

The Effects of Social Interaction and Social Isolation and Handling on Male and Female
Sprague-Dawley Rats When Learning to Navigate a Multiple T-Maze

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Submitted to the Psychology Department, Allegheny College
in partial fulfillment of the requirements for the degree of
BACHELOR OF SCIENCE

December, 2011

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Sprague-Dawley Rats When Learning to Navigate a Multiple T-Maze

A Senior Comprehensive Project

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ACKNOWLEDGEMENTS

Dr. Clark – I am very grateful to have had the opportunity to know you as a person. You are a great professor, advisor, and friend. I always know that I can count on you if I need you. I am really glad to have taken your Behavioral class two years ago. I know I would not be where I am today if you had not introduced me to Kris so that I could help her with her senior project. In fact, I may never have realized that working with animals as a psychology major was even a possibility. Thank you so much for your guidance and your friendship. I will miss seeing you in Carnegie every day.

Dr. Knupsky – Thank you for all of your experience. You have found issues with my project and paper that I never would have considered. Because of this I was able to work to make it better. I am very grateful to have picked you as my second reader and I am even more thankful that you accepted the offer.

John Michael – Thank you for putting up with me through all of this and for helping me out as you have. More than that, I thank you for always being there when I need you most. I love you.

Kris – Thank you so much for letting me help you with your comp two years ago. I would not have been nearly as prepared if I had not had the opportunity to see the process first hand. I learned so much from you and I cannot thank you enough for the experience you have shared with me. I wish you the best in all that you do!

Mom, Dad, and Bradley – Thank you for always being there for me. When I needed your help, I always knew you were only a phone call away—and now, Bradley is here on campus. Thank you for helping me put together my maze and thank you for helping me troubleshoot my project. I am more than proud to be your daughter and sister. I love you all.

Rachel – Thank you for being a great boss, mentor, and friend. Thank you for feeding me through the hard times and making sure I maintained some level of health during this process. I could not have made it through this without you.

Val and Ollie – Thank you both for donating pieces that eventually became part of my maze. I would not have been able to do my project without them.

Victoria – Thank you so much for all of your help. I honestly have no idea what I would have done without you. I wish you the best of luck throughout the rest of your years here. I know you will do great things. If you need any help with your comp, make sure to let me know!

ABSTRACT

Many studies have been conducted on what effects isolation has on the body and on ability to perform tasks, but there has not been much work done concerning how to overcome the negative effects of isolation. Nor has there been much research conducted on how to improve learning through social interaction methods. The purpose of Experiment 1 was not only to examine the effects of isolation and interaction, but also to see how to overcome the negative effects of isolation while enhancing the positive effects of social interaction. There was a handling component involved in this study in an attempt to simulate interaction with isolated and grouped rats. The main purpose of Experiment 2 was to see which rats retained the learned behavior after a short period of time had passed. Only one rat was tested in each condition. There were eight total conditions. All rats were housed in the same colony and all rats were placed in their condition for ten days prior to testing. Each rat was also allowed two days to habituate to the maze so as to reduce the chance of this novel environment impacting results. Latency and number of errors were recorded for each rat. Results showed that while handled isolated rats met criteria the fastest in Experiment 1, handled grouped rats performed better error and latency wise. In Experiment 2, isolated rats demonstrated the best performance. Possible reasons for the results, limitations of the studies, and future research questions are considered.

Introduction

Preface

Learning is an integral part of all of our lives. Learning is how we interact with the world around us. Everything from proper dinner etiquette to tying a shoe to washing a dish has to be learned before we can do it properly on our own. Whether we realize it or not, our environment influences how and what we learn. The big question is how much of our learning ability is shaped by our environment and how much is shaped by other factors.

Learning has been studied for a long time and researchers have always aimed to find better ways to understand how and why learning works. Recently, many studies on learning have started to include environmental factors to determine how much of an impact social environment has on learning. There has been a lot of research conducted concerning isolation and how it impairs learning ability, but what about possible ways to prevent this problem? How much is actually known about varying levels of social learning environments and which ones most aid learning?

These types of studies are important as they can help improve our education system. These types of studies may also help to come up with new ways of preventing learning disabilities from manifesting in children. Even more so, studies on learning and social environment may help children who have already developed a learning disability overcome such a challenge.

This study has attempted to add new information to what is currently known about learning by putting rats in various social or isolated conditions and having them run timed trials. The goal of Experiment 1 was to discover which environmental condition fostered the best learning environment. The goal of Experiment 2 was to determine which condition would allow for the best retention of learned behavior.

The Effects of Isolation on Rats

Although learning has been studied for years, there have been several studies conducted recently that have suggested that environmental factors can affect cognitive development, and subsequently, affect a rat's ability to learn and perform certain tasks. For instance, in a study about the social transmission of avoidance behavior, it was mentioned that rats can pick up all sorts of information depending on the type of social interaction they are engaged in (Masuda & Aou, 2009). The researchers explain that social interaction with other animals (in this case rats) and observation of them can have effects on aspects of life such as food preference. They also explain that rats can apply what they have learned in previous situations to help them adapt to new situations and that social cues among rats can be even more important when adaptation to a novel environment is necessary.

In another study, one that examined the secretion of reelin within the hippocampus, researchers reared Wistar rats in isolation and compared them with socially reared rats of the same age (Cassidy, Mulvany, Pangalos, Murphy, & Regan, 2010). They then proceeded to test rats in both conditions at postnatal day 60 and postnatal day 80 in a water-maze paradigm. They discovered that although isolation reared rats did not display significant latency differences between ages, socially reared rats did produce different latency times depending upon their age on the testing day. These results seemed to indicate that environmental factors alone could be capable of altering a rat's ability to learn and perform tasks.

Similarly, a study conducted by Manni, Aloe, and Fiore (2009) suggested that socially isolating mice from one another led to impaired learning and memory processes. To attempt to counteract the effects of isolation on these mice, the researchers in this study used electro-

acupuncture. They discovered that daily sessions of electro-acupuncture led to a reduction of the impairments induced by individually housing the mice.

Handling as a Means of Counteracting the Effects of Isolation

Even though, electro-acupuncture may be a good way to reduce impairments created by isolation rearing, handling has been a more accepted method of reversing or preventing these effects. Rats are very social animals and touch plays an important role in the social and emotional aspects of their lives, as well as in learning ability. Many researchers have examined the benefits of touch and have explained that early handling may be able to alter decreased social interaction and learning capabilities. In order for handling to properly impact rats, however, researchers must consider multiple aspects of the variable.

In Hertenstein, Verkamp, Kerestes, and Holme's (2006) study, the researchers examined the effects that handling (specifically human handling) and maternal behavior had on learning. They found that the age of the subject when handled, the quality of handling, and the duration and consistency of handling all affected how powerful handling was on learning overall. Hertenstein et al. (2006) determined that if human handling was to have the greatest impact on rats, it should be started between the period of birthing and weaning—ideally within the first week of the rat's life. The researchers also noted that while any sort of handling was better than no handling, gentle handling was better than harsh handling. Finally, they found that the relationship between the time spent handling and adult learning appears to be curvilinear. This indicates that handling aids learning to a certain point, but too much handling can actually diminish learning in rats. If done correctly, handling can improve learning and memory processes. Handled rats are less likely to make errors when participating in maze tasks and their spatial memory is less likely to become impaired with age when compared with non-handled rats

(Hertenstein et al., 2006; Daskalakis, Kaperoni, Koros, Kloet, & Kitraki, 2009; Stamatakis et al., 2007).

