

SQAB 2006 at a Glance



Friday Morning, May 26 International Ballroom South

- 7:00 Registration, Coffee and Pastries
8:15 William Baum (President's Introduction)
- 8:30 Edmund Fantino et al.
9:05 Warren K. Bickel et al.
9:40 Steven R. Hursh & Alan Silberberg
- 10:15 Coffee Break
- 10:30 Paul Glimcher
11:05 Michael Platt
11:40 Allen Neuringer et al.
- 12:15 Lunch Break

Saturday Morning, May 27 International Ballroom South

- 7:00 Registration, Coffee and Pastries
- 8:15 Douglas Elliffe
8:50 Adam H. Dougherty & Kennon A. Lattal
- 9:25 Coffee Break
- 9:40 J. J. McDowell
10:15 John A. Nevin & Anthony P. McLean
10:50 End of SQAB

Thursday Evening, May 25 International Ballroom South

5:00-8:00+ Registration and Cash Bar

Friday Afternoon, May 26 International Ballroom South

- 1:45 Gordon R. Foxall
2:20 Stephen E. G. Lea
2:55 Alex Kacelnik
- 3:30 Coffee Break
- 3:45 Thomas R. Zentall et al.
4:20 J. Jozefowicz et al.
4:55 Amy L. Odum & Ryan D. Ward
- 5:35 Business Meeting
- 6:15 Poster Session / Cash Bar
until 9:00 pm

Saturday Afternoon, May 27 International Ballroom South

SQAB-Invited Preeminent Tutorials From Basics to Contemporary Paradigms

- 1:00 Charles P. Shimp
2:00 José E. Burgos
3:00 M. Christopher Newland & Wendy Donlin
4:00 A. Charles Catania

SQAB



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Map of Atlanta, 1919

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Twenty-Ninth Annual Conference
Hyatt Regency Hotel
May 26-27, 2006



Atlanta Skyline, 2003



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Notes

7:00-8:15 **Registration, Coffee and Pastries**

8:15-8:30 **Welcome to SQAB 2006: President's Introduction**

William M. Baum
University of California - Davis (USA)



8:30-9:05 **How Reinforcer Type Affects Choice in Economic Games**

Edmund Fantino, Santino Gaitan, Art Kennelly & Stephanie Stolarz-Fantino
University of California - San Diego (USA)

Behavioral economists stress that experiments on judgement and decision-making using economic games should be played with real money if the results are to have generality. Behavior analysts have sometimes disputed this contention and have reported results in which hypothetical rewards and real money have produced comparable outcomes. We report the results of two experiments. In the first, using the Sharing Game, developed in our laboratory, subjects choices differed markedly depending on whether or not the rewards were real or hypothetical. In the second, using the Ultimatum and Dictator Games, we again found sharp differ-

ences between real and hypothetical rewards. However, in this experiment we also showed that time off from a tedious task could serve as a reinforcer every bit as potent as real money. In addition to the empirical and theoretical contributions of these studies, they make the potentially important methodological point that meaningful studies may be conducted with economic games without spending money: time off from a tedious task can serve as a powerful reward.

$$f(x; \mu, \sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-(\ln x - \mu)^2 / 2\sigma^2}$$

9:05-9:40

Discounting of Past Rewards: Comparison of Cigarette Smokers and Controls

Warren K. Bickel, Richard Yi, Kirsten Gatchalian, Diana Lindquist, & Ben Kowal
University of Arkansas (USA)

Recent evidence from our laboratory demonstrated that humans discount rewards in the past similarly to how they discount the future (Yi et al., in press). Specifically, discounting of the past has been shown to be orderly, hyperbolic, demonstrate the magnitude and correlated with future discounting. Here we report on a study to examine whether the greater discounting of future rewards evident among cigarette smokers relative to controls can be extended to the discounting of past monetary rewards.

Twenty-nine smokers and nonsmokers participated in discounting procedures for future and past hypothetical money rewards (\$10, \$100, \$1,000). Hyperbolic discounting rates were determined, and the prevailing magnitude effect was observed. Smokers were found to discount future and past rewards more than nonsmokers with age, gender, income, and education serving as covariates. Future and past discounting of rewards exhibited similar goodness-of-fit measures, were correlated with each other and were not statistically different from each other. This study suggests that addiction produces similar changes in the processes that underlie future and past rewards.

9:40-10:15

The Essential Value of Reinforcers

Steven R. Hursh & Alan Silberberg
Johns Hopkins University School of Medicine & American University (USA)

Skinner found the strength of a rat's eating reflex was correlated with degree of hunger when strength was measured by the frequency of a response that preceded eating. Based on this finding, he argued that response frequency could index reflex strength. Subsequent work documented difficulties with this notion because responding proved to be a function not only of the strengthening properties of the reinforcer, but also of the rate-shaping effects of the schedule by which reinforcement was arranged. The present report argues this problem can be obviated by an economic approach to measuring strength. This approach

favors the use of different fixed-ratio schedules to create a demand curve: a mapping of how total consumption of the reinforcer changes with changes in the "price" that different ratio sizes impose. An equation with one free parameter is presented that does an acceptable job in modeling the demand curves so generated. The value of this parameter can be used to scale the strength or essential value of a reinforcer, independent of the scalar size of the reinforcer. Essential value determines many important aspects of performance: the level of consumption to be expected at particular prices; the level of responding that will occur to support that consumption; the price that generates the most responding; the maximal level of responding, and the highest price that will sustain consumption. This economic approach provides a parsimonious method for comparing reinforcers that differ in kind.

10:15-10:30

Coffee Break

$$f(x; k, x_m) = k \frac{x_m^k}{x^{k+1}} \text{ for } x \geq x_m.$$

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Randolph C. Grace & Anthony P. McLean. Rapid acquisition in concurrent chains: Evidence for a decision model.

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Pauline J. Horne, J. Carl Hughes, and C. Fergus Lowe. Naming and categorization in young children: IV: Listener behavior training and transfer of function.

— SPECIAL ARTICLE —

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— MAY 2006 —

E.B. Papachristos and C.R. Gallistel. Autoshaped head poking in the mouse: A quantitative analysis of the learning curve.

Matthew O'Daly, Samuel Angulo, Cassandra Gipson, and Edmund Fantino. Influence of temporal context on value in the multiple-chains and successive-encounters procedures.

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Sara Tapaeru Minster, Max Jones, Douglas Elliffe, and Suresh D. Muthukumaraswamy. Stimulus equivalence: Testing Sidman's (2000) theory.

