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The Effects of Visual Cue Facilitation in Spatial Pattern Learning in Rats

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EFFECTS OF VISUAL CUE FACILIATION IN SPATIAL PATTERN LEARNING IN RATS

by

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Abstract

Recently published research has shown that a consistent but not coincident visual pattern facilitated the learning of a diamond spatial pattern in humans (Katz, Brown & Sturz, 2014). The purpose of the present experiment was to examine if this could be done in rats, using a square spatial pattern. For each trial, 16 towers were arranged in a 4 X 4 matrix, with one of the nine possible 2 X 2 baiting patterns baited with cheese. The visual pattern group also had four striped towers placed in a 2 X 2 spatial pattern within the larger matrix, while the visual random group had four striped towers placed randomly throughout the matrix. On 25% of the trials, there was overlap between one baited tower and a striped tower, while the remaining 75% of the trials contained no overlap. There were 50 trials, and the goal for the rats was to find all four of the baited towers in each. Results of the experiment revealed that the visual pattern group performed significantly better than the visual random group in the last 20 trials, showing that that the visual pattern facilitated the learning of baited 2 X 2 pattern. As well, both groups were significantly faster at finding all the baited towers during the non-overlap trials than on the overlap trials. Finally, both groups showed that they were making a good tower choice relative to chance after visiting the second and third baited towers.

Acknowledgements

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Introduction

Much research has been done on the effects of visual cues on spatial learning in both humans and animals. Specifically focusing on rats, over time, researchers have been able to show that not only can they learn and use geometric properties to learn a task, but they can use that knowledge to learn spatial patterns. Other researchers have also shown that additional cues can overshadow, block or facilitate the learning of patterns. The present research takes an experiment done in humans and tries to replicate its findings in rats.

Early research by Cheng (1986) and Gallistel (1990) found that rats learned to use geometric cues to get to a goal location even in the presence of presumably more-salient visual cues. In Cheng's (1986) study, he placed rats in a rectangular box that had four different distinct corners. The corners were differentiated in appearance and by smell. The goal of each trial was for the rat to go to a specific target location in one of the four corners. He found that the rats were able to correctly go to the correct corner after numerous trials. Cheng (1986) also found that if they did make errors, that they were symmetric in the sense that the rats went to a target location that was 180^{o} from the correct target location. This was because that target location was geometrically the same compared to the other two corners. When Cheng moved the appearance and smell 90^{o}, the rats followed the geometric cues instead of following the visual and olfactory cues. Their studies suggested that rats did not just depend on landmarks to guide them, but also used geometric properties to help them to get to a target location. It was an early account of spatial learning, because it showed that there is some aspect of learning that is separate from visual learning when using geometric properties to find a goal location in an environment. As well, it showed that the salient geometric cues failed to overshadow the visual and olfactory cues, which violated a mathematical model created by Rescorla and Wagner (1972). Both of their studies have led to numerous further studies to see how visual cues and geometric cues are used together.

Rescorla and Wagner (1972) formulated a mathematical model that was used for predicting outcomes when two redundant stimuli served as a compound conditioned stimulus. Their work was based on the ground-breaking research of Pavlov who found that when an unconditioned stimulus was paired with a neutral stimulus, it could become a conditioned stimulus. Two important examples they provided were blocking and overshadowing. Blocking was when a single conditioned stimulus was paired with an unconditioned stimulus and then another conditioned stimulus was later added so that both preceded the unconditioned stimulus. The second stimulus did not get conditioned because the associative strength between the first conditioned stimulus and the unconditioned stimulus was too strong. Overshadowing was when there were two conditioned stimuli from the outset, but one was more salient and so garnered most of the associative strength. This model has had a large impact on later research looking at whether spatial cues or visual cues were more salient than the other when paired together.

Brown and Terrinoni (1996) did an experiment using patterns of food location instead of geometric environmental cues in the position with visual landmark cues. In their experiment, they used 25 black poles placed in a 5 X 5 matrix and had a 2 X 2 square spatial pattern of poles in the larger matrix baited. There was a depression on the top of each of the poles where pellets could be placed but not seen by the rats without rearing up on the pole. The 2 X 2 square spatial pattern randomly moved from trial to trial within the larger 5 X 5 matrix. An example of a trial can be found in Figure 1. Over trials, the rats used the spatial cues to learn where the baited poles were. Brown and Terrinoni's (1996) results showed that the rats controlled their choice of what

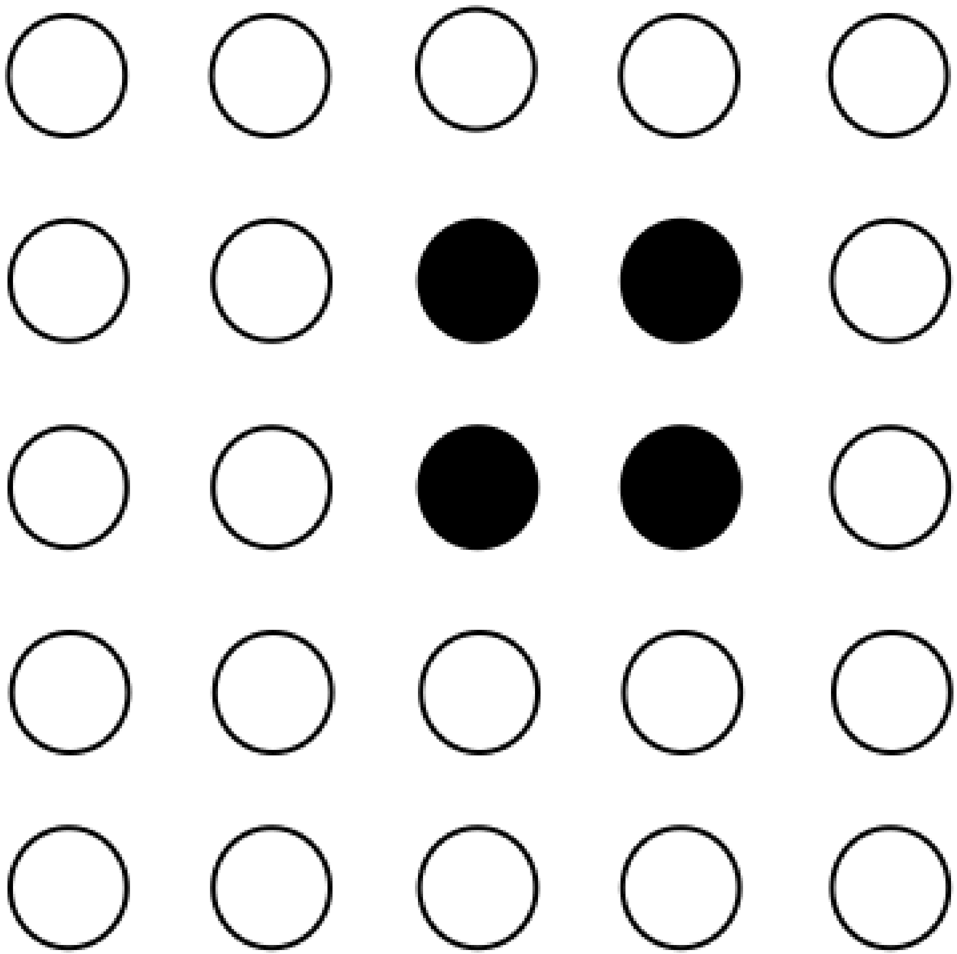

Figure 1. This is an example of a trial. The circles represent the poles and the black circles represent the baited poles. There are 16 possible variations of the baited square spatial pattern.

poles to visit by learning the spatial pattern and applying it after they found the first goal location.

