



2007

## Satiation, Habituation, and Elasticity: An Economic Analysis

Amanda Zang '07  
*Illinois Wesleyan University*

Follow this and additional works at: [https://digitalcommons.iwu.edu/psych\\_honproj](https://digitalcommons.iwu.edu/psych_honproj)



Part of the [Psychology Commons](#)

---

### Recommended Citation

Zang '07, Amanda, "Satiation, Habituation, and Elasticity: An Economic Analysis" (2007).  
*Honors Projects*. 30.

[https://digitalcommons.iwu.edu/psych\\_honproj/30](https://digitalcommons.iwu.edu/psych_honproj/30)

This Article is protected by copyright and/or related rights. It has been brought to you by Digital Commons @ IWU with permission from the rights-holder(s). You are free to use this material in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/ or on the work itself. This material has been accepted for inclusion by faculty at Illinois Wesleyan University. For more information, please contact [digitalcommons@iwu.edu](mailto:digitalcommons@iwu.edu).

©Copyright is owned by the author of this document.

Running head: SATIATION, HABITUATION, & ELASTICITY

Satiation, Habituation, and Elasticity:

An Economic Analysis

Mandy Zang

Illinois Wesleyan University

## Abstract

Response rates typically change systematically within operant conditioning sessions. Proposed explanations for this phenomenon include habituation and satiation. The present study investigated these explanations. Six Sprague-Dawley rats were exposed to a series of variable interval (VI) schedules. Each schedule consisted of a baseline, same pre-feed, and different pre-feed condition. During the same pre-feed, the rats received the same food as was earned during the session, whereas in the different pre-feed, the rats received a food that differed from that earned during the session. A larger decrease in responding during a same food pre-feed condition would support habituation as the explanation. As predicted, there were greater decreases in responding in the same pre-feed conditions. These effects were seen at the higher VI schedules. The results support habituation theory and replicate earlier results from our lab. This research has implications for both habituation and satiation theories as well as eating disorders.

## Satiating, Habituation, and Elasticity: An Economic Analysis

Behavioral psychology is built upon the core concept of reinforcement. Thorndike's (1911) formulation of the *Law of Effect* represents the earliest formal presentation of a reinforcement law. The *Law of Effect* has subsequently been modified many times. The most commonly used version of the law comes from Skinner (1938) who stated that when a response is followed by a reinforcer, the response will increase in frequency. This leaves open the question of what exactly a "reinforcer" is, and how reinforcers actually work. The present paper examines one dimension of this question.

*Traditional Models of Reinforcement*

Traditional models of reinforcement (e.g., Thorndike and Skinner) define reinforcers as universal strengtheners of behaviors. Thorndike (1911) proposed the Law of Effect stating that if a response is followed by satisfaction, everything else being held equal, a positive connection forms between the situation and response. Therefore, the next time the animal is in that situation, it will be more likely to produce the same response. Satisfaction is defined as "something that the animal does nothing to avoid, often doing things to attain and preserve it" (Thorndike, 1911, p. 245). Thus, the animal engages in a response that produces satisfaction, which is something the animal strives to attain by making a response.

One problem with Thorndike's model of reinforcement is that it is circular. Satisfaction is defined by something the animal strives to attain, but is not the action of pushing the lever to get out of the puzzle box striving to attain something? Thorndike does not provide an independent definition of a reinforcer. Something is "satisfying" if the animal strives to attain it. Substituted into the Law of Effect, the result is "the animal strives to attain (by pressing the lever) something that it strives to attain."

Skinner attempted to refine the definition of reinforcement by eliminating the word “satisfaction.” Skinner (1938) defined a reinforcer as a stimulus that strengthens the operant. The operant was described as a behavior that operated on the environment. Skinner’s version of the Law of Effect stated that if an operant were followed by a reinforcing stimulus, its strength would be increased (Skinner, 1938). This attempt at refining Thorndike’s definition resulted in a definition of reinforcement that is even more circular than Thorndike’s was. Skinner’s definition stated that a response followed by something that increases the response will lead to the response increasing. Skinner did not define the concept of reinforcer outside of the Law of Effect.

In 1950, Meehl offered a solution to the circularity issue. In his trans-situational reinforcement law, Meehl stated that a particular reinforcer would be reinforcing in all situations (1950). He went on further to posit the Weak Law of Effect – that all reinforcers are trans-situational (Meehl, 1950). This Weak Law of Effect suggests that all reinforcers are reinforcing in all situations. Meehl’s Weak Law of Effect effectively removed the issue of circularity in the traditional models of reinforcement because it was falsifiable. To falsify Meehl’s principle, one would simply require a reinforcer to work in one situation but not another. Future research would show exactly that.

### *Violations of Traditional Models*

Several researchers have found violations of Meehl’s trans-situational theory of reinforcement. Premack formulated the rate differential, which he believed to be a necessary and sufficient condition for reinforcement. In the rate differential, a contingency exists between responses so that the response with the low rate produces the opportunity to engage in the response with the higher rate (Premack, 1959). A contingency could be created with a low preference activity being reinforced with a high preference activity. An example of this would

be a student finishing homework in order to go to a movie. According to Premack's theory, anything can be a reinforcer as long as a rate differential exists. Premack conducted several experiments examining the reversibility of the reinforcement relationship. For example, Premack (1962) examined whether bar pressing could reinforce eating or drinking. Prior to this experiment, most held the belief that this idea was unlikely; therefore, Premack's results were surprising. The results showed that it was possible to reinforce eating or drinking with bar pressing. Thus, the reinforcement relationship is in fact reversible (Premack, 1962). Consequently, reinforcers are not trans-situational, which directly contradicts Meehl's Weak Law of Effect. Reversibility of reinforcers is problematic for Meehl's Weak Law of Effect because according to the trans-situational theory, a reinforcer should always be reinforcing no matter what the situation is.

