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Is Competitive Behavior Controlled by its Consequences?

The Effects of Omission Training on Competitive Behavior in Rats

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Abstract

Recent research has examined competitive behavior in rats. When multiple rats are placed in an open field with a single feeder delivering pellets on a Variable Interval Schedule, the rats typically engage in a competitive wrestling response near the feeder tube. This response has been observed in several different experiments, but little is known about its specific nature. One possibility is that the response is a traditional operant. Although there is no explicit contingency with reinforcement, rats that do not engage in the response are unlikely to consume pellets. Alternatively, the competitive response might represent a species-specific foraging mode, controlled by the competitive foraging environment but not controlled by its consequences. The present experiments utilize an omission procedure, in which engaging in competitive responses cancels delivery of reinforcement. In Experiment 1 there was no difference in the rate of competitive response between the omission phase and the baseline phases. Although it would be tempting to conclude from these results that the behavior is not subject to its consequences, additional explanations must first be ruled out. The second experiment was aimed at eliminating any possible variables that may have affected these results to rule out possible alternate explanations. The results have implications for various biologically-oriented models of foraging.

Introduction

The proposition that behavior is controlled by its consequences is perhaps the most basic theoretical statement in all of behavioral psychology. The study of the correlation between behavior and associated consequences began with Thorndike (1911) who developed the *Law of Effect* as a theoretical statement of this relationship. According to the Law of Effect:

> "Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. (Thorndike, 1911)."

Skinner refined the Law of Effect in his book *The Behavior of Organisms* (1938), which introduced the theory of the operant. Skinner did not believe that all behavior could be described by a simple stimulus-response formula and attempted to explain the large array of behavior that does not appear to be elicited. Skinner referred to this seemingly "spontaneous" behavior as an operant. Operants are not conditioned by a stimulus that precedes them, as in Classical Conditioning, but rather are reinforced by stimuli that follow them. From this, Skinner developed the Law of Conditioning Type R, which states, "If the occurrence of an operant is followed by presentation of a reinforcing stimulus, the strength is increased (Skinner, 1938)."

Research after Skinner adhered to the methodology and technology he developed. Research in operant psychology has typically used highly controlled environments and studied one animal at a time. For example, Skinner designed an operant conditioning apparatus, which is often referred to as the "Skinner Box." This box contains a lever, which the animal must press in order to receive some sort of reinforcement, usually a small consumable. Skinner used this apparatus because it utilized physical behavior that was not extraordinary for the species and could be shaped reliably in almost every subject. Also, the response is unambiguous and will be made approximately the same way upon each occasion (Skinner, 1938). This apparatus and similar ones were used almost exclusively to study operant psychology for approximately 40 years after its invention. With this methodology came the belief that operant and classical conditioning were the only influences on behavior. Learning theorists at this time believed that any and all behaviors stemmed from these two types of conditioning.

One criticism of the Skinner Box methodology and learning theorists' emphasis on operant and classical conditioning as the only source of behavior was that it lacked biological relevance (Bolles, 1970). That is, animals very rarely perform these kinds of conditioned behaviors in their natural setting. Furthermore, animals are often faced with many other factors such as competition and predation that may affect their behavior in ways that cannot be observed using this equipment. Also, studies have shown that some responses are more quickly associated with a stimulus than others (Bolles, 1970). Neither classical nor operant conditioning accounts for this difference in association time. Clearly, behavior involves more than learning theorists originally believed. The Skinnerian highly-controlled study of behavior also came with three important basic assumptions: species differences do not matter, all animals enter the experiment as a blank slate, and that all responses are equally conditionable to all stimuli. This last assumption is known as the equipotentiality principal and was one of the most widely held. Behavior researchers at this time believed that a reinforcer has the same effect no matter what it is reinforcing. They thought that any stimuli that had previously been shown to elicit a conditioned response would be effective in conditioning any other response.

Over the last 30 years, there has been more emphasis on biological relevance in behavioral psychology. Several studies (Breland & Breland, 1961; Garcia, McGowan, & Green, 1972) have found that a highly controlled laboratory setting can influence the behavior of an organism in such a way that conditioning results may not accurately represent natural behavior. Instinctive behavior is one of the main areas of interest in this movement, and often seems to contradict Thorndike and Skinner's original theories of behavioral conditioning.