Brown, Yang and DiGian (2002) later did an extension of the previous experiment to see if visual cues showing where food was located would facilitate or compete with the learning of a 2 X 2 square spatial pattern of food locations. In their experiment, 16 poles were placed in a 4 X 4 square matrix in an open box with bedding on the floor. The experiment had two phases, both of which contained a control and experimental group. For each of the groups, nine 2 X 2 spatial patterns were possible within the larger 4 X 4 matrix and the pattern moved randomly from trial to trial. During the training phase, the control group had to search for pellets placed in a 2 X 2 spatial pattern that was within the larger 4 X 4 matrix of poles. All the poles were painted black, so the group had no visual cues as to where the food was hidden. The experimental group also had to search for pellets placed in a 2 X 2 spatial pattern that was within the larger 4 X 4 matrix of poles, but with added visual cues. The 12 poles that were not baited were painted black and the four poles that were baited were painted with white and black stripes. Examples of training phase trials for each of the different groups can be found in Figure 2. During the test phase, both conditions received the same trials. Both had to search for pellets placed in a 2 X 2 spatial pattern that was within the larger 4 X 4 matrix of towers. There were no visual cues in that all 16 poles were black. Brown et al. (2002) found that their results showed that the rats in the experimental group were more efficient in finding the baited towers than were rats in the control group in Phase 1. The results of the test phase were interesting in that the experimental group performed just as well as the control rats when the visual cues were taken away in the test phase. Thus, it appeared that presumably more-salient visual cues did not overshadow the spatial cues

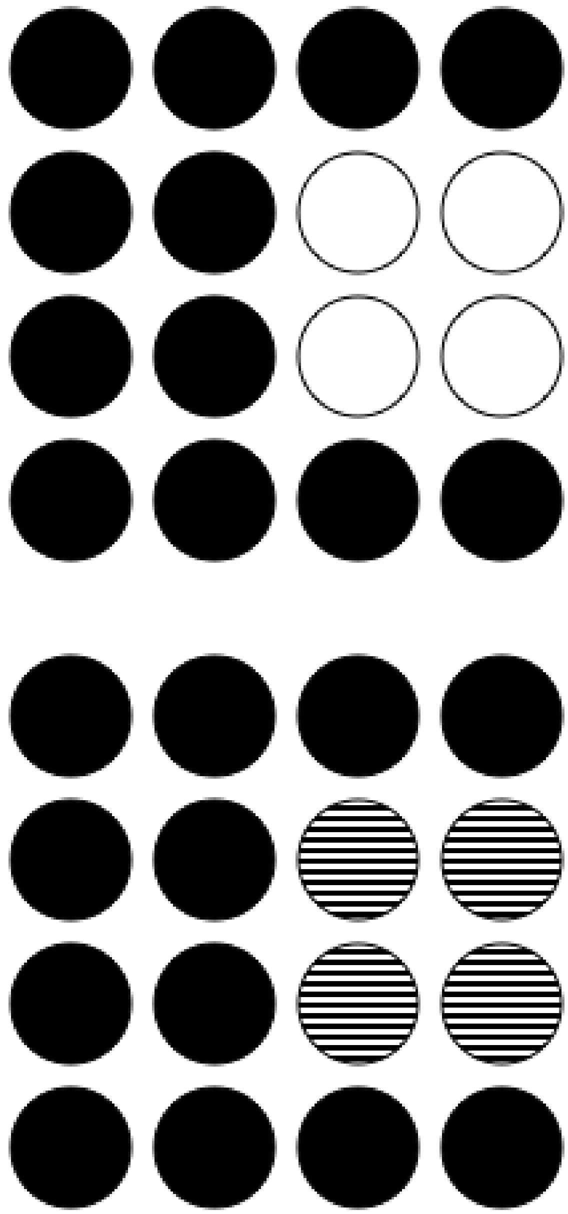

Figure 2. The black circles represent the poles that are not baited, the white circles represent the poles that are baited and the striped circles represent the poles that are baited and have the visual cues. The top matrix is an example of a trial for the control group and the bottom matrix is an example of a trial for the experimental group, both during the training phase.

during Phase 1. Brown et al. thought that it was possible that visual learning and pattern learning were independent from each other since performance did not dramatically decrease when the visual cues were taken away. Despite that, visual cues did facilitate learning during Phase 1 because the experimental group still outperformed the control group in the training phase. In short, the presumably more-salient visual cues did not overshadow the presumably less-salient pattern cues during Phase 1.

More current research by Clipperton, Cole, Peck and Quirt (unpublished manuscript) was done to assess pattern cue and visual cue competition in rats using freestanding food towers instead of poles. The first experiment was a replication of the Brown et al. (2002) study but with greater space in between the towers. This was done because Brown et al. had proposed that it was possible that the visual cues were not as salient as they had originally thought, and that the visual cues merely got the rats to the right general location but after that, the rats may have just rotated their bodies using proprioceptive cues to find adjacent poles since there was not a lot of space in between them. Clipperton et al. spaced their towers 30 cm apart instead of the 13 cm that had been used in the Brown et al. experiment. Twelve towers during Phase 1 for the experimental group were white and four had black and white stripes. The results were the same as those in the original Brown et al. experiment, which showed that whereas the Visual + Pattern rats did better than the Pattern Only rats during Phase 1, both groups performed equally during Phase 2. Thus, the failure to see overshadowing in the Brown et al. study was not likely due to close proximity of the towers.

The third and fourth experiments by Clipperton et al. were designed to discover whether pattern learning or visual cue learning was stronger. In the third experiment, the rats were randomly assigned to either the Visual + Pattern → Visual + Pattern Unreliable (V+P → V+PU) group or the Visual + Pattern Unreliable → Visual + Pattern Unreliable (V+PU → V+PU) group. During the training phase, the V+P → V+PU group had the same training that was used for the experimental groups in Experiment 1 by Clipperton et al. and in the Brown et al. experiment. They had four baited towers in a 2 X 2 pattern and striped. For the V+PU → V+PU group, the four baited towers were striped but not in a 2 X 2 pattern. During the test phase, the baited towers were striped but not set out in a 2 X 2 pattern for either group. The results of this experiment showed that the groups did not significantly differ in performance overall in Phase 2. This meant that the pattern cues did not facilitate the learning of finding the baited towers. Despite this, it seemed to suggest that visual cues are important since the rats' performance did not decline significantly during Phase 2.

In the fourth experiment by Clipperton et al., rats were randomly assigned to either the Visual + Pattern → Visual Unreliable + Pattern (V+P → VU+P) group or the Visual Unreliable → Visual Unreliable (VU → VU) group. During the training phase, the V+P → VU+P group had the same training as the V+P → V+PU group in Experiment 3. The VU → VU group had four baited towers that were in one of the nine possible 2 X 2 spatial patterns but with no distinctive visual cues. The four striped towers were randomly placed in the larger 4 X 4 matrix and were not baited. During the test phase, both groups were given the same training as the VU → VU group had been given during the training phase. The results of this experiment showed that the V+P → VU+P group performed significantly better than the VU → VU group during Phase 1. However, the V+P → VU + P group's performance declined significantly during Phase 2. This showed that visual cues were very important in learning where the food was located. Overall, the series of experiments showed that the learning of the visual cues was more robust than that of the pattern cues when it came to learning the location of food.

The facilitation of spatial pattern learning by visual cues has also been studied with humans. Sturz, Kelly and Brown (2010) conducted an experiment designed to find out if visual cues facilitated the learning of a diamond spatial pattern and if the visual cues were more effective if they were coincident or not with the goal locations. They did the experiment using two different environments. The first was a real environment in which 25 bins were placed in a 5 X 5 matrix. There was shredded paper on the ground and also in the bins. The participants had to search in the shredded paper in the bins to see if there was a ball hidden in the bin. A ball in a bin was considered a goal location. The second was a computer-generated three-dimensional virtual environment. The participants had to use the keyboard to move around and “jump” into the bins to find a hidden ball in a bin. In both versions, the participants were placed in one of three groups: pattern only, landmark and pattern, or cue and pattern. In the pattern only group, the goal locations formed a diamond spatial pattern within a larger 5 X 5 matrix of bins. The diamond spatial pattern moved randomly from trial to trial and there were no other cues as to the location of the balls present. The landmark and pattern group also received a diamond spatial pattern of baited boxes within a larger 5 X 5 matrix of bins. However, they also had a visual cue bin placed in the centre of the diamond spatial pattern. The visual cue was a different coloured bin from the other bins. The visual cue was always in that spot and again the diamond spatial pattern moved randomly from trial to trial. The cue and pattern group also had the diamond spatial pattern of locations containing a ball, but each bin that made the diamond was marked visually as well. Examples of a trial for all the groups during the training phase can be found in Figure 3. During the test phase of the experiment, all the groups received the diamond spatial pattern of goal locations, but no visual cues were present for any of the groups. All 25 bins looked the same. Sturz et al. (2010) found that the results showed that the participants in the groups that received