The importance of the age of the rat at the start of a handling treatment and the amount of time the rat is handled is further supported by studies conducted by Frisone, Frye, and Zimmerberg (2001), Kosten, Lee, and Kim (2007), and Frankola et al. (2010). While none of these studies definitively agrees upon what age a rat pup should be handled or separated from its mother and group, they do agree that handling and isolating rats as pups affects learning ability and performance in adult rats.

Frankola et al. (2010) put rat pups through 15 minute handling sessions (in the early handling condition) and through 180 minute separation sessions (for the maternal separation condition) in order to study cognitive performance in prepubescent male and female rats. After testing the rats on various tasks (some were maze tasks and some were object recognition tasks), the researchers reported that male rats were impaired in their spatial and non-spatial memory after being separated from their mothers when compared with male rats in the early handling condition. It is not clear, however, whether early handling in male rats enhanced performance or maternal separation impaired performance. Interestingly, female rats were not impaired after undergoing maternal separation when compared with female rats in the early handling condition at all. In fact, maternally separated female rats even performed better on memory tasks than early handled female rats in some instances.

Differences Between Males and Females

Frankola et al. (2010) also found differences between sexes, not just in the handling/separation variables. The researchers reported that adult male rats, regardless of their assigned condition, were able to learn spatial information faster and remember it better than adult

female rats. Male rats also made fewer errors when participating in maze tasks. Female rats, on the other hand, were less likely to become impaired cognitively when they were exposed to stress as adults (an example of a stressor would be extended isolation) than male rats. Sandstrom (2005) also found that adult females were less likely than adult males to be cognitively impaired after undergoing six hours of social isolation a day as pups.

Another study (Kosten et al., 2007) found sex differences as well. When completing some of the tasks (there was an object recognition task, a circular maze task, and an inhibitory avoidance task), it was noticed that females performed better on the inhibitory avoidance task than male rats and that male rats performed better on the object recognition task than female rats.

A final study (Ribeiro et al., 2010), also found differences between sexes. When conducting their experiment on aversive memory in rats, the researchers reported that male rats are often better at spatial learning tasks, while female rats are better at developing and retaining strong emotional memories. For instance, female rats avoided the aversive stimulus arms of a plus-maze, even 24 hours after aversive stimulus testing had been completed and the aversive stimulus (a foot shock) had been removed. It was also found that male rats were more likely to display a freezing response after aversive conditioning than female rats. It was proposed that because of the lack of a freeze response, female rats were experiencing a deficit in learning. Later, however, the researchers noticed that even though female rats would not show a freeze response, they were more likely to exhibit escape behavior than male rats. This led them to believe that even though male rats and female rats perform differently on memory tasks they do not necessarily exhibit characteristics typical of a learning deficit.

Hypotheses

Experiment 1

Despite all of the research that has been done on isolation, the experimenters were unable to find any study that placed rats in an isolated condition for longer than a few hours a day. They wanted to investigate what effects long term isolation would have on male and female Sprague-Dawley rats. Because of the research done on isolation, this study investigated the hypothesis that rats placed in isolation for the entire experiment would take the longest to meet criteria and would spend the most time in the multiple T-maze during timed trials. The researchers also hypothesized that rats housed in a group condition would meet criteria the fastest and would spend the least amount of time in the multiple T-maze during timed trials.

In addition to the hypotheses the researchers made concerning isolated rats and rats in group conditions, they also made hypotheses concerning handling and sex differences. After doing a lot of research, they hypothesized that rats in a handled isolated condition would meet criteria faster than completely isolated rats because the handling would alter any impairment caused by the isolation condition. However, the researchers did not think that rats in the handled isolated condition would perform better than rats in a group condition because even though those rats would be handled, they would still be isolated from other rats. Finally, the researchers hypothesized that there would be a significant difference between male rats and female rats when learning the maze task and that the male rats would be able to learn the maze task faster and spend less time in the maze than their female counterparts. This is because much of the research has stated that male rats generally perform better at spatial learning tasks than female rats do.

Experiment 2

The goal of Experiment 2 was to determine which condition would foster the best long-term retention of the learned behavior. In this experiment, the researchers expected the handled isolated rats to perform the best, both latency and error wise, because they were the first rats to finish Experiment 1. They also hypothesized that the control group rats would exhibit the least impressive performance since the male control group rat was the last to finish Experiment 1 and the female control group rat, who did not complete Experiment 1 at all, was not eligible to participate in the second experiment.

Materials and Methods

Subject Population: A population of 16 Sprague-Dawley rats was used for this study; however, only 8 of them were tested in the maze. They were randomly selected from the rat colony in Carnegie Hall at Allegheny College. They were all experimentally naïve prior to the start of the study. All procedures were reviewed and approved by the Animal Review Committee at Allegheny College prior to the start of experimentation.

Apparatus: For this study, a small multiple T-maze (Appendix, Figure A1) was constructed to be the main testing apparatus for rat learning. Data was collected by hand and recorded in a three-ring binder. The experimenters used a stop watch to record the time it took each rat to complete each timed trial.

Procedure:

Housing Environment and Conditions.

First the rats were divided into male and female groups, so as not to confound the study and allow female rats to get pregnant. Next, the rats were randomly assigned to their conditions for the study. Not all of the rats were used in the final study (for example, if a rat was placed in a

group condition, only one of them was actually put in the maze for testing). Each rat was assigned to one of four housing conditions: complete isolation, complete isolation except for handling, a group (which served as the control in this experiment as these rats were neither handled nor isolated), or a group with handling.

The rats were exposed to light whenever they were in the colony, due to a twenty-four hour lighting system. Housing consisted of wire-floored cages and a radio playing country music was on at all times. The rats had access to water at all times. They also had access to food at all times except for days directly prior to testing due to a twenty-three hour food deprivation period.

Behavioral Testing of Rats in Their Respective Conditions.

The rats were approximately 130 days old when they were divided into their housing conditions. The rats in the handled condition underwent a gentling process in which they were continuously held and stroked for ten minutes each day for ten days. All other rats were handled during testing days, but received no additional handling. All rats remained in their respective conditions for ten days before they were introduced to the maze.

Each rat was put under a twenty-three hour food deprivation schedule prior to its testing day, but water was still available to it all times. Before testing began, the rats were placed one at a time into the maze to be habituated with the novel environment. During this time, they were able to explore freely without being timed. Once testing actually started, the rat was placed under a continuous reinforcement schedule (CRF), meaning that they received a food reinforcer (in this case a piece of Honey Nut Spins® cereal—comparable to Cheerios® cereal) upon each completion of the maze. During each testing period, the time it took for each rat to complete the maze task, or the latency, was recorded and the number of wrong turns, or errors, was also recorded. Each rat completed between six and eight trials per testing day. However, on one

occasion only five trials were completed and on one other occasion nine trials were necessary to meet criteria. All rats continued to go through testing until they completed the learning criteria of four or more errorless trial runs—in a row—for three consecutive testing days.

As the rats began to meet criteria, the experimenters thought it would be a good opportunity to run a second “mini-experiment” because there appeared to be extra time at their disposal. This experiment took place after each rat met criteria. Four days after meeting criteria, the rat ran the maze for one final testing day. Just as before, each rat underwent a twenty-three hour food deprivation period prior to testing, but was allowed full access to water. This time each rat ran exactly six trials. Upon completing the second experiment, each rat was returned to the general colony of Allegheny College in Carnegie Hall.

