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Abstract

The purpose of this study was to see what rats learn about the elements of a compound stimulus (a stimulus composed of two different stimuli), and whether their learning differs if the compound is from the same modality (intra-modal), i.e. both visual, or from different modalities (inter-modal), i.e. visual and auditory. We hypothesized that the rats would respond more to the compound stimuli than to the single stimuli (Pearce and Wilson, 1990), more to the compound modality of inter-modal elements than to the compound modality of intra-modal elements (Miller, 1971 and Gingras, 2009), equally to the intra-modal elements (Rescorla, 1972), and unequally to the inter-modal elements, possibly due to which element they paid attention to (Reynolds, 1961) or which element was of the greatest intensity (Birkimer, 1969). Our results showed that the rats learned the experimental (inter-modal) compound better than the control (intra-modal) compound, but that there was no difference in responding to any of the elements, so there was no attentional bias or intensity effect.

Investigating the Effects of Sensory Learning in Rats Using Intra and Extra Stimulus Modalities

Much psychological research has focused on animal learning and behavior. This is because so much can be learned about the intelligence of animals by how, what, and if, they learn. Learning is defined as a relatively permanent change in knowledge and behavior caused by past experiences, due to the formation of associations. It is said to be a relatively permanent change in knowledge and behavior because an animal may not always act the way that they have been taught to act. Learning is due to the formation of associations, which help an animal to predict the future. An association could form between a stimulus, response, and reward (Robbins, 2015).

A stimulus is anything that causes a response in the animal we are studying. Stimuli can be used in many experiments, such as behavioral task experiments. A researcher could present an animal with a stimulus and look for a target behavioral response – any response that the researcher has decided to have the animal learn. After learning this response, it will be used to document how, what, and if the animal is capable of learning. Stimuli can come from any of the sensory modalities – sight, smell, taste, touch, or hearing. Another aspect of stimuli is how they can be presented. A researcher could present a single stimulus to an animal, meaning that the animal would only have one stimulus, such as a tone, that would cause them to perform the target response. On the other hand, a researcher could present an animal with two separate stimuli presented at different times, such as a tone for 10 seconds and then a light for 10 seconds once the tone has finished, causing the animal to perform the target response (Robbins, 2015).

Finally, the researcher could present the animal with a compound stimulus. This compound stimulus could be made up of the same sensory modalities presented at the same time, such as 10 seconds of two lights flashing. Conversely, the compound could be made of different sensory modalities presented at the same time, such as 10 seconds of a tone paired with 10 seconds of a flashing light. As with the single stimulus, the researcher would measure the responding of the animal using a behavioral task, such as lever pressing, if they were working in a behavioral experiment (Robbins, 2015). Compound stimuli that are made of different sensory modalities are called intermodal or extra-modal, and compound stimuli of the same sensory modality are called intramodal (Miller, 1971).

The animal often learns to make the target response from the researcher pairing the response with a certain reward, often a food or drug reward. This reward will reinforce the behavior. For example, the stimulus could be a tone and the target response could be for a rat to look at the left side of the cage that it is in. If the tone plays and the rat looks at the left side of the cage, the rat would receive a food pellet for reward. This would train him to look at the left side of the cage whenever the tone is played (Robbins, 2015).

Three terms often seen with learning are acquisition, discrimination, and extinction. Acquisition training is the process of the animal learning the target behavioral task. Discrimination is defined as a different response to a new stimulus. In discrimination training, an animal may learn that a certain stimulus matched with a certain response culminates in a certain reward. After learning this, the researcher may present them with a different stimulus. If they respond differently to this stimulus, they have discriminated between the old learned stimulus and the new unlearned stimulus. Extinction is used when testing if the animal has discriminated. They will be shown their stimulus and perform their target behavioral task, but will not be given a reward. Although the animals do not receive a reward, the associations that they formed by learning during acquisition training do not disappear in extinction (Robbins, 2015).