Francois Tonneau, Fara Arreola, & Alma Gabriela Martinez. Function transformation without reinforcement.

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Marc N. Branch. How research in behavioral pharmacology informs behavioral science.

— PERSPECTIVE ON BEHAVIOR —

Howard Rachlin. Notes on discounting.

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Friday Morning/Afternoon

Paper Session

Int'l Ballroom South

10:30-11:05 Neuroeconomic studies of Choice and the Matching Law

Paul Glimcher

New York University (USA)

Over the past five years our laboratory has begun a reanalysis of Matching law-type behavior in both human and non-human primates. In both cases we have gathered choice data from subjects facing a discrete trial version of the original CVI schedule of Herrnstein. Humans and monkeys face a sequence of trials at fixed arming ratios for blocks that average 100 trials in length. Arming ratios then switch without warning. For typical human subjects we have data for ≤ 1000 choices for real monetary rewards. For monkeys we have data from upwards of 200,000 choices per subject working for fluid rewards. Using a non-linear regression-based analysis we have estimated the influence of previous rewards and pre-

vious choices on future choice in a manner similar to transfer function analysis. We find that the future choices of humans and monkeys similarly reflect both a recency weighted average of recent rewards (a measurement of first order reinforcement learning) and a more complicated choice function. Neurophysiological measurements in the monkeys suggests that the recency weighted average is computed from the activity of Dopamine neurons in the ventral midbrain. Studies of choice behavior on human Parkinson's patients on and off medication support this conclusion. Finally, studies of neurons in the monkey caudate nucleus during this task suggest models of how Value functions are computed from these recency weighted averages.

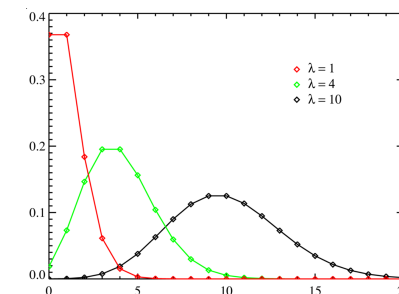
11:05-11:40 Economics in the Primate Brain

Michael L. Platt

Duke University (USA)

Decision-making models in economics, psychology, and behavioral ecology propose that organisms choose amongst options based on expected payoffs. Recent neurophysiological studies suggest that neurons in several brain areas linking visual perception with orienting track fluid reward value associated with visual targets. Here we show that neurons in cingulate and parietal cortex track subjective orienting biases for targets associated with uncertain rewards and the opportunity to view preferred social images, respectively, even when target fluid value is held constant. These data suggest that orienting decisions are made by scaling neuronal responses to targets by their subjective utility. Future studies focus on uncovering the sources of these biases, as well as how internal states, such as hunger or thirst, as well as social context, modulate psychological thresholds for scaling utility.

$$f(k; \lambda) = \frac{e^{-\lambda} \lambda^k}{k!},$$



11:40 - 12:15 **Operant Variability Theory of Voluntary Action**

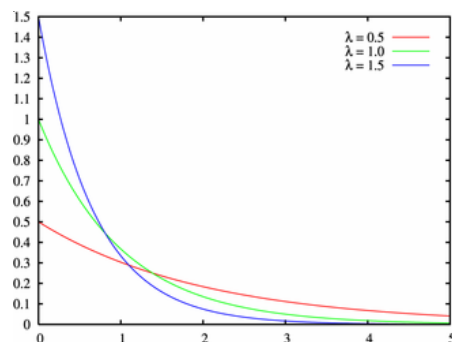
Allen Neuringer, Greg Jensen & Paul Piff
Reed College & Stanford University (USA)

A key problem in explaining voluntary (or free-willed) action is this: how can voluntary behaviors be both functionally related to environmental contexts and independent of environmental influences. On the one hand, voluntary behaviors are thought to be goal-directed, purposeful, and reinforced. On the other hand, they are also thought to be self-generated, "free," and potentially unpredictable. We proposed that voluntary behaviors are operant responses whose levels of variability (from repetition to random-like, unpredictable responding) are influenced by reinforcement contingencies. The theory, referred to as the operant variability theory of voluntary action (OVVA), was tested using the generalized matching function proposed by Baum. Human participants observed and compared the choices among three alternatives emitted by small icons (characters) on computer screens. The participants' task was to judge how well each icon represented voluntary human choice. The icons' differed in terms of their sensitivities to reinforcements (as provided by the sensitivity, or s ,

exponent in the matching function). For example, a "matcher" icon ($s = 1.0$) distributed choices proportional to experienced reinforcement frequencies. Thus, when reinforcements were equal across the three alternatives, and therefore choice probabilities were equal, prediction of the matcher's individual responses was no better than chance. On the other hand, when most reinforcers were obtained from one of the alternatives, the matcher's choices were generally confined to that alternative, and therefore easily predicted. "Undermatcher" icons ($s < 1.0$) tended to respond always unpredictably and "overmatcher" icons ($s > 1.0$) tended to choose the highest-valued alternative, making their behaviors more easily predictable under all reinforcement conditions. The results showed that matching icons were judged to best represent voluntary human choice. Control conditions showed that the appearance of volition depended upon probabilistic emission of choices (patterned matchers were not judged highly) and could not be explained by differences in overall frequencies of experienced reinforcement. The results are consistent with OVVA theory: volition is perceived when response predictability is functionally related to environmental contingencies.

12:15 - 1:45 **Lunch Break**

$$f(x; \lambda) = \begin{cases} \lambda e^{-\lambda x} & , x \geq 0, \\ 0 & , x < 0. \end{cases}$$



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Friday Afternoon

Paper Session

Int'l Ballroom South

1:45-2:20

Explaining consumer choice: Coming to terms with intentionality

Gordon Foxall

Cardiff University (UK)

Scientific explanation is verbal behavior, and any attempt to understand the nature of behaviorism as a philosophy of science, to depict the essence of its distinctive explanatory system, or to delimit the scope of its capacity to explicate behavior, requires an appreciation of how its practitioners use language. I propose that three behaviorist theories that are especially relevant to the explanation of economic behavior - radical behaviorism, teleological behaviorism, and picoeconomics - provide a necessary array of theoretical perspectives in that each contributes uniquely to understanding consumer choice. Despite the differences that separate them at a methodological level, and the internecine disputes in which their adherents

sometimes address one another, these three perspectives play complementary roles in the depiction of everyday consumer behavior. I argue, moreover, that this vital combination of behavior theories owes much to the way in which each has responded to the challenge of intentional explanation. In order to demonstrate this, I offer a framework of analysis which portrays the essential differences between intentional explanation and the extensional approach towards which many behaviorists have striven, and argue that while radical behaviorism scrupulously avoids intentional terms, teleological behaviorism and picoeconomics have in differing ways come to terms with the necessity of combining a behaviorist perspective with the explanatory value of intentional terminology. This continuum of explanations is applied to recent findings of consumer behavior analysis on consumer choice in natural environments.