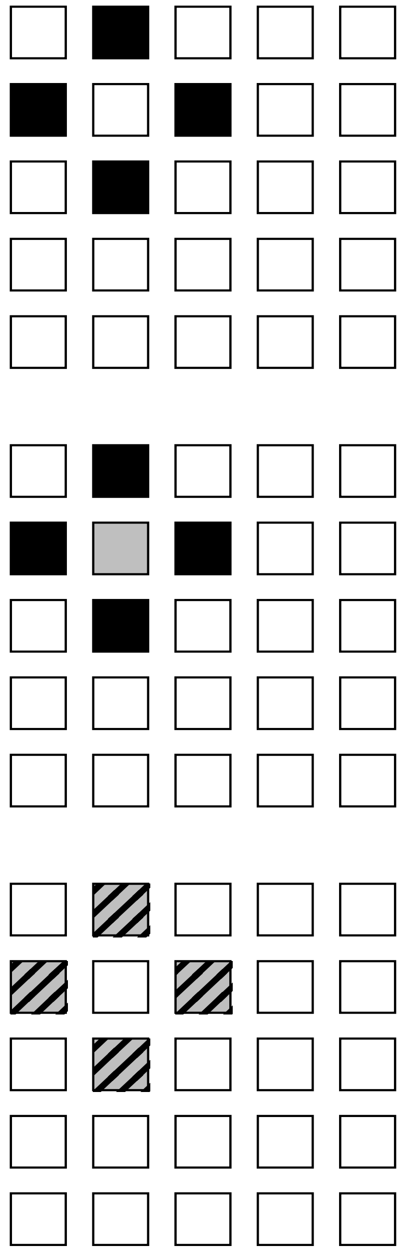

Figure 3. The black squares represent the goal bins, the grey squares represent the visual cues and the black squares with the grey stripes represent the goal bins that also have visual cues. The top matrix is an example of a trial for the Pattern Only group. The middle matrix is an example of a trial for the Landmark and Pattern group. The bottom matrix is an example of a trial for the Cue and Pattern group. These are all examples of training phases.

visual cues performed more efficiently than the group that did not receive any visual cues in both the training and the testing phase. The results were consistent in both the real and the virtual environment as well. This showed that the learning of the spatial pattern was not due to just the visual cues since the performance of the visual groups with visual cues was still significantly better than the group with no visual cues. Also, since the landmark and pattern group performed almost as well as the cue and pattern group, it showed that visual cues did not have to be coincident with baited locations to be effective in the facilitation of learning a spatial pattern. Overall, Sturz et al. found that visual cues did facilitate the learning of a diamond spatial pattern, but they did not have to be coincident with the spatial pattern to be effective.

Recently published research has extended the Sturz et al. (2010) experiment and shown that a consistent but not coincident visual pattern facilitated the learning of a diamond spatial pattern in humans (Katz, Brown & Sturz, 2014). Using a computer generated three-dimensional environment, participants were randomly assigned to one of two groups. Both were given the task of finding a hidden diamond spatial pattern in a matrix of 5 X 5 bins. The goal locations were always in the same diamond spatial pattern, but the pattern moved from trial to trial. The participants were split either into a visual pattern or visual random group. For the visual pattern group, the visual cues were red bins and they were always placed in a diamond spatial pattern similar to the goal bins. The visual pattern moved randomly from trial to trial, but never completely overlapped with the goal locations. There was a maximum of two overlapping bins found in a trial, but there was not necessarily overlap in every trial. For the visual random group, the visual cues were red bins randomly placed in any of the 25 possible locations of the 5 X 5 matrix. As with the visual pattern group, the visual bins moved from trial to trial and never completely overlapped with the goal bins. In Figure 4, examples of training phases for each of

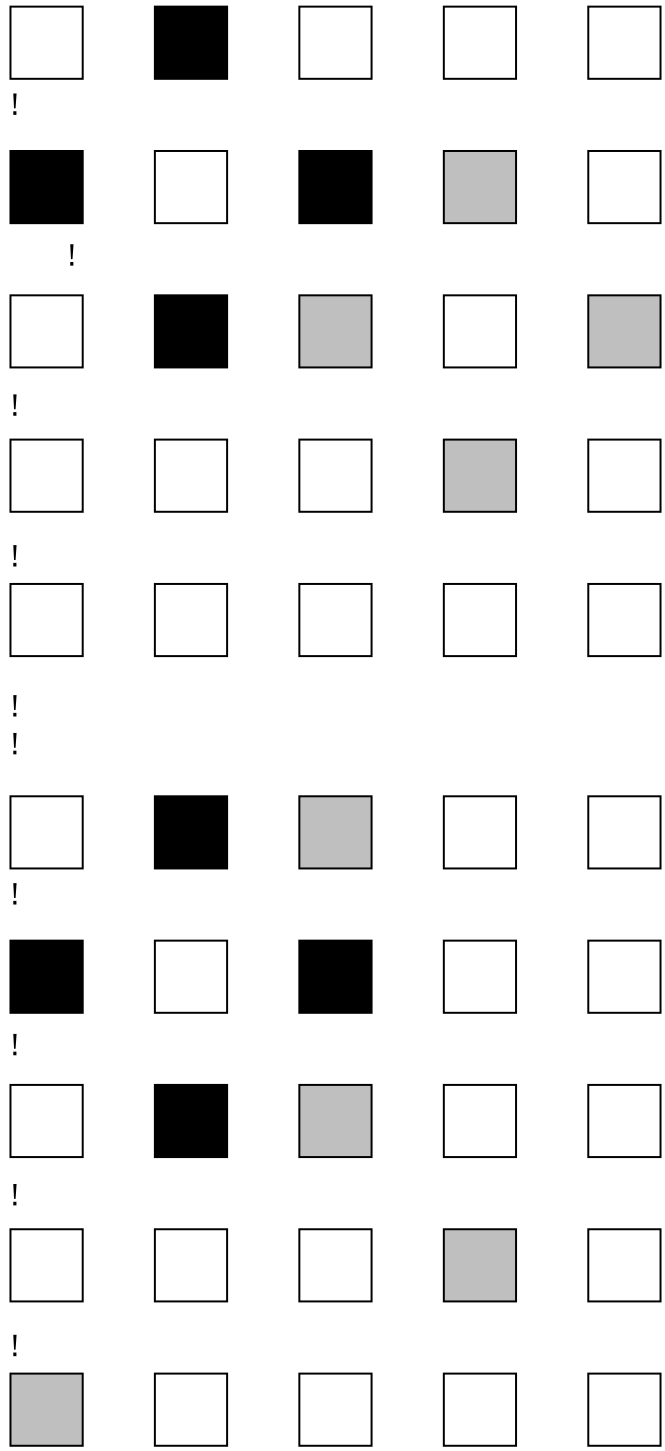

Figure 4. The black squares represent the goal bins and the grey squares represent the visual cues. The top matrix is an example of a trial for the visual pattern group and the bottom matrix is an example of a trial for the Visual Random group.

the groups can be found. The results of this study showed that the number of bin visits to complete a trial decreased for both groups across the trials, but the visual pattern group did significantly better than the visual random group. This meant that the participants learned the diamond spatial pattern and understood what they had to do each trial so that over time they could perform the task more efficiently. Katz et al. (2014) concluded that even though the visual diamond pattern was never coincident with the diamond spatial pattern of goal locations, the visual cues that were in the shape of a diamond facilitated the learning of the diamond spatial pattern.

The current experiment was designed to test whether the Katz et al. (2014) experiment could be replicated, with minor alterations, in rats. The main changes were switching the matrix from 5 X 5 to 4 X 4 and the baited locations in a 2 X 2 square pattern rather than a diamond shape. Since previous research had shown that rats could learn a 2 X 2 square pattern, but there was no research showing that they could learn a 5 X 5 diamond pattern, the change was made knowing that the rats had the ability to learn the 2 X 2 spatial pattern. The hypothesis was that having a largely unbaited 2 X 2 square pattern of striped towers would facilitate the learning of the food locations in a 2 X 2 spatial pattern.

