An Examination of Spatial Memory in Domestic Horses: A Preliminary Study Using an Eight Arm Radial Maze

Lindsay Lockwood
Huron University College

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A Preliminary Study Using an Eight Arm Radial Maze

Lindsay Lockwood

Huron University College at Western

Abstract

The spatial memory of domestic horses was tested using an eight arm radial maze. The main measure of performance used was number of novel feeding site choices made in the first eight visits. For the most part, horses performed above chance levels of 5.25 novel choices in the first eight choices. These results indicate that domestic horses are capable of place learning and possess spatial memory for places visited. The results are discussed in terms of optimal foraging theory and the feeding behaviour of large grazing animals. Applications of the results and future research opportunities are also discussed.

For decades, the field of animal cognition has fascinated psychologists, scientists, and researchers alike. Perhaps it is due to the ever-evolving nature of this field and the unique challenges researchers who work with animals must overcome. Countless theories have attempted to explain animal thought and to quantify the cognitive abilities of numerous species. Some models have examined tool use as a means of understanding the extent of animal cognition; others have used language-learning abilities to achieve this. Animal memory is yet another rich field within animal cognition that has provided a plethora of insight into the minds and abilities of animals.

According to McLean (2004), prospective memory can be indicative of higher level thinking in animals. The ability to remember that a future action must be performed suggests that species with this ability also possess the broader ability to plan their actions. McLean tested prospective memory ability in horses using a food rewarded

discrimination task. Horses were allowed to observe as an experimenter placing a food

reward in one of two buckets. Horses were either allowed to immediately choose a

bucket, or they were delayed for 10 seconds before being allowed to make their choice. It

was discovered that domestic horses performed well on the immediate response trials, but

barely above chance levels of 50% accuracy on delayed trials (McLean, 2004). These

results suggest that horses are indeed capable of learning and in particular learning a

discrimination task. However, subjects' poor performance on delayed trials suggests they

do not possess a natural capability to construct mental representations of choices for

prospective memory purposes (McLean, 2004).

Although the results of McLean (2004) suggest that horses lack significant

prospective memory abilities, perhaps these results should not be generalized to all forms

of short-term memory. Evolutionarily, it would seem that horses have little use for

prospective memory, but rather their behaviour is better predicted by past events and

present stimuli. Spatial memory may be a more representative measure of the short-term

memory capabilities in horses and other grazing animals. According to Edwards,

Newman, Parsons, and Krebs (1996) the feeding style of grazing animals favours high

spatial memory abilities. It is suggested that large grazing herbivores feed in "patches",

and that they choose to eat from certain patches based on desirability (Edwards et al.,

1996). Organisms could only be successful at this type of selective mixed diet through

either continuous sampling or a remembrance of the spatial location of various patches

(Edwards et al., 1996). Naturally, optimal foraging theory supports that remembrance of

patches already visited would favourably result in fewer revisits, more efficient feeding,

and the ability of grazing animals to be selective in the patches they choose to eat from.

Optimal foraging theory is typically thought of as an explanation for distinctly separate patches of food such as nuts stored by squirrels. However, grazing animals typically feed in heterogeneous fields. Edwards et al. (1996) conducted a study using sheep to test the abilities of grazing animals to recall food patches already visited in a heterogeneous environment. Plastic bowls were arranged in a field in grids of varying sizes as artificial patches. Highly desirable feed was placed in a select few of the patches and sheep were allowed to graze. In later trials sheep almost exclusively visited the patches were the feed had repeatedly been placed in preceding trials (Edwards et al., 1996). These results suggest that grazing animals are indeed capable of recalling the spatial location of desirable food patches, and that they use this information to optimize foraging (Edwards et al., 1996).