An early example of instinctive behavior overriding a learned behavior is found in Breland and Breland's "The Misbehavior of Organisms" (1961). In training animals for displays, they found that behavior other than that which they were conditioning often occurred unexpectedly. For example, when attempting to train a raccoon to place a coin in a container through traditional operant conditioning methods as described by Skinner, Breland and Breland found that after the behavior had been conditioned, over time, the raccoon would cease performing the behavior. They noticed that instead the raccoon displayed instinctive behaviors having to do with eating, such as rubbing the coin up against the inside of the container, pulling it back out, and clutching it. These behaviors mimicked those of "washing-behaviors" that raccoons often do before eating.

Breland and Breland (1961) termed this phenomenon "instinctual drift," because it was a situation in which specific learned responses gradually drifted into behaviors different from those that were conditioned. The behavior occurred even though it was not reinforced and prevented the animal from receiving a reward. This represents a clear failure of conditioning theory. Breland and Breland believed that instinctual drift sufficiently refuted the three previously held assumptions of behavioral conditioning theories. The fact that each of the animals treated the object differently, even when the researchers were attempting to condition them to treat it in the same way, demonstrated that species differences do matter. Secondly, it was clear that the animals did not enter the exercise as a blank slate since the conditioned response was quickly overridden by biological behaviors. Finally, instinctual drift violates the equipotentiality principal. The food, which for some time acted as a sufficient reinforcer, suddenly was no longer able to elicit the conditioned response.

Garcia et al. (1972) also studied biological influences on the equipotentiality principal in animal behavior. In their study, they paired sweet water ("sweet tasty water"), and water with an audio-visual cue ("bright noisy water") with shock, poison or x-rays. They found that not all conditions were conditioned equally. Taste aversion to the sweet tasty water was successfully conditioned to the poison and the x-ray, but not the shock. The bright noisy water, on the other hand, had the exact opposite effect. Taste aversion of bright noisy water was successfully conditioned to the shock but not the poison or the x-ray. These findings violate the equipotentiality principal because the conditioned stimulus was only effective in some of the cases but not others. They found that stimulus pairings that were most likely to occur in nature were more easily conditioned. For example, in nature, things that make an animal sick are likely to be paired with a specific flavor. Likewise, physical pain usually comes from an attack, which often has an audiovisual cue. This study suggested that what was most important was not that a stimulus had elicited a conditioned response previously, but that the pairing of stimuli was biologically relevant.

As a result of these and several other studies that found similar effects on behavior when studied in unnatural laboratory settings, research began to move away from Skinner box technology. Research has moved to larger enclosures that more closely mimic the animal's natural environment. Also, researchers studying behavior now examine many different species, and observe species-specific behavior. Perhaps most importantly, research has begun studying more than one animal at a time. This adds an additional element of competition into the equation, and creates a more realistic setting.

It is well known that competition is an important aspect of every animal's life. Animals in nature compete for many things including food, territory, and mating partners. Before the recent shift to a more natural approach to behavioral psychology, competition was almost exclusively studied in a natural setting. Only recently has there been a movement to investigate competitive behavior in the laboratory.

Competitive behavior has been observed in previous studies (Farmer-Dougan & Dougan, 2005; Farmer-Dougan, Wise, Calderala, Tichardson & Dougan, 2008). Farmer-Dougan and Dougan (2005) studied behavioral contrasts in a group foraging paradigm. They observed that when two rats were in an open field environment with one feeder, they would engage in a sort of "competitive wrestling" behavior in the area of the feeder. In this behavior, the rats would climb over each other in an apparent attempt to be nearer to the feeder when food was delivered. This behavior was later formally studied and coded by Schnupp (2008). Schnupp classified two main behaviors under the category of the competitive wrestling behavior: number of jumps over the other rat and number of times pushing the other rat with a paw. Schnupp also found that rats spent significantly more time engaging in this competitive wrestling behavior when the competitor was predictable (present in every trial) and more time away from the feeder when the competitor was unpredictable (introduced only on the test trial). Although this competitive behavior has been found to be robust, its origin is still unknown.

Two different theories could be applied to this competitive wrestling behavior. Farmer-Dougan and Dougan (2005) hypothesized that the response could be the result of operant conditioning. The wrestling behavior may be an example of a naturally occurring operant as defined by Skinner (1938). Once the behavior began it became virtually necessary for a rat to continue to engage in the response in order to be near the feeder when the food was delivered. Therefore, when it received the food it was reinforced for the wrestling behavior. However, reinforcement was not contingent upon the wrestling behavior and therefore it was not necessary for the rats to engage in the behavior to receive a reinforcer, and thus operant theory may not explain the behavior.

