Undergraduate Research Grant Proposal

Hedonic Scaling in the Rat:
Towards an Absolute Measure of Reinforcer Value

Joseph D. Mintz

University of Alaska Anchorage

Abstract

The development of a valid and reliable operational measure of reinforcer value is an important objective in the field of behavior analysis (Miller, 1976). While some experimental and quantitative methods have been developed to investigate the value of qualitatively similar reinforcers in animals, the behavior of animals in response to qualitatively different reinforcers is still poorly understood (Killeen, Cate & Tran, 1993). Because reinforcers are multidimensional, a method to account for the effect of each dimension is in need of development. The method of paired comparison is a common way of determining a group of animals' preferences for one reinforcer over another, but the information gained from such a procedure is limited in predictive power and scope (Thurstone, 1927). Baum's (1974) generalized matching law, however, is an effective descriptor of operant choice behavior but is typically limited to cases in which the value of a given reinforcer is varied via the dimensions of amount or immediacy (Boutros, Elliffe & Davison, 2011). A combination of the two methods will allow for the computation of a ratio-level scale of reinforcer quality, opening the door to a molecular analysis of reinforcer properties and the formulation of new quantitative principles of behavior.

Specific Aims

1. I will quantitatively determine four rats' preferences for four qualitatively different reinforcers via the method of paired comparison and Thurstone's (1927) law of comparative judgment.
2. I will measure the same four rats' behavior when exposed to the same reinforcer pairs in a concurrent-schedule operant conditioning paradigm.
3. I will analyze the data obtained in the first two phases of the experiment in the context of Baum's (1974) generalized matching law and determine the quality of each reinforcer on a ratio scale by determining the scaled values that correct for the deviations from perfect matching.

Introduction

The matching law is commonly used to describe a research subject or participant's behavior when presented with two concurrent choices with differing rates of reinforcement (Pierce, & Epling, 1995; Poling, Edwards, & Weeden, 2011; Spiga, Maxwell, Meisch, & Grabowski, 2005). A reinforcer is simply anything that, when its delivery to an animal is contingent upon a behavior, increases the frequency of that behavior in the future; in colloquial terms, a reinforcer is a *proven reward.* The generalized matching law takes the following form, where B is the rate of a particular behavior, R is the rate of obtained reinforcement, b is a parameter representing bias for a particular reinforcer, and a is a parameter representing sensitivity to reinforcement (Baum, 1974).

$$\frac{B_i}{B_j} = b\left(\frac{R_i}{R_j}\right)^a \tag{1}$$

Under ideal conditions both b and a are equal to one, and the ratios are directly proportional; i.e. they form a line through the origin with a slope of one. Data are rarely so orderly. Therefore, Equation 1 can be logarithmically transformed to facilitate linear regression in the case that the animals exhibit non-ideal bias or sensitivity to reinforcement (Baum, 1974; Poling et al., 2011).

$$\log\frac{B_i}{B_j} = \log b + a\log\frac{R_i}{R_j} \tag{2}$$

Rachlin (1971), Killeen (1972) and Miller (1976) describe the multiplicative interaction of dimensions contributing to reinforcement. Equation 2 can thus be rewritten to take into account the contribution of quality to the true rate of reinforcement where the bias parameter b is defined by the ratio of reinforcer qualities.

$$\log\frac{B_i}{B_j} = \log\frac{Q_i}{Q_j} + a\log\frac{R_i}{R_j} \tag{3}$$

Relatively few empirical investigations of reinforcer quality have been conducted. Miller (1976) used the generalized matching law to derive the quality of three types of grain from a group of pigeons' bias b and has been widely cited, but his method is too time-consuming to be practical. Killeen et al. (1993) derived a scale of the preferences of a group of pigeons for a large number of different reinforcers using the method of pairwise comparison and Thurstone's (1927) law of comparative judgment, but the method yields an interval-level scale that, while useful for determining the properties of the reinforcer via correlations with physical properties, does not lend itself to strong, quantitative predictions about animal behavior. An ideal scale would be a ratio-level scale, in which there can be a direct relationship between quality, Q, and some function of quality like behavior, $B = f(Q)$.