2:20-2:55

Antelopes, Berries and Children: The ABC of behaving in a consumer culture with a Stone Age brain.

Stephen E. G. Lea & Lesley Newson

University of Exeter (UK)

We are currently seeking to construct an evolutionary economic psychology, making use of the view that biological and cultural evolution interact, and that behaviour (including economic behaviour) is therefore ultimately moulded by gene-culture co-evolution. In the hunter-gatherer economy of the Pleistocene Environment of Ecological Adaptation (EEA), everything is adapted to the production of the greatest possible number of children who will survive to produce grandchildren. We are adapted to the pursuit of Antelopes and Berries for the purpose of producing Children. However, within the consumer culture of a modern economy, virtually all needs and desires are fulfilled by the purchase of goods or services rather than by direct action on the physical or social world. So what behaviours do brains adapted to a complex pursuit of Antelopes, Berries and Children now produce in a consumer culture? There is some evolutionary continu-

ity. Demand curves must have looked much the same in a subsistence economy as in a modern one, since basic principles of demand apply even to animal foraging. But in the production of children, there has been striking change. As societies modernize, they undergo the "demographic transition": their members begin to limit the number of children they have. Instead of being reproducers, members of modern societies have evolved into consumers. We argue that this evolution of consumer behaviour is linked to a decline in the motivation to produce children, resulting from a change in the source of cultural information, from small groups with shared genetic interests to mass groups including marketers. This weakened motivation to produce offspring could have led to a reduction in the effort we put into extracting resources from the environment; but it seems that our hunting and gathering motivations are mechanistically independent of our reproductive motivation. Freed by our consumer culture from the need to hunt and gather, our Stone Age brains still instruct us to expend effort on shopping and buying.

2:55 - 3:30

Tool Oriented Behaviour in New Caledonian Crows: A Challenge to Behavioural Analysis

Alex Kacelnik

Oxford University (UK)

New Caledonian crows are almost unique among animal species for the intensity and sophistication of their manufacture and use of tools. It is not known whether this extraordinary ability is accompanied by exceptional cognitive properties, but some of their deeds are hard to study from a reinforcement perspective. I shall review evidence for creating and selecting tools and for planning sequences of actions, and discuss the relative contribution of inherited and learned capabilities.

3:30 - 3:45

Coffee Break

3:45 - 4:20

Wrinkles in Time Assessment in Animals: Production, Discrimination, Detection, and Subjectivity

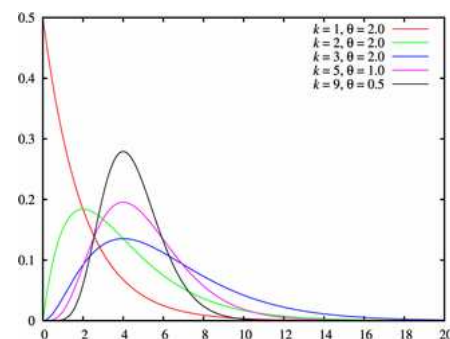
Thomas R. Zentall, Andrea M. Friedrich,
Emily D. Klein, & Rebecca A. Singer

University of Kentucky (USA)

Theories of animal timing have had to account for findings that the memory for the duration of a timed interval appears to be dramatically shortened within a short time of its termination (the choose-short effect). This finding has led to the subjective shortening hypothesis. We propose that the choose-short effect, as well as several findings using the peak procedure in the timing of intervals, is an artifact resulting from the similarity be-

tween the retention interval and the intertrial interval. Furthermore, using the bisection procedure, we report two findings that suggest the passage of time is influenced by context. First, when pigeons learn to discriminate between two durations, they respond to both their absolute and relative durations (the durations are represented as the 'shorter' one and the 'longer' one). Second, pigeons tend to underestimate the passage of time when they are active or when their attention to time related cues has to be shared.

$$f(x; k, \theta) = x^{k-1} \frac{e^{-x/\theta}}{\theta^k \Gamma(k)} \text{ for } x > 0$$



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Friday Afternoon

Paper Session

Int'l Ballroom South

4:20-4:55 Choice, Timing and the Modularity of Behavior

J. Jozefowicz, D.T. Cerutti and J.E.R. Staddon
Duke University (USA)

There are two contrasting frameworks regarding the general organization of behavior. On one hand, the "Cartesian" view considers that all information available to the organism ultimately reaches a central agency where they are integrated and coordinated into a unified picture to determine action. This is a very intuitive position, certainly the most widespread among behavioral scientists. On the other hand, the "modular" view, popular in behavior-based artificial intelligence, denies

the existence of such a central agency: the organism is a collection of independent processes, sensitive to specific information and controlling specific aspects of the organism's performance. Some recent data we obtained with pigeons working in concurrent fixed-interval schedule seem to support this latter view: various aspects of the pigeons' performance (i.e. overall vs. relative response rate, response timing vs. response location) appear to be controlled by independent processes, tuned only to their own set of environmental variables and blind to any manipulation outside of that set.

4:55-5:30 Characterizing the Effects of Drugs on Temporal Discrimination

Amy L. Odum & Ryan D. Ward
Utah State University (USA)

Although the generalized timing model is a prominent account of the neurological basis of timing, results from a surprising number of studies do not match its predictions. We have been investigating procedural differences that could contribute to discrepancies across studies. Recently we have been examining the effects of amphetamine on timing under different symbolic matching to sample procedures with pigeons. In the color variant, a temporal sample is followed by two keys that differ in color. For example, pecking the green key is reinforced after short samples, and pecking the red key is reinforced after long

samples. In the position variant, the keys differ in location. For example, pecking the left key is reinforced following short samples and pecking the right key is reinforced following long samples. Across a variety of arrangements of these procedures, amphetamine dose-dependently decreases the range of the psychophysical function relating key choice to sample duration. The range decreases tend to be more pronounced in the color version of the procedure than in the position version. These changes can be interpreted as a decrease in attention to the samples. We have found little evidence with either variant that amphetamine affects perceived duration of the samples.