Timberlake and Allison (1974) suggested another violation of the trans-situational theory of reinforcement with their theoretical paper on response deprivation. Contrary to what Premack suggested, Timberlake and Allison (1974) found that a higher rate response will not always be a reinforcer. Response deprivation predicts that the animal must be deprived of a response in order for the response to be a reinforcer. Therefore, a low rate response can be a reinforcer if it has been deprived. To deprive a reinforcer means that the animal is allowed to do less of a response than it would during a baseline condition. If the animal has not been deprived of the response, engaging in that response will not be reinforcing. The grand implication of Timberlake and Allison's work is that anything can serve as a reinforcer if it has been deprived below its baseline rate.

*Behavioral Economics*

Recent developments in the field of behavioral economics have also attacked the trans-situational notion. Behavioral economics, which developed out of the work by Premack and Timberlake and Allison, views “reinforcers” as economic commodities (Allison, 1983). An important paper by Hursh found several points of intersection between economics and behavioral psychology. One such point of intersection states, “a behavioral experiment is an economic system and its characteristics can strongly determine the results” (Hursh, 1980, p. 219). Labor and wage are at the root of economics. In the Skinner box, the rat is being asked to do work (labor) and is “paid” with food or water (wage).

Another point of intersection is that “reinforcers can be distinguished by a functional property called elasticity of demand that is independent of relative rate” (Hursh, 1980, p. 219). Hursh defined three types of elasticity – unit elasticity, inelasticity, and elasticity. Unit elasticity expresses the concept that for every increase in the price of a commodity, there is a corresponding decrease in consumption. Inelasticity refers to the idea that as the price of a commodity increases, consumption decreases only subtly. Elasticity occurs when the price of a commodity increases and the consumption of the commodity decreases rapidly. Elasticity will be explained in more detail below.

*Elasticity*

Elasticity concerns the relationship between the price and the consumption of a commodity. Elasticity is said to exist when the price of a commodity increases and the consumption of the commodity decreases. Elasticity is independent of the value of the reinforcer, the value being determined by the response rate (Hursh, 1980). This means that sometimes very valuable things are very elastic; if the price increases, consumption decreases

rapidly. At the same time, very cheap things can be inelastic; if the price increases, so does consumption. Hursh (1980) provides the example of a family's elastic demand for fish. As the price for fish has increased, the family has decreased their consumption of fish to nearly none and their annual expenditures for fish have decreased.

A particular commodity does not have a fixed elasticity of demand (Hursh, 1980). Therefore, depending on the situation, a commodity may be in more demand or less demand than previously. Demand and demand elasticity are subject to change by factors, such as open vs. closed economies and the availability of substitutable reinforcers (Hursh, 1980). These factors will be discussed further below.

### *Behavioral Experiments*

In behavioral experiments, price is typically manipulated by varying how many responses are required for a reinforcer. Hursh (1980) has outlined various types of demand. When demand is elastic, a graph depicts steeply decaying curve – a small change in the price of a commodity has a big effect on the quantity of the commodity that is consumed (Hursh, 1980). When demand is inelastic, a graph would depict a more gradually decaying curve because changes in the price of a commodity has a smaller effect on the quantity of the commodity that is consumed (Hursh, 1980). Hursh cites a behavioral experiment done by Elsmore (1979) which looked at the effect of changing income on the consumption of food and heroin in baboons. Elsmore allowed each baboon a limited number of trials per day in which choice responses on one key would provide food pellets and choice responses on another key would provide an infusion of heroin (Hursh, 1980). Only one reinforcer was permitted per trial. Elsmore decreased income by increasing the time between trials and decreasing the number of trials per day (Hursh, 1980). Under the decreased income condition, subjects gave up more heroin reinforcers than food



reinforcers (Hursh, 1980). Therefore, the demand for heroin was more elastic than the demand for food. In general, then, it has been shown that elasticity affects response rate – divergences in elasticity for different reinforcers produce different changes in response rate (Hursh, 1980).

As previously noted, the concept of elasticity (and behavioral economics in general) is a violation of the traditional models of reinforcement proposed by Skinner, Meehl, and others. Skinner did not consider this complexity. Hence, the traditional reinforcement theory was missing something.

### *Satiating vs. Habituation*

It has long been known that response rate declines during a session (Skinner, 1938). This decrease in response rate has been traditionally attributed to satiation. Satiation refers to a decrease in rate of responding as more and more reinforcers are consumed. In the language of folk psychology, satiation is the “fullness” that one experiences after consuming a meal. Skinner, as a behaviorist, rejected such reliance on unobservable, internal states. He did, however, recognize satiation as having an influence on responding. Skinner (1938) stated that an animal eats only when it is hungry. By providing a hungry animal with food, it is possible to observe a decline in response strength (Skinner, 1938). When a very low strength is reached, the animal ceases eating. Then, some time must elapse before the food is presented again in order to observe the revival of response strength.