An alternate interpretation is that this wrestling behavior might represent a species-specific foraging mode, controlled by the competitive foraging environment but not controlled by its consequences. Because receiving the food is not contingent upon the response, yet it still occurs reliably, some believe that instinct may better describe this particular behavior. If the response is a species-specific instinctive foraging behavior and not controlled by its consequences it should occur regardless of whether or not the food is presented and should persist even if the food is removed as a result of the behavior, much as was seen in Breland and Breland's (1961) examples of instinctual drift.

Timberlake (1994) created a biologically determined organization of behavior called the behavior systems theory that may accurately describe this kind of instinctive response. According to this theory, animals possess instinctive behavior systems such as feeding, mating and defense. Each system serves a specific need and is independent of all other systems. In this theory, the environment can modify instinctive behavior systems.

There are five hypothesized levels within the behavioral systems theory: system, subsystem, mode, module, and action pattern. The system level includes the categories mentioned before and refers to the tendency for behavior to be organized around biologically important functions. Subsystems are strategies for advancing the function of the overall system. For example, predation is a subsystem of the feeding system that involves an increased likelihood of chase or capture responses. Modes are motivational substates underlying the sequential and temporal organization of strings of responses such as handle or consume. Modules are groupings of stimulus filters such as socialize or investigate. Action patterns are individual specific responses such as paw or grab. These five levels represent the complex biologically predetermined behaviors within an animal, and the environment determines which system will be activated.

To differentiate between conditioned behavior and instinctive behavior, the temporal relationship between the response and the reinforcer must be eliminated.

Omission testing is a common method used to accomplish this. In omission testing, the reinforcer (e.g. food) becomes contingent upon the behavior not occurring and therefore ensures that the response will never be reinforced. Williams and Williams (1969) used omission testing for a similar purpose in their study of the Auto-Maintenance phenomenon in pigeons. Brown and Jenkins (1968) had discovered that pigeons would reliably peck at a lighted key that indicated the arrival of food even when receiving the food was not contingent upon the pecking response. This experiment appeared to be an example of classical conditioning with the light acting as the Conditioned Stimulus and the pecking as the Unconditioned Response. However, before this it was believed that classical conditioning only occurred with visceral, or involuntary, muscle responses. Auto-maintenance appeared to be an example of classical conditioning of a skeletal muscle response, which opposed the previous distinction between classical and operant conditioning responses.

By using omission testing, Williams and Williams found that the key pecking persisted even when the response prevented obtaining the food. Furthermore, Jenkins and Moore (1973) found that the pecking response qualitatively differed when the reinforcer was food or water and most closely imitated the responses associated with eating or drinking, respectively. This is an example of stimulus substitution in which the key became a substitute for whatever the reinforcer was and therefore the animal reacted instinctively toward the light as it would the stimulus itself. This substitution persisted even in the absence of the reinforcement much as instinctive behavior occurs without reinforcement.

The present study used omission testing to examine whether the wrestling behavior in rats previously observed was an operant or if it represented a species-specific biological foraging behavior. Rats were placed in an open field environment with one feeder dispensing food at variable intervals. When the wrestling behavior occurred, the food was not given. A discontinuation of competitive behavior would be strong evidence to support that the response was subject to its consequences. However, if the behavior continued despite the lack of reinforcement, it would suggest that the behavior was governed by biological factors.

Experiment 1

Methods

Subjects

Eight male Sprague-Dawley rats, approximately six months old, served as subjects. Rats were housed two to a cage and kept on a 12-hour light/dark cycle with free access to water. Rats were maintained at a minimum of 80% *ad libitum* body weight throughout the experiment. Animal care followed the guidelines advised by the Guide for the Care and Use of Laboratory Animals.

Apparatus

A rectangular open field box of approximately 1.25 m by .75 m with 30 cm walls was used for all testing. One feeder was mounted inside the box at the north corner. One stainless steel "foraging" pan was located directly below and in front of the feeder. The pan was positioned such that food pellets dropped from the feeder fell directly into the foraging pan. This apparatus was similar to that used by Schnupp (2008). All experimental events were controlled via a Windows PC running Med Associated Med-State software connected to a Med Associated interface.

Procedure

All rats were acclimated to the foraging box prior to the start of the experiment. The experiment proper began after all rats, when alone in the apparatus, were reliably approaching the feeders when a pellet was delivered. The experiment consisted of three distinct phases – a baseline phase, followed by the omission testing, followed by a second baseline phase. Each rat was randomly paired with a rat other than that with which it was housed, and the same pairs were maintained throughout the experiment.