5:35-6:15 Business Meeting

6:15-9:00 Poster Session/Cash Bar

$$f(x; k) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2}$$

Haloperidol, Dynamic Choice, and the Parameters of the Matching Law**Carlos F. Aparicio***University of Guadalajara-CUCS-CEAA (Mexico)*

The idea that dopamine mediates the reinforcing effects of positive stimuli, subsist in the field of neurosciences. The present study will show that haloperidol does not interfere with the rat's behavior of pressing on a lever to obtain food reinforcers that varied in magnitude and probability of occurrence. Within sessions the ratio of reinforcers changed seven times in two levers, modeling a dynamic environment. Magnitude of reinforcement was manipulated independently of the ratio of reinforcer provided by the levers. Four doses of haloperidol were assessed (ip) over periods of twelve days. Haloperidol did not stop the discrimination that the rats established between rich and lean levers, response distributions favored the lever associated with the highest probability of reinforcement and the largest number of pellets. The parameters of the generalized matching law (bias and sensitivity to reinforcement) indicated that haloperidol acted upon the motor system, but it did not affect the rat's motivation for food reinforcers.

Effects of Methamphetamine on the Fine Structure of Schedule-Controlled Behavior**J. Adam Bennett, Christine E. Hughes and Raymond C. Pitts***University of North Carolina - Wilmington (USA)*

A detailed analysis of the effects of methamphetamine (0.3 mg/kg - 3.0 mg/kg) on operant behavior of four pigeons responding on a multiple RI 1' RI 4' schedule of reinforcement was conducted. Individual interresponse times (IRTs) were collected and analyzed to determine if the log-survivor analysis described by Shull et al. (2001) would extend to pigeon key pecking and serve as a baseline for the study of drug effects. Results suggested that, under the present experimental conditions, the utility of the log-survivor analysis does not extend to pigeon key pecking. However, order was revealed in the IRT analysis described by Palya (1992). Clear bands of IRTs were evident at approximately 35ms for each bird and also at approximately 70ms for 3 of the 4 birds. Administration of methamphetamine tended to produce a dose-dependent decrease in overall response rates. Doses of methamphetamine which produced a moderate reduction in overall response rates tended to do so by decreasing the occurrence of IRTs at the 35ms and 70ms bands, whereas doses that produced increases in overall rates for one bird did so by increasing the occurrence of IRTs at these same bands.

$$f(t) = \frac{\Gamma((\nu + 1)/2)}{\sqrt{\nu\pi} \Gamma(\nu/2)} (1 + t^2/\nu)^{-(\nu+1)/2}$$

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Friday Evening

Poster Session

Int'l Ballroom South

The Context Shift Effect in Artificial Neural Networks

José E. Burgos & Esther Murillo

CEIC - University of Guadalajara & Tec. de Monterrey, Campus Edo. Mexico (Mexico)

When a conditioned stimulus (CS) is paired with an unconditioned stimulus (US) in a context A and tested in another context B, the conditioned response (CR) is weaker in B. The model proposed by Donahoe, Burgos, and Palmer can simulate this phenomenon. Two groups of experimentally naïve artificial neural networks ($n = 4$) with the same architecture (three inputs, two hidden layers, one CR output, full feedforward connectivity), free parameters, and initial connection weights (.01) from previous simulations, were given two phases (training and testing) of 150 cycles of 15 time-steps (ts). A context was defined as the activation of one input with a constant medium level of 0.5 for the entire experiment. Units I1 and I2 were designated as the inputs for A and B, respectively. CS was defined as the activation of I3 with a level of 1.0 for the last six ts of each cycle and US as the activation of a separate input with the same level at the last ts of each cycle. For one group, A and B were the train and test contexts, respectively. The order was reversed for the other group. The output activation of all networks was substantially smaller in testing than training. These results are explained in terms of the dynamics of activations and weights.

Memorization and Relearning of Discriminative Fixed Intervals in Rats

Marcelo S. Caetano, Paulo Gulhardi & Russell M. Church

Brown University (USA)

When trained under two or three discriminative fixed intervals that were signaled by different stimuli, rats adjusted their pattern of responses in two different ways: memorization or relearning (Caetano, 2006). Under some conditions the pattern of responses early in a session was controlled by the fixed interval (memorization), but under other conditions it was similar at different fixed intervals, but rapidly adjusted within the session (relearning). The goal was to investigate the conditions under which rats memorized or relearned. A previous experiment on the between-session acquisition of discriminative fixed intervals did not examine this within-session effect (Gulhardi & Church, 2005). A reexamination of these data (secondary data analysis) provided both a replication and an extension of the previous conclusions to additional conditions. Twelve rats that were trained with three discriminative fixed intervals within each session, memorized the intervals; 12 other rats that were trained in successive blocks of 10 sessions on each interval learned the three discriminative intervals but did not initially discriminate between intervals when presented with the three intervals within a session. The conclusion from both studies is that rats relearn when rapid relearning is possible, and they memorize when it is not.

Temporal Discounting in Rats Using Qualitatively Different Rewards

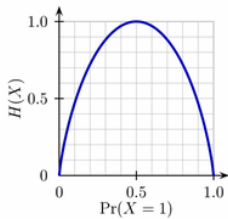
Amanda L. Calvert, Leonard Green, and Joel Myerson
Washington University in St Louis (USA)

Previous research with humans has revealed a magnitude effect in which large amounts of hypothetical consumable and monetary rewards are discounted less steeply than small amounts, but we have not observed a magnitude effect in either pigeons or rats discounting different amounts of delayed food rewards (Green et al., 2004; see also Richards et al., 1997). The present research seeks to uncover whether rats show magnitude effects when choice involves qualitatively different food rewards, assuming that a highly preferred food might be discounted at a lower rate than a less-preferred food. Preference tests conducted prior to the discounting procedure revealed that each of the rats overwhelmingly preferred 50% sucrose precision pellets to 75% cellulose/25% sucrose pellets. An adjusting-amount procedure then was used to find the amount of immediate reward that was valued equally to the delayed reward. Reward amount (10 or 30 pellets) and type (sucrose or 75% cellulose pellets) were varied across conditions. Four discount functions, well-described by simple hyperbolas, were obtained for each rat, but no magnitude effect was found when either reward amount or reward type was manipulated.