Foraging and patch sampling have been studied in numerous species using various apparatuses. Roberts (1991) explores the optimal foraging methods of rats in a four arm radial maze. In this experiment the radial maze proved to be an effective apparatus for testing the spatial memory and foraging tendencies of rats. Prior to the development of the radial maze the majority of place learning research was conducted using a two arm T-maze. Although the T-maze is useful for discrimination learning, it only allows subjects to make one choice per trial. In order to study spatial memory an apparatus had to be designed that would allow researchers to examine the ability of subjects to recall places already visited. In Olton & Samuelson (1976) the eight arm radial maze was designed and constructed to serve this specific function. The maze was constructed of a central platform, with eight equidistant arms extending from it. At the end of each arm was a food pellet, which served as bait to draw the rats down the arms of

the maze. Essentially, this allowed the rats to either repeat choices, or make novel ones. If the rats made primarily novel choices, it could be concluded that they have the ability to remember which arms they have already visited, and eaten the bait from. The results of Olton & Samuelson (1976) suggest that rats do indeed have this ability as they rarely re-visited arms from which they had already eaten before visiting novel ones (Olton & Samuleson, 1976). Further, these results are supportive of optimal foraging theory as the rats appeared to have made choices that maximized energy intake and minimized energy expenditure.

As suggested by Edwards et al. (1996) sheep and other grazing animals seem to have spatial memory for feeding sites. The current study is an extension of this work and focuses on the spatial memory of domestic horses. The eight arm radial maze used in Olton & Samuelson (1976) was adapted to test horses' memory for places visited. It is hypothesized that subjects will select novel arms of the maze more often than making return choices. These results would indicate that horses do indeed possess spatial memory for feeding sites already visited, and may use this skill to optimize selective grazing.

Method

Subjects

The subjects of this study were five domestic quarter horses (*Equus Caballus*), four male geldings ages 6 years, 7 years, 8 years, and 12 years and one mare, age 6 years. All horses had diverse backgrounds and experiences in various riding disciplines, but none of the subjects was involved in any memory training or testing prior to the current study. For the night before the experiment horses were housed individually overnight in standard equine box stalls approximately 12 ft by 12 ft in size located in a heated barn.

Stalls were fully lined with sufficient pine shavings. As the experiment took place over

one day, horses' regular feeding schedules were not disrupted for the purposes of this

study. They received two flakes of hay at 8 am on testing day prior to the commencement

of the study at 10 am. Horses were allowed ad lib. water whenever they were outside of

the radial maze including overnight before the experiment began. Following the

conclusion of the experiment all horses were returned to their outdoor pastures where

they were allowed ad lib hay and water.

Apparatus

The current study made use of an eight arm radial maze, the design of which was adapted

from the maze utilized by Olton & Samuelson (1976). The maze was constructed in the

centre of a heated riding arena approximately 60 ft wide and 200 ft long. The base of the

arena was made of compacted clay and covered in six inches of soft sand blasting sand

footing. The maze was comprised of a centre circle approximately 22 ft in diameter and

eight arms of equal size extending from it. The arms of the maze were 8 ft wide and 11 ft

long. There was an 8 ft wide opening on the circumference of centre circle which served

as a gate for horses to enter and exit the maze. The maze itself was constructed using 25,

6 ft tall steel posts and 730 ft of orange polypropylene plastic baling twine. The posts

were used to create the outline of the maze and served as anchoring points for the baling

twine. The posts were secured approximately 1 ft deep into the arena floor using a

bobcat. Nine posts were spaced equally around the centre circle such that each arm of the

maze shared an anchoring post with the neighbouring arm (or the gate). As a result, there

was no significant space between the entrances of the arms. Two posts placed 8 ft apart

were used to create the end of each arm. The baling twine was then used to connect the

posts and enclose the perimeter of the maze. Three levels of baling twine were wrapped around the entire perimeter, the first level being approximately 2ft above the ground. The next level was wrapped 1 ft above the first level and the final level was wrapped 1 ft above the middle level. One length of baling twine was secured 4 ft above ground level to create the 8ft wide gate. A loop was tied at one of the baling twine so that the gate could be opened and closed by placing the loop over the adjacent steel post. The bait used were Equinox Enterprises Horse Cookies manufactured in Clive, Alberta. Bait was placed in eight, Little Giant, 7.6 litre, flat back buckets, manufactured by Miller Manufacturing located in Glencoe, MN. The buckets measured approximately 7.5 inches in height, with diameters of 10 inches and 8.5 inches at the top and base of the bucket respectively. Four of the buckets were black and four of the buckets were dark blue. One bucket was placed in each of the eight arms alternating by color. An aerial view representation of the apparatus can be found in Figure 1.