Results

Due to limited number of subjects available, only one rat per condition, results are not presented in the form of a MANOVA as would normally be expected for an experiment of this nature. Instead, total, mean, and standard deviation data are presented in a series of tables and graphs as deemed appropriate.

Overall

The female rat in the handled isolated condition was the first rat to meet criteria. It took her five days from the time she started testing to the time she finished. Three of those days were required to meet criteria. Many of the other rats finished soon after. Three rats finished on their sixth testing day. On the other hand, some rats took a much longer time to meet criteria. In fact, one rat—the female in the control condition—never met criteria even though she was tested for seventeen days. The total number of days each rat took to complete Experiment 1 is presented in Table 1. The total number of trials taken to complete Experiment 1 is also presented (Table 2).

These numbers depict similar results in order of completion, but help to break down which rat finished first in actuality when multiple rats finished on the same testing day.

Table 1.

Total Number of Days Took to Finish Experiment 1

<u>Sex of Rat</u>	<u>Condition</u>			
	<u>Handled Isolated</u>	<u>Handled Group</u>	<u>Completely Isolated</u>	<u>Control Group</u>
Male	6	6	9	15
Female	5	6	13	17*

*Note: Even though the female rat in the control group did not meet full criteria, she did participate in the experiment for 17 days.

Table 2.

Total Number of Trials Completed in Experiment 1

<u>Sex of Rat</u>	<u>Condition</u>			
	<u>Handled Isolated</u>	<u>Handled Group</u>	<u>Completely Isolated</u>	<u>Control Group</u>
Male	42	38	56	105
Female	32	40	87	105*

*Note: The female rat in the control group completed 105 trials by the time the experiment ended.

It may also be helpful to see which rats made the most and least errors, as well as which rats spent the most and least amount of time in the maze overall. Completing criteria quickly does not necessarily correlate with learning ability. A chart depicting the highest number of errors in one trial can be found in Figure 1. No figure exists for the lowest number of errors in one trial because all rats had at least one errorless trial during the course of the experiment. The next two charts (Figure 2 and Figure 3) are of the fastest times each rat had in one trial and the slowest times each rat had in one trial. The time was measured in seconds for both cases.

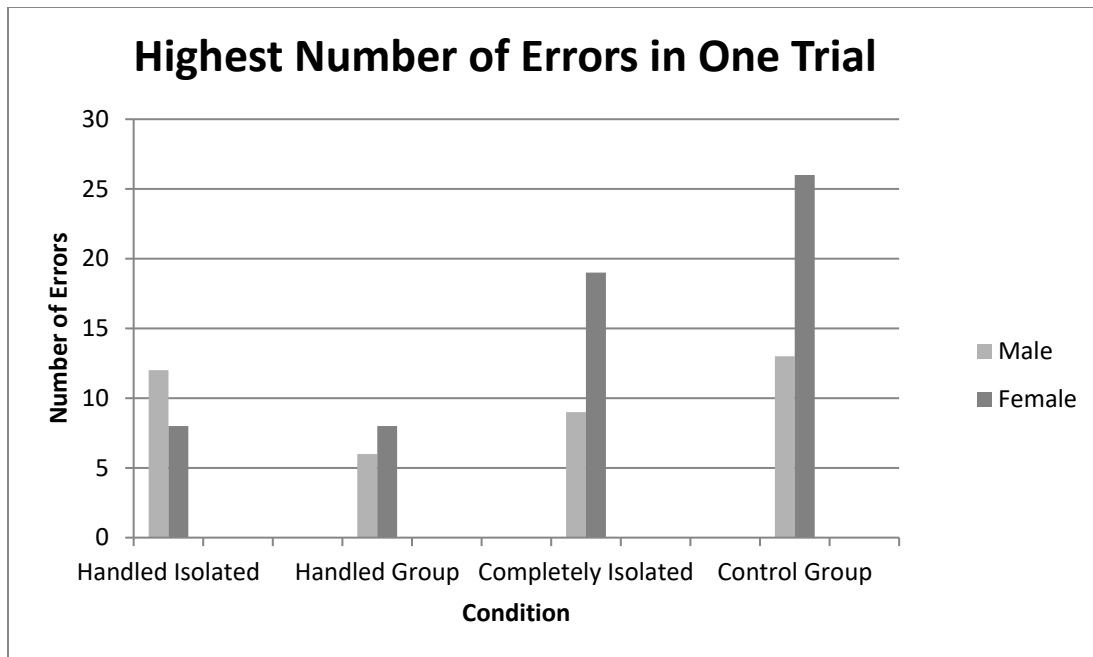


Figure 1: The female rat in the control group made the highest number of errors with 26 errors. The male rat in the handled group made the least amount of errors with 6 errors being the most he made in one trial.

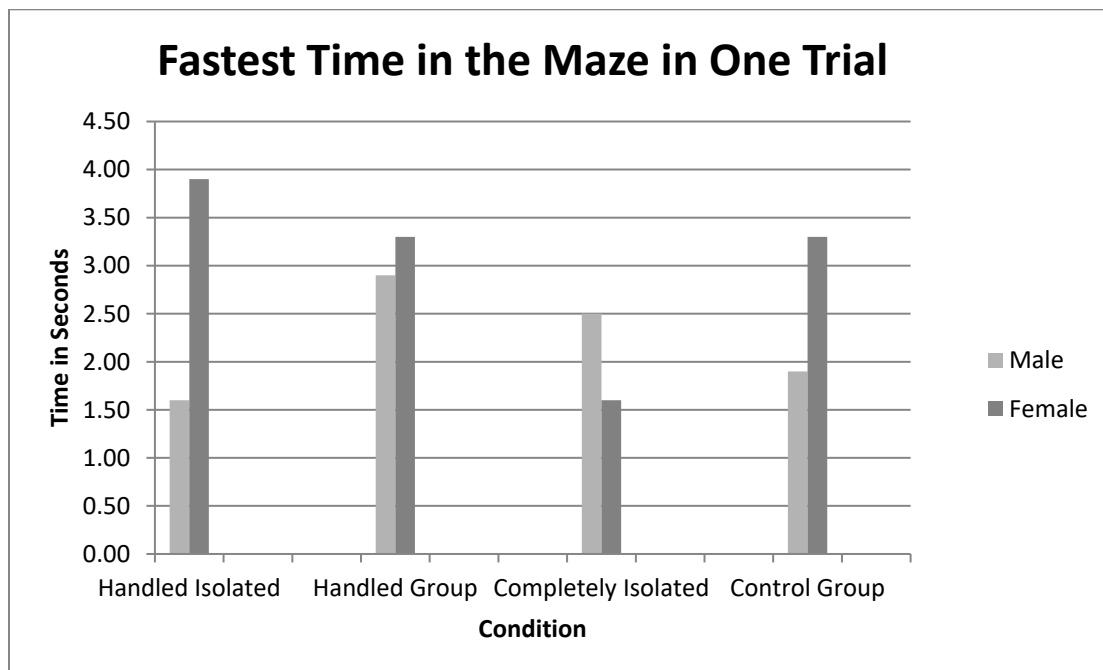


Figure 2: The male rat in the handled isolated condition had the fastest time in one trial at 1.60 seconds. The female rat in the handled isolated condition had the slowest time with 3.90 seconds being the fastest time she had in one trial.