Choice and Timing in Concurrent Chains when Terminal-Link Delays Follow a Within-Session Ascending and Descending Series

Darren R. Christensen & Randolph C. Grace
University of Canterbury (NZ)

Eight pigeons were trained in a concurrent-chains procedure in which the log ratio of terminal link immediacies followed an ascending and descending series. In each session, one terminal link delay changed from 2 s to 32 s to 2 s or from 32 s to 2 s to 32 s, while the alternative was constant at 8 s. To allow measures of timing to be obtained, six no-food trials similar to the peak procedure were included for each terminal link per session. Both initial-link response allocation and stop times from individual peak trials tracked changes in terminal-link delays. However, within-session changes in preference were abrupt, whereas corresponding changes for stop times were gradual. These results suggest that initial-link response allocation is determined by a decision process that operates in parallel with a timing system for learning reinforcer delays.



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(Continued on next page)

3:00-3:50 **Applied Modeling and the Identification of Behavioral Mechanisms of Action**

M. Christopher Newland & Wendy Donlin
Auburn University & Johns Hopkins School of Medicine (USA)

Chair: Mark Reilly
Central Michigan University (USA)

A good model will reduce behavior to its fundamental elements. If successful, then this distillation can be exported to other research domains to address mechanistic questions. In our case, for example, the goal is the understanding of how environmental contaminants disrupt operant behavior. We describe our application of models to address the behavioral consequences of exposure to methylmercury: Models of choice using the matching relationship and Shull's mathematical model of behavior as a pattern of engagement bouts. We describe how we selected these models and then the stages of application. For example, with Shull's model we replicate it, extend it to high-rate behavior under percentile and DRH schedules of reinforcement, reproducing its essential features, scale it up and automate parameter estimation it so that it can be applied with a large number of conditions and subjects. Finally, using multiple regression, we test the application to confirm that the model parameters provide independent descriptors of behavior under these reinforcement schedules. The model's parameters can then be used as dependent measures to parse two distinctive effects methylmercury: alterations in reinforcer efficacy and motor competence. In a sense, this application represents, we think, a variation of another model, namely, Pennypacker's model of technology transfer.

4:00-4:50 **Creating Artificial Behavior: A Tutorial on Modeling**

A. Charles Catania
University of Maryland - Baltimore County (USA)

Chair: John E. R. Staddon
Duke University (USA)

A model that generates good approximations to real behavior can help us see how behavior works. Both moment-to-moment features of behavior as shown in cumulative records and global input-output functions as derived from parametric studies of reinforcement schedules can be simulated by a variant of Skinner's Reflex Reserve. Skinner's model, in which reinforced responses added to a reserve depleted by later responding, could not handle the higher rates maintained by intermittent than by continuous reinforcement, but would have worked if not just the last but also earlier responses preceding a reinforcer, each weighted by a delay gradient, contributed to the reserve. With this modification, reinforcement schedules generate steady states in which reserve decrements produced by responding balance increments produced when reinforcers follow responding. Some recommendations about modeling follow from this example: (1) Be explicit about the terms, units and dimensions that enter into the model; (2) Study intermediate details of the simulation, not just end-products, but keep things simple by minimizing inferred entities; (3) Avoid transformations that distance behavior from contingencies or reduce absolute measures to relative ones; and, (4) Design the model so variables can be tinkered with much as experimenters tinker with them in the laboratory.

Knowledge About Behavior in Artificial Neural Networks: Another Case Study

Nadia Corral-Frías & José E. Burgos
Instituto Tecnológico de Estudios Superiores de Occidente & CEIC - University of Guadalajara (Mexico)

A previous work (Burgos, 2002, <http://psycprints.ecs.soton.ac.uk/archive/00000218/>) demonstrated that sameness in structural complexity hindered knowledge about behavior in McCulloch-Pitts systems. In that work, two cases were analyzed. In each case, one system was designated as the to-be-known system (O) and the other as the knowing system (K), and K's task was to achieve a complete and maximally-fine classification of O's behavior (set of input-output relations O could perform), with a single set of connection weights. In one case, both systems consisted of one input connected to one output. In the other case, both systems consisted of two inputs connected to one output. In both cases, K lacked the minimal input and output capacities necessary to achieve the task. For the present paper, a third case was analyzed where K had the minimal input and output capacities necessary to achieve the task (O consisted of one input connected to one output and K consisted of two inputs connected to two outputs). However, K could not achieve the task. Hence, K needs to be even more complex. The implications for the possibility of a significant knowledge of human behavior are discussed.

Learning and Memory Abilities of Turtles (*Pseudemys nelsoni*) for a Cognitive Task

Karen M. Davis
University of Tennessee - Knoxville (USA)

Cognitive abilities in non-avian reptiles have received considerably less attention compared to mammals and birds. Freshwater pond turtles (Emydidae) are long-lived, can be easily conditioned with small food rewards, and prior studies have shown that they are particularly adept at visual discriminations. We developed a procedure for training 9 Florida red-bellied cooters, *Pseudemys nelsoni*, to an instrumental task (dislodging clear plastic bottles to obtain food pellets). The training phase involved stages of shaping until the animals reliably performed the task. Then the animals were tested in a 2-choice (non-correction) design on their ability to choose the bottle containing pellets. All nine turtles learned the task and showed an average of 71% success rate. After two months, and again after another 8 months of no interaction with the bottles, turtles were retested. Significantly fewer days were needed to retrain turtles in session 2 and 3. Furthermore turtle strategies changed, with a significant increase in latency to task completion between the first session and last session. This preliminary study of future more automated studies, demonstrates in a laboratory context the long-term memory skills that may be used by emydid turtles in returning to nest sites.

Maternal Nutrition and Choice in a 4-alternative Analog to the Within-Sessions Procedure

Michael Davison^{1,2}, Christian Krageloh², Mhoyra Fraser² & Bernhard Breier²

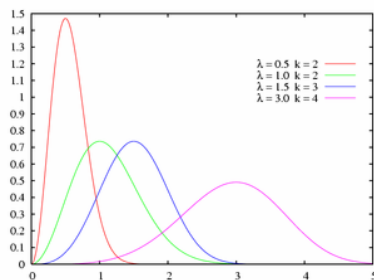
¹Department of Psychology ²National Research Centre for Growth & Development, University of Auckland (NZ)

Two groups of rats, one of which had been subjected to decreased maternal nutrition, were trained in a 4-alternative procedure in which pellets were provided every 15 s on average, and the alternatives produced different rates of pellets in the ratio 27:9:3:1. The locations of the different rates were randomized across alternatives after every 10 pellets or after every 20 pellets. Choice adapted to the locations of the reinforcer rates after only a few pellets, but generalized matching failed to describe the behavior allocation. However, choice was excellently described by a contingency-discriminability model with just 3 parameters.

