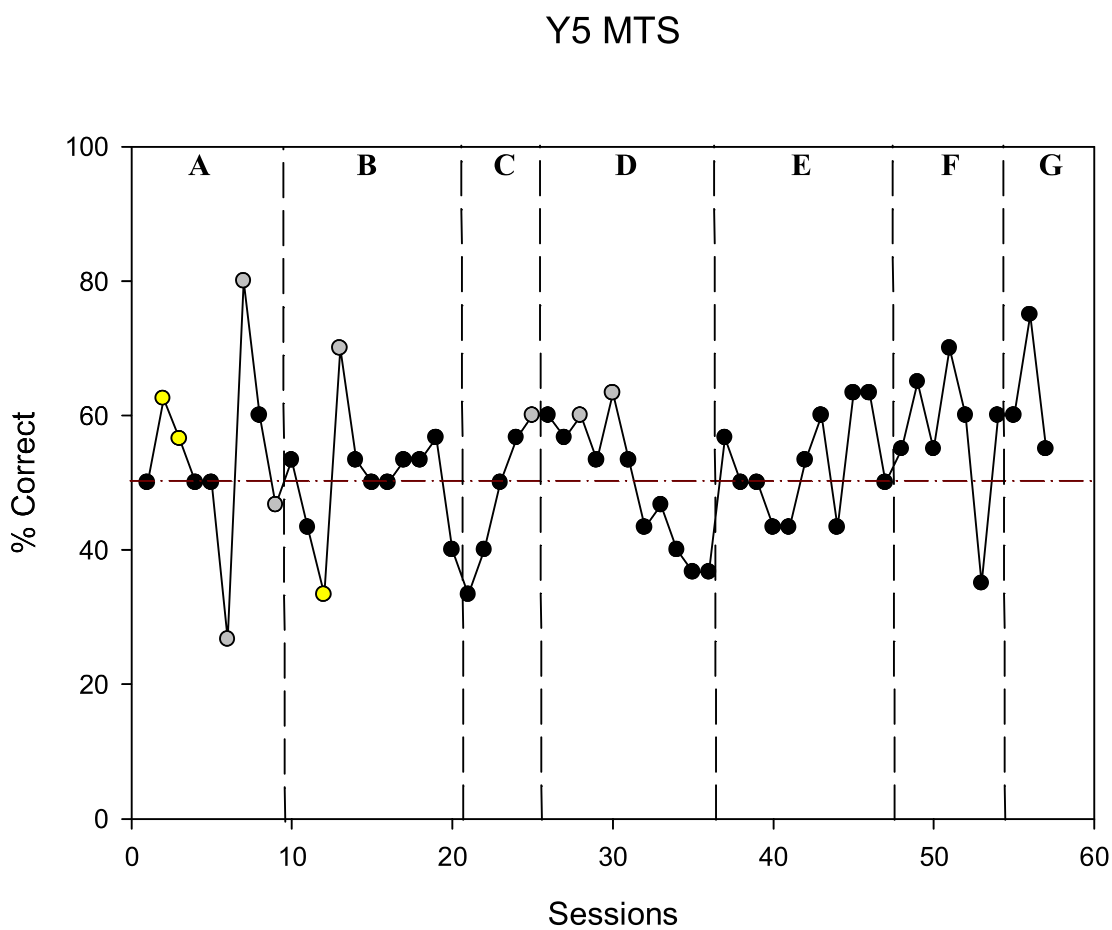


Figure 10: Experiment I graph for Y5. Gray circles represent SB prevention Sessions while yellow circles represent a session that did not have the total number of trials presented. Panel A represents the sessions where the cardboard doors were in use and a 2 s response requirement was in effect. Panel B represents when the new doors and light were installed with the 3 s response requirement. Panel C represents when the 3 s sample response requirement and the 4 s response requirement for the comparisons began. Panel D represents when the sample response requirement was changed to 4 s. Panel E shows when the 10 s correction procedure was implemented. Panel F represents when the subject was placed on the Simple Discrimination task with a 1.5 s response requirement and the 10 s correction procedure. Panel G is when the response requirement was changed to 2 s in duration.