Habituation has traditionally been confused with satiation, which is an ingestive factor. The decline in responding has been attributed to satiation. However, habituation provides yet another violation of traditional theories of reinforcement. Reinforcers lose effectiveness because of habituation. Habituation occurs when a stimulus is repeatedly presented and the response to

that stimulus decreases. The decline in response rate occurs because the reinforcers are just no longer reinforcing.

Many studies have shown that operant responding often changes within experimental sessions during operant conditioning procedures. Some studies have shown within-session changes in responding during the first session (e.g. McSweeney, Weatherly, & Swindell, 1995c). These within-session changes are frequently bitonic, with increases in responding occurring early in the session and decreases in responding occurring later in the session (Melville, Rue, Rybiski, & Weatherly, 1997).

Both satiation for the reinforcer and habituation to the reinforcer have been presented as potential explanations for these within-session changes in responding. Sensitization-habituation typically refers to an increase followed by a decrease in responding to a repeatedly presented stimulus (Melville et al., 1997). Satiation, on the other hand, typically refers to the factors that control the consumption of ingestive stimuli such as food and water (McSweeney, Hinson, & Cannon, 1996a; Melville et al., 1997).

Satiation is one proposed explanation for within-session changes in responding, but is somewhat less supported than sensitization-habituation. Cannon and McSweeney (1995) investigated the contribution of satiation to within-session changes. They assumed that subjects given larger reinforcers would satiate more quickly than subjects given smaller reinforcers. Their results showed that although satiation sometimes contributes to within-session patterns of responding, it is not necessary to produce those changes (Cannon & McSweeney, 1995). Furthermore, they found an increase in responding early in the second session, which seems to contradict a satiation-based explanation (Cannon & McSweeney, 1995). A satiation-based explanation would expect to find a decrease in responding early in the second session because

the animal would be “full.” Manipulations that should not alter satiation do alter the results (e.g. changing the reinforcer in the middle of the session). In addition, the likelihood that animals deprived below their free-feeding weights become satiated after consuming a limited number of reinforcers is very low (McSweeney, Roll, & Weatherly, 1994b). Campbell and Dougan (1995) replicated this result and also found that within-session changes occur in similar ways with different types of reinforcers. These authors claim that it seems unlikely that different reinforcers would have the same satiation rates. This would suggest that simple satiation is not the only factor involved in within-session changes in responding.

Some have argued that sensitization-habituation provides a better explanation than satiation for the within-session changes that occur during operant responding. First, McSweeney et al. (1996a) asserted that sensitization-habituation and within-session changes in operant responding share several fundamental characteristics. When stimuli are presented at higher rates, habituation is often faster and more pronounced than when stimuli are presented at lower rates. Similarly, McSweeney (1992) found that operant responding typically peaks earlier and declines more steeply when reinforcers are presented at higher rather than lower rates. Furthermore, variables related to the act of responding (e.g. warm-up or fatigue) do not produce sensitization, nor do they contribute significantly to within-session changes in operant responding (McSweeney, 1992; McSweeney et al., 1996a). Additionally, the manipulations of several variables traditionally thought to contribute to satiation produce little or no effect on the within-session pattern of operant responding (McSweeney et al., 1996a). Another reason that sensitization-habituation may be a better explanation than satiation is that sensitization-habituation can occur for noningestive stimuli as well as for ingestive stimuli, whereas satiation is normally constrained to ingestive stimuli (McSweeney et al., 1996a). In fact, habituation to

the sensory properties of ingestive stimuli may be a contributing factor to satiation for that stimulus. Another advantage of the sensitization-habituation argument is that sensitization-habituation, but not satiation, can account for within-session changes that are reported when no reinforcers are given (McSweeney, Weatherly, & Swindell, 1996e).

In order to determine whether the within-session pattern of responding is due to satiation or habituation, Melville et al. (1997) looked at the effects of varying the quality or intensity of the reinforcer on the within-session pattern of responding. Both manipulations altered the within-session pattern of responding in a manner that is consistent with sensitization-habituation. Thus, qualitative changes in the reinforcer affect the within-session changes in responding.

As discussed above, the availability of substitutable reinforcers alters elasticity. It is unknown, however, what specific mechanism is responsible for this. Elasticity is affected by reinforcers available outside the session. Hursh (1980) identified two types of economies: open and closed. An open economy is a situation in which the subject's total daily consumption of food is not a result of the subject's interaction with the environment during the session (Hursh, 1980). In an open economy, the researcher determines the subject's food consumption. For example, the researcher gives the subject supplemental feedings following the experimental sessions to maintain a fixed body weight.

A closed economy is a situation in which the subject's total daily consumption of food is a result of the subject's interaction with the environment during the session (Hursh, 1980). Thus, in a closed economy, the subject determines its own food consumption – no supplementary feedings are provided. In closed economies, subjects increase response rates when food is scarce even when its price increases (Hursh, 1980). The response rate must increase in order to minimize changes in consumption of the reinforcer.