Method

Subject

The subjects used for the experiment were eight male rats (*Rattus norvegicus*) of the Long-Evans strain. They were received from Charles River Laboratories in Montreal, Quebec. The rats all weighed approximately 350 g upon arrival. They were given ad lib. food and water for a few days to establish a free-feeding weight. Then, by calculating 90% of the free-feeding weight, a redline weight was produced. An estimate of the free-feeding weight, had they remained on free feed, was made for all the rats every week thereafter for 10 weeks to provide for gain due to growth. The rats were continued with a restricted diet to maintain their redline weight while various procedures were performed. When the procedures were completed, the rats were once again given ad lib. food and water until the current experiment was ready to begin and redline weights were once again established. Preceding the current experiment, the rats' weights ranged from 555 g to 670 g. Most of the rats weighed slightly more than the redline weight throughout the experiment.

The rats were housed in pairs at the animal laboratory at Huron University College. They lived in plastic breeding cages with lids constructed from stainless steel bars. The bottom of the cages contained bedding, Beta Chip ®, from Northeastern Products Corporation (NEPO) in Warrensburg, NY, which was changed twice a week. Each cage contained two pipes and nesting material for environmental enrichment. The two black pipes were short lengths of 10-cm-in-interior diameter of PVC pipe. The nesting material was called Crink-l'Nest ™ from The Andersons, Inc. in Maumee, OH. The lids of the cages had depressions to hold food and two water bottles. The food was Prolab ® RMH 3000 by PMI ® Nutrition International LLC in Brentwood, MO.

All eight rats were kept in a cage room together. The room was kept at 23^{o}C with 18 fresh air changes every hour. The lights in the cage room were on a 12-hour light-on-light-off cycle, being off at 4 a.m. and turning back on at 4 p.m. There was also a radio in the room, which was on when the lights were off that was tuned to CBC 2, which played mostly classical music. The rats were tested almost all of the time when the lights in the cage room were off.

Prior to the current experiment, seven of the eight rats were subjects in other procedures in the lab. They had been exposed to many conditioning procedures in an operant chamber, which included magazine training and autoshaping (and hand shaping if autoshaping did not produce a lever-pressing response). The rats also were given a single session of operant maintenance on a continuous reinforcement schedule followed by two sessions of extinction. During that time, six of the rats were exposed to a fixed-time schedule and one of the rats was exposed successively to responding on a variable ratio 10 schedule and a yoked-control variable-interval schedule. The rats were then used in an experiment in which they foraged in a circle of food towers under conditions of white and red light. The remaining rat had no previous experimental experience.

The rats were treated in accordance with the ethical standards of the Canadian Council of Animal Care.

Apparatus

The principle apparatus used for the experiment consisted of 16 food towers. The towers were made of 10.0 cm by 10.0 cm cedar fence posts that were cut into 15.0 cm lengths. The towers were covered in sleeves made from white Bristol Board covered with clear packing tape. Four of the towers also had horizontal black stripes, made by wrapping black friction tape around the white Bristol Board. The striped towers had three black stripes and two white stripes each approximately 3 cm wide. At the top of each of the towers was a food cup created from a black plastic 35 mm film canisters cut down to approximately 2 cm in height, which was 3 cm in diameter. The 16 towers were placed 30 cm apart from each other center to center in a 4 X 4 matrix. For each trial, the food cups on top of four towers contained small pieces of cheese. The cheese was President's Choice Medium Cheddar cut into approximately 0.5-cm^3 blocks.

The experiment took placed in a testing room in the animal laboratory. The towers were placed on the floor of the room, which was made of industrial grade vinyl and was grey coloured. The two side walls of the room were made of cinder block (and were 2.1m in width and 2.4 m in height), while the rear and front walls were made of green board (and were 1.8 m in width and 2.5 m in height). The walls were painted a creamy yellow. The wall to the right, when entering the test room, had on it an electrical outlet and the front wall to the right of the door to the room had on it a light switch. In the middle of the ceiling there was four fluorescent tubes covered by plastic translucent lens that were illuminated during the experiment.

Procedure

Preliminary Phase. Each pair of rats was given six pieces of cheese in their home cages before any training began to ensure that they would eat it. After that, preliminary training began by having four training towers of various heights put into the testing room with cheese placed in the food cups on top of them. The rats were put into the testing room, one at a time, and were observed from the door window. The rats had successfully completed the preliminary training when they found all the cheese quickly and ate it. This took five sessions for all eight rats.

Training Phase. There were nine possible 2 X 2 baiting patterns in the 4 X 4 tower matrix and they were preselected for the experiment. The nine possible baiting patterns can be seen in Figure 5. The patterns were not selected completely randomly because the same baiting pattern was not permitted twice in a row. Four rats were assigned to a visual pattern group and the other four rats were assigned to a visual random group. For the visual pattern group, the four striped towers also had nine possible 2 X 2 patterns in the 4 X 4 matrix. The striped tower patterns were preselected after the baiting patterns had been selected. The striped tower configurations could overlap with no more than one of the towers from the baiting pattern. Approximately 25% of the trials had such a one-tower overlap. For the visual random group, the four striped towers were randomly assigned to four of the 16 possible positions in which they could be placed. Again,

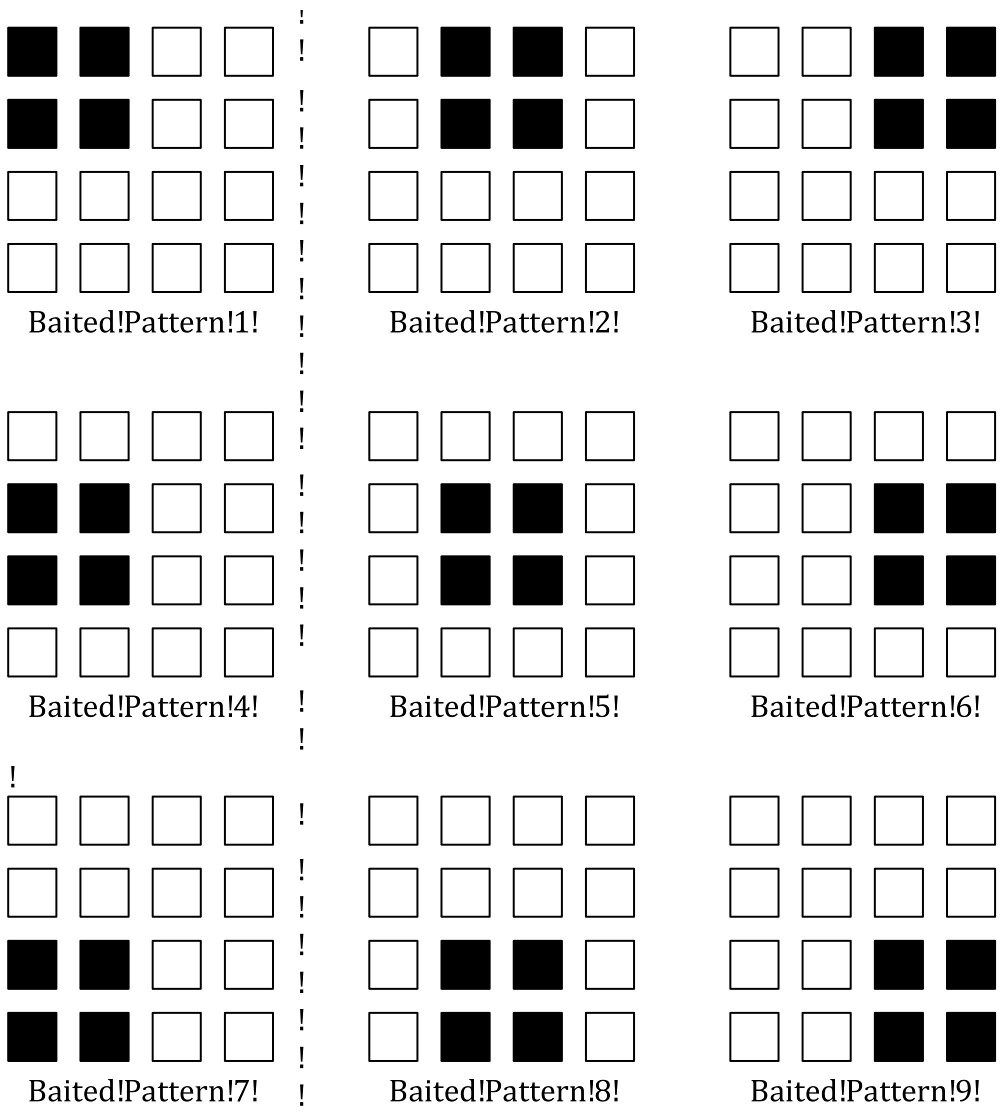

Figure 5. The black squares represent the baited towers and the white squares represent the unbaited towers. These are the nine possible baiting patterns.

they could overlap with no more than one of the baited towers. An example of a non-overlap and overlap trial for both groups can be found in Figure 6. All of the towers that were not baited were rubbed with a little bit of cheese at the beginning of each trial so that the rats could not find the cheese by using their olfactory senses.