Baseline Phase 1: At the start of each session, both rats were placed in the center of the apparatus simultaneously. The session began immediately after the rats were placed in the chamber and continued for 20 minutes. The feeder delivered food pellets on a variable interval (VI) 30 second schedule independent of the rat's behavior. During the session researchers recorded the amount of time he or she observed the rats engaging in competitive wrestling behaviors and used a stopwatch to record the amount of time. The baseline phase lasted for nine days.

Omission phase: These sessions began the same as the baseline sessions with the rats being placed in the apparatus together, and also lasted 20 minutes. The researchers had a switch that was turned off when competitive wrestling behavior was observed and turned on again when the behavior ceased. This switch blocked any food from being delivered when it was in the off position and allowed food to pass when it was on. Therefore, the competitive wrestling behavior was never followed by reinforcement.

The researchers once again timed the behavior using a stopwatch. The omission phase lasted six days.

Baseline Phase 2: The second baseline phase was conducted the exact same way as the first baseline phase. This phase lasted three days.

In the event that the any rats became aggressive to the point of injury during the study the experimenters removed them as quickly as they could without risking injury to themselves.

Results and Discussion

The mean time spent engaged in the competitive behavior for the last three days of each session was calculated for each pair of rats. A graph of these means can be found in Fig. 1. As seen in Figure 1, there were no clear systematic trends across any of the phases. Three of the pairs of rats (1&3, 5&7 and 6&8) did show a slight decline from the baselines to the omission phase, but this difference is too small to draw any conclusions. Furthermore, rats 2&4 showed a steady increase in behavior over all three phases. Overall, Figure 2 shows that the competitive behavior during the omission phase was not systematically different from the behavior in either of the baseline phases.

The means from the last three sessions of each of the phases were analyzed using a one-way within subject ANOVA. No significant differences were found across any of the three stages, F(2,6)=1.23, p=.357. It would be tempting to conclude from this that competitive behavior is not subject to its consequences. However, this would amount to confirming the null hypothesis. All that can be concluded from the data in Experiment 1 is that there is no current evidence that the behavior is the product of operant conditioning.

Because Experiment 1 yielded non-significant results, a second experiment was necessary to eliminate other alternative explanations for the data. One possibility was that the rate of food delivery was not high enough, leading to a minimal amount of competitive behavior overall. Secondly, it was possible that too few subjects were used to detect significant results. It was also possible that the lack of consistency in days in each phase as well as the short amount of time spent in each phase could have affected the results. Finally, during the experiment, it was observed that the rats often began engaging in the competitive behavior following the sound of the feeder. It was possible that the rats associated the sound of the feeder with the food and were responding to the sound.

Experiment 2 attempted to address these possible variables. A shorter VI schedule was used to increase the rate of food delivery. Each session was longer and conducted over a uniform amount of days. Additionally, a second feeder was placed next to the original feeder. The second feeder regularly sounded as if food were being delivered, yet delivered no actual food. Thus, the rats were unlikely to be able to associate the sound of the feeder with receiving food.

Experiment 2

Method

Subjects

This experiment used 16 male Sprague-Dawley rats. Eight of the rats were from the previous experiment and thus approximately nine months old and eight were experimentally naïve and were approximately six months old. The housing arrangements were the same as in Experiment 1, and the rats were once again maintained at a minimum of 80% *ad libitum* body weight throughout the experiment.

Apparatus

This experiment utilized the same open field box as the previous experiment. The only alteration made was the addition of a second feeder next to the first, which sounded as if it were distributing food, but did not actually deliver any food. This feeder was not connected to the omission switch, and therefore continued to make sound during the omission phase, regardless of whether or not food was being delivered.

Procedure

The experimentally naïve rats were acclimated to the foraging environment. The experiment proper began after all rats, when alone in the apparatus, were reliably approaching the feeder when a pellet was delivered. The rats from the previous experiment were kept in the same pairs and the experimentally naïve rats were randomly paired, once again avoiding pairs that were housed together. This experiment consisted of the same three phases as Experiment 1: baseline 1 phase, omission phase, and the second baseline phase. Each phase lasted eight days. A VI-15 schedule was used in this experiment to increase the rate of competition. Each session lasted ten minutes. The second feeder was placed next to the first feeder and ran on a different VI-15 schedule.