*The Current Research*

Elasticity differs between open and closed economies. However, it is uncertain whether satiation or habituation causes this discrepancy. As previously noted, habituation may alter elasticity. One important research question that remains unanswered is: When substitutable reinforcers are made available outside of sessions, do they cause a reduction in response rate because of habituation or satiation?

In an attempt to begin to answer this question, Campbell and Dougan (1995) investigated the effects of food density on within-session changes in responding. Food density was defined as “the amount of food consumed within a given time window before and during the session” (Campbell & Dougan, 1995, p. 96). Food density effects are also known as satiation effects. However, changes in responding to food density could be a habituation effect.

Campbell and Dougan (1995) exposed rats to four different variable interval schedules that were in effect for 24 consecutive days. These sessions were divided equally into three types: baseline sessions, pre-feed sessions, and no-pre-feed sessions. In the pre-feed sessions, the rats were given a number of pellets equal to the average number consumed during the first 20 minutes of the 30-minute baseline sessions. The no-pre-feed sessions were exactly similar to the pre-feed sessions except that no food was given prior to the session.

Campbell and Dougan found within-session changes in the response function. The response functions were more sharply bitonic in the pre-feed condition than in the no-pre-feed condition (Campbell & Dougan, 1995). Their results showed that the pre-feed condition produced a response function that was significantly different from the one produced during the first 10 minutes of baseline, but was indistinguishable from the function that was produced during the final 10 minutes of baseline (Campbell & Dougan, 1995).

The present experiment expanded on a previous study done in the laboratory at Illinois Wesleyan University (McGrady & Dougan, 2006). It altered the parameters of the previous study. The present study utilized variable interval (VI) schedules instead of fixed ratio (FR) schedules. A benefit of variable interval schedules is that they sustain a relatively high rate of responding (McSweeney, Weatherly, & Swindell, 1996g). There were two different pre-feeding conditions, each with different foods. Different foods were used in order to examine both explanations for within-session changes in responding: satiation and habituation. If response rates were the same in both of the pre-feed conditions, satiation would be the suggested explanation. If there were a bigger decrease in the pellet pre-feed condition, it would suggest habituation as the explanation.

It was proposed that habituation should alter elasticity. More accurately, elasticity should be greater when the food during the pre-feed condition is the same as that earned during the session. Elasticity should be less when the food during the pre-feed condition differs from that earned during the session.

## Method

### *Subjects*

The subjects were six Sprague-Dawley rats, commercially obtained from Harlan. The rats were approximately 90 days old at the start of the study. The subjects were housed individually and had water freely available in the home cage at all times.

### *Apparatus*

Two types of apparatus were used, one for pre-feeding and the other for conditioning. The pre-feeding apparatus consisted of a white plastic housing/breeding tub measuring 46 cm

long, 25.5 cm wide, and 20 cm deep, fitted with a tight wire mesh cover. The conditioning apparatus consisted of two identical standard operant conditioning units for rats (BRS/LVE Model RTC-028). The chambers measured 30 cm in length, 26.5 cm in height, and 24 cm in width. Two side walls and the ceiling of the chamber were made of Plexiglas, and the front and rear walls were made of stainless steel. Metal bars composed the floor of the chamber. A 5-W houselight, located in the center of the front wall, 1 cm from the ceiling, illuminated the chamber.

The front wall contained two retractable response bars, each 5 cm from the floor and 3 cm from the nearest side wall. When the bars were extended, they projected 2.5 cm into the chamber and had a width of 3 cm. When the bars were retracted, they were flush with the front wall. In this experiment, only the left bar was used. Three cue lights (red, white, and green) were located 5 cm above each bar. Each light was 2 cm apart (center to center). Only the red cue light on the left side of the chamber was used during the experiment. The front wall also had a food cup, extending 1.5 cm into the chamber, located 11 cm from the right wall and 2 cm from the floor. The entire apparatus was enclosed in a sound-attenuating chamber.

A PC computer running Windows and MED-PC® software arranged all programming of experimental events and all data collection. The computer and interface were located in an adjacent room.

### *Procedure*

All of the rats were deprived to 80% of their *ad libitum* weights. Pressing the left response lever was shaped using successive approximations with food pellets as the reinforcer (Bio-Serv 45mg Dustless Precision pellets). The experiment began after all of the rats were reliably pressing the lever.

Each rat was exposed to a series of four different variable interval (VI) schedules (VI 7.5 s, VI 15 s, VI 30 s, and VI 60 s). Previous experiments have shown that these intervals represent a range over which variable interval responding changes dramatically (e.g. Dougan, Kuh, & Vink, 1993). Each schedule was in effect for 20 consecutive days, with the order of the schedules counterbalanced across animals to avoid systematic order effects.

The 20 sessions on each VI schedule were further divided into three types. The first ten sessions for each schedule were baseline sessions. At the beginning of each baseline session, the rats were placed in the dark chamber with the response bar retracted. After approximately 30 s, the session began, signaled by illumination of the houselight and red cue light and insertion of the bar into the chamber. The bar remained present for 30 min, during which time the rat was able to respond for food on the relevant VI schedule. Sessions were terminated after 30 minutes, signaled by the extinction of both lights and the retraction of the response bar. The rats were then returned to their home cages.