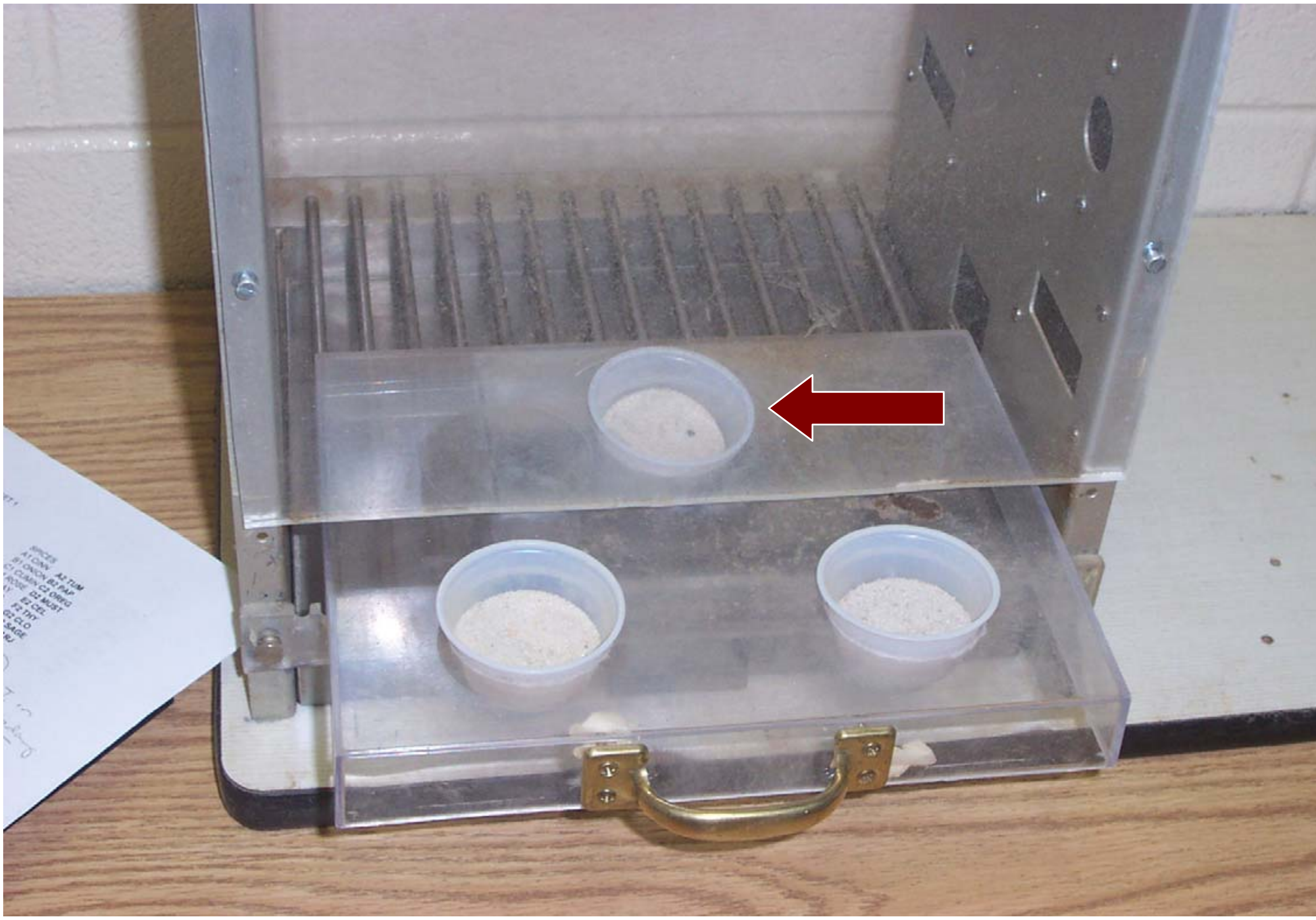
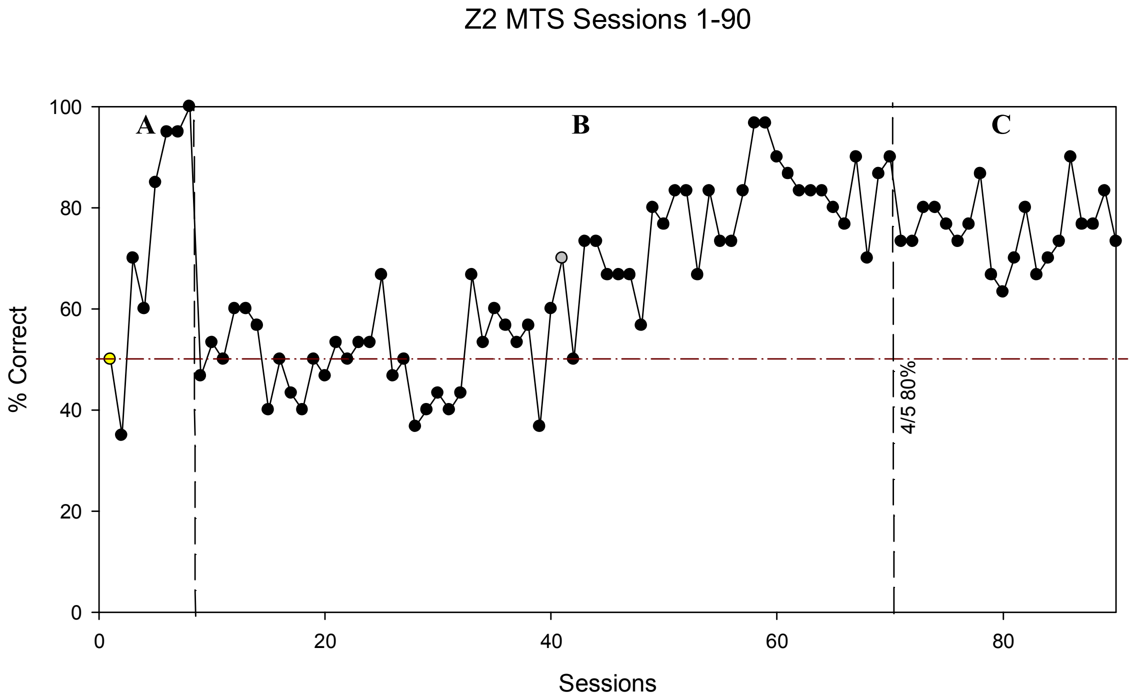


Figure 11: Manual apparatus used in Experiment II with Z6 and Z12. The sand cup indicated by the red arrow is the sample stimulus cup that is presented first. Once the subject responded by digging in this cup, the two comparison stimuli cups were pushed into the chamber. This is the same apparatus used in Peña, Galizio and Pitts.