Many experiments have shown that animals respond better when trained with a compound stimulus rather than a single stimulus. One such experiment is the Miller (1971) experiment. They trained 11 male albino rats with compound stimuli of the same modality, compound stimuli of different modalities, and a single stimulus. Using a lever press response, they investigated if rats respond more to compound stimuli than to a single stimulus. They found that rats responded better to compound stimuli, especially when the compound was formed from two different sensory modalities rather than the same modality (Miller, 1971).

Another experiment looked at the redundant target effect, where responses increase because two stimuli are presented rather than only one stimulus. The Gingras, Rowland, and Stein (2009) experiment looked at 4 adult male cats who experienced within modal (intra-modal) and cross modal (inter-modal) compounds of visual and auditory sensory stimuli, as well as the elements of each stimuli, to see if the increased responses would be attributable to the redundant target effect. The behavioral task was for the rats to orient to and approach the stimulus. Their results found that behavior increased more for cross-modal compounds than it did for within-modal compounds (Gingras, Rowland, and Stein, 2009).

A third experiment focused on the configural-cue approach and its impact on discrimination learning. The configural-cue approach assumes that a stimulus made up of different parts is learned as the summation of its parts rather than discriminated between its parts. Pearce and Wilson (1990) used three forms of compound stimuli as well as a single stimulus. They trained 48 male Sprague-Dawley rats to bar press and 28 adult homing pigeons to peck at a light when the compound stimuli were presented. Pearce and Wilson wanted to see if the animals would use a configural-cue approach to discrimination learning with the compound stimuli. They found that the animals that were presented with compound stimuli rather than the single stimulus responded more, meaning that they used the configural-cue approach (Pearce and Wilson, 1990).

The Nakagawa (2003) experiment looked at stimulus discrimination with compound stimuli of the same modality. Using 46 Sprague-Dawley male and female rats, they were looking at if rats would discriminate between compound stimuli of the same modality. Rats were trained to press down a stimulus card and enter a goal box for their food reward. They found that rats will discriminate between the separate elements of the same sensory modality (Nakagawa, 2003).

Robert Rescorla, a famous behavioral researcher, has studied responses to a compound stimulus compared to the responses to the compound's elements. Rescorla (1972) experimented with 16 male Sprague-Dawley rats to see if repeated reinforcement of a compound stimulus of the same modality could cause configural conditioning. They trained the rats to bar press when they are presented with the stimuli, which resulted in termination of the stimuli and presence of food reinforcement. They found that the responding to the compound and the responding to the elements of the compound were not significantly different, meaning that the rats did learn about the elements separately (Rescorla, 1972).

An additional experiment looked at discrimination and attention. The Reynolds (1961) experiment used a red background with a white triangle to look at attention and whether pigeons would show stimulus discrimination between the red and white stimuli when trained together and tested apart. They used 2 adult male White Carneaux pigeons and looked at the pecking response of pigeons to see if they show stimulus discrimination. He found that the pigeons discriminated between the elements – they would only pay attention to one element, so they only learned that one element meant food. Interestingly, each pigeon had paid attention to a different element, so there was no stimulus intensity effect. They pigeons pecked significantly more to the element that they had paid attention to (Reynolds, 1961).

Finally, the Birkimer (1969) experiment questioned if training with a compound stimulus, with different intensity elements, would cause differences in responding to the elements of the stimulus. They trained 4 albino male Sprague-Dawley rats to bar press during each presentation of the compound stimulus and then tested them in extinction with the elements of the compound stimulus presented separately. They found that the element with higher intensity exerted greater control over responding, while the element with lower intensity exerted less control over responding (Birkimer, 1969).

Succinctly, the Miller (1971) and Gingras, Rowland, and Stein (2009) studies showed that responding increases for compounds of different modalities over compounds of the same modality. Pearce and Wilson (1990) showed that compounds increase responding over single stimuli. Nakagawa (2003) showed that rats will discriminate between elements of the same modality. Rescorla (1972) showed that rats will responding equally across the board to the compound and to its elements when formed using the same modality. The final two studies theorized why they saw discrimination in the responses. Reynolds (1961) saw discrimination based on what element the pigeons paid attention to in the original compound. Birkimer (1969) saw discrimination based on what element was of the highest intensity.