The remaining ten sessions were designated pre-feed sessions. Approximately one minute prior to the start of pre-feed sessions, the rats were placed in the plastic tub. The rats were given an amount of food (pellets or cereal) equivalent to what they consumed during baseline. After 20 minutes in the pre-feeding tub, the rats were removed and placed in the conditioning apparatus. Once the animals entered the conditioning apparatus, the pre-feed sessions were identical to those during baseline. Determination of which pre-feed condition occurred was done randomly.

There were two different pre-feed conditions. Each condition was in effect for a total of five days. In one condition, the rats were fed the same type of pellets as was available during the



session. In the other condition, the rats were fed a calorically equivalent amount of cereal (Cheerios). The two conditions were controlled for by calories.

Sessions were conducted once per day, 6 to 7 days per week. Supplementary feedings were given approximately 2 hours after the session to maintain 80% *ad libitum* body weight.

## Results

Response rates for individual animals in all sessions were calculated by dividing the number of responses in a session by the number of minutes in the session for baseline, pellet pre-feed, and cereal pre-feed conditions. Only the last five sessions of the baseline condition were used as the first five were considered a period in which the animals were adjusting to the schedule. This is standard procedure in the literature. All five of the pellet pre-feed and cereal pre-feed conditions were used. The means across animals were calculated for all conditions.

Figure 1 plots mean response rate as a function of VI value for each condition. As seen in Figure 1, there was an initial increase followed by a decrease in response rate across schedule. The pattern was seen in all three conditions. For the pellet pre-feed condition, responding was lower than for the baseline and cereal pre-feed conditions during the two lowest VI values (higher rates of reinforcement), but was very close to the baseline and cereal pre-feed conditions at the two higher VI values (lower rates of reinforcement). Very little disparity occurred between the baseline and cereal pre-feed conditions. Despite the rats receiving twice as many calories in the cereal pre-feed condition (because the number of calories in the pre-feed was equal to the amount normally consumed in the session), there was virtually no difference from the baseline condition.

A two-way (schedule x pre-feed condition) within-subjects analysis of variance (ANOVA) confirmed the visual analysis of Figure 1. The ANOVA yielded a significant effect

of pre-feed condition,  $F(2, 10) = 9.02$ ;  $p = .006$ , and a significant schedule x pre-feed condition interaction,  $F(6, 30) = 4.35$ ;  $p = .003$ . There was no statistically significant main effect for schedule,  $F(3, 15) = 2.67$ ;  $p = .085$ . Thus, responding changed as a function of VI schedule, but changed differently depending on the pre-feed condition.

Mean reinforcer consumption as a function of VI value for each condition is plotted in Figure 2. As seen in Figure 2, there was a decline in reinforcer consumption across schedules. A decline in reinforcement was evident in all three conditions. This decline was steepest for the baseline and cereal pre-feed conditions. Again, the largest differences between the pellet pre-feed and cereal pre-feed conditions were at the lower VI values.

A two-way (schedule x pre-feed condition) ANOVA confirmed the visual analysis of Figure 2. The ANOVA yielded significant effects for schedule,  $F(3, 15) = 349.07$ ;  $p = .000$ , pre-feed condition,  $F(2, 10) = 64.90$ ;  $p = .000$ , and a significant schedule x pre-feed condition interaction,  $F(6, 30) = 58.21$ ;  $p = .000$ . Accordingly, reinforcer consumption changed as a function of VI schedule, but changed differently depending on the pre-feed condition.

Elasticity is defined as a change in consumption as a function of reinforcer cost. In the present study, elasticity would be viewed as the slope of the function relating reinforcer consumption to VI value (Figure 2). As seen in Figure 2 (and confirmed through statistical analysis), the baseline and cereal pre-feed conditions had nearly identical elasticity. The pellet pre-feed condition, however, had a far lower elasticity (indicated by the shallower slope).

### Discussion

The purpose of the present study was to examine theories of satiation and habituation as explanations for changes in responding during operant conditioning procedures. The current experiment expanded on a previous study done in our laboratory by altering that study's

parameters (McGrady, 2006). The current study used VI schedules instead of FR (fixed ratio) schedules. If habituation theory is correct, pre-feeding should have a different effect on responding when the pre-feed food substance is the same as that consumed during the session than when the pre-feed food substance is different. It was proposed that pre-feeding the subjects before the session would alter elasticity. Specifically, greater elasticity would occur when the food during the pre-feed condition was the same as that earned during the session. Less elasticity would occur when the food during the pre-feed condition was different from that earned during the session.

The present results did not fully support the hypotheses. Elasticity, as estimated from Figure 2, was greater during the cereal pre-feed condition than during the pellet pre-feed condition. Elasticity was nearly equal between the baseline and cereal pre-feed conditions. In the pellet pre-feed condition, elasticity was lower. This finding is the opposite of what was originally proposed. Pre-feeding the subjects had an effect, but it occurred in the opposite direction of what was predicted. Additionally, it was predicted that an effect would be seen across all schedules. However, the effect was seen just on the first schedule (VI 7.5).

Closer examination of the data reveals why this effect occurred. Elasticity is indicated by the slope of the relationship between response rate and VI value. The majority of the pre-feeding effect was evidenced in the lowest VI values. Since responding decreased primarily at low VI values, the endpoint of the function was pulled lower, and resulted in a shallower elasticity function. Furthermore, since a greater decrease in responding was evidenced in the pellet pre-feed condition, the slope of that function is lower than the slopes of the baseline and cereal pre-feed conditions.