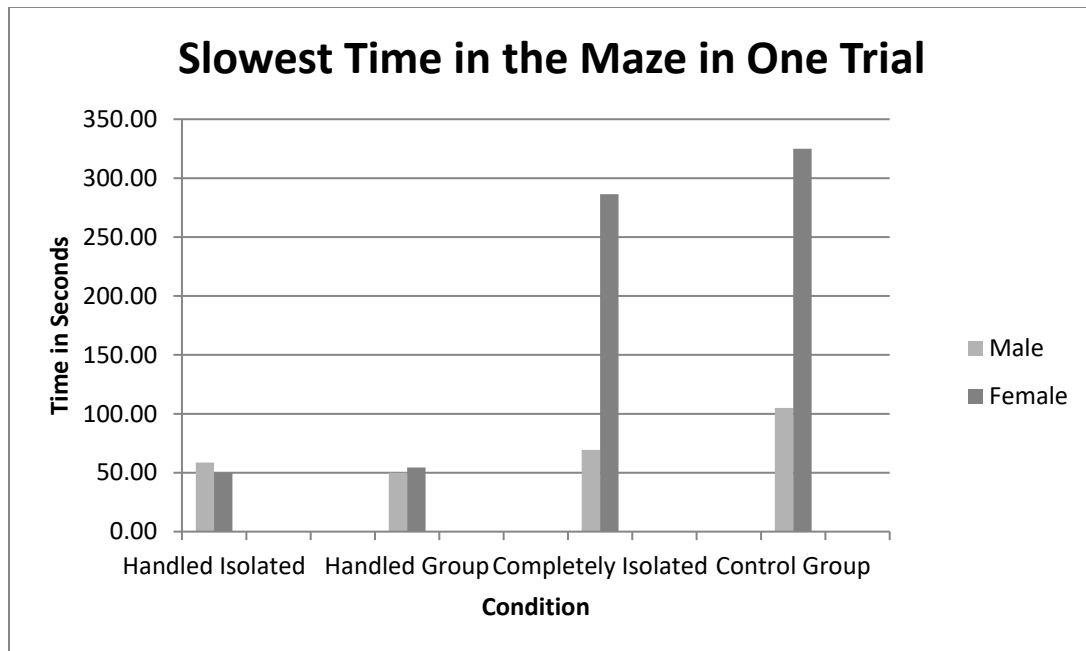


Figure 3: The female rat in the control group had the slowest time in one trial at 324.90 seconds. The female rat in the handled isolated condition had the fastest time with 49.80 seconds being the slowest time she had in one trial.

Experiment 1

Rats placed in isolation were expected to take the longest to meet criteria and were expected to make the most errors. However, the isolated rats took fewer days to meet criteria than grouped rats (isolated rats took 33 days total to meet criteria; grouped rats took 44 days). Isolated rats also made fewer errors total (428 errors) than grouped rats (564 errors), but more errors ($M = 12.97$ errors) per day on average than grouped rats ($M = 12.86$ errors). Isolated rats were also expected to spend the most time in the maze. Even though isolated rats spent more time ($M = 177.23$ seconds) in the maze on average per day than grouped rats ($M = 140.76$ seconds), they spent less time in the maze overall (isolated = 5848.70 seconds; grouped = 6193.60 seconds).

Handled isolated rats were expected to meet criteria faster than completely isolated rats and they did (handled isolated rats took 11 days to meet criteria; completely isolated rats took 22

days). They also made fewer errors total (145 errors) than completely isolated rats (283 errors). However, completely isolated rats made fewer errors ($M = 12.86$ errors) on average per day than handled isolated rats ($M = 13.18$ errors). Handled isolated rats also spent less time in the maze (1328.70 seconds) than completely isolated rats (4520.00 seconds) overall and less time in the maze ($M = 120.79$ seconds) than completely isolated rats ($M = 205.45$ seconds) per day on average.

Handled group rats met criteria before control group rats (handled group rats took 12 days to meet criteria; control group rats took 32 days). They made fewer errors (109 errors) than control group rats (455 errors) overall and fewer errors ($M = 9.08$ errors) than control rats ($M = 14.22$ errors) on average per day. Handled group rats also spent less time in the maze (1328.70 seconds) than control group rats (5028.10 seconds) and less time in the maze ($M = 97.13$ seconds) than control group rats ($M = 157.13$ seconds) per day on average.

Handled isolated rats, while expected to perform better and faster than completely isolated rats, were not expected to perform better than grouped rats. However, handled isolated rats met criteria faster than handled group rats and control group rats (handled isolated rats met criteria in 11 days; handled group rats took 12 days; control group rats took 32 days). Handled isolated rats made fewer errors (145 errors) than control group rats (455 errors), but more than handled group rats (109 errors). They also made fewer errors per day on average ($M = 13.18$ errors) than control group rats ($M = 14.22$ errors) did, but again, they did not perform as well as handled group rats ($M = 9.08$ errors). Handled isolated rats spent less time in the maze (1328.70 seconds) than control group rats (5028.10 seconds), but more time than handled group rats (1165.50 seconds). They also spent less time in the maze ($M = 120.79$ seconds) per day on

average than control group rats ($M = 157.13$ seconds), but more than handled group rats ($M = 97.13$ seconds).

Male rats were expected to meet criteria faster than female rats and they did (male rats met criteria in 36 days; female rats took 41 days). Male rats made fewer errors overall (323 errors) and fewer errors per day on average ($M = 8.97$ errors) than females (669 errors; $M = 16.32$ errors). Male rats were also expected to spend less time in the maze than females. They spent less time in the maze overall (male rats = 3711.10 seconds; female rats = 8331.20 seconds) and less time in the maze per day on average (male rats: $M = 103.90$ seconds; female rats: $M = 203.20$ seconds).

The breakdown for the means and standard deviations for the total number of errors made for each rat in Experiment 1 can be found in Table 3 and the means and standard deviations for the total time taken during Experiment 1 can be found in Table 4 below.

Table 3.

Means and Standard Deviations for Total Number of Errors Made for Experiment 1

Sex of Rat	Condition							
	Handled Isolated		Handled Group		Completely Isolated		Control Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Male	1.93	6.42	1.24	3.52	1.63	2.81	0.99	3.67
Female	2.00	5.32	1.55	4.38	2.21	7.44	3.34	8.98

*Note: Higher numbers indicated more errors made. Each value refers to the average number of errors made (per trial) over the course of the entire experiment.

Table 4.

Means and Standard Deviations for Total Time Taken (in seconds) in Maze for Experiment 1

Sex of Rat	Condition							
	Handled Isolated		Handled Group		Completely Isolated		Control Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Male	17.74	47.30	12.61	36.28	18.51	51.64	13.81	43.35
Female	18.23	46.66	17.16	45.15	40.04	134.50	34.08	92.12

*Note: Higher numbers indicated more time spent in the maze. Each value refers to the average amount of time spent in the maze (per trial) over the course of the experiment.

The total number of errors each rat made in Experiment 1 can be seen in Figure 4 and the total time spent in the maze for each rat can be seen in Figure 5. These numbers are what the means and standard deviations of Table 3 and Table 4 are based off of.