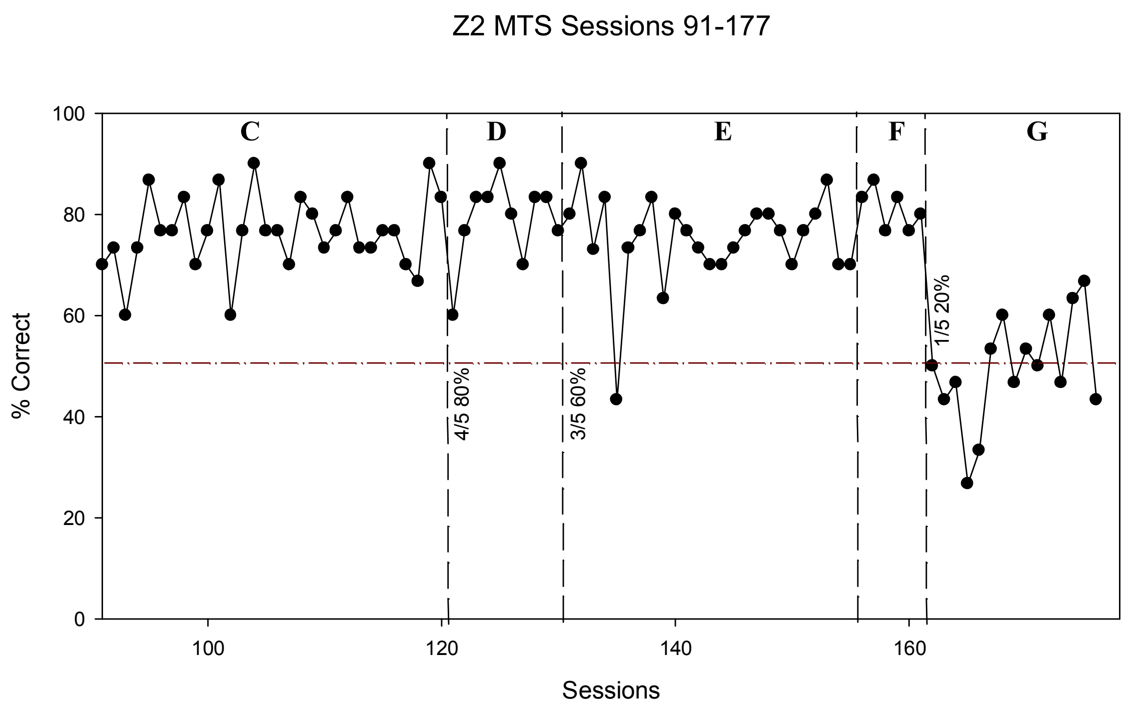
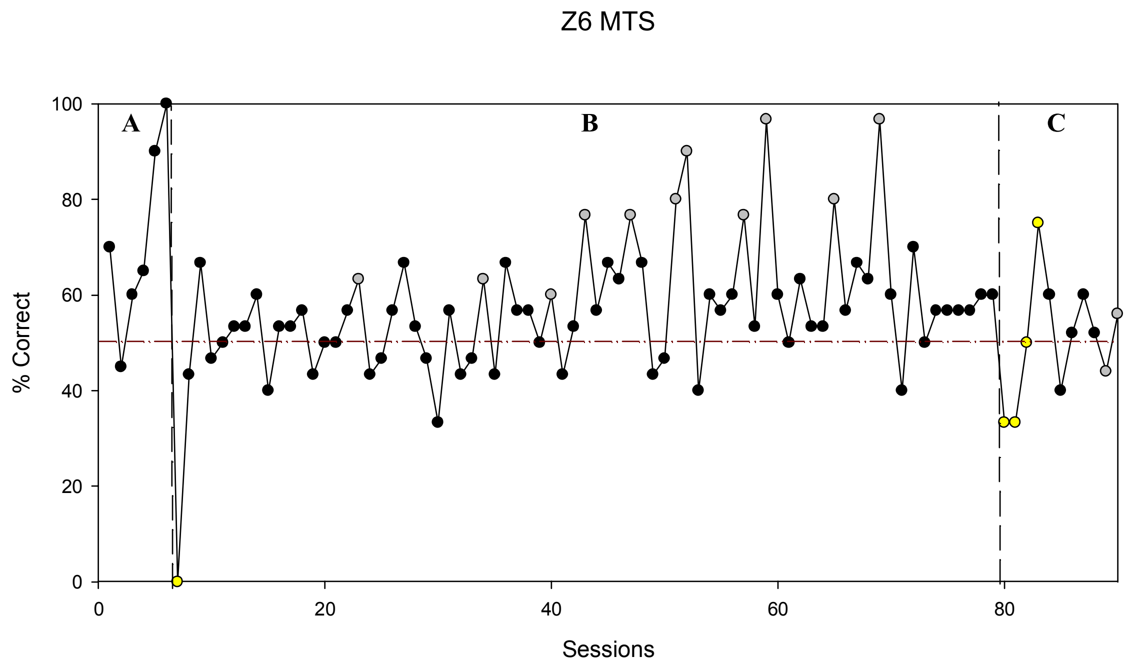


Figure 12: Experiment II graphs for Z2. Gray circles represent SB prevention sessions, while yellow circles represent a session that did not have the total number of trials presented. Panel A represents Z2's sessions on the simple discrimination task. Panel B represents the subject's progression to the MTS program with a 2 s response requirement and 10 s correction procedure. Panel C, D and E demonstrates Z2's progression to a new stimulus set. Panel F shows where savory was removed and substituted with anise. Panel G represents Z2's transfer to the reversal procedure.