The pre-feeding effect occurred where the biggest pre-feeding amount was provided. The current study held the size of the pre-feed constant relative to baseline. Thus, the size of the pre-feed was largest at lower VI values (i.e. 7.5 and 15). This may explain why a pre-feeding effect can only be seen at the lower VI values. Future research might consider keeping the size of the pre-feed constant in all conditions. It is possible that a larger pre-feeding amount would have a greater effect on responding at higher VI values, which would in turn produce the predicted results.

The present data support habituation, not satiation, as the explanation for the changes that occur during operant responding. According to the definition of habituation, when a stimulus is repeatedly presented, the response to that stimulus decreases. The subjects evidenced a substantial decline in operant responding when fed pellets during the pre-feed condition. In this instance, the repeatedly presented stimuli were the pellets. After the pellet pre-feed condition was over, the pellets were no longer reinforcing to the subjects leading to a decreased response rate in the operant session. There was virtually no decline in operant responding after the cereal pre-feed conditions compared with the baseline conditions. Since the subjects did not receive pellets during the cereal pre-feed conditions, the pellets were still reinforcing during the operant sessions. Satiation theory is unable to account for the observed differences between the pre-feeding conditions.

McSweeney (1992) found that responding changed with variations in the schedules to which the subjects were exposed. Response rates were highest with the highest rates of reinforcement. Additionally, McSweeney's results propose the idea that the factors responsible for the decline in response rate during the highest rates of reinforcement were not present at the start of the session. While at that time those factors were unknown, both satiation and

habituation are factors that would develop as the session continued. Although the present experiment did not measure within-session changes in responding, it did find a large habituation effect. An implication of this study is that habituation has more of an effect than satiation during within-session changes in responding. Thus, the present study supports the explanation of habituation. Future research should look at the effects of pre-feeding subjects within sessions.

The findings of the present study could possibly be generalized to other animal subjects as well as to humans. For example, this finding could be instrumental in research on obesity in animals and humans as it may help explain why some are unable to recognize the signal to stop eating. It may be that individuals continue to eat because they are presented with a variety of food substances and do not become habituated to them (Ernst, 2001). The study by Ernst consisted of two conditions involving repeated presentations either of the same food or of a variety of food to human participants. All participants showed changes in operant responding during the testing session. The participants that responded for the one type of food more rapidly decreased responding than the participants that responded for the variety of food. The food stimuli were isocaloric; that is, they had similar caloric values. When presented with a novel food stimulus, responding resumed for all participants. The study illustrated that changes in human responding for food can be attributed to habituation. The current study shares some similarities with the Ernst study. In both experiments, participants received presentations of the same food or a different food. Additionally, both sets of participants demonstrated decreased responding when the same food was repeatedly presented. The results of Ernst's study and the current study could lead to a recommendation for people who are trying to lose weight to eat a diet that does not vary much.

There are several limitations to the present study. For example, while the subjects responded for pellets during the operant conditioning sessions, it was not possible for them to respond for Cheerios. Due to the construction of the Skinner boxes used, it was not possible to dispense Cheerios instead of pellets during the operant responding sessions. Therefore, the effects of the two types of pre-feed were only demonstrated on pellet responding. This presents a possible confound in the study. Future researchers could profit from examining the effects of the two pre-feed conditions on cereal responding. McGrady (2006) was able to look at the effects of the two pre-feed conditions on both pellet and cereal responding. Both pre-feed and operant conditions were done in the pre-feeding tubs. The results of that study are consistent with those of the current study.

Another potential limitation to the current study was that the subjects were not exposed to the Cheerios prior to their introduction in the pre-feed condition. The presentation of an unfamiliar food substance could have resulted in a hesitance to consume the Cheerios. Many rats are neophobic, meaning they have a fear of new things (Moron & Gallo, 2007). In this case, the cereal was unfamiliar to the subjects. This may provide an explanation for why not all of the rats consumed all of the Cheerios during the pre-feed conditions, at least initially. Future research could explore the effects of exposing the rats to the food used during the pre-feed condition before beginning that condition.

The next step might be to alter the parameters of each of the conditions. The present study was only concerned with four specific variable interval schedules. Future research might benefit from looking at a wider variety of interval schedules. For example, researchers could use variable intervals longer than 60 seconds. It might also be beneficial to utilize more interval schedules during the course of the experiment.

Another future alteration might be to examine the effects of different foods in the pre-feed conditions. Different flavored pellets (e.g. banana) would be a good place to start. An advantage of using flavored pellets is that they can be used in the Skinner boxes and the researchers could examine the effects of the two (or more) types of pre-feeding conditions on responding for the differently flavored pellets. The effects of other types of cereal could also be investigated. The animals may exhibit a preference for different flavors that is independent of calories. Thus, these effects may involve other dimensions than calories.

Future studies might also alter the amount of food used in the pre-feeding conditions. The present study adjusted the pre-feed amount according to the amount of food consumed during the operant responding sessions. As discussed above, this may have had an impact on the current study's results. It would be interesting to ascertain the effects of keeping the pre-feed amount of food constant. For instance, the amount of food for the VI 7.5 condition could be utilized in all of the pre-feeding conditions. This might result in a bigger habituation effect and an elasticity effect. The present difficulty in demonstrating a habituation effect across all VI schedules illustrates the complexity of the response-reinforcer relationship.