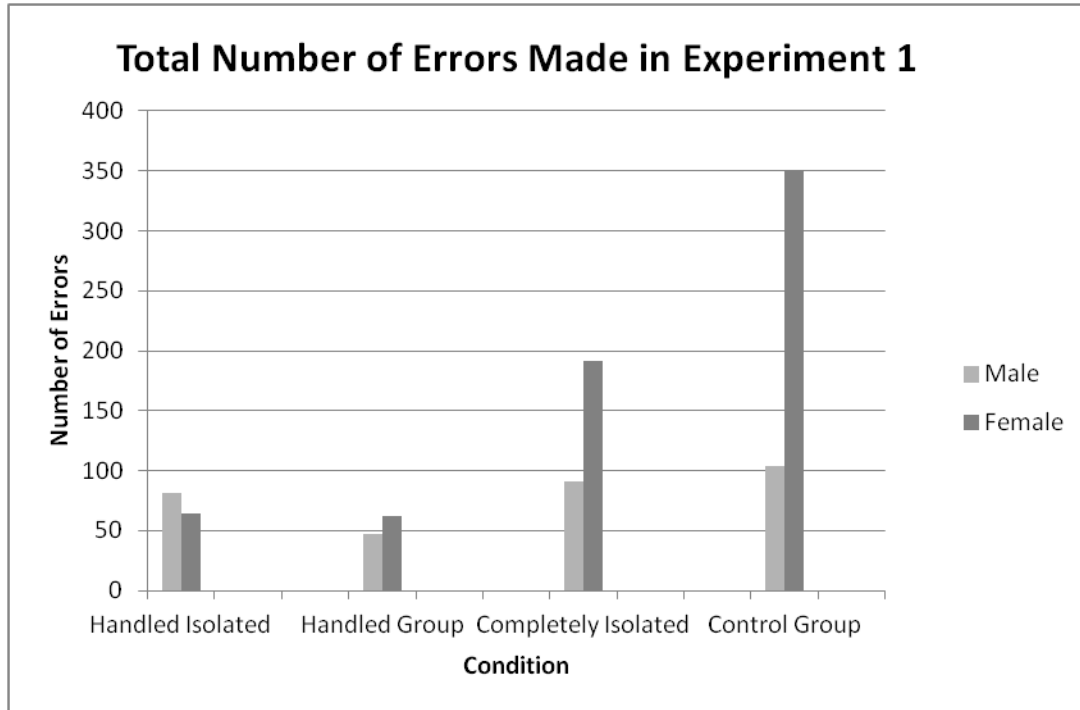


Figure 4: The female rat in the control group made the most errors overall with 351 errors. The male rat in the handled group condition made the least amount of errors overall with 47 errors.

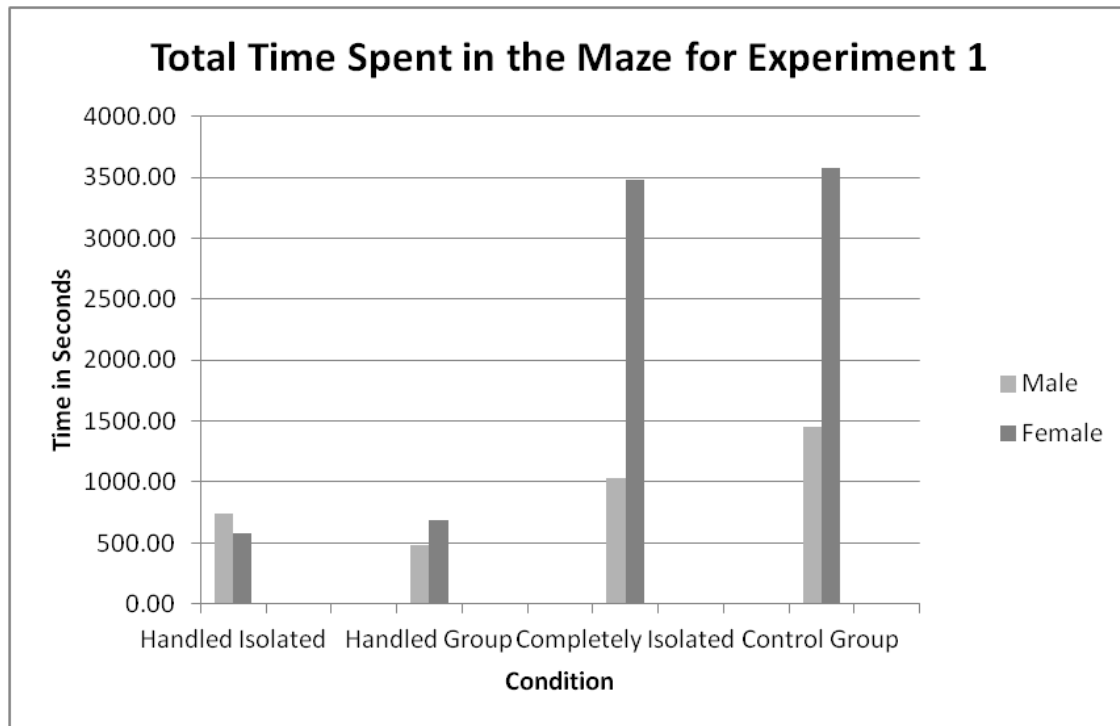


Figure 5: The female rat in the control group spent the most time in the maze overall at 3578.30 seconds, followed closely by the female rat in the completely isolated condition at 3483.20 seconds. The male rat in the handled group condition spent the least amount of time in the maze overall at 479.30 seconds.

Experiment 2

In this experiment isolated rats made fewer errors (15 errors) than grouped rats (19 errors). They also made fewer errors on average ($M = 3.75$ errors) than grouped rats ($M = 6.33$ errors). They spent less time in the maze (isolated = 209.50 seconds; grouped 587.10 seconds) and they spent less time in the maze on average (isolated: $M = 52.38$ seconds; grouped: $M = 195.70$ seconds).

Handled isolated rats made more errors (12 errors) than completely isolated rats (3 errors). They also made more errors on average ($M = 6$ errors) than completely isolated rats ($M = 1.5$ errors). They spent more time in the maze (135.10 seconds) and more time in the maze on average ($M = 67.55$ seconds) than completely isolated rats (74.40 seconds; $M = 37.20$ seconds respectively).

Handled group rats made more errors (13 errors) than control group rats (6 errors). They also made more errors on average ($M = 6.5$ errors) than control group rats ($M = 6$ errors). However, they spent less time (143.50 seconds) in the maze than control group rats ($M = 443.60$ seconds) overall and less time ($M = 71.75$ seconds) than control group rats ($M = 443.60$ seconds) on average.

Handled isolated rats made fewer errors (12 errors) than handled group rats (13 errors), but more than control group rats (6 errors). They also made fewer errors on average ($M = 6$ errors) than handled group rats ($M = 6.5$ errors), but did equally well as control group rats ($M = 6$ errors). Handled isolated rats spent less time in the maze overall (135.10 seconds) than both handled group rats (143.50 seconds) and control group rats (443.60 seconds). They also spent less time in the maze on average ($M = 67.55$ seconds) than both handle group rats ($M = 71.75$ seconds) and control group rats ($M = 443.60$ seconds).

Male rats made fewer errors (12 errors) than female rats (22 errors) overall. They also made fewer errors on average (male: $M = 3$ errors; female: $M = 7.33$ errors). Female rats spent less time in the maze (242.50 seconds) than males (554.10 seconds) overall and they also spent less time in the maze on average ($M = 80.83$ seconds) than males ($M = 138.53$ seconds).