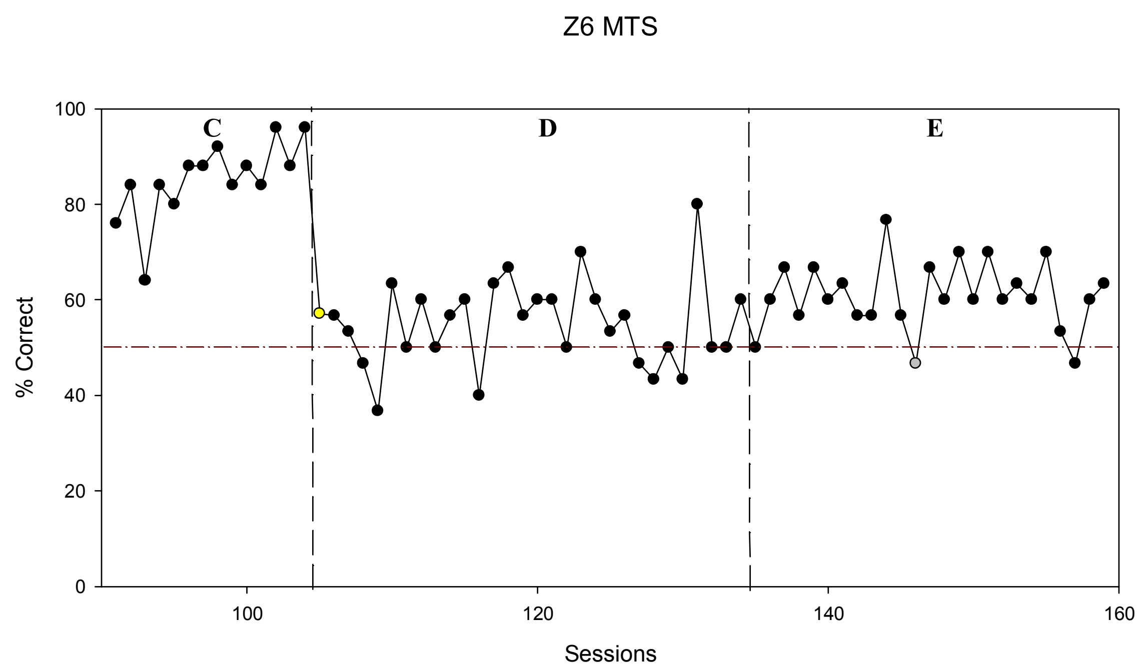


Figure 13: Experiment II graphs for Z6. Gray circles represent SB prevention sessions while yellow circles represent a session that did not have the total number of trials presented. Panel A represents the simple discrimination task Z6 was placed on. Panel B marks when Z6 was progressed to a MTS set. Panel C marks the subject’s move to the manual apparatus, while Panel D marks his return to the ODAR chamber. Panel E demonstrates where a light contingency was added to the ODAR chamber.