Testing The Ideal Free Distribution With Street Children

Gerald Disma, Michel B. C. Sokolowski & Francois Tonneau
University of Amiens & University of Guadalajara (France, Mexico)

We observed groups of three to six children foraging for money on the streets of Istanbul, Turkey. The children sold bottles of water to car drivers distributed in two lanes. As predicted by the ideal free distribution, the proportion of children in the two lanes tracked the proportion of cars (hence, potential buyers) occupying these lanes. Deviations from the predictions of the ideal free model arose in part from restrictions on the set of ratios compatible with a small group size. When these constraints are taken into account, adherence to optimal behavior emerges as a robust aspect of our findings.



$$f(x; k, \lambda) = (k/\lambda)(x/\lambda)^{(k-1)} e^{-(x/\lambda)^k}$$

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1:00-1:50

Explicit Methods and Implicit Human Values in Quantitative Behavioral Models

Charles P. Shimp
University of Utah (USA)

Chair: Randolph C. Grace
University of Canterbury (NZ)

Quantitative models of behavior will be described, sorted, and informally categorized in terms of their underlying metaphors, including geometric, mechanical, hydraulic, electromechanical, statistical, computer, cosmological, philosophical, political, ecological, and logical metaphors. They will also be categorized in terms of the purposes for which they are constructed, including to summarize data, predict new phenomena, to identify basic mechanisms, and to integrate diverse phenomena in terms of similar underlying mechanisms. The diverse means by which they are evaluated will also be described, for example, in terms of parsimony, descriptive accuracy against data, descriptive accuracy compared to

2:00-2:50

Neural-Network Modeling in Conditioning Research

José E. Burgos
CEIC - University of Guadalajara (Mexico)

Chair: Steven Stout
Jacksonville State University

This tutorial is a primer to neural-network modeling in conditioning research. After a brief historical introduction to this kind of modeling and philosophical disquisition on model plausibility in empirical science, the elementary concepts of neural processing element, connection, activation function, and learning function, are presented. Emphasis is made on the concept of a neural network as a set of (inter)connected realizations of a neurocomputational model. Then three well-known models (McCulloch-Pitts, perceptron, and backpropagation) are reviewed and judged as neuro-behaviorally too implausible. The model proposed by Donahoe, Burgos, and Palmer (1993; JEAB, 60, 17-40) is presented as a more plausible (albeit admittedly incomplete) alternative. Its behavioral plausibility is exemplified through simulations that have implications for persistent conceptual issues in behavior science, such as the operant-responder dichotomy. To show its heuristic value, two novel predictions for Pavlovian conditioning are discussed.

9:25-9:40 **Coffee Break**

9:40-10:15 **Undermatching as an Emergent Property of Selection by Consequences**

J. J. McDowell
Emory University (USA)

Research has shown that a computational dynamics of instrumental behavior based on selection by consequences yields steady state responding that can be described by Herrnstein's hyperbola. The computational model implements the idea that behavior evolves in response to selection pressure exerted by the environment in the form of reinforcement. The model requires specific fitness rules, and specific selection, reproduction, and mutation methods, but computational experiments have shown that the steady-state outcome of the model does not depend on any specific implementation of these components. In addition, analyses of fits of the hyperbola to data from the computational model indicate that the residuals are random, although deviations from randomness were detected

in 12 of 57 published fits (21%). A separate line of theoretical work suggests that Herrnstein's original hyperbola should be abandoned in favor of a hyperbolic form that allows for bias and undermatching, where undermatching is accommodated by an exponent on reinforcement rate. Fitting this modern form of the hyperbola to data from the computational model yields substantially improved residual profiles. This finding suggests that the steady-state outcome of the computational model is better described by the modern form than the original form of Herrnstein's hyperbola, and hence that undermatching is an emergent property of selection by consequences. Interestingly, the estimated value of the exponent was about 0.8 for all fits to the computational data. No quantitative or qualitative detail of the model caused the exponent to vary systematically from this value.

10:15-10:50 **A Unified Model of Response Rates and Resistance to Change in Multiple and Concurrent Schedules**

John A. Nevin & Anthony P. McLean
University of New Hampshire & University of Canterbury (USA & NZ)

A model derived from behavioral momentum theory describes both response rate and resistance to change in Component 1 of a multiple schedule as an increasing function of Component 1 reinforcer rate and a decreasing function of Component 2 reinforcers functioning as disruptors. The model gives a good account of the data in multiple chains, serial schedules, and standard two-component multiple VI VI schedules with different reinforcer rates, by assuming different degrees of a confusion process in which some reinforcers may effectively be reallocated between components and thus affect both response

rate and resistance to change in both. It also accounts for the decrease in response rate and increase in resistance to change when VT reinforcers are arranged in one component of a multiple VI VI schedule, or an alternative response is reinforced concurrently. Applied to standard concurrent schedules, the model states that response rate on Alternative 1 is a decreasing function of Alternative-2 reinforcers functioning as disruptors, and resistance to change is an increasing function of the combined reinforcer rates on both alternatives. The model gives a good account of response rate in concurrent schedules, and predicts, consistent with some data, that resistance to change for concurrent operants is essentially the same regardless of reinforcement rate.

Changing Lever Force Requirements Alters Parameter Estimates Relating to Reinforcer Efficacy: Modeling Fixed-Ratio Functions with Mathematical Principles of Reinforcement and Matching Theory

Andrew T. Fox, Dennis J. Hand & Mark P. Reilly
Central Michigan University (USA)

Four male Long-Evans rats were trained to lever press under fixed-ratio schedules of food reinforcement. The force requirement for lever pressing was manipulated across conditions. Response rates were a bitonic function of ratio value; response rates increased then decreased as the ratio increased. When the force requirement increased, response rates decreased, more so at larger ratio values. Response rate functions were well accounted for by Mathematical Principles of Reinforcement (Killeen, 1994) but not by single-response Matching Theory, which failed to account for the bitonic nature of the functions. Both models assume invariance between the putative parameters that represent response capacity and reinforcer efficacy. However, as response capacity was reduced by increasing the force requirement, reinforcer efficacy declined. The effects of two different types of food pellets on response rates were also investigated to attempt to show that under certain conditions, the parameters of the two models can be shown to be independent. The results showed that the parameter representing reinforcer efficacy changed but the parameter representing response capacity remained unchanged. Both models' parameter estimates of reinforcer efficacy were affected by different force requirements, supporting the idea that response effort is linked to reinforcer value.