The rats were placed one at a time on the floor of the testing room at the beginning of each trial. After the door was closed, a timer was started and the rat remained in the setting until all four of the baited towers had been visited once. The rats were allowed up to 24 choices before they were stopped. During the 50 trials, there were 13 overlap trials and 37 non-overlap trials. Between each trial for each rat, the towers were moved around and the floor was washed so that there was no possible way that the rats could pick up scents or cues that could have possibly been left by previous rats. The rats were tested almost every day and experienced two to three trials per day. All the trials were run between the hours of 10:00 a.m. and 6:00 p.m.

Results

The number of choices to criterion was recorded for each of the rats for all 50 trials. These data were grouped into five blocks of 10 trials for each rat for analysis and can be found in Figure 7. The figure suggests that the performance improved for each group of rats over the blocks of trials, however by the fourth block the visual pattern group appeared to begin to perform better than the visual random group. A 2 X 5 mixed analysis of variance (ANOVA) was conducted with group (visual pattern, visual random) as the between-subjects factor and the blocks of 10 trials as the within-subjects factor. The results did not show a significant main effect for group, $F(1, 6) = .63$, $p > .05$, partial $\eta^2 = .10$. However, a significant main effect for the blocks of trials was found, $F(4, 24) = 28.12$, $p < .05$, partial $\eta^2 = .82$. There was also a significant group by trial interaction, $F(4, 24) = 15.54$, $p < .05$, partial $\eta^2 = .55$. A summary of the analysis

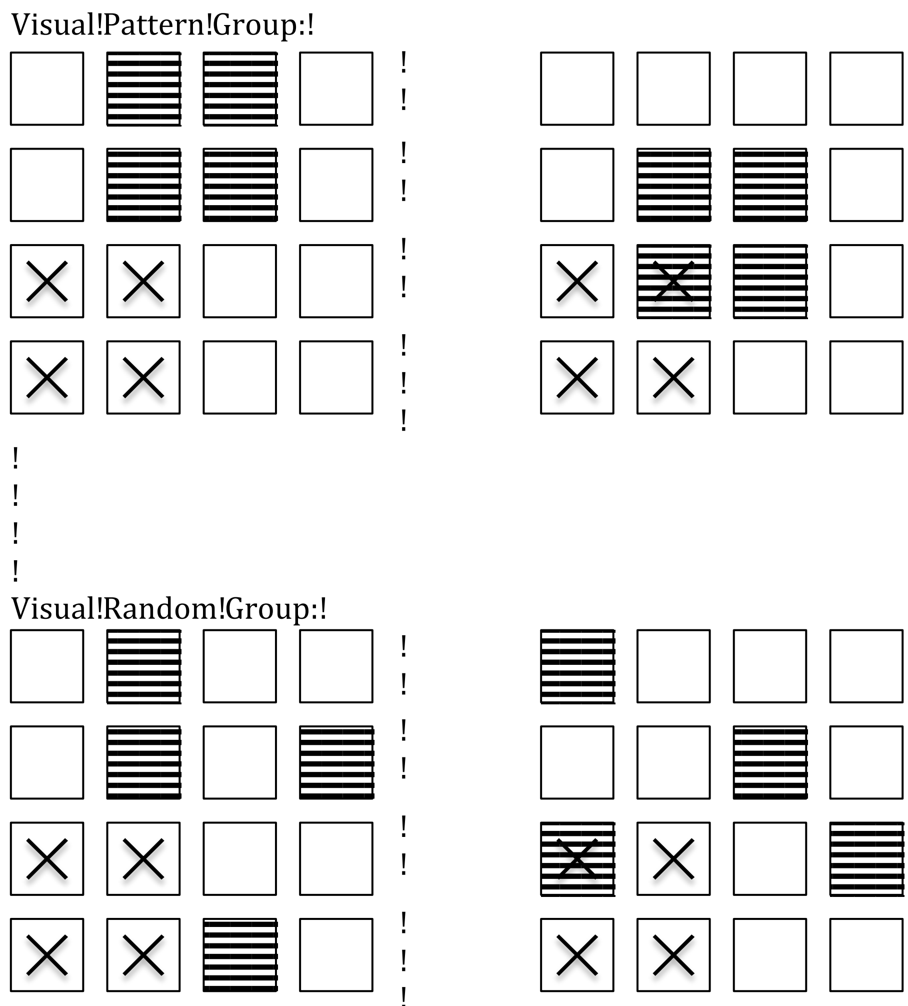

Figure 6. The squares with an "X" represent the baited towers, the striped squares represent the striped towers and the squares with an "X" represent striped and baited towers. These are examples of trials for both groups. The top left matrix is an example of a non-overlap trial for the visual pattern group. The top right matrix is an example of an overlap trial for the visual pattern group. The bottom left matrix is an example of a non-overlap trial for the visual random group. The bottom right matrix is an example of an overlap trial for the visual random group.

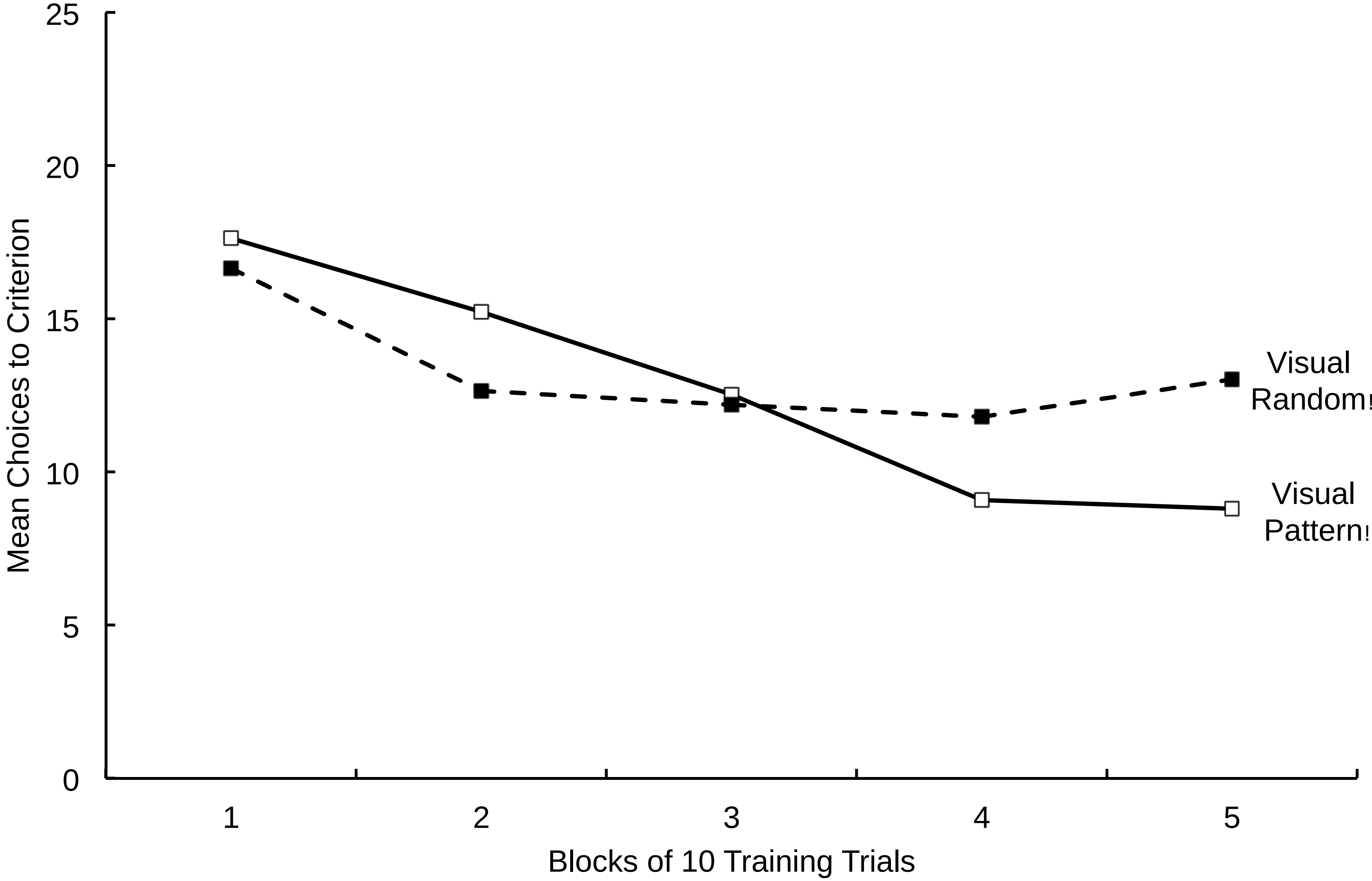

Figure 7. The graph shows the mean choices to criterion over five blocks of 10 training trials.