Procedure

Each subject completed one preliminary training trial (trial 1) and three standard trials. The purpose of the preliminary trials was to familiarize horses with the maze and the presence of bait in the buckets. Prior to the preliminary trials all buckets were baited with one horse treat and placed in the centre of one of the eight arms 2 ft from the arm entrance. Following baiting the first subject was brought into the testing arena. The experimenter led the subject by halter around the outside of the apparatus once to eliminate any fear of the maze. The experimenter then placed the subject in the centre of the maze in any direction and removed the halter. The experimenter exited the maze and the subject was allowed to travel freely within the maze. Their arm choices were then
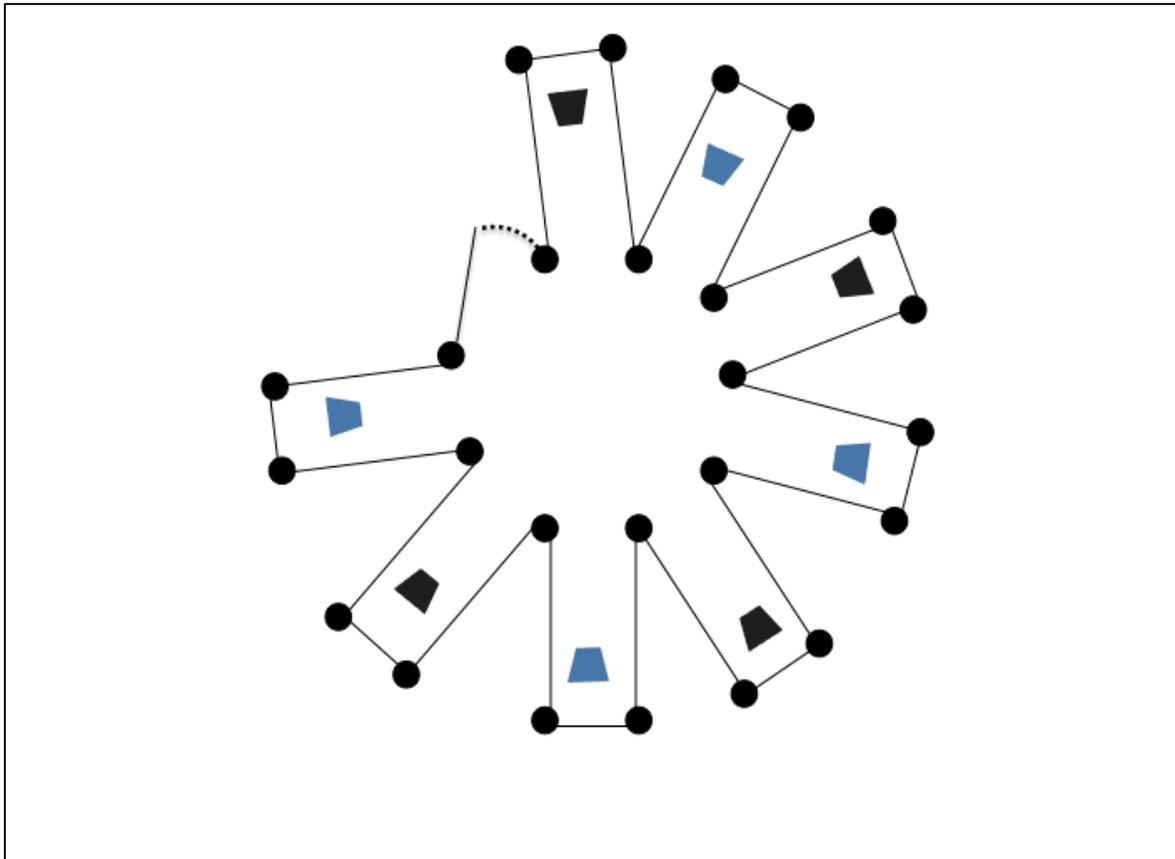
F*igure 1*. The apparatus, a visual representation of the eight arm radial maze.

recorded. For the purposes of this study, a choice was defined as the subject entering the arm and directing attention at the bucket. Following the subject's first eight choices the experimenter re-entered the maze collected the horse by halter and led the subject back out of the maze. The subject was allowed a 2-minute break in the testing arena while the buckets were re-baited for the first standard trial. For standard trials buckets were again baited with one horse treat and placed in each of the eight arms. However, buckets were centred further down the arms approximately 6 ft from the arm entrance. The subject was then placed in the centre of the maze and choices were once again recorded. Following the conclusion of the first standard trial the subject was returned to its stall and allowed ad lib. water for 1 hour while the above process was repeated for all remaining subjects. All subjects then completed two more standard trials in the same order, all being returned to their respective stalls after each individual trial.

