Place Power: Learn How Your Spatial Memory Works

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Abstract

The place cell is a fundamental concept of spatial memory in the hippocampus. Place cells recorded from rats running the radial arm maze show that neurons fire only when a rat is in a specific place. Alcohol affects performance on the radial arm maze, and inhibits some spatial memory in rats (Devenport et. al., 1982). Our model combined these two concepts and simplified them for the fifth grade students. We built a life-size radial arm maze for two students to run through; one was allowed to run through normally, the other was spun each time he went back to the base of the maze to simulate the effects of alcohol. Evaluations of our exhibit conclude that many of the students enjoyed the presentation. We placed first in our group, and received the highest evaluation scores. For simplicity, we compromised the level of accuracy in our model. Next time, I would make the model less complicated by focusing on only place memory, instead of place cells. This would be an easier concept for the kids to understand.

Introduction

The hippocampus of a mouse has a large number of pyramidal cells. Many of these cells are called *place cells*, which codes for a specific position in space (Kandel et al, 2000). When the animal moves around, some place cells fire, while others do not. This causes a unique representation of the animal's surroundings within the hippocampus. Such a representation of spatial surroundings is called a *place field* (Kandel, 2000). New place fields are formed very quickly when an animal comes into a new environment, and can be used for weeks to months (Kandel, 2000).

The hippocampus is involved in spatial memories, or memories of an animal's surroundings. In 1971, John O'Keefe and John Dostovsky discovered that the hippocampus is involved in the development of these memories (O'Keefe, 1971). Two groups of rats were used in this study. One group of rats were lesioned in the hippocampus, and electrodes were mounted onto the skull of the rats; the other group intact, with the same electrode apparatus attached to the skull. Recordings of units of cells were taken while the rats performed spontaneous behaviors. The intact animals were able to notice environmental changes immediately, and specific units of cells fired as the rats returned to a place they had been before. Lesioned animals could not recognize where they had already been and could not learn to go to a particular place using a particular route (O'Keefe, et al. 1971).

Other brain areas have been implicated in spatial memory processes, however experiments have shown that the hippocampus is the most important in these processes (Becker et. al, 1980). Performance of rats with lesions in the amygdala, caudate nucleus or the frontal cortex in a radial arm maze was not significantly different from controls. Hippocampal lesioned rats showed significant deficits in performance compared to controls, thus the hippocampus is needed for spatial memories and the other areas are not (Becker, 1980).

Ethanol effects performance of animals in the radial arm maze (Devenport, et. al. 1982). Normally, rats display a wide variability in their behavioral patterns in the radial arm maze. For example, a rat normally explores most available arms before returning to a previous arm (Devenport, 1982). Rats given ethanol treatments had a dramatic decline in behavioral variability. The rats entered fewer arms, and sequences the rat used became predictable (Devenport, 1982). This study shows that alcohol has effects on spatial memory, an important concept for children to

understand. Ethanol may also have made the rat less motivated, which would explain the results in the study, or might have just made the rat incapable of performing the task. Regardless of the true cause of the diminished responses by the rats, it is important to teach the kids about the importance of not using alcohol.

Our first goal for the 2004 Kids Judge Neuroscience Fair was to develop a child sized radial arm maze and to educate the children on neural place cells and spatial memory. The second goal of this project was to inform the children what the effects alcohol might have on spatial memory. We needed a large space to build a life-size radial arm maze, a small table to put the rat radial arm maze on, as well as the poster presentation. Two children ran the maze in each group. To simulate alcohol effects on spatial memory, one of the kids was spun around while inside the maze. This was so they were disoriented enough to simulate the effects of alcohol on special memory, and to help eliminate visual cues that they had. Because we cannot give children ethanol, disorientation simulated the effects of alcohol on spatial memory and the effects alcohol has on judgment. Disorientation does not allow for visual cues to be processed as well as a normal person would be able to process them. This means they may not be able to have the place memories formed after going through each arm.