can be found in Appendix A. Independent samples *t* tests were then conducted for each of the blocks of trials. The results indicated that the visual pattern group performed significantly better than the visual random group over Block 4 (Trials 31 to 40), $t(6) = 4.70$, $p < .05$ and Block 5 (Trials 41 to 50), $t(6) = 2.95$, $p < .05$.

A 2 X 2 mixed ANOVA was then conducted with group (visual pattern, visual random) as the between-subjects factor and the type of trial (no overlap, overlap) as the within-subjects factor. The number of choices to criterion was only examined for Blocks 4 and 5 since that was where significance was found between the two groups and the results of the analysis can be found in Figure 8. The results revealed a significant main effect for group, $F(1, 6) = 29.91$, $p < .05$, partial $\eta^2 = .83$. The visual pattern group made fewer choices to criterion than the visual random group. A significant main effect was also found for the type of trial, Greenhouse-Geisser adjusted $F(1, 6) = 16.97$, $p < .05$, partial $\eta^2 = .74$. There were fewer choices to criterion made in the non-overlap trials versus the overlap trials. However, there was no significant trial by group interaction, $F(1, 6) = 2.04$, $p > .05$, partial $\eta^2 = .25$. Overall, once again the visual pattern group outperformed the visual random group, but both did significantly worse during the overlap trials. A summary of this analysis can be found in Appendix B.

A probability of choice analysis (Brown & Terrinoni, 1996) was also conducted. A full explanation of the calculation can be found in Appendix C. Two 2 X 2 mixed ANOVAs were then calculated with group (visual pattern, visual random) as the between-subjects factor and the probability [p(observed) vs. p(expected)] as the within-subjects factor. The p(observed) was the degree to which the rats made the right choice in going to a possibly correct tower after visiting the second or third baited tower. The p(expected) was the probability that the rats would go to a possibly correct tower by chance, after visiting the second or third baited tower. If the rats

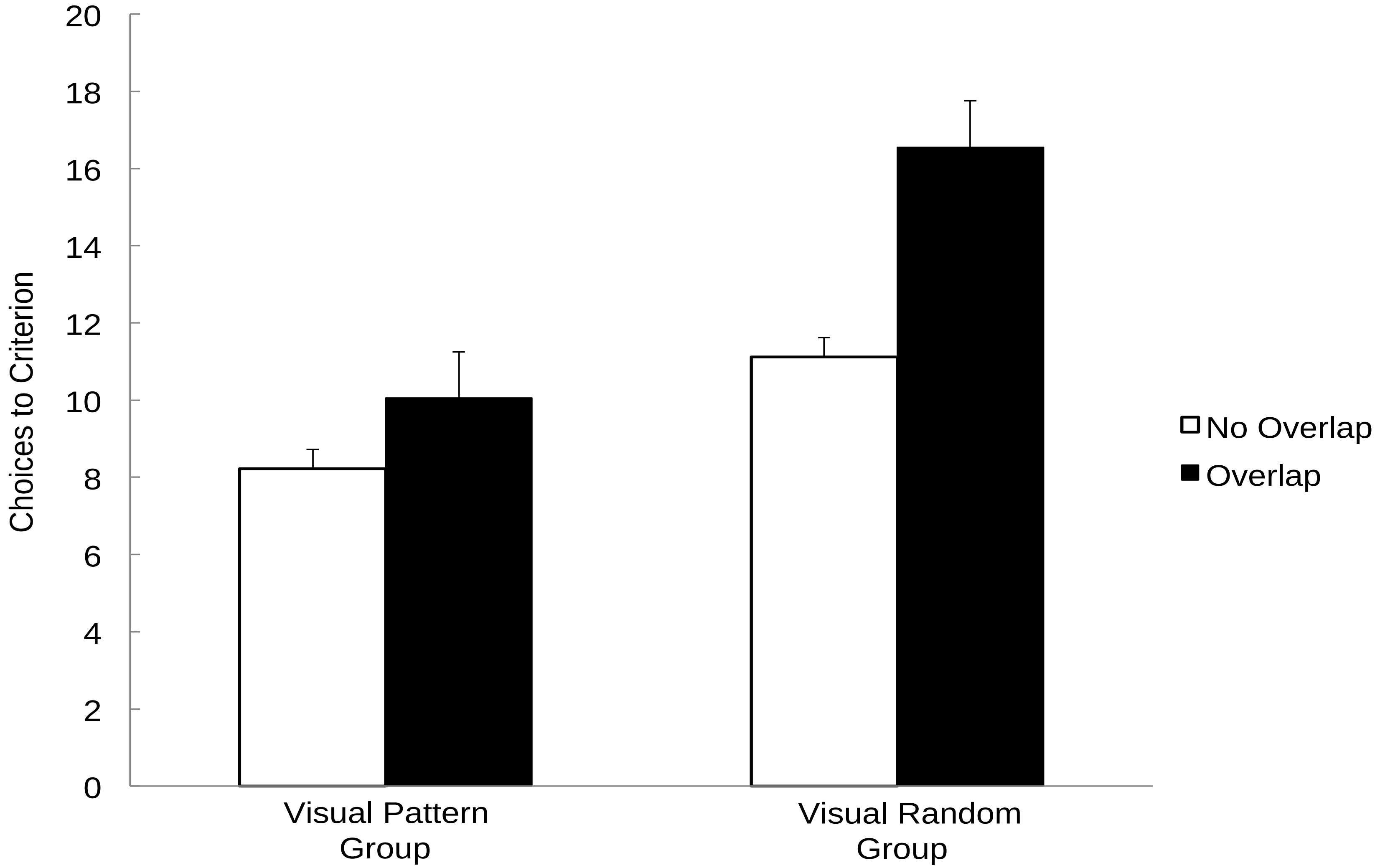

Figure 8. The bar graph shows the differences in choices to criterion made in the overlap versus non-overlap trials between the visual pattern group and the visual random group over the last two blocks of trials.

performed better than chance, showing that they had learned the 2 X 2 pattern, then p(observed) would be greater than p(expected).

The first ANOVA was conducted to calculate the probability of the rats going to a possibly correct previously unvisited adjacent tower on their next choice after their second baited tower visit. The towers did not have to be baited in reality, but part of a possible 2 X 2 pattern. The results revealed that there was a significant main effect of group, $F(1, 6) = 8.26$, $p < .05$, partial $\eta^2 = .58$. There was also a significant main effect for the probabilities, $F(1, 6) = 48.60$, $p < .05$, partial $\eta^2 = .89$. This meant that the rats were going to a possibly correct tower after their second baited tower visit better than expected by chance and can be seen in Figure 9. There was also a marginally significant probability by group interaction, $F(1, 6) = 5.40$, $p = .059$, partial $\eta^2 = .47$. A summary of the analysis can be found in Appendix D.