Shifts in the Psychophysical Function in Rats

Paulo Guilhardi, Mika L. M. MacInnis, & Russell M. Church
Brown University (USA)

The goal was to compare results from a free operant procedure using pigeons (Machado & Guilhardi, 2000, Experiment 2) with new results obtained using rats. Moreover, the goal was to use the primary data obtained from the pigeons to compare the results of both experiments using dependent variables that were not necessarily used in the original publication. As in the original study with pigeons, rats were trained on a two-alternative free-operant psychophysical procedure in which left lever press responses were reinforced for the first and second quarters of a 60-s trial, and right lever press responses were reinforced for the third and fourth quarters of the trial. The quarters were reinforced according to four independent variable interval schedules of reinforcement (VI). The VI duration was manipulated in each quarter and shifts in the psychophysical functions that relate the two responses were measured. Results reported by Machado & Guilhardi (2000) using pigeons were compared to those obtained with rats. In addition, results not originally reported were also compared. The availability of primary data provides the possibility of direct comparisons of results that were not necessarily published in the original study (e.g., conditions not reported, individual subjects, additional dependent measures).

Reln* Dosage, Schizophrenia, and Temporal Processing*Ruth Hurst & Walter Salinger***University of North Carolina - Wilmington & University of North Carolina - Greensboro (USA)*

As in schizophrenics, brain regions in heterozygous reeler (+/*rl*) mice synthesize *Reln* at subnormal rates and display abnormal structural and histochemical phenotypes. Standard high throughput assays, however, repeatedly fail to detect behavioral abnormalities in +/*rl* mice. Reported here, *rl/rl* mice on fixed interval schedules (FI) of reinforcement for lever pressing reveal impairment of behavior control with respect to time (also impaired in schizophrenia, attention-deficit/hyperactivity disorder, and autism). Additional testing with reinforcement only when mice responded below a criterion rate (DRL) controls for possible dyskinesia and confirms that +/*rl* and *rl/rl* mice measure time with adequate sensitivity and reliability while revealing that they are inferior to wild types (+/+) at inhibition of inappropriate responses, in a *Reln* gene dose dependent manner.

Choices by Pigeons Under Concurrent Schedules when Reinforcement Availability and Disappearance are both Probabilistically Controlled by Responses**Greg Jensen & Allen Neuringer***Reed College (USA)*

In most studies of choices under concurrent schedules of reinforcement, once a reinforcement becomes available (or sets up), it remains available until collected. However, in natural environments, reinforcement availability is generally limited, e.g., by competition (other animals might get the reinforcer) or degradation (e.g., spoilage or other loss). That is, in nature, previously available reinforcers often disappear. In the first of two experiments, pigeons responded under a three-key (A, B, and C) concurrent schedule of reinforcement. A peck to any of the keys caused three probability generators to "fire," with each generator governing availability of reinforcement on one of the keys. Once a reinforcer became available, it remained so until collected. The schedule was therefore analogous to the more commonly studied concurrent Variable Interval, except that reinforcement availability was response-based rather than time-based. Programmed probabilities of reinforcement were systematically varied, with 5 sessions per set of values. Relative frequencies of choices during the last session of each set approximately matched obtained relative frequencies of reinforcement, with both calculated as $[A/(B+C)]$, $[B/(A+C)]$, and $[C/(A+B)]$. In the second experiment, a single set of reinforcement probabilities was maintained throughout [0.10, 0.06, and 0.04] while the probabilities of reinforcement disappearance (analogous to limited hold, and representing competition and degradation), were systematically varied (the disappearance probabilities were always equal across the three keys). Response distributions were highly sensitive to this manipulation, with preferences for the high-probability-of-reinforcement key A increasing as probabilities of disappearance increased. However, again, matching of relative response frequencies to obtained relative reinforcement frequencies was observed. Thus, competition (or other causes of reinforcement disappearance) has strong influences on choice but leaves matching intact.

7:00-8:15

Registration, Coffee, Pastries

8:15-8:50

Problems in Comparing Quantitative Models: Variability, Replication, and Constraint**Doug Elliffe***University of Auckland (NZ)*

A central task of a quantitative analysis of behavior is the evaluation of quantitative models. Often, these models differ in the number of free parameters they contain or, equivalently, in whether the value of a parameter is constrained to be constant across some experimental manipulation. Extra parameters or parameters that are free to vary always increase goodness of fit, but at the cost of reduced parsimony. Several ways of judging the balance of those costs and benefits have appeared in our literature, including fitting of residuals, calculating incremental variance accounted for, looking for an interaction in an ANOVA model, testing for significant differ-

ences in parameter values, and calculating the Akaike or Bayesian information criteria. Judgments based on these techniques will be explored using a data set from a concurrent VI VI experiment in which both reinforcer rates and magnitudes varied, and using some examples from the literature. Different techniques produce different conclusions, and no technique is identifiably best practice. Two imperatives are in conflict - the need to recognize that parameter estimates are only best fits to data, and the need to take advantage of the replication across subjects that our experiments arrange. One or other of these has usually been ignored. The problem of objective model comparison is also bound up with the difficulty of proving the null hypothesis. "Not significantly different" doesn't necessarily mean "interestingly and importantly constant".

8:50-9:25

Studying Applied Compliance Procedures in Pigeons**Adam H. Doughty & Kennon A. Lattal***College of Charleston & West Virginia University (USA)*

Compliance procedures derived from applied behavior analysis and social psychology were studied with pigeons. A discrete-trial procedure operated such that a trial was a single stimulus presentation (i.e., baseline conditions) or multiple stimulus presentations (i.e., test conditions). In 3 experiments, a sequence of reinforced high-probability responses, or free food presentations, did

or did not precede a low-probability response (i.e., high-p or foot-in-the-door procedures). The probability of completing the low-probability response (i.e., compliance) was controlled both by the sequences and its own reinforcement schedule. In a final experiment, the probability of completing the low-probability response was increased by a sequence of nonreinforced stimuli (i.e., door-in-the-face procedure). Different accounts of these findings (e.g., in terms of behavioral momentum theory and incentive theory) are discussed.

$$F(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^x \exp\left(-\frac{(u - \mu)^2}{2\sigma^2}\right) du.$$

Applications of Timing Theories to a Peak Procedure

Linlin Yi

Brown University (USA)

This study presents applications of timing theories to a Peak procedure. A multiple cued-interval experiment (houselight and white noise) with two fixed intervals (FI 60 and 120 s) was conducted in 12 rats. Twenty-five percent of cycles were 360 s long without food (Peak 60 and 120 s). An outline of the general computational approach to fitting the data to quantitative timing models will be presented. Both individual and averaged data were fitted with explicit solutions of Packet theory, Scalar expectancy theory (SET), and Learning to time theory (LeT).