Methods

We made a life-size radial arm maze to illustrate how spatial memory works. We used four coat racks to represent the base of the radial maze. Masking tape marked out the arms, and landscaping plastic covered the base, so no visual cues were available to the kids. (Please see figure 1). Masking tape was used to make a circle around the entire maze, so that the other kids could observe without interfering with the person running the maze. At the end of each arm, we placed a cup with a Skittle® in it. Each cup was numbered 1-8 with a piece of masking tape. To reinforce the concepts introduced with the life-size maze, we also had a real radial arm maze with a mouse running it. We compared the life-size radial arm maze with the real one and compared the way their memory works with that of the mouse.

Before we allowed the kids to participate, a general explanation was given about what the maze tests. We explained to them that the radial arm maze was used to test the memory of places. We introduced the term “spatial memory” and described this as the memory of their surroundings. A general explanation was given on how to run the maze, and how the maze tested spatial memory. We told them that the hippocampus, a special part of the brain was involved in spatial memory. The children were also introduced to place cells, and how they work. Alcohol can cause memory impairments, and the kids were told that drinking alcohol might not only impair their judgment, but also their spatial memory.

To make these two concepts clear, two children ran the maze. One child ran the maze without any interference. The children were given the instructions that they start in the middle of the maze. They cannot go into two arms at one time and must return to the middle of the maze each time they get the candy at the end of the arm. A mistake was then made if the kids went into the next arm without returning to the base of the maze. A mistake was also made if the kid returned to an arm that they had been before. The mistakes were tallied for each kid that ran the maze in each group, to clearly demonstrate the effects of alcohol on spatial memory.

When the second child ran the maze, the instructor spun him around inside the base each time he returned from an arm. This simulated the effects of alcohol on spatial memory. The other

kids in the group were given clipboards and lab coats, and were the researchers. They recorded mistakes made by the two running the maze. The instructor tallied results to show the kids the effects of alcohol on spatial memory. We did not score the tallies any particular way; we just showed them that the kids who drank alcohol always made the most mistakes.

Lastly, we showed the students a real radial arm maze. A more detailed description of place cells and spatial memory was given to them at this time. We explained the way the mouse run the maze was through feeling their way along the walls of the maze with their whiskers. We explained that alcohol given to the mice disrupts spatial memory. This was the most important concept that we wanted the kids to take with them. We also had a poster that included an aerial view of the maze and the title of the exhibit.

Results

With limited time, the first group could only run through the maze, and did not get a full explanation of how alcohol affects spatial memory. We were able to adjust by cutting the time allowed for each child to run the maze to 3 minutes. After the two students ran the maze in each group, we showed the children the differences in mistakes made by the "drunk" person and the mistakes made by the normal person. 16 total students ran the maze, 8 spun around to simulate alcohol, 8 not spun around. The average number of mistakes made by the kids who were not spun around was around 1.5 and the average number of mistake made by the kids spun around was 3.5. We do not have the statistics on these numbers at this time; however, I feel that it would be very interesting to see if there was any significant difference between groups. This really enforced the point that we were trying to make about using alcohol.

The children were able to ask questions after seeing the demonstration of the real radial arm maze. Most of the questions asked were about how mice are able to feel and know places they've been. Other questions dealt with how alcohol inhibits memory. After each group finished their questions, we asked them what their favorite part of the presentation was. While most of the kids thought that getting the candy skittles was the best part, some of them really liked the ideas presented and we could really their eyes light up as they talked about the radial arm maze. The students then were allowed to fill out their evaluations of the presentation.

There were five questions on the evaluation sheets: 1) How well did you understand the material presented? 2) How friendly were the presenters? 3) How fun was the presentation? 4) Would you like to learn more about the ideas presented in the presentation? And 5) What did you learn from this presentation? Table 1 shows tallied results of these questions in summarized form, as well as the other presenters' results. We had the highest average of our group of presenters and placed first in the judging of the presentations by the kids. The 5th graders also wrote additional comments on the evaluation sheets. Some of these comments included: "alcohol is bad," "the mouse was cool!" and "I liked this exhibit."

Discussion

The children's ability to comprehend such a complex topic as place cells surprised both my partner and me. The children were also able to understand how the radial maze worked very quickly, which I think saved the presentation. If we were to spend more time on explaining how the maze worked, we would not have been able to explain what really mattered: place cells and spatial memory. We had the highest averages of the other presenters; however, this does not

mean that we had the best exhibit. Although we had the highest rankings and received the first place vote, we did not accomplish the goal of our presentation. This meant teaching the kids about a complex neuroscience topic with enough simplicity for them to remember it afterwards.