The history of the physical sciences provides a ready analogue to reinforcer quality. Prior to the work of William Thomson, also known as Lord Kelvin, temperature too was an interval-level measurement; the absolute zero of the temperature scale was basically undiscovered (Erlichson, 2001). Thomson was able to empirically determine absolute zero temperature in the context of the relationship between the thermodynamic temperature and pressure of a gas and the thermodynamic principles underlying the Carnot cycle (Erlichson, 2001).

Reinforcer quality is amenable to a similar analysis. The ratio values of Q can be determined by scaling the rats' pairwise preferences via Thurstone's (1927) law of comparative judgment and using the theoretical framework of the generalized matching law to find the distance between the arbitrary zero of the scale and the true zero. Such a scale would open the door to substantially better understanding of the property of reinforcer quality and allow for precise quantitative predications about human and non-human animal behavior in response to reinforcer quality as it varies.

Experimental Design

The proposed study will utilize four adult Wistar rats ($N = 4$) in order to investigate the effect of the variation of reinforcer flavor on operant choice behavior. Only four rats will be used because both the matching law and the law of comparative judgment were designed to describe the behavior of individual subjects (Herrnstein, 1961; Thurstone, 1927). The exploratory nature of the proposed study and the intense labor associated with the procedure further justify the use of a relatively small number of subjects. Rats will be maintained at 85% of their free-feeding weight in order to increase the probability of food-motivated behavior.

The study will consist of two phases. Prior to the onset of data collection each animal will be allowed free access to all four reinforcers under investigation for one week: 45 mg purified, grain, chocolate and banana-flavored BioServ Dustless Precision Pellets. The pellets are calorically similar in order to control for potential variability in satiety (BioServ, 2011). Exposure of the animals to each reinforcer prior to the onset of data collection is important for the development of preferences and the attenuation of neophobia (Killeen et al., 1993).

Phase I: Food Preference Test

In the first phase, each animal will be presented with each possible pair of four different reinforcers for five minutes on each side of a paired-comparisons apparatus (a large cage); a total of sixteen pairs will be presented to each animal. All sixteen possible permutations with replacement will be tested in order to either identify or rule out bias towards a particular side of the apparatus. A fixed amount of 20 g of each reinforcer will be available in each trial and the number of pellets pre- and post-exposure will be counted by weighing. I will also videotape each session and calculate the time allocated to each reinforcer. The order of the trials will be randomized for each animal in order to control for the effects of order and adjacency on repeated measures. The obtained ratios of the consumed pellets and time allocated will constitute the dependent variables in this phase.

Phase II: Operant Choice Behavior

In the second phase, each animal will be exposed to six concurrent schedules of reinforcement in an operant conditioning apparatus. Previous research suggests that operant choice behavior is most likely to conform to the predictions of the matching law under the condition of variable interval schedules of reinforcement (Baum, 1974; Miller, 1976), in which a variable amount of time with a fixed mean over the session elapses after each reinforcer delivery before a lever press will result in the delivery of another reinforce (i.e. a food pellet). The proposed study will utilize a variable interval (VI) schedule; specifically a concurrent VI 30 s — VI 30 s schedule. I will also program a 6-s changeover delay to discourage rapid switching from one lever to the other (Herrnstein, 1961). Each schedule will contain a unique pair of reinforcers and all six combinations of the four reinforcers will be represented.

The four animals will be divided into two groups and each group will work through the conditions in reverse order relative to the other group in order to partially control for the effects of order. True counterbalancing would be impossible due to the small number of subjects in the experiment, and randomization of condition order would introduce a significant source of additional error because of difficulty of emptying and refilling pellet dispensers in the particular operant conditioning apparatus that will be utilized. Each condition will consist of the number of experimental sessions required to reach stable response; experience suggests that this will be on the order of 15-20 sessions per condition. Each session will last sixty minutes.