Results

The mean time spent engaged in the competitive behavior for all eight days of each session was calculated for each pair of rats. These means are plotted across sessions in Fig. 2. As seen in Figure 2, there were no consistent changes in competitive behavior during the omission phase relative to the surrounding baseline phases. Only two of the eight pairs of rats (2&4, and 5&8) showed a lower rate of competitive behavior in omission relative to both baselines, and the effect was quite small. However, two of the pairs (9&11 and 14&16) showed the opposite effect more substantially, while the remaining four pairs showed a general decline across all conditions of the experiment.

The data in Figure 2 were further analyzed using a one-way within subjects ANOVA. The ANOVA revealed a significant difference: $F(2,14)=3.86, p<.05$. Two dependent sample t-tests were used as post hoc tests. Since this experiment focused on any changes between baseline and omission phases, the two t-tests tested whether there was a significant difference between the first baseline phase and the omission phase, as well as whether the omission phase was different than the second baseline phase. There was no significant difference found between the first baseline phase and the omission phase: $t(7)=.386, p=.711$. A significant difference was found between the omission phase and the second baseline phase: $t(7)=2.644, p<.05$. However, this difference was not in the direction predicted by the hypothesis. The amount of time the rats spent engaging in the competitive behavior decreased from the omission phase to the second baseline phase. The hypothesis predicted that the behavior would decrease during the omission phase or remain constant.

General Discussion

The present study examined whether competitive behavior observed by Schnupp (2008) and Farmer-Dougan and Dougan (2005) is sensitive to its consequences. Two experiments were conducted in which rats were placed in an open field box with one source of food, and competitive behavior was observed and timed. An omission procedure in which engaging in competitive responses canceled delivery of reinforcement was used to determine whether or not the behavior was subject to its consequences. The second experiment was aimed at eliminating possible variables that may have influenced the results of the first.

Overall, no significant results were found in the hypothesized direction, thus there was no evidence to suggest that the competitive behavior is sensitive to its consequences. The rats showed no decrease in the amount of time spent engaging in the behavior significantly during the omission phase relative to the baseline phases in either experiment.

The present results may have implications for the classic distinction between operants and respondents. Skinner (1938) defined two classes of learned behavior: operants and respondents. Among several defining characteristics, operants are controlled by their consequences. Respondents, on the other hand, are elicited by stimulus conditioning. For example, bar pressing for food reinforcers would be an example of an operant, while the classical conditioning described by Pavlov (1927) in which dogs were conditioned to salivate to the sound of a bell, would be classified as a respondent. Distinguishing between operants and respondents is not always easy. The omission procedure used in the present experiment is one way this has been done.

In the past, omission procedures have been used to argue that a particular response is a respondent and not an operant. For example, Williams and Williams (1969) also used omission training to determine whether an autoshaped keypecking behavior was operantly conditioned or a biologically determined respondent. They found that the behavior being examined did not decrease during omission training when compared to baseline levels. The lack of decrease in behavior indicated that contingencies of reinforcement alone did not determine when or how strongly this behavior would occur. There is something other than operant conditioning shaping and influencing the rate of this behavior.

The results of the current study suggest that the competitive behavior is not an operant as Skinner defined it, because the behavior did not significantly decrease during the omission phase. Instead, the behavior continued at a fairly consistent rate, indicating that it is more influenced by inherent biological factors than the environment.

If this competitive behavior is not an operant, what could it be? The behavior is consistent with the behavior systems model proposed by Timberlake (1994). There are many subsystems within the system of feeding that Timberlake has discussed, including foraging and predation. It is likely that there is also a subsystem of competition that contains within it all of the behaviors necessary for animals to eat in an environment in which there are multiple organisms vying for the same food source. Since rats are social animals and tend to forage in packs, it would be necessary for them to be able to effectively compete for limited resources. It is likely that any rat that was not biologically predisposed to competing would receive very limited amounts of food and would therefore not survive very long in the wild. The behavior observed in this experiment may be a specific action response within this competition subsystem. If this is the case, then the competitive behavior is biologically programmed into the rats and is activated by the feeding environment in which they are placed within the procedure of the experiment. Knowledge of these behavior systems may enable successful prediction of the form of conditioning as a function of the type of stimulus being used and its relationship to the behavior being elicited.