The previous experiments form a basis for the present experiment, which examined if rats show stimulus discrimination when an association is first formed using a compound stimulus of different sensory modalities as well as a compound stimulus of the same sensory modality. These compounds were formed using two elements presented simultaneously. A food pellet reward was paired with each compound stimuli. The rats were then tested with their compound modality as well as the separate elements of their compound during extinction. We used 12 Harlan Sprague-Dawley rats to investigate what rats learned about each compound stimulus – if they learned about the elements of the compound as well as the overall compound. The behavioral task was nose pokes into the hopper. We have research to support of our hypotheses – that the rats would respond more to the compound stimuli than to the single stimuli (Pearce and Wilson, 1990), more to the compound modality of inter-modal elements than to the compound modality of intra-modal elements (Miller, 1971 and Gingras, 2009), equally to the intra-modal elements (Rescorla, 1972), and unequally to the inter-modal elements, possibly due to which element they paid attention to (Reynolds, 1961) or which element was of the greatest intensity (Birkimer, 1969).

Method

Subjects

Twelve male Harlan Sprague-Dawley rats, experimentally naïve. Species – Ratus norvegicus. Approximately 8 months old at start of experiment and an average of 461 grams at start of experiment. Housed individually and handled and weighed daily. Food deprived and kept at 83%-85% of adult free-feeding weight. They were kept on a light/dark cycle and tested during the dark phases. Water was continuously provided in the home cage.

Materials

Throughout the experiment we utilized the Coulbourn *Habitest*® - 11R 1 TC Rat 3X3 cage (dimensions 30 cm x 26 cm x 30 cm) with an H10 - 11R T C NSF non-shock floor. We also used an H14 – 23R 45 milligram pellet feeder with magazine opening 3.2 cm wide x 5 cm high and Graphic State V.2 software throughout the experiment. Throughout the experiment we used an H11-01R House light, an H12-06 Tone cue, and a Coulbourn Instruments LED. We also used the SONEic travel Sleep, Relax and Focus Sound Machine, model: SC3260GN on the brown noise setting in each room to muffle the sound of the tones in the other rooms. Coulbourn Instruments infared detectors were used to record nose poke data, which was measured in frequency, not duration, of the nose pokes. In the operant chambers, the hopper was placed in the middle of the wall with the house light on the left side above it and the LED lights pointing towards each other, level with the house light. In phase 1 the recorded data was the number of times the rat nose poked into the magazine opening during the 10 seconds of the compound stimulus, the 10 seconds before the compound was presented, and nose pokes for the pellet that dropped from the hopper. The rats were reinforced with TestDiet AIN-76A Rodent Tablet 45mg sugar pellets. Phase 2 was the number of times the rat nose poked during each single stimulus as well as during the compound stimulus in extinction. We could not adjust the intensity of any of the stimuli or measure the intensity.

Procedure

The pre-experimental training procedure was magazine training. The subjects were then randomly assigned to two groups using blocked randomization (see table 1). Group 1 (Control): compound stimulus was 2 LED lights placed together and house light (intra-modal). Group 2 (Experimental): compound stimulus was house light and tone (inter-modal). The experiment was then conducted, beginning with presentations of the compound stimuli. In Phase 1 there were 8 acquisition sessions where nose poking for the compound stimulus was reinforced by a sugar pellet reward. We operationally defined nose pokes as a single poke across the infared light, into the hopper. Each acquisition session consisted of 20 presentations of the rats' respective compound stimuli. Each presentation was 10 seconds of the compound and an average inter-trial interval (ITI) of 90 seconds. They were reinforced with sugar pellets on a variable interval (VI) schedule of 90 seconds. The software randomized the order of the trials, so that the order was different for each session. The acquisition sessions lasted an average of 36 minutes and 10 seconds. We then tested the rats in extinction with 2 presentations of each element and of the compound for the rats' condition, for a total of 6 presentations. This was also a randomized order with an average ITI of VI 90 seconds. During extinction, nose pokes were recorded during the 10 second compound stimulus presentations and the 10 seconds before the compound stimulus (see table 1). The test session lasted 10 minutes.