The independent variable in this case is the reinforcer pair presented to the animal during the trial. The dependent variables are the obtained rates of reinforcement, measured in pellets per elapsed trial interval, and the rates of response, measured in lever presses per elapsed trial interval, for each lever in the operant conditioning apparatus. Data will be averaged over the first five sessions for each animal in each condition after a minimum of ten sessions once stability has been reached. Stability is defined for the purposes of this study as ratios of response and reinforcement rates that fall within the total range of the sessions up to the last five in each condition for a given subject (Lupfer-Johnson, Murphy, Blackwell, LaCassse & Drummond, 2010; Murphy, McSweeney, Kowal, McDonald & Wiediger, 2006).

Phase III – Data Analysis

Case V of the law of comparative judgment defines the interval between two scale values as being proportional to x_{ij}, the *Z*-score associated with the probability of choosing one reinforcer, *i*, over another, *j* (Thurstone, 1927).

$$S_i - S_j = \sqrt{2}x_{ij} \tag{4}$$

As previously mentioned, the zero point on the scale generated by the Law of Comparative Judgment is arbitrary; in order to find the equivalent value on a ratio scale more information is needed. I will define the quality score for a particular reinforcer *Q* in terms of *S*.

$$Q_i = S_i + C \tag{5}$$

C is the distance between the arbitrary zero and the true zero. I can then use the generalized matching law to solve for C by substituting Equation 5 into Equation 3.

$$C_{ij} = \frac{\left(S_i - S_j\left[\frac{B_i}{B_j}\left(\frac{R_j}{R_i}\right)^a\right]\right)}{\left(\left[\frac{B_i}{B_j}\left(\frac{R_j}{R_i}\right)^a\right] - 1\right)} \tag{6}$$

Equation 6 is only soluble if the sensitivity parameter a is assumed to be equal to one; precedent for such an assumption was set by Miller (1976). An estimate of C will be obtained by taking the mean of C_{ij} for the six combinations of reinforcers. The estimate of C will be used to convert the Thurstone scale values to ratio-level quality measurements via Equation 5. Both transformed and untransformed data sets will be plotted and the test of differences between independent Pearson correlations will be used to compare the goodness-of-fit of the accompanying regression equations.

Anticipated Results

Miller (1976) and Killeen et al. (1993) were both able to estimate the quality of the reinforcers under investigation using the generalized matching law and Thurstone's law of comparative judgment respectively. The success of the experiment depends on the stability of the rats' preferences; luckily, there is evidence from the field of applied behavior analysis that preferences tend to stabilize across time and environment once they are established (Piazza, Fisher, Hagopian, Bowman & Toole, 1996). I therefore anticipate, first, that the values of reinforcer quality that I determine will successfully correct for the deviations from matching as a result of using qualitatively different reinforcers, and second, that the value of C will have a small variance and thus the quality of each reinforcer will truly be on a ratio scale.

The successful execution of the experimental procedure would immediately suggest a number of additional experiments. The unit of the Celsius scale is defined by setting the freezing point of water at zero and the boiling point at one-hundred; a similar set of standards would aid in communication between researchers. The initial zero value could be plain water or cellulose, for example, while one hundred could be a 1 M sucrose solution or a pure sucrose pellet. It would be extremely interesting to investigate the way in which varying single dimensions within quality like flavor, sweetness, texture, and acidity would impact the ratio-scale value of a reinforcer. The development of a ratio scale would allow for the determination of the quality of a reinforcer as a *function* of its sweetness etc, potentially leading to the development of new quantitative principles of sensation and behavior.