Timberlake's behavior systems theory is an interesting alternative to previous theories on respondent behaviors. Before Timberlake's theory, stimulus substitution (Jenkins & Moore, 1973) was considered one of the best explanations for the origin of respondents. Jenkins and Moore (1973) found that often the response to the conditioned stimulus mimics the response to the unconditioned stimulus. For example, in Pavlov's experiment, dogs salivated to the sound of a bell. Although salivation is typically a digestive response to eating food, the animal began to respond to the bell as it would respond to eating food over the course of classical conditioning, and thus the respondent was formed. Using high-speed photographs, Jenkins and Moore's found that pigeons would peck at a lighted key differently if this stimulus were followed by food or water. When the key was followed by food the pigeons made short pecking motions, whereas when it was followed by water, the response mimicked that of drinking. This showed that respondents were not simply a response to the stimulus but an actual substitution of one stimulus for the other.

Although the stimulus substitution theory is interesting and can be applied to a wide variety of respondents, there are still many responses to stimuli that cannot be explained by this theoretical framework. For example, approaching a stimulus is a respondent that could not be explained using this theory, however it is a common response for many animals that are confronted with a stimulus such as food. Furthermore, the competitive behavior observed in this experiment is not an example stimulus substitution. In this case the food is the unconditioned stimulus and the competitive behavior is the respondent. Smacking and fighting are not typical responses made by a rat toward food when it is presented, and therefore this competitive behavior is not an example of an animal substituting one stimulus for another.

Timberlake's theory of behavior systems does a better job of explaining these behaviors that are not a result of stimulus substitution. Instead of focusing on the role of the unconditioned stimulus in strengthening associations, this theory focuses on the relation of conditional responding to the preorganized perceptual, motor, and motivational organization engaged by the unconditioned stimulus. In doing so, it takes into account the biological as well as environmental factors, and how they influence each other in shaping and eliciting behavior.

Although the present results are consistent with a behavior-systems model, strong conclusions cannot be drawn at this time. It is possible that the results found were due to methodological issues. First, the overall decline of the baseline phases in the second experiment could be a sign that the data collected were unstable. It is possible that the rats did not have enough days in each of the phases to adjust to the environment. Further research may be needed to investigate whether more sessions would even out this trend. Typically, in behavior experiments, sessions are run in each phase until the behavior becomes stable. By doing this, researchers can be confident that the animals have become accustomed to the environment, and that any change in behavior is the result of experimental manipulations and not to unrelated factors. This process may require each schedule to run for a month or more. However, due to time constraints in the present experiment, sessions were limited to a certain number of days rather than allowed to run until stabilization.

A second possible methodological issue that may have affected the results of the second experiment was that there was a one week break in between the last day of the omission phase and first day of the second baseline phase. During this week, the rats remained food deprived, but no experimental sessions were run. Since there was a significant overall decrease in behavior from the omission phase to the second baseline phase, it is possible that this lack of activity had an effect on the rate of behavior. Ideally, the experiment would be conducted over consecutive days with no such break.

Finally, there could be some other unknown variable causing the overall behavior to decrease over time. It is possible that there were additional confounds present, but not mentioned here. Further research is necessary to determine whether there are additional variables other than these that are affecting the overall rate of the behavior over baselines.

In addition to methodological issues that may account for the declining baselines, other issues may have affected the results in different ways. As in the first experiment, it is possible that either the VI schedule used or the length of each session did not allow the behavior to occur at an optimum rate. There also may have been minute differences in the sounds of the two feeders that could have been detected by the rats and allowed them to discriminate between them. If this is the case, it is still possible that they were responding to the sound of the feeder rather than spontaneously engaging in the competitive behavior. Also, the second feeder continued to run on a VI-15 schedule during the omission phase regardless of whether or not the reinforcing feeder was shut off. This meant that the rats may have still heard and responded to the sound of the second feeder even though they were not receiving any actual food reinforcement. This could have lead to more competitive behavior during the omission phase than there would have been if both feeders had been silenced when the behavior was occurring.

It would be beneficial to have a control group of rats for which the VI schedule was manipulated during the omission phase. During this phase, all reinforcement ceases for a substantial amount of time, essentially altering the rate of reinforcement delivered. This could affect the rate of the behavior apart from whether or not it is subject to its consequences. By having a group of rats that receive a VI-15 schedule on the baseline phases and a straight VI-30 schedule during the experimental group's omission phase may help control for this lesser rate of reinforcement.

Beyond the elimination of possible alternative explanations, the present research has implications for future studies in competitive foraging behavior in general. Similar studies could be done using more than two rats to increase the level of competition. Another possibility would be to increase the number of feeders available, and vary the rate of reinforcement of each.