Results

We performed elevation ratios on the acquisition data from day 8 to determine which rats to include in the test data. We divided the compound nose pokes by the sum of the compound nose pokes and the pre-compound nose pokes. An elevation ratio above 0.5 shows that the rats learned about the compound, which allows us to factor them into the test data because we cannot look at what they learned about the discrimination if the rats had not learned the discrimination (see table 2). This is what allowed us to not use the data for rats 3, 7, and 11 because it is obvious that they were unmotivated during acquisition and had not learned the discrimination.

We calculated the means and standard deviations of responding during the same and different compounds at test. The control compound (M = 2.833, SD = 3.764) and the experimental compound (M = 6.000, SD = 5.899) were found to differ significantly when using a Mann-Whitney U test to compare the median number of nose pokes occurring during the extinction data; $p = 0.048$. The Mann-Whitney U test, rather than an independent samples t-test, was used because we had high variability in responding and a small sample size. Figure 1 compares the mean nose pokes during the compound presentations. These results suggest that rats learned the experimental compound better than they learned the control compound.

We compared the house light extinction responding in the same way. The control condition (*M* = 3.333, *SD* = 7.229) and the experimental condition (*M* = 0.600, *SD* = 1.341) were found not to differ significantly when using a Mann-Whitney U test to compare the median number of nose pokes occurring during the extinction data; $p = 0.206$. Figure 2 compares the mean nose pokes during the house light presentations. These results suggest that neither condition was more conducive to learning about the house light.

Again, we compared the individual stimuli extinction responding in the same way. The control condition (LED) (*M* = 0.833, *SD* = 1.329) and the experimental condition (tone) (*M* = 4.166, *SD* = 5.344) were found not to differ significantly when using a Mann-Whitney U test to compare the median number of nose pokes occurring during the extinction data; $p = 0.524$. Figure 3 compares the mean nose pokes during the individual stimuli presentations. These results suggest that rats did not learn the LED better than they learned the tone and vice versa.

Discussion

Our results showed more responding to the experimental compound than to the control compound, but no difference between the stimuli elements. We expected more responding to experimental than to control, as was shown in Miller (1971) and Gingras (2009). We did not run a statistical test comparing compounds to elements because Pearce and Wilson (1990) have already shows that there is more responding to the compound, which they have been trained with, than to the elements, which they have never seen alone before. We expected no difference in the control condition elements (Rescorla, 1972) but were surprised to see no difference in the experimental condition elements (Reynolds, 1961 and Birkimer, 1969). This suggests that there were no intensity effects (Birkimer, 1969) and no attentional bias in either condition (Reynolds, 1961).

Future research should use at least 30 rats to show a significant result and correctly counterbalance with more stimuli, including other sounds. The large number of rats would also help if some of the rats do not respond. There should be more acquisition sessions as well as longer acquisition sessions. They should take place daily and be comprised of more trials. Ideally, there should be a way to control the intensity of the stimuli (Birkimer, 1969). Future research could also use a more desirable reinforcement, such as cocaine, to increase responding. The weights of the rats should also be more controlled and kept in the 83-85% range.