The breakdown for the means and standard deviations for the total number of errors made for each rat in Experiment 2 can be found in Table 5 and the means and standard deviations for the total time taken during Experiment 2 can be found in Table 6 below.

Table 5.

Means and Standard Deviations for Total Number of Errors Made for Experiment 2

Sex of Rat	<u>Condition</u>							
	Handled Isolated		Handled Group		Completely Isolated		Control Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Male	0.00	0.00	0.50	0.00	0.50	0.00	1.00	0.00
Female	2.00	0.00	1.67	0.00	0.00	0.00		

*Note: Higher numbers indicated more errors made. Each value refers to the average number of errors made (per trial) over the course of the entire experiment.

Table 6.

Means and Standard Deviations for Total Time Taken (in seconds) in Maze for Experiment 2

Sex of Rat	<u>Condition</u>							
	Handled Isolated		Handled Group		Completely Isolated		Control Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Male	4.22	0.00	6.50	0.00	7.70	0.00	73.94	0.00
Female	18.30	0.00	17.42	0.00	4.70	0.00		

*Note: Higher numbers indicated more time spent in the maze. Each value refers to the average amount of time spent in the maze (per trial) over the course of the experiment.

The total number of errors each rat made in Experiment 2 can be seen in Figure 6 and the total time spent in the maze for each rat can be seen in Figure 7. These numbers are what the means and standard deviations of Table 5 and Table 6 are based off of.

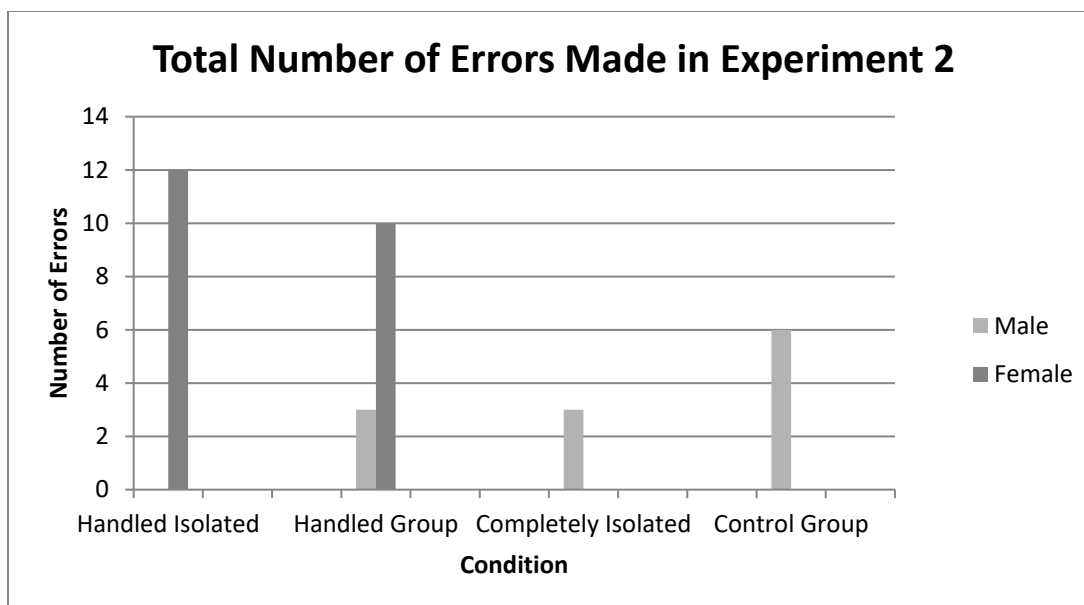


Figure 6: The female rat in the control group did not participate in Experiment 2 because she did not meet criteria in Experiment 1. The female rat in the handled isolated condition made the most errors in Experiment 2 with 12 errors. Both the male rat in the handled isolated condition and the female rat in the completely isolated condition made the least amount of errors in Experiment 2 with 0 errors each.

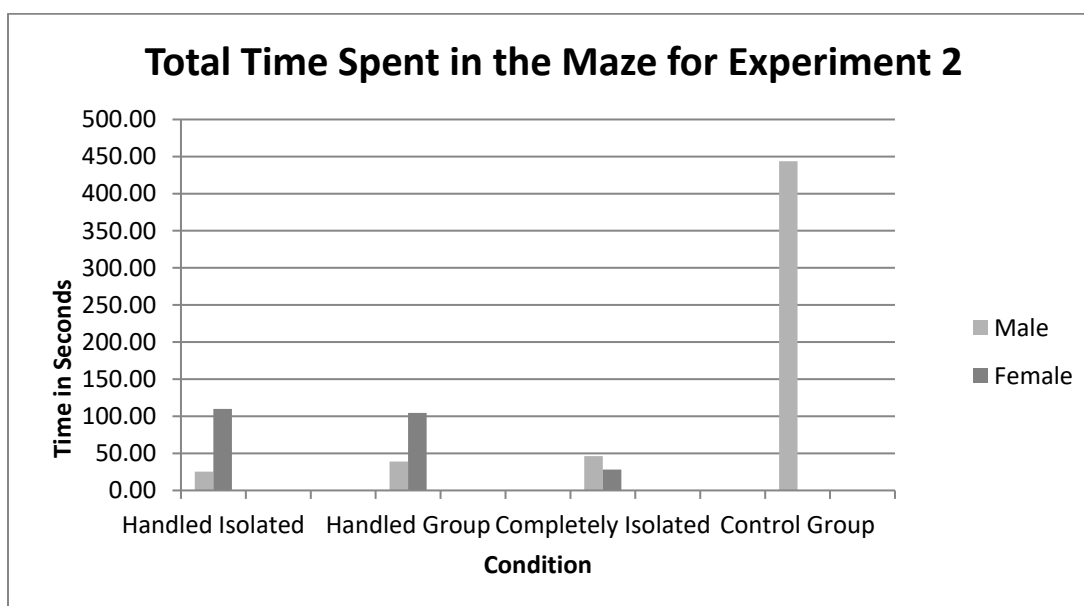


Figure 7: The female rat in the control group did not participate in Experiment 2 because she did not meet criteria in Experiment 1. The male rat in the control group spent the most amount of time in the maze during Experiment 2 at 443.60 seconds. The male rat in the handled isolated condition spent the least amount of time in the maze during Experiment 2 at 25.30 seconds.

Discussion

In Experiment 1 the female handled isolated rat was the first rat to meet criteria. Next, the male handled isolated rat completed the experiment, followed by male and female handled group rats, then the male completely isolated rat. Next the female completely isolated rat finished the experiment, then the male control group rat, and finally the female control group rat (who never actually met criteria for Experiment 1 at all). Even though the handled isolated rats were the first to meet criteria, the handled group rats were the ones who completed Experiment 1 with the least number of errors and spent the least amount of time in the maze overall. The control group rats still finished last, having made the most number of errors and having spent the most amount of time in the maze overall.

In Experiment 2 the completely isolated rats performed the best, making the least amount of errors and spending the least amount of time in the maze overall. While the handled group rats made the least amount of errors in Experiment 1, they made the most errors in Experiment 2. And even though the female control group rat did not partake in Experiment 2, the control group rats still spent the most amount of time in the maze overall.