Results

Data was collected from all five subjects regarding their performance on one preliminary and three standard trials. These results were then compared and analyzed to assess subjects' spatial memory capabilities. The chosen measure of performance for each trial was the number of novel bucket choices in the first eight visits. More novel choices indicated better memory for places already visited and therefor better performance. According to Cole and Chapell-Stephenson (2003) should a subject in an eight arm radial maze choose eight arms at random the chance number of novel choices would be approximately 5.25. Figure 2 shows the performance of the 5 subjects with respect to this chance level. Figure 3 shows the average performance of all subjects on a trial-by-trial basis, again compared to chance level.
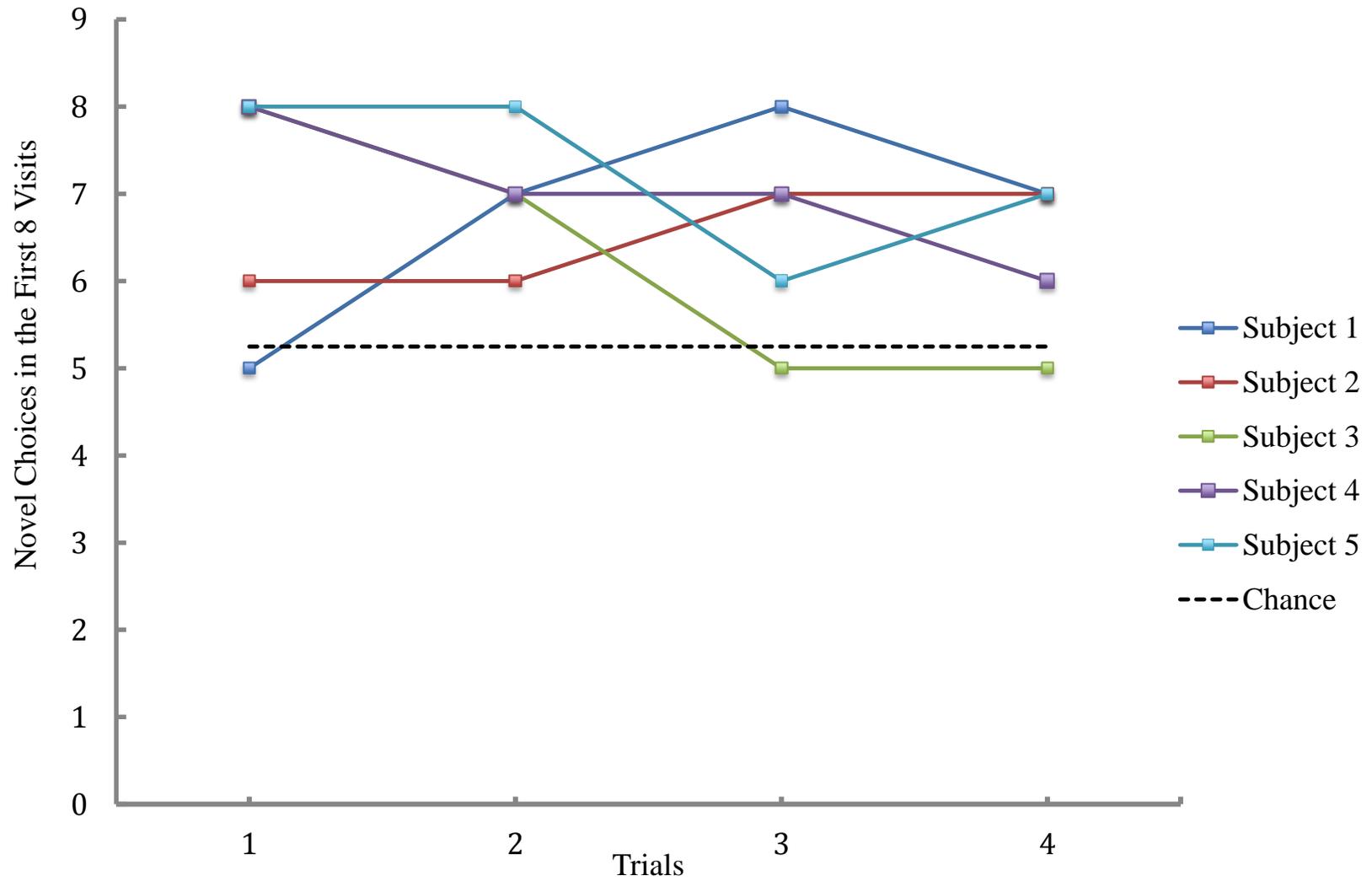
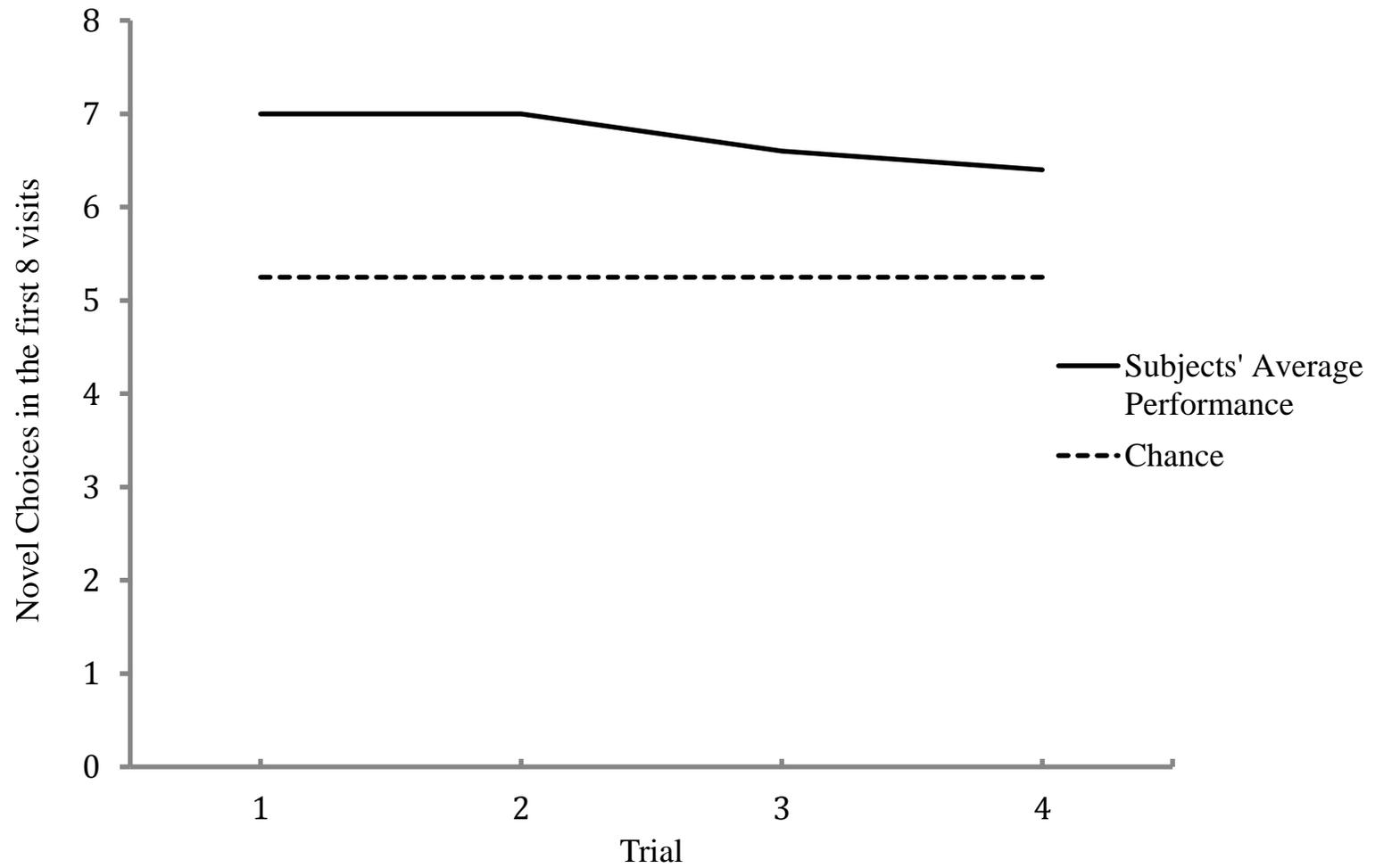*Figure 2.* The number of novel arm choices made in the first eight visits.