Experimental errors begin with how little time and subjects we had for the experiment. Because we had such little time and subjects, we were not able to counterbalance correctly. We should have had another noise, preferably white noise, and two of each similar and different compounds, but we did not have enough stimuli to counterbalance correctly. It was also evident that our tone was much more intense than the light, especially with the knowledge that rats have good hearing and terrible vision. While running our experiment, there was a lot of outside noise from the hall. We also lacked consistency when running the rats – they were not run at the same time every day due to conflicting school and work schedules. The rats began magazine training and acquisition training before they were at the 83-85% range, which may have reduced their motivation. Another day of magazine training and more acquisition trials would have helped the rats to learn the discrimination. The rats' weights also fluctuated greatly during training. Three of the rats did not learn the discrimination, so we were not able to use them in our test data or analysis.

Our results showed that the rats learned the experimental (inter-modal) compound better than the control (intra-modal) compound, but that there was no difference in responding to any of the elements.

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	Phase 1		**Test**	
Compound	Stimuli	Measure	Stimuli	Measure
Control (Compound Visual)	2 LEDs and House Light	Nose Pokes (During presentation, 10 seconds pre-compound, and at pellet retrieval)	2 LEDs	Nose Pokes (During presentation and 10 seconds pre-compound)
			House Light	
			Visual Compound	
Experimental (Compound Visual + Audio)	Tone and House Light	Nose Pokes (During presentation, 10 seconds pre-compound, and at pellet retrieval)	Tone	Nose Pokes (During presentation and 10 seconds pre-compound)
			House Light	
			Visual + Audio Compound	

Table 1. Description of experimental procedure including stimuli and measurements during phase 1 and during testing.

Rat	Condition	Pre-CS	CS	Elevation Ratio
1	Experimental	11	52	0.825
2	Control	8	39	0.829
3	Control	0	0	Undef
4	Experimental	6	141	0.959
5	Control	16	198	0.925
6	Experimental	4	55	0.932
7	Control	5	1	0.166
8	Experimental	7	97	0.932
9	Experimental	0	105	1.000
10	Control	10	15	0.600
11	Experimental	0	0	Undef
12	Control	3	49	0.942

Table 2. Condition, pre-CS and CS responding from day 8 of acquisition, and elevation ratios for each rat, less than 0.5 were not included in test data.

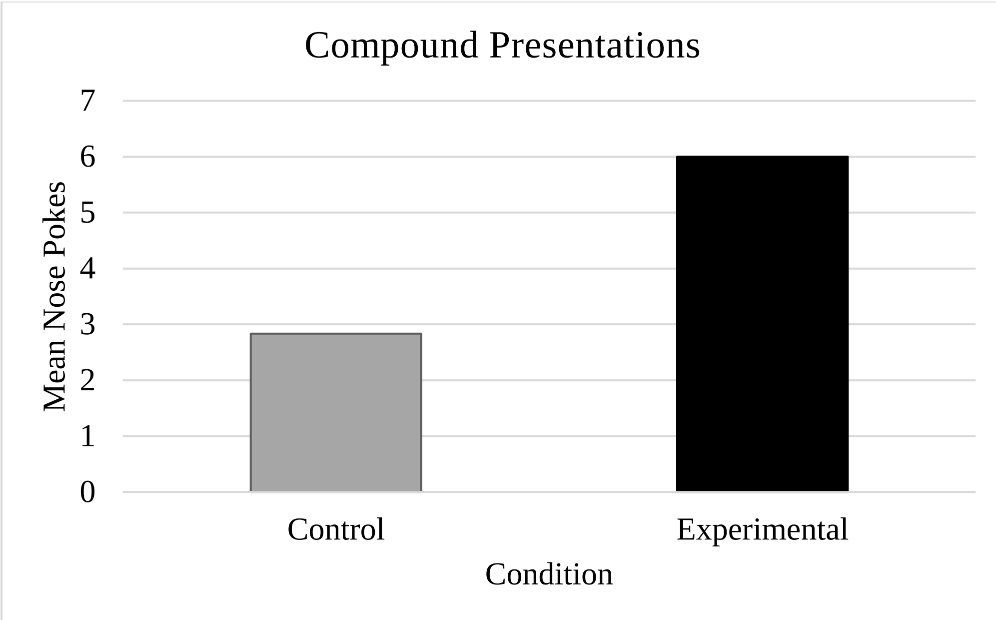

Figure 1. Mean nose pokes during presentations of the compound in extinction.