Traditional models of reinforcement (e.g. Skinner and Thorndike) suggested a very simple relationship between responding and reinforcement. Although formulated differently, both essentially stated that reinforcers increase response strength. However, both theories appear to be too simplistic to adequately define the relationship between responding and reinforcement. More recent models (Premack, 1959; Timberlake & Allison, 1974; Hursh, 1980; McSweeney, 1992) have suggested that the relationship is much more complex. For example, Premack (1959) proposed the response hierarchy which stated that something could be a reinforcer only if the response for that thing is higher than the response for another. Timberlake and Allison (1974)

introduced the concept of response deprivation, stating that something is a reinforcer only if it has been deprived below baseline. Behavioral economics contends that economic factors such as substitutability, complementarity, and elasticity alter responding (Hursh, 1980). McSweeney (1992) suggested that habituation alters responding.

The present results indicate additional complexity in the relationship between responding and reinforcement. The habituation effect did occur, but only at the highest rates of reinforcement. In the present study, a huge effect was seen at VI 7.5, but there was not much of an effect at higher VI values. As mentioned previously, future research can alter the amount of food in the pre-feed condition to observe the subsequent effects. By doing so, the habituation effect may be evident at other rates of reinforcement than the highest rate.

In summary, the present experiment shows that habituation is an important factor in the changes that occur during operant responding. Simple satiation was not a factor in the decrease in responding evidenced in the current study. While not completely answering the debate on whether satiation or habituation is responsible for changes in operant responding, the current study helps advance the research. Both the design of the present study as well as its implications for humans and other animals generate novel venues for future research to pursue.



## References

- Allison, J. (1983). *Behavioral Economics*. New York: Praeger Publishers.
- Campbell, L.S. & Dougan, J.D. (1995). Within-session changes in the VI response function: Separating food density from elapsed session time. *Journal of the Experimental Analysis of Behavior*, 64, 95-110.
- Cannon, C.B. & McSweeney, F.K. (1995). Within-session changes in responding when rate and duration of reinforcement vary. *Behavioural Processes*, 34, 285-292.
- Dougan, J.D., Kuh, J.A., & Vink, K.L. (1993). Session duration and the VI response function: Within-session prospective and retrospective effects. *Journal of the Experimental Analysis of Behavior*, 60, 543-557.
- Ernst, M.M. (2001). Within-session changes in operant responding for food in humans. *Dissertation Abstracts International: Section B: The Sciences and Engineering*. 61(9-B), pp4979.
- Hursh, S.R. (1980). Economic concepts for the analysis of behavior. *Journal of the Experimental Analysis of Behavior*, 34, 219-238.
- McGrady, M.E. & Dougan, J.D. (2006). *Habituation, Satiating, and Demand Elasticity*. Unpublished manuscript.
- McSweeney, F.K. (1992). Rate of reinforcement and session duration as determinants of within-session patterns of responding. *Animal Learning & Behavior*, 20, 160-169.
- McSweeney, F.K. & Hinson, J.M. (1992). Patterns of responding within sessions. *Journal of the Experimental Analysis of Behavior*, 58, 19-36.
- McSweeney, F.K. & Johnson, K.S. (1994). The effect of time between sessions on within-session patterns of responding. *Behavioural Processes*, 31, 207-218.

- McSweeney, F.K. & Roll, J.M. (1993). Responding changes systematically within sessions during conditioning procedures. *Journal of the Experimental Analysis of Behavior*, 60, 621-640.
- McSweeney, F.K., Hinson, J.M., & Cannon, C.B. (1996a). Sensitization-habituation may occur during operant conditioning. *Psychological Bulletin*, 120, 256-271.
- McSweeney, F.K., Roll, J.M., & Cannon, C.B. (1994a). The generality of within-session patterns of responding: Rate of reinforcement and session length. *Animal Learning & Behavior*, 22, 252-266.
- McSweeney, F.K., Roll, J.M., & Weatherly, J.N. (1994b). Within-session changes in responding during several simple schedules. *Journal of the Experimental Analysis of Behavior*, 62, 109-132.
- McSweeney, F.K., Swindell, S., & Weatherly, J.N. (1996b). Within-session changes in concurrent schedules with different reinforcers in the components. *Journal of the Experimental Analysis of Behavior*, 66, 369-390.
- McSweeney, F.K., Swindell, S., & Weatherly, J.N. (1996c). Within-session changes in responding during autoshaping and automaintenance procedures. *Journal of the Experimental Analysis of Behavior*, 66, 51-61.
- McSweeney, F.K., Swindell, S., & Weatherly, J.N. (1998). Exposure to context may contribute to within-session changes in responding. *Behavioural Processes*, 43, 315-328.
- McSweeney, F.K., Swindell, S., & Weatherly, J.N. (1996d). Within-session changes in adjunctive and instrumental responding. *Learning and Motivation*, 27, 408-427.