The second ANOVA was done for the probability of the rats going to the correct adjacent, previously unvisited baited tower after their third baited tower visit. The results revealed that there was no significant main effect of group, $F(1, 6) = .63$, $p > .05$, partial $\eta^2 = .10$. There was a significant main effect found for the probabilities though, $F(1, 6) = 10.03$, $p < .05$, partial $\eta^2 = .63$. This meant that once again the rats went to the final baited tower after the visiting the third baited tower better than expected by chance and can be found in Figure 10. However, once again there was no significant probability by group interaction, $F(1, 6) = .01$, $p > .05$, partial $\eta^2 = .002$. A summary of the analysis can be found in Appendix E.

Discussion

Previous research by Sturz et al. (2014) has shown that a consistent but not coincident visual pattern facilitated the learning of a diamond spatial pattern in humans. The current

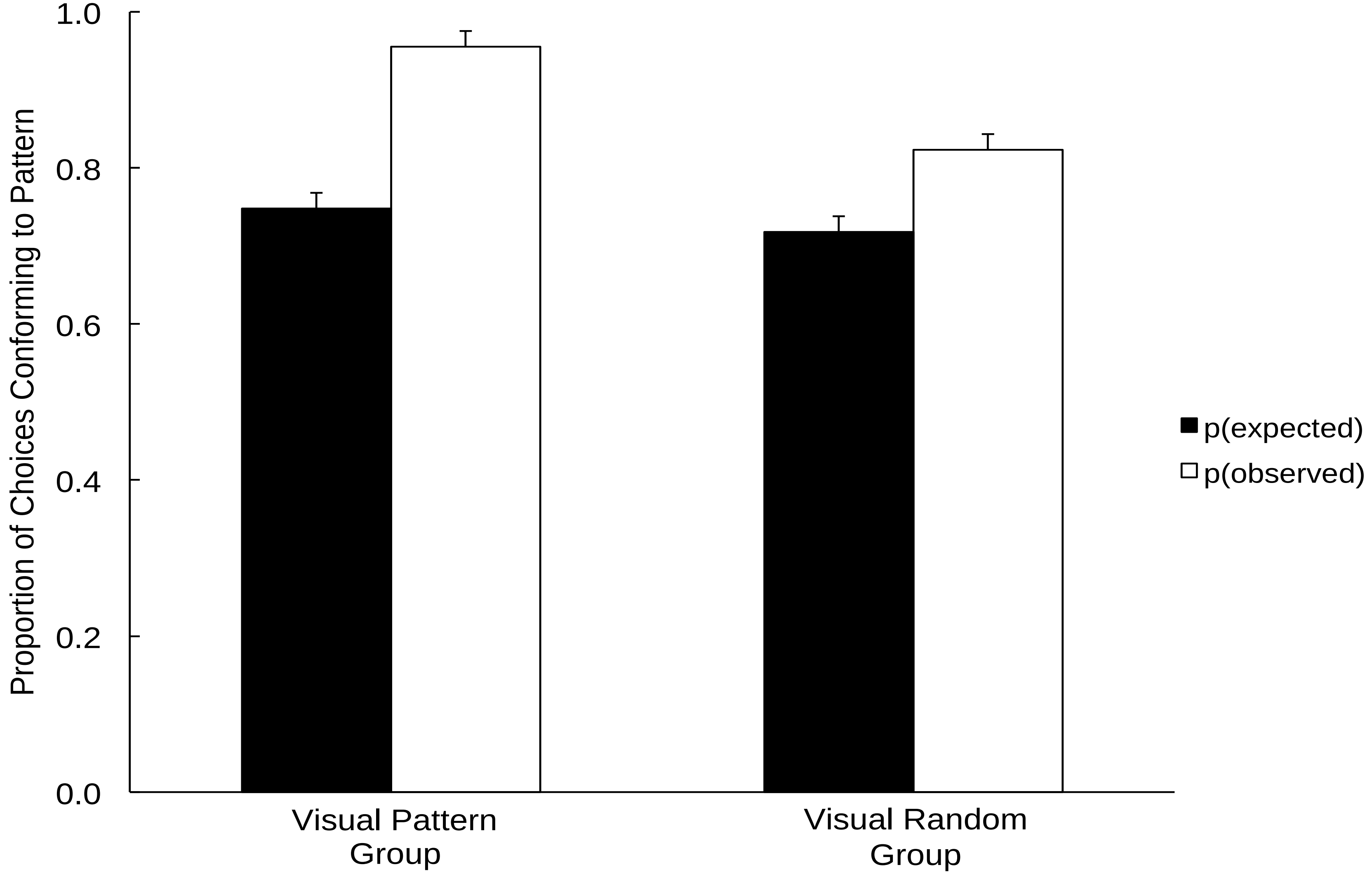

Figure 9. The bar graph shows the differences between the visual pattern group and the visual random group in the proportion of choices conforming to the pattern after visiting the second baited tower.

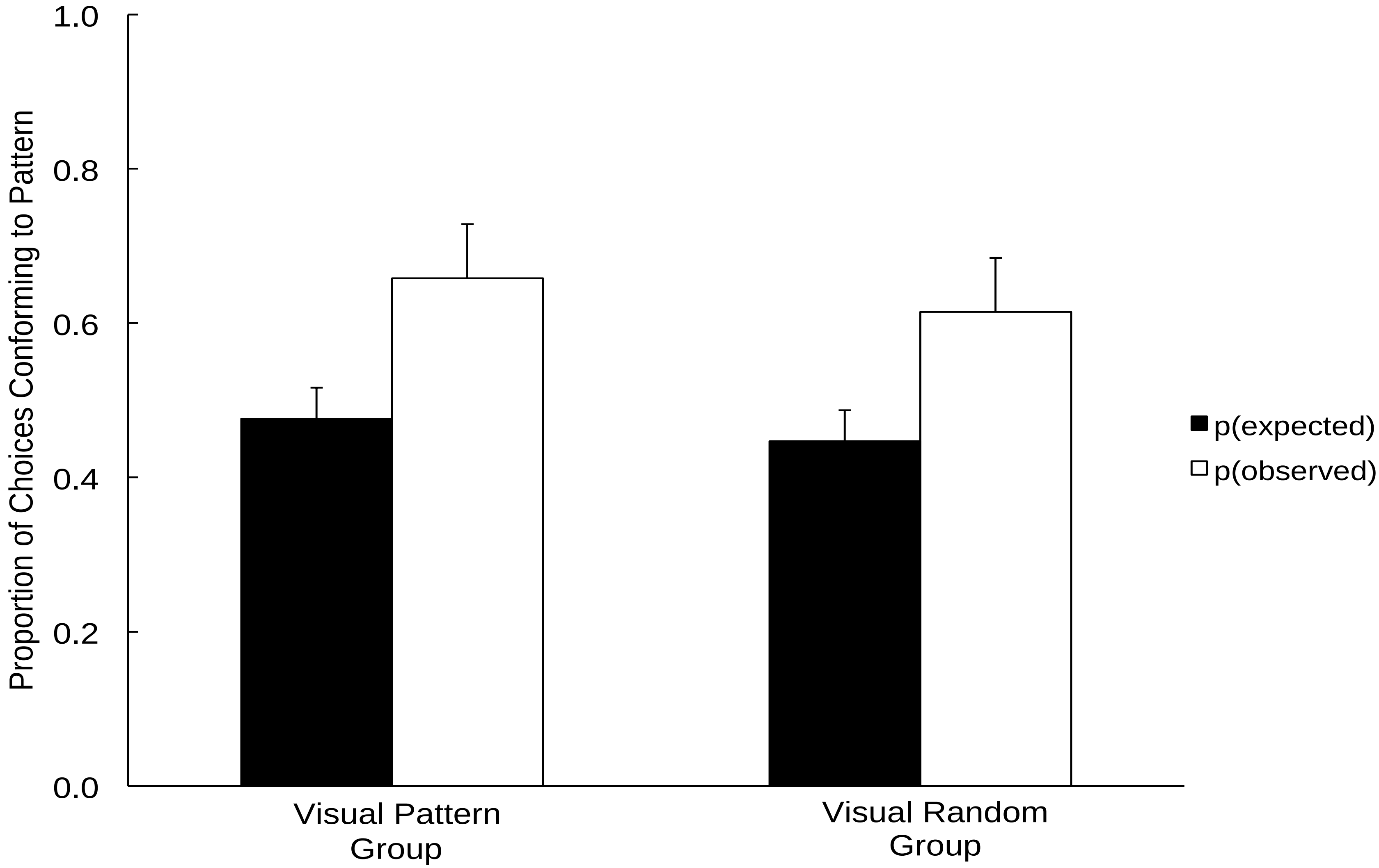

Figure 10. The bar graph shows the differences between the visual pattern group and the visual random group in the proportion of choices conforming to the pattern after visiting the third baited tower.

experiment was conducted to show whether or not this experiment could be replicated in rats, with some modifications. The results did support Sturz et al., and the rats that had a consistent but not coincident visual pattern learned the pattern of the baited towers significantly faster and more efficiently than the rats that had randomly placed visual towers.