We had two objectives to teach the kids when we started this project. One of these was to teach the kids the about place cells and spatial memory. The other goal was to impress upon them that alcohol affects spatial memory. I think the latter goal was achieved because most of the responses were about not using alcohol. Question 1 on the evaluation sheet asks the kids how well they understood the presentation. If they fully understood, they would have commented about place cells or said something about place memory in their comments. There was an obvious discrepancy in what the kids actually learned and what they put down on paper. We did win 1st place, and even our evaluations were the highest; however, by reading their comments, I realize the kids did not learn what we intended them to learn. Thus, our presentation was not successful even though it won first place and ranked highest in the evaluations.

The potential cost of the project could have been another pitfall. Our original idea was to use 2x4s and shower curtains to construct our maze. This would have been too expensive. Luckily, we were able to borrow the coat racks and the landscaping plastic and masking tape were given to us. The only cost that we had was the cost of the poster board, which did not cost much. The construction of the maze only took two hours, but it was very frustrating. The maze itself was not tall enough to accommodate one of the presenters and one of the kids at the same time, which could have been disastrous. It may have been disastrous because the students were very excited to run the maze. If they had been running full steam, the taller kids would have bumped their heads or could have hurt the instructor. Because of careful instructions we gave them, the children took precaution not to bump their heads and not to run through the maze, which saved a lot of headaches.

We also faced the problem that kids who ran the maze to simulate alcohol effects could easily see how the first child ran the maze and adjust accordingly to make fewer mistakes. This is why we ended up spinning the "ethanol" group around each time they entered the base of the maze. This made some of them dizzy, and one kid bumped his head on one of the coat racks. Even though the maze had some problems, the kids really enjoyed the hands on interaction with the maze the fact that they contributed to their own research. This was an integral part of our project; without it, our presentation may have not scored as high as it did.

If I had to present this model again, I would change our limitations on space, make the maze base taller, and spend more time explaining the importance of place cells. The radial arm maze was big and the kids needed more room to stand round the maze and record the mistakes. Furthermore, the base needed to be taller so the kids did not have to crouch while running the maze. More time would have been helpful to explain such concepts as place cells and the hippocampus. I would focus on one topic or one goal instead of two. Place cells may be too of an abstract topic for 5th graders, so I would talk just generally about place memory. The children also seemed distracted by the real radial arm maze and more interested in the mouse that we had than learning about place cells. Overall, I was very impressed by the amount of knowledge the kids had about neuroscience. They seemed to grasp concepts quite quickly and this allowed us to cover so much in such a limited amount of time.

References:

Becker, James T., Walker, John, and David Olton. "Neuroanatomical Bases of Spatial Memory." *Brain Research,* 200 (1980) 304-320.

Devenport, L.D., Merriman, V.J., and J.A. Devenport. "Effects of Ethanol on Enforced Spatial Variability in the 8-Arm Radial Maze." *Pharmacology Biochemistry & Behavior,* Vol. 18 (1983), pp. 55-59.

Kandel, Eric R., Schwartz, James H., and Thomas M. Jessell. Principals of Neural Science: Fourth Edition. (2000). New York: McGraw Hill.

O'Keefe J., and J. Dostrovksy. "The hippocampus as a spatial map. Preliminary evidence from unit activity in the freely-moving rat." *Brain Research,* 34 (1971) 171-175.

Figure 1. Here is a life-size radial arm maze. Notice the masking tape arms and styrene cups the end of each arm. The center of the maze, or the starting point is where I am standing.

Table 1. Tallied results of the responses by the 5th graders. Responses were graded 1-5, 5 being the highest response. Place power ranked the highest in every category.

Team	**How well kids Understood presentation**	**Friendliness of the presenters**	**How Fun the Presentation was**	**Desire of the children to learn more about the presentation**	**Average of all responses**
A1, Place Power	**4.86**	**4.95**	**4.85**	**4.5**	**4.79**
A2	4.55	4.75	4.55	4.13	4.5

A3	4.84	4.89	4.69	4.27	4.68
A4	4.8	4.8	4.7	4.4	4.68