As far as number of errors is concerned, the control group rats made the highest amount of errors in one trial overall. More specifically, the female control group rat made the most errors. The handled group rats had the lowest amount for the highest number of errors made in one trial. The male handled group rat had the lowest number of errors for his highest total number of errors in one trial. All rats had at least one trial where they made no errors. As far as latency goes, the completely isolated rats had the fastest time recorded in one trial. However, both the male handled isolated rat and the female completely isolated rat had the fastest time of 1.60 seconds overall. The handled group rats had the slowest fast time recorded in one trial, but

the female handled isolated rat had the slowest fast time overall. Meanwhile, the control group rats had the slowest slow time recorded in one trial. More specifically, the female control group rat had the slowest time in one trial overall. On the other hand, the handled group rats had the fastest slow time recorded in one trial; however, the female handled isolated rat had the fastest slow time recorded overall of 49.80 seconds.

Even though the final results of Experiment 1 did not confirm all of the hypotheses, they did confirm some of them. In fact, the order in which each condition of rats met criteria does make sense. Pretend that the rats were actually students and the experimenters were actually teachers. In this scenario, the handled isolated condition would be equivalent to each student having a one on one teacher or private tutor. The handled group condition would be similar to a teacher instructing a very small group of students. The completely isolated condition would be equivalent to a student trying to learn everything on their own, but having no access to material except on testing days. Finally, the control group condition would be similar to a group of students who have no teacher and are forced to teach each other everything without proper access to materials. In this scenario it makes sense that the students with the one on one instructor would perform the best and learn the fastest and the group of students without a teacher would perform the worst.

In Experiment 2, the handled isolated rats did not perform the best and the control group rats did not perform the worst in both number of errors and latency. Instead, the completely isolated rats performed the best, the handled group rats made the most number of errors, and the control group rats spent the most amount of time in the maze. A few reasons may explain why the results of Experiment 2 turned out the way they did. First, the completely isolated rats were the second to last rats to meet criteria in Experiment 1, so they spent the most amount of time in

the maze, but were still able to learn. Once they met criteria for the first day, they hardly made any more mistakes throughout the course of the rest of the experiment. Because of this constant rehearsal, it makes sense that they were able to “recall” the learned behavior the easiest and the fastest of all the rats. Just because someone or something can do a task well and can do it quickly does not mean that they have truly mastered a concept. Second, the handled group rats may have made the most errors in Experiment 2 due in part to the fact that the female had made so many errors. The male rat only made three errors, while the female rat made ten errors (second behind the female handled isolated rat with twelve errors). It is possible that they did the worst because they met criteria in Experiment 1 third and did not get enough practice. It might also be possible that the female just did not have as good of a long term spatial memory as the male rat. Finally, the male control group rat most likely spent as much time in the maze as he did due to an unfortunate event that happened on his last day of testing. This event will be explained more in future paragraphs.

These two studies and their results could mean a lot of good things for people—particularly for teachers and students, adopted and foster children and their caretakers, and other people suffering from neglect or mistreatment. These studies could also mean good things for animal trainers and rehabilitators.

For instance, social interaction may positively influence learning ability and learning speed. It may also override the negative effects of social isolation, even after complete isolation has occurred and started to cause deficiencies in learning ability. It is also possible that complete isolation may allow for longer retention of a task or concept once properly learned. This may be because the amount of stimuli the person or non-human animal is subjected to is minimal, so they have more incentive to hold on to anything they learn. Perhaps anything they learn could be

thought of as something that will help them to survive, on the most basic level. In cases where learning disabilities have already manifested, it is believed that social interaction paired with patience and care can lead to better behavior, better communication skills, and a better understanding of how the individual views the world around them (Rees, Home, & Beswick, 1995; Bunning, 1998; Johnson, Douglas, Bigby, & Iacono, 2010). It has also been thought that social interaction can lead to a longer life span, whereas social isolation may lead to a shorter life span (Seeman, 1996 and House et al., 1988 as cited in Babygirija, Zheng, Bülbül, Ludig, & Takahashi, 2010).

For teachers, knowing that a small class size may be most beneficial to students due to the opportunity for more one on one interaction, may be very important. With a smaller class size, students may be able to learn more quickly and obtain learned material for longer periods of time. For any teacher or caregiver dealing with a child who comes from a background of neglect, social interaction could be a preventative treatment. Especially if started at a young age, more social interaction could help reduce the chances of learning disorders. For animal trainers and animal rehabilitators, this information could be beneficial because it may help in the behavioral training of animals. Engaging with animals, such as cats and dogs, could save the lives of many good pets that otherwise may have to be euthanized due to overly aggressive behavior or other behavioral problems.

Some strange things happened over the course of the experiment. At one point, the experimenters thought that the male completely isolated rat was exhibiting self-mutilation behavior as his tail was often riddled with scabs that looked to be from scratching and biting. The experimenters began to grow very concerned for the rat's well-being when it was discovered that the female handled isolated rat was actually responsible for the wounds. The two rats were

housed next two each other in separate cages, but she had been biting the male completely isolated rat's tail whenever it accidentally slipped underneath the cage divider. Another strange aspect of the study was the fact that it had taken the control group rats so long to meet criteria when they were expected to be the first ones finished. Eventually, the experimenters had to use peanut butter to get them to eat the Honey Nut Spins® on a consistent basis. Prior to the introduction of the peanut butter, these two rats would only eat every other piece of cereal offered to them, and sometimes they would eat none at all. This goes to show that not all rats find Honey Nut Spins® rewarding. However, it was rather peculiar that both of the control group rats had acted this way, when none of the other rats had. The strangest occurrence of all happened during the male control group rat's last day of testing for Experiment 1. Somehow he managed to cut one of his front paws while in the maze. He had just completed criteria, but he was unable to finish the last trial of the day, so he was only able to complete five trials that day instead of the expected six. It is possible that this incident impacted his performance in Experiment 2.

Several limitations of this study exist. First, there were severe time constraints on this study. If given more than a semester to complete the studies, the female control rat would have actually been able to meet criteria for Experiment 1 and partake in Experiment 2. This would have allowed for a better understanding of how long it would take for a female control rat to meet criteria. Second, the experimenters only had access to a small sample size and unfortunately, could only test one rat per condition. In future research, experimenters should use a much larger sample size to ensure that the data collected are as accurate and as applicable as possible. One study with one rat being tested per condition does not yield the most reliable information possible. Third, the data from the rats may not transfer to humans. It is not ethical to

place people in complete isolation for the sake of science. Experimenters looking to further this research in humans would have to test the effects of social interaction in a classroom setting. As far as isolation is concerned, they would have to look to foster homes or other places where people who have experienced neglect or abuse are likely to go. This is a study that would have to be conducted on people after the effects of isolation have already set in. The results would most likely be collected through self-report and comprehensive tests, not by running through a maze. But this will not be able to be examined for quite some time.

What can and should be done in the near future, is to rerun the current experiment with more rats. Once that data is collected and considered beneficial, if the results are the same or similar, then the next step should be to focus more on the benefits of the handled isolated condition and the handled group condition. The goal of these experiments is to find the best learning environment, so it would not be as important to continue to look at isolation by itself.

In conclusion, it is possible that social interaction can enhance learning abilities as well as override the negative effects of social isolation. It is also possible that social interaction can lead to better, long term retention of a concept when paired with regular practice. Although the results of these studies came from a small sample of rats, this is a topic that deserves further investigation as it can positively impact society at large.