Having a largely unbaited 2 X 2 square pattern of striped towers facilitated the learning of the food locations in a 2 X 2 visual pattern. There are two possible explanations for this. The first is that there was a process of elimination that the rats in the visual pattern group could infer. Once they learned that there was no food in the striped towers, other than on occasion, they could rule out those four towers, leaving 12 to choose from that might be baited. The problem with this, however, is that the same logic would go towards the rats in the visual random group as well. And since the rats in the visual pattern group performed significantly better than the rats in the visual random group, there had to be more done than a process of elimination. So, the second possible explanation is that the rats in the visual pattern group were able to use the striped towers as a “hint” to learn the pattern of the baited towers and facilitate in finding them. Since the visual random group did not perform as well as the visual pattern group, this explanation seems more likely because the visual random group did not have any “hint” as to where the baited towers may be other than with a process of elimination.

The modifications made from the Sturz et al. (2014) experiment deemed to be effective for the purposes of this study. All the rats, including the rats in the visual random group were able to learn the 2 X 2 square spatial pattern in the larger 4 X 4 matrix by the end of the testing. Extending research from the current experiment could focus on making the matrix larger from 4 X 4 to 5 X 5 to have a closer replication to the original experiment, and possibly change the shape of the baited spatial pattern. The risk with this, however, is that making the matrix and the baited spatial pattern larger may be too complicated for the rats to learn. Nonetheless, these changes would be a closer replication to what Sturz et al. originally conducted.

An alternative to this study that could be undertaken in the future would be to do a replication of the Sturz et al. (2010) experiment. This experiment could be a good segway into seeing if the rats can learn a diamond spatial pattern in a 5 X 5 matrix. The rats could be split up into three groups: Pattern Only group, Pattern and Landmark group, and Cue and Pattern group. The Pattern Only group would have the diamond spatial pattern only with no visual cues, the Pattern and Landmark group would have the diamond spatial pattern with a visual tower in the middle of the spatial pattern, and the Cue and Pattern group would have the diamond spatial pattern striped so that it was visually obvious which ones were baited. An example of what these would look like can be found back in Figure 3. However, since this was done originally in humans, the goal bins would now be baited towers with cheese and the coloured bins would be striped towers. The results would hope to replicate Sturz et al. (2010) in that the Pattern Only group would perform the worst, followed by the Pattern and Landmark and then the Cue and Pattern group performing the best. If the rats in the Cue and Pattern group performed significantly better than the Pattern and Landmark group, it would show that visual cues have to be coincident with baited locations to be effective in learning the more complex spatial pattern. However, if they replicate Sturz et al. and the Pattern and Landmark group does not significantly differ from the Cue and Pattern group too much it would demonstrate that the rats do not need visual cues to be coincident for the learning of the diamond spatial pattern. If no significant results were to be found anywhere, it would just show that overall having a baited diamond spatial pattern in a larger 5 X 5 matrix is just too complicated for rats to learn.

If this study were to be done again with minimal changes, the overlapped trials could be removed. Although the rats in both groups were able to learn the pattern of the baited towers during testing, their choices to criterion were significantly different when there was an overlap versus non-overlap trial. The rats, in both groups, made more choices to criterion during the overlap trials than the non-overlap trials. The purpose of this would be to see if the rats in both groups could have learned the 2 X 2 baited pattern more quickly than if the striped towers were never baited. Since no significance was found between the two groups until the last two blocks of trials, it left to question if this was truly how long it took for the rats to figure out the baited pattern or if the overlap trials made it more complicated to learn the baited pattern since approximately 25% of the trials had a striped tower overlap with a baited tower. Therefore, if the overlap trials were removed, for the visual pattern group, the 2 X 2 striped tower pattern would be for facilitation purposes only and possibly lead to faster learning of the baited pattern.

In summary, this experiment was successful in being a preliminary study of showing that rats can be facilitated by a consistent but not coincident visual pattern to learn a 2 X 2 baited spatial pattern in a larger 4 X 4 matrix of towers. There are numerous possibilities in which direction this experiment could be taken next to see the capability of rats' spatial learning.

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Appendix A

Table 1

Summary Table for 2 (Group) x 5 (Blocks of 10 Trials) Analysis of Variance

Source	*SS*	*df*	*MS*	*F*	*p*
Group	3.78	1	3.78	0.63	>0.05
Error	35.93	6	5.99		
Blocks of Trials	234.55	4	58.64	28.12	<0.05
Group*Blocks of Trials	62.14	4	15.54	7.45	<0.05
Error (trials)	50.05	24	2.09		

Appendix B

Table 2

Summary Table for 2 (Group) x 2 (Type of Trial) Analysis of Variance

Source	*SS*	*df*	*MS*	*F*	*p*
Group	74.00	1	74.00	29.91	<0.05
Error	14.84	6	2.47		
Type of Trial	65.09	1	65.09	16.97	<0.05
Group*Type of Trial	7.83	1	7.83	2.04	>0.05
Error (trials)	23.01	6	3.83		

Appendix C

Probability Calculation of Finding the Correct Baited Towers After the 2nd and 3rd Baited Towers

The probability analysis was originally used by Brown and Terrinoni (1996). The analysis was used to evaluate the choices the rats made after finding the second and third baited towers when the baited pattern was in a 2 X 2 matrix, within the larger 4 X 4 matrix. The two measures calculated were the expected (E) and observed (O) choices. The p(E) was the expected outcome, by chance, of the rats choosing a possibly baited tower on the next tower choice. The p(O) was the observed outcome of the rats' actual choice. If p(O) was greater than p(E) then that showed that the rats learned the spatial pattern and were not making their choices by chance.

The first calculation was the probability after finding the second baited tower. The number of possibly baited towers that had not been visited before and were directly adjacent (not diagonal) to this tower were noted. These towers did not have to be actually baited, just in a 2 X 2 pattern. This number was known as P_S. The number of not possibly baited towers that had not been visited before and were directly adjacent to the second baited tower were also noted. This number was known as P_a. The E was then calculated over blocks of 10 trials for the purposes of this study. E was equal to the sum of all the P_s for the block of 10 trials divided by the sum of all the P_s for the block of 10 trials plus the sum of all the P_a for the block of 10 trials. The rats then had three possibilities of what they could have actually done. If they visited a previously unvisited and possibly baited tower on their next choice, the number was M_s and they are given a point of 1. If they visited a previously unvisited but not possibly baited tower on its next choice, the number was M_a and they were given a point of 1. If the rats went to some completely different tower, both M_s and M_a were 0. Just like with E, the O was then calculated over blocks of 10 trials. O was equal to the sum of all the M_s values over the block of 10 trials divided by the sum of all the M_s for the block of 10 trials plus the sum of all the M_a for the block of 10 trials. The same was done for the probability of finding the fourth baited tower after finding the third baited tower.

Appendix D

Table 3

Summary Table for 2 (Group) x 2 (Probability) Analysis of Variance – After 2nd Tower

Source	*SS*	*df*	*MS*	*F*	*p*
Group	0.02	1	0.02	0.03	>0.05
Error	0.02	6	0.003		
Probability	0.10	1	0.10	48.60	<0.05
Group*Probability	0.01	1	0.01	5.40	0.06
Error (trials)	0.01	6	0.002		

Appendix E

Table 4

Summary Table for 2 (Group) x 2 (Probability) Analysis of Variance – After 3rd Tower

Source	*SS*	*df*	*MS*	*F*	*p*
Group	0.006	1	0.01	0.63	>0.05
Error	0.06	6	0.01		
Probability	0.12	1	0.12	10.03	<0.05
Group*Probability	0.00	1	0.00	0.01	>0.05
Error (trials)	0.07	6	0.01		

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