Another theoretical issue that future research could investigate is what role, if any, ideal free distribution (Fretwell & Lucas, 1970) and the matching law (Herrnstein, 1961, Baum, 1974) would play in shaping this and other similar competitive behaviors. Ideal free distribution is an equation that predicts how a group of animals will distribute themselves among a limited amount of resources. The equation is $N_1/N_2 = R_1/R_2$, in which N is the number of animals and R is the rate of response. In other words, animals will distribute themselves among areas of resources in proportion to the number of resources that are in each area. According to this equation, the two factors that affect where an animal will choose to feed are competition and rate of food delivery. The matching law is a similar equation, however it predicts how an individual animal will allocate its time to multiple sources of resources. The equation is $B_1/B_2 = r_1/r_2$ wherein B is the behavior and r represents the rate of reinforcement. This means that the amount of time an animal should spend at one area should be in proportion to the rate of reinforcement there, compared to the rate of reinforcement elsewhere.

Although these two models were developed independently, they work well together and represent similar ideas. One way that they work together is that if there is a group of animals in which each animal is following the matching law, then on average the group will follow ideal free distribution as well. It would be interesting to see whether the rate of competitive behavior changes when rats are forced to choose how to allocate their time among several food sources. In addition to how they allocate their time, future research could also investigate whether the behavior itself is altered when there are more than two rats competing for multiple food sources.

Future research could also be conducted to investigate whether dominance plays a role in this competitive behavior. In the present experiment, it was observed that when the rats were not competing during the trials, one of the rats often stayed at the feeder with its nose inside the feeding tube, preventing the other rat from receiving any food pellets. The other rat would often sniff around other parts of the cage or position itself below the other rat, eating any food pellets that were dropped. Throughout all of the sessions, it seemed that the same rat in each of the pairs monopolized the time at the feeder, which could mean that it was the dominant of the two. Future studies could investigate whether or not this rat receives more food than the other rat, or if the rats are able to compete for equal amounts of food. Studies could also purposefully pair rats that have been shown to be dominant or non-dominant in other groups to investigate whether these dominance roles affect the rate or manner in which the animals compete for food.

Another way in which this study could be applied to future research would be to observe species other than rats in similar competitive situations. In particular, it would be interesting to investigate whether species that are less social than rats develop an equally ritualistic fighting behavior as the subjects observed in this experiment. It is possible that less social animals that do not normally forage in groups may display more aggressive or violent behavior when forced to fight for a limited supply of food, rather than engaging in a mostly non-violent leaping behavior.

In summary, Experiments 1 and 2 found no significant difference in competitive behavior when receiving food was contingent upon not engaging in the behavior. This behavior seems to more closely follow theories of biological behavior rather than conditioned or learned behavior. However, further research is still necessary to eliminate any possible methodological concerns as well as any other variables that may have influenced the current results. The findings of this and future experiments regarding this competitive behavior may lead to more insight into and further research on biologically oriented models of behavior.