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Appendix

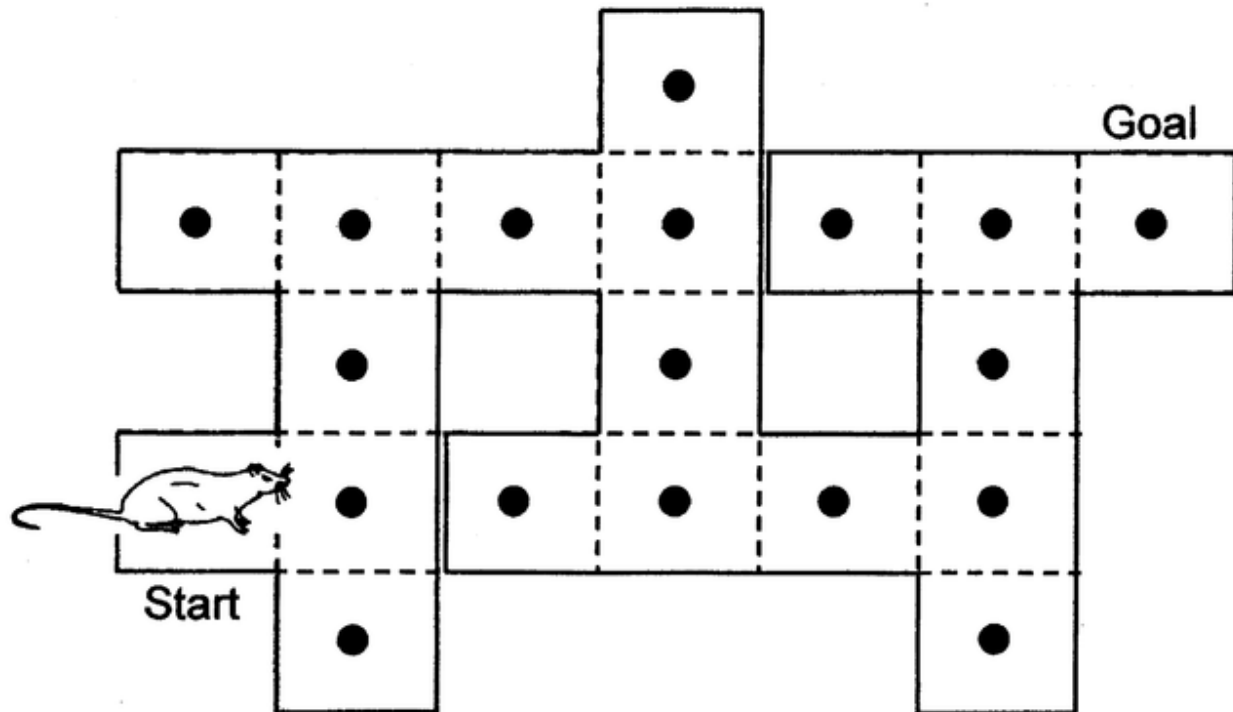


Figure A1: This is an MIT version of a Multiple T-Maze—three “T”s hooked together. This is what the experimenter looked at when trying to come up with a design for constructing her own Multiple T-Maze.

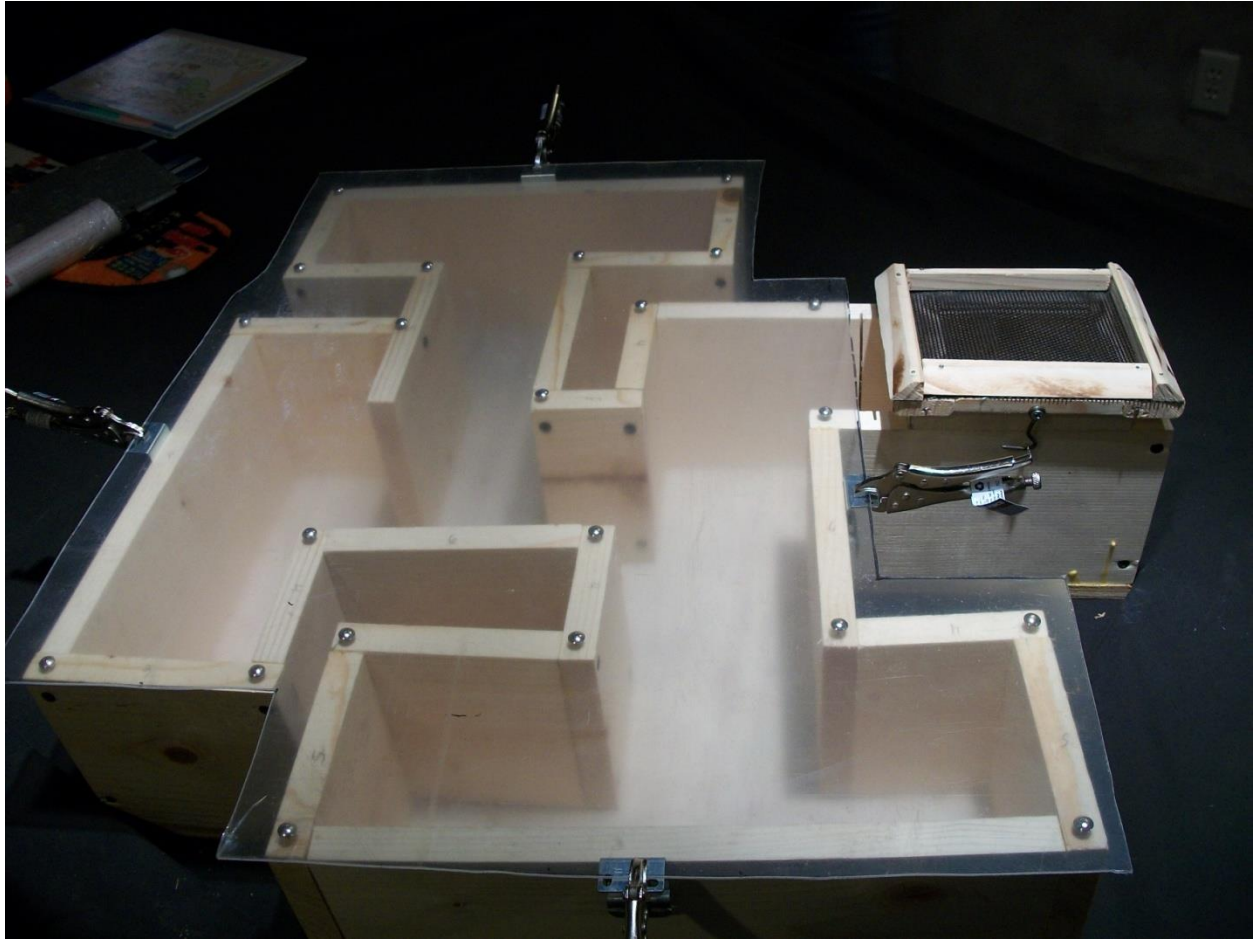


Figure A2: This is a picture of the actual maze used in the experiments. This was taken right after the maze was built.



Figure A3: This is a picture of the male handled isolated rat. He was the second rat to meet criteria. This picture was taken after the experiment was completed.



Figure A4: This is a picture of the female handled isolated rat. She was the first rat to meet criteria. This picture was taken after the experiment was completed.