Figure 3. Subjects' collective average performance compared to chance levels.

Discussion

Although there has been considerable research exploring various memory abilities in animals there has been very little research directly relating to the current study. There have been no notable studies using a radial maze to test the spatial memory of domestic horses. Due to the novel nature of this study there is no expected performance level to compare the results with. However, it is useful to compare subjects' performance to chance levels of performance. According to Cole and Chapell-Stephenson (2003), if a subject in an eight arm radial maze were to select 8 arms at random to feed from without utilizing any memory strategy approximately 5.25 of those choices would be novel ones. The remainder would be repeat visits. The results of this study show that most horses are performing above chance levels in their selection of feeding sites. Taken together, the average performance of all subjects was above chance levels on all trials, with the lowest average number of novel visits being 6.4 on trial 4. These results provide strong evidence for the ability of domestic horses to remember places visited.

In addition, the results of this study provide further evidence for the conclusions made in Edwards et al., (1996). In this study it was found that sheep were capable of recalling the locations of previous feeding sites. These results were generalized to suggest that grazing animals seem to not only possess strong spatial memories, but that they use this ability to optimize foraging. In the current study domestic horses were found to make novel choices of feeding site more often than return choices to sites from which they already fed. These results are complimentary to those found in Edwards et al., (1996), as they suggest that grazing animals are not only capable of remembering the location of desirable feeding sites, but they are also able to recall which of those sites they have

visited. Taken together, the results of these two studies strongly support the theory that selective patch feeding by large grazing animals is made possible by high spatial memory capacities.

There does not appear to be any significant trends in the data by successive trials. Future research may wish to replicate the current study with more trials to better test for any trends in learning and performance. There was a slight decrease in the total average performance of subjects over trials. One hypothesis to explain this trend is that subjects simply bore of the task. According to Fureix, Jego, and Sankey (2009), horses possess a specific memory for humans, which they generalize to an overall significance of humans that may affect their behaviour in certain situations. Perhaps horses in this study became more interested in the experimenters surrounding the maze than they were in the spatial memory task at hand. Should future experimentation conduct a greater number of trials they should be spread out over time to address this issue.

There are various extensions and improvements to the current study for future research to consider. Firstly, increasing the number of subjects and trials conducted could significantly strengthen the data. Performing more trials would allow any trends in learning to be identified. Including a larger and more diverse group of subjects would allow any influence of individual differences on performance to be noted. Although the current study revealed a general ability of domestic horses to perform in a radial maze there was no manipulation to test for memory capacity. Future studies may wish to manipulate the number of arms in the radial maze to determine any differences in spatial memory performance with increasing maze complexity. Finally, the current study was limited in that it did not explore the potential methods used by horses to remember spatial

locations. Mazmanian & Roberts (1983) manipulated rats' views of extramaze cues and concluded that rats seem to use extramaze cues to improve performance on radial mazes. A similar experiment could be performed to better understand the methods used by horses on spatial memory tasks such as this.

The results of the current study, although limited, have proved to be a solid foundation for future research to grow and expand from. In fact, the use of radial mazes may have a practical role in equine research. Sappington, McCall, Coleman, Kuhlers, and Lishak (1997), attempted to identify a relationship between young horses performance on a discrimination task and a practical riding task. The results were negligible, and there was no significant correlation found between horses' performance on the discrimination task and their performance crossing a trail bridge or jumping a cross jump. Although these two specific tasks were not correlated Sappington et al. (1997) created a unique platform where psychological studies could be used to help the equine community quantify the cognitive ability of individual horses on actual riding tasks. Perhaps Sappington et al. (1997) was correct in its method, but incorrect in choosing the tasks to compare. In the future, performance on radial mazes and other cognitive tasks may prove to be indicative of horses' capabilities in other capacities.

Understanding the cognitive abilities of animals has not only been a fascinating challenge throughout history, but it has very practical applications, especially with regard to working animals such as horses. Gaining insight into how horses learn and remember may help improve equine training methods, and the relationship between horse and rider.

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