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Graphs and Figures

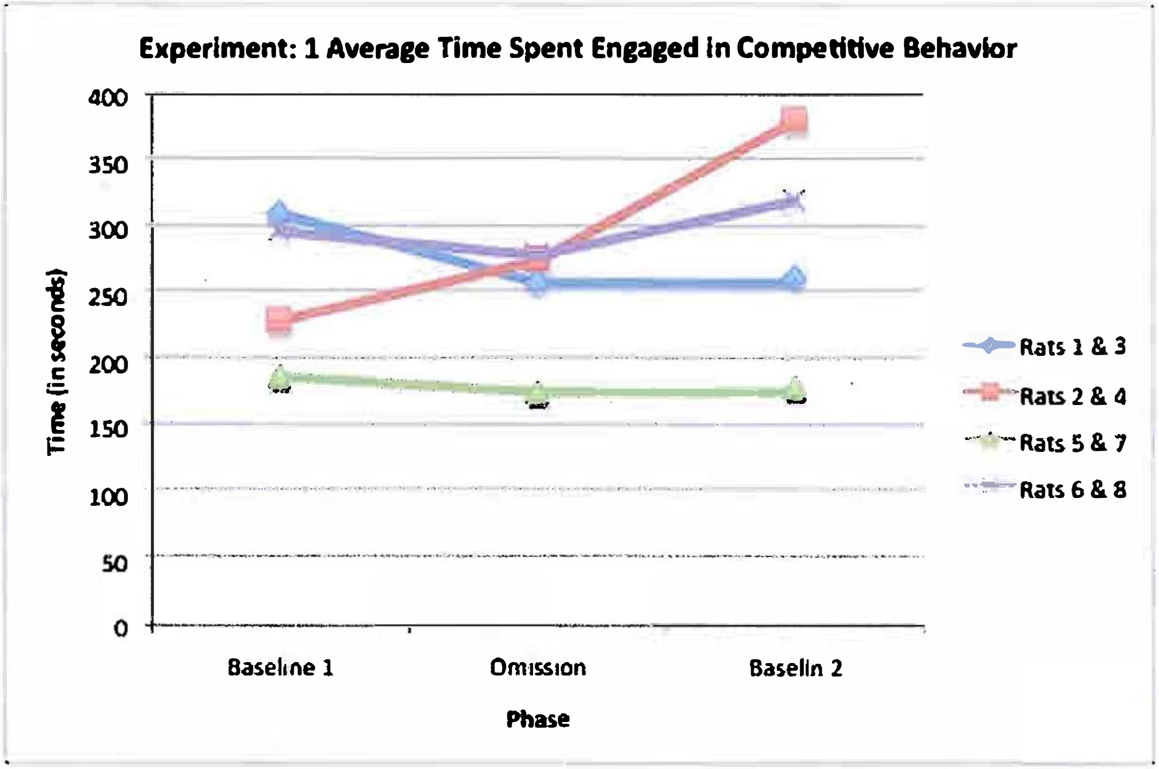

Fig. 1 Graph of the mean time each pair of rats spent engaged in competitive behavior in the last three days of each of the three phases.

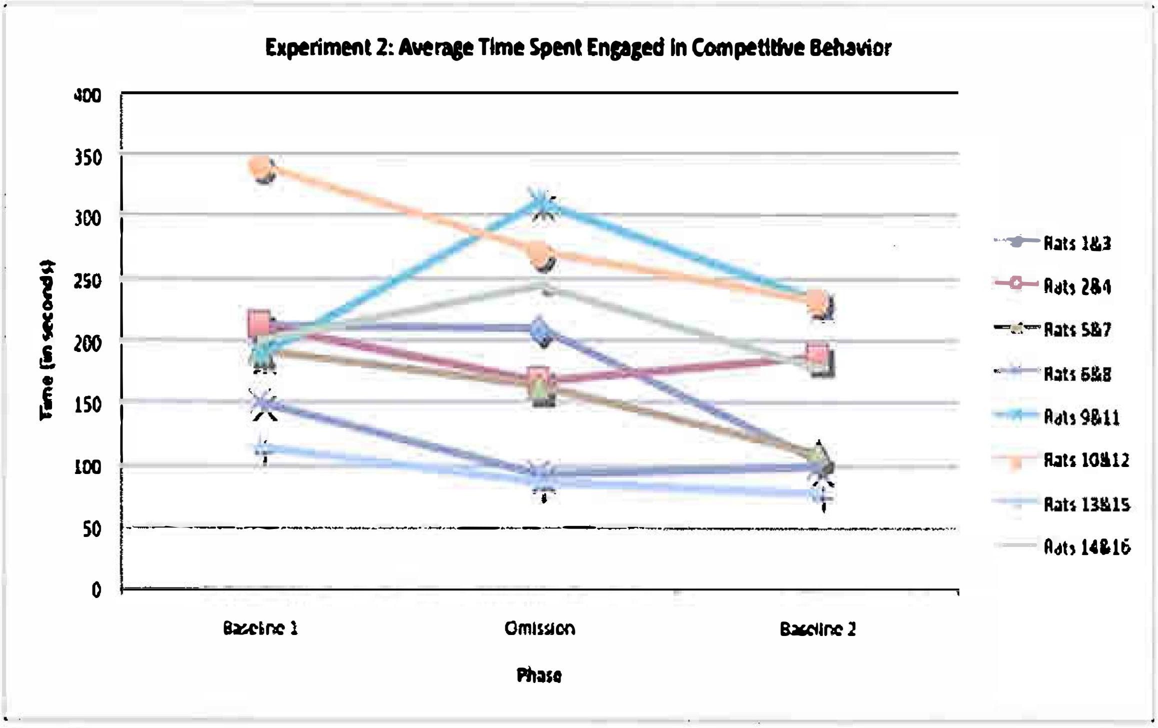

Fig. 2 Graph of the mean time each pair of rats spent engaged in competitive behavior in each of the three phases.