- McSweeney, F.K., Weatherly, J.N., & Roll, J.M. (1995a). Within-session changes in responding during concurrent schedules that employ two different operanda. *Animal Learning & Behavior*, *23*, 237-244.
- McSweeney, F.K., Weatherly, J.N., & Swindell, S. (1995b). Prospective factors contribute little to within-session changes in responding. *Psychonomic Bulletin & Review*, *2*, 234-238.
- McSweeney, F.K., Weatherly, J.N., & Swindell, S. (1995c). Within-session changes in key and lever pressing for water during several multiple variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, *64*, 75-94.
- McSweeney, F.K., Weatherly, J.N., & Swindell, S. (1996e). Reinforcer value may change within experimental sessions. *Psychonomic Bulletin & Review*, *3*, 372-375.
- McSweeney, F.K., Weatherly, J.N., & Swindell, S. (1996f). Within-session changes in responding during delayed matching-to-sample and discrimination procedures. *Animal Learning & Behavior*, *24*, 290-299.
- McSweeney, F.K., Weatherly, J.N., & Swindell, S. (1996g). Within-session changes in responding during variable interval schedules. *Behavioural Processes*, *36*, 67-76.
- McSweeney, F.K., Weatherly, J.N., Roll, J.M., & Swindell, S. (1995d). Within-session patterns of responding when the operandum changes during the session. *Learning and Motivation*, *26*, 403-420.
- Meehl, P.E. (1950). On the circularity of the law of effect. 52-75.
- Melville, C.L., Rue, H.C., Rybiski, L.R., & Weatherly, J.N. (1997). Altering reinforcer variety or intensity changes the within-session decrease in responding. *Learning and Motivation*, *28*, 609-621.

- Melville, C.L., Rybiski, L.R., & Kamrani, B. (1996). Within-session responding as a function of force required for lever press. *Behavioural Processes*, 37, 217-224.
- Moron, I. and Gallo, M. (2007). Effect of previous taste experiences on taste neophobia in young-adult and aged rats. *Physiology & Behavior*, 90, 308-317.
- Premack, D. (1959). Toward empirical behavior laws. *Psychological Review*, 66, 219-233.
- Skinner, B.F. (1938). *The behavior of organisms*. New York: Appleton, Century, Crofts.
- Thorndike, E.L. (1911). *Animal intelligence: Experimental studies*. New York: Macmillan.
- Timberlake, W. & Allison, J. (1974). Response deprivation: An empirical approach to instrumental performance. *Psychological Review*, 81, 146-164.
- Weatherly, J.N. & McSweeney, F.K. (1995). Within-session response patterns when rats press levers for water: Effects of component stimuli and experimental environment. *Behavioural Processes*, 34, 141-152.
- Weatherly, J.N., McSweeney, F.K., & Swindell, S. (1995). On the contributions of responding and reinforcement to within-session patterns of responding. *Learning and Motivation*, 26, 421-432.

Figure Captions

Figure 1. Mean response rate as a function of variable interval (VI) value for each condition.

Figure 2. Mean reinforcer consumption as a function of variable interval (VI) value for each condition.

Figure 1

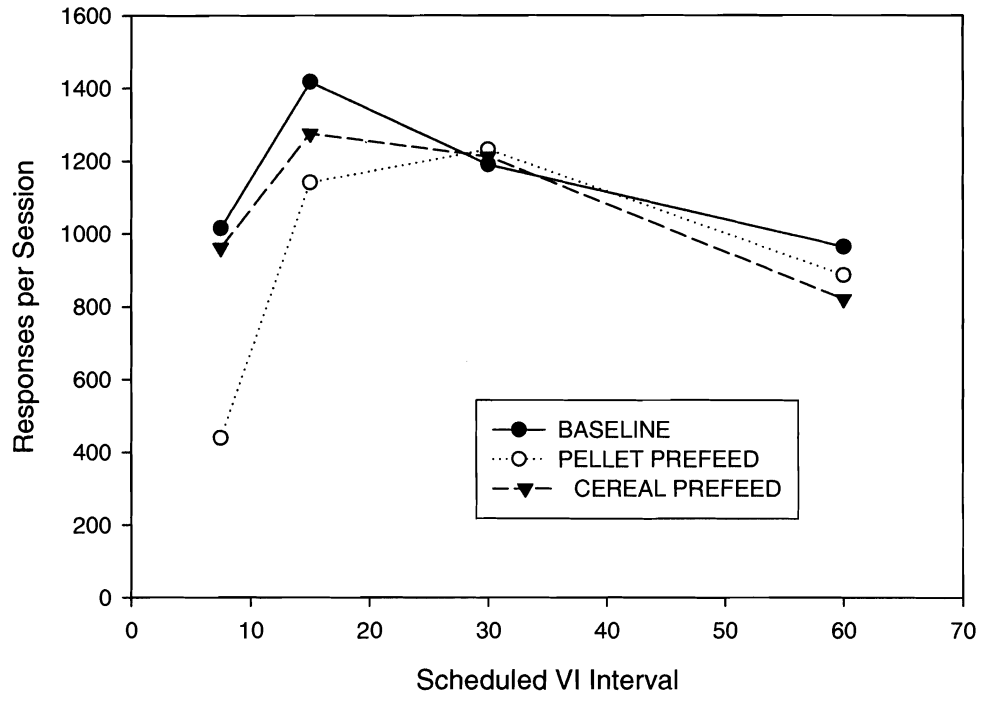


Figure 2