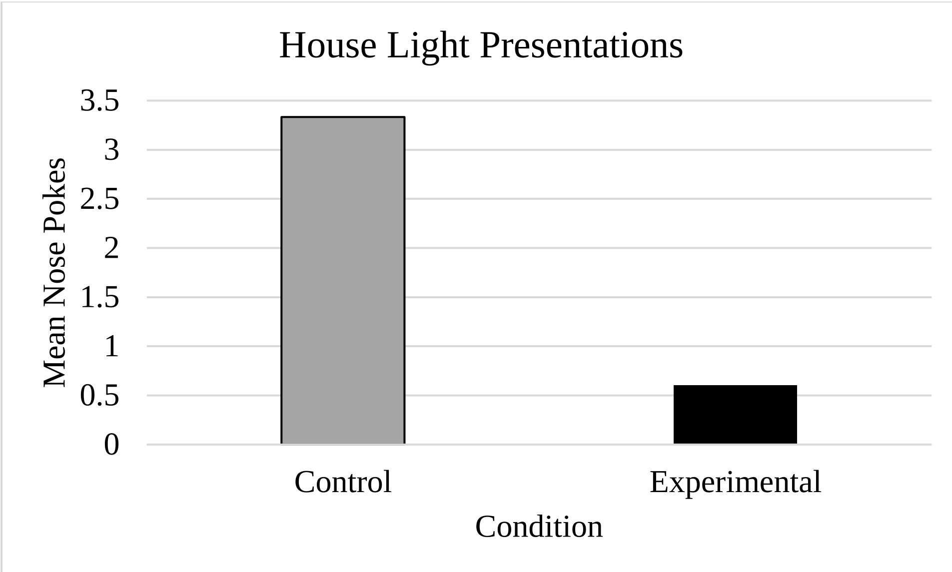

Figure 2. Mean nose pokes during presentations of the house light in extinction.

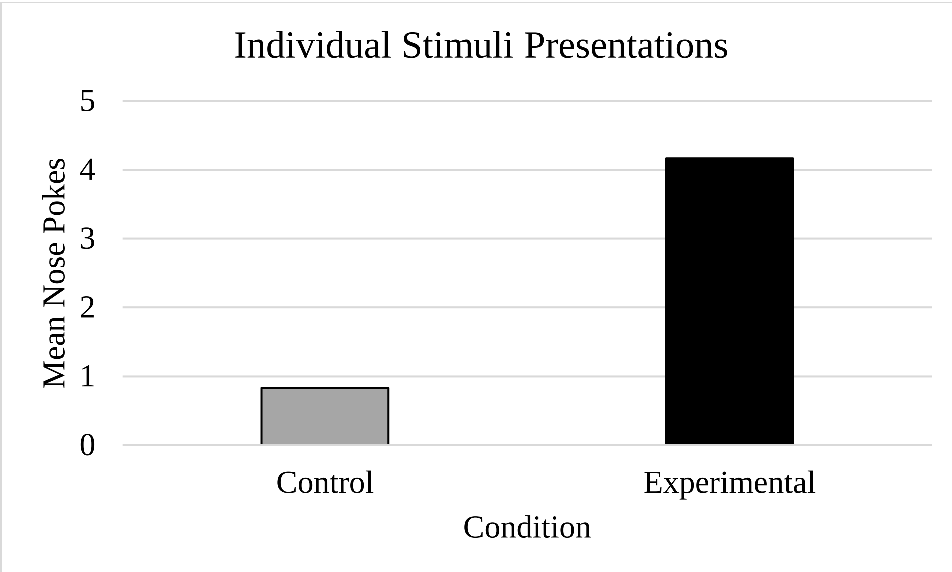

Figure 3. Mean nose pokes during presentations of the individual stimuli (control – LED, experimental – tone) during extinction.