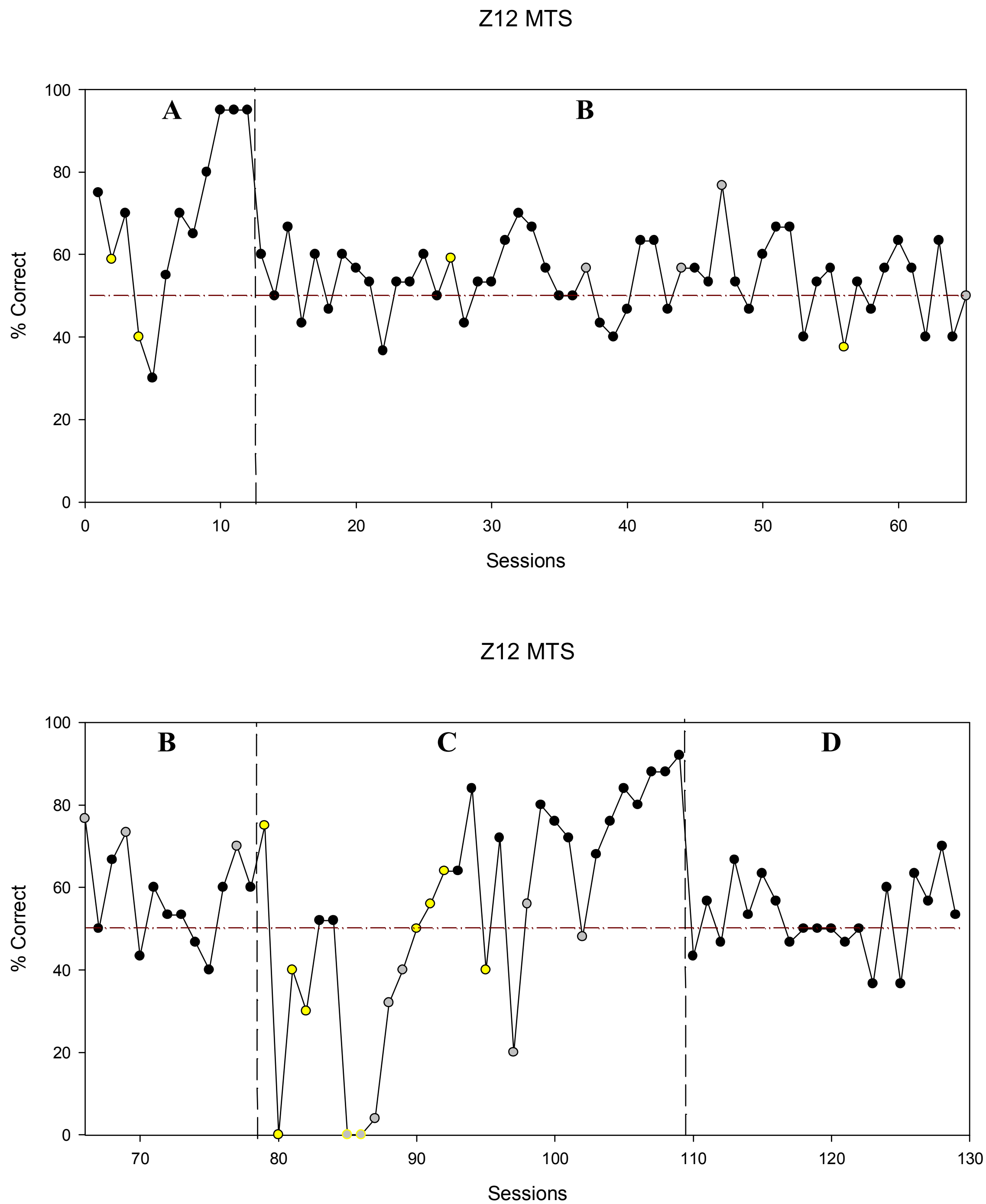


Figure 14: Experiment II graphs for Z12. Gray circles represent SB prevention sessions while yellow circles represent a session that did not have the total number of trials presented. Gray circles with yellow outlines represent SB prevention sessions that did not have the total number of trials presented. Panel A represents the simple discrimination task. Panel B marks when Z6 was progressed to the MTS set. Panel C marks the subject's move to the manual apparatus, while Panel D marks his return to the ODAR chamber.

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