Budget

Item	#	Price	Total
50,000 BioServ Dustless Precision Pellets, 45 mg, Rodent, Purified	2	$76.00	$152.00
50,000 BioServ Dustless Precision Pellets, 45 mg, Rodent, Grain-Based	2	$69.00	$138.00
50,000 BioServ Dustless Precision Pellets, 45 mg, Rodent, Chocolate	2	$76.00	$152.00
50,000 BioServ Dustless Precision Pellets, 45 mg, Sucrose, Banana	2	$84.50	$169.00
Med-Associates ENV-203 Pedestal Mount Pellet Dispenser	1	$375.00	$375.00
ABAI Annual Convention Registration Fee	1	$96.00	$96.00
Poster Printing Fee	1	$100.00	$100.00
Airfare	1	$500.00	$500.00
Accomodations	1	$300.00	$300.00
			$1982.00

Budget Justification

The proposed study is fundamentally an examination of individual preferences for qualitatively different reinforcers; therefore the purchase of qualitatively different reinforcers in the form of BioServ Precision Pellets is essential to the study's execution. The number of reinforcers requested is based on an estimate of the number of sessions in each phase that will be necessary to complete data collection.

The components of operant conditioning boxes are known to occasionally break down. In order to ensure the timely completion of data collection I have requested a spare pellet dispenser in order to expedite repair of the experimental apparatus should there be a need to do so.

I intend to present the data collected in the proposed study at the Association for Behavior Analysis International Annual Convention in Seattle, WA in the spring of 2012. In order to facilitate my presence at the conference I request funds to register, print a poster, fly to Seattle, and stay in a hotel room for the duration of the conference.

References

Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 22*(1), 231-242.

Erlichson, H. (2001). Kelvin and the absolute temperature scale. *European Journal of Physics, 22*, 325-328.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4*(3), 267-272.

Herrnstein, R. J. (1974). Formal properties of the matching law. *Journal of the Experimental Analysis of Behavior, 21*(1), 159-164.

Killeen, P. (1972). The matching law. *Journal of the Experimental Analysis of Behavior, 17*(3), 489-495.

Killeen, P. R., Cate, H., & Tran, T. (1993). Scaling pigeons' choice of feeds: Bigger is better. *Journal of the Experimental Analysis of Behavior, 60*(1), 203-217.

Lupfer-Johnson, G., Murphy, E. S., Blackwell, L. C., LaCasse, J. L. & Drummond, S. (2010). Operant behavior in dwarf hamster (*Phodopus campbelli*): Effects of rate of reinforcement and reinforcer flavor variety. *Behavioural Processes, 84*(2), 573-580.

Miller, H. L. (1976). Matching-based hedonic scaling in the pigeon. *Journal of the Experimental Analysis of Behavior, 26*(3), 335-347.

Murphy, E. S., McSweeney, F. K., Kowal, B. P., McDonald, J. & Wiediger, R. V. (2006). Spontaneous recovery and dishabituation of ethanol-reinforced responding in alcohol-preferring rats. *Experimental and Clinical Psychopharmacology, 14*(4), 471-482.

Piazza, C. C., Fisher, W. F., Hagopian, L. P., Bowman, L. G. & Toole, L. (1996). Using a choice assessment to predict reinforcer effectiveness. *Journal of Applied Behavior Analysis, 29*(1), 1-9).

Pierce, W. D., & Epling, W. F. (1995). The applied importance of research on the matching law. *Journal of Applied Behavior Analysis, 28*(2), 237-241.

Poling, A., Edwards, T. L., & Weeden, M. (2011). The matching law. *The Psychological Record, 61*, 313-322.

Rachlin, H. (1971). On the tautology of the matching law. *Journal of the Experimental Analysis of Behavior, 15*(2), 249-251.

Spiga, R., Maxwell, R. S., Meisch, R. A., & Grabowski, J. (2005). Human methadone self-administration and the generalized matching law. *The Psychological Record, 55*, 525-538.

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review, 34*, 273-286.

Project Timeline

December 1, 2011	Initial purchase of budget items completed.
January 1, 2011	Completion of Phase 1: Food Preference Test.
February 1, 2012	Deadline for Poster Submission to the ABAI Convention.
May 1, 2012	Completion of Phase II: Operant Choice Behavior.
May 7, 2012	Completion of Data Analysis.
May 15, 2012	Completion of Poster and Written Report.

May 22, 2012	Final purchase of budget items completed.
May 24, 2012	ABAI Convention.