A comparison of Two Algorithms in Computerized Temporal Discounting Procedures

Richard Yi, Reid D. Landes, Amanda C. Erisman, Casey S. Pierce & Warren K. Bickel

University of Arkansas for Medical Sciences (USA)

Temporal discounting refers to the reduction in the present, subjective value of an outcome that is delayed in time. Interactive, computerized temporal discounting procedures ask participants to choose between an immediate outcome and a delayed outcome on each of numerous trials; the immediate outcome is titrated from trial to trial according to a specified algorithm with the goal of approaching the point at which both outcomes are subjectively equivalent. The purpose of this study was to compare two titration algorithms that are being increasingly applied in interactive, computerized discounting procedures: the double-limit procedure and the decreasing-adjustment procedure. Twenty individuals participated in the two discounting procedures for hypothetical money gains that were identical with the exception of the titration algorithm. Analyses indicate a systematic difference between the algorithms, with significantly higher indifference points obtained in the double-limit procedure; this was confirmed with comparison of hyperbolic discounting rates.

*I would like to express the Society's appreciation
to each of the presenters,
and to the following journals:*

*Learning & Behavior
Journal of the Experimental Analysis of Behavior
Journal of Applied Behavior Analysis
The Behavior Analyst*

*Randolph Grace
(Program Chair)*

Reinforcement Processes in the Spontaneously Hypertensive Rat (SHR) - An Animal Model of Attention Deficit / Hyperactivity Disorder

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¹University of Oslo & ²Arizona State University (Norway, USA)

Attention-deficit/hyperactivity disorder (ADHD) is characterized by a pattern of inattention, hyperactivity and impulsivity that is cross-situational, persistent, and produces social and academic impairment. A behavioral theory of ADHD links ADHD symptom development to a steeper and shorter delay-of-reinforcement gradient. The spontaneously hypertensive rat (SHR) has been validated as an animal model of ADHD: Behavioral testing of SHR and children with ADHD using the same reinforcement schedules shows that they share the same behavioral characteristics. Using SHR and Wistar Kyoto (WKY) controls, the present studies examined properties of the delay-of-reinforcement gradient in a hole-box procedure using water reinforcers, and in a second procedure tested the effects of varying reinforcer value (electric current) using intra-cranial self-stimulation (ICSS). The results from the hole-box show a steeper and shorter delay-of-reinforcement gradient in SHR compared to WKY. The results from ICSS show that response rate as a function of ICSS current intensity is (a) higher for both strains at higher rates of reinforcement; (b) reaches its maximum sooner at higher rates of reinforcement in SHR than in WKY; and (c) reaches a higher maximum for SHR than for WKY at lower rates of reinforcement. In conclusion, reinforcer contiguity, value, and rate affect behavior differently in SHR than in WKY controls.

A Comparison of Probability Discounting Procedures with Delay Discounting: A Matter of Choice?

Robert Johnson, Darlene E. Crone-Todd & Barrie J. Todd

Delta State University (USA)

Recent research on human choice involving delay and probability discounting functions indicates that these measures can be used as a measure of self-control. However, little research has directly compared different methods of administering the probability discounting and comparing the methods to delay discounting. The present experiment directly examines two different probability discounting (PD, where the probability varies from .10 to .90) procedures and a delay discounting (DD) procedure as follows: (1) PD1, in which the certain (100% probability) amount is varied within the trial and the probability of the higher amount (either \$500 or \$5000) varies between trials; (2) PD2, in which the probability of the higher amount varies with each trial, and the certain amount is varied between trials (from 10% to 90% of the higher amount); (3) DD, in which the delayed amount varies from 1 day to 1 year. Using a transitive mixed factorial design, three groups of participants (N = 54) were presented with PD1 versus PD2, PD1 versus DD, or PD2 versus DD. Analyses will be presented regarding the relationship between the measures, and the ability of the hyperbolic function to describe the data.

The Effects of Response Contingency on Timing

Richard Keen, Paulo Guilhardi & Russell M. Church

Converse College & Brown University (USA)

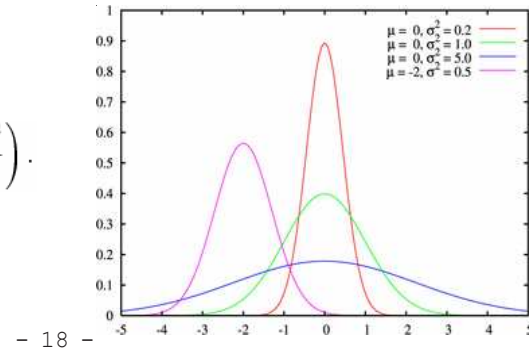
The goal of the present study was to examine how the contingency between response and reinforcement affects timing behavior. In appetitive head entry experiments, rats received food contingent on their head being in the food cup (Dwell), their head entering the food cup (Entry), or independently of any response (Classical). These contingencies were either in a fixed interval or random interval procedure. The reinforcement schedule (Fixed or Random) had a strong effect on the response distribution, but a minimal effect on the response probability. Conversely, the response contingency (Dwell, Entry, or Classical) had a strong effect on the probability of a response, but a negligible effect on the response distribution.

Multiple Unreliable Time Markers and a Packet Theory of Timing

Richard G. Keen, Mika L.M MacInnis & Linlin Yi

Converse College & Brown University (USA)

The goal of this study was to determine how rats use multiple time markers (stimulus and food) to anticipate the time of the next food availability when both time markers are unreliable (not presented on every cycle). Rats were trained on an operant appetitive head entry procedure in which food was available (primed) every 120 s and a 1-s white noise stimulus was presented 30 s prior to food prime. Following training four trial types were presented to the rats on each session: 1) "normal" trials in which both the food and the stimulus were presented, 2) "food" trials in which only the food was presented, 3) "stimulus" trials in which only the stimulus was presented, and 4) "empty" trials in which neither the food nor the stimulus was presented. On the odd trials of each session "normal" trials were presented. On the even trials of each session each of the four trial types had an equal probability of being presented. Results showed that both the food-to-food and the stimulus-to-food intervals were learned. A Packet theory of timing was used to model the data, and produced fits that well characterized the response patterns observed.



$$f(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x - \mu)^2}{2\sigma^2}\right).$$

A Method for Measuring Domestic Hens' Preferences for Sounds

Amy Tannahill

University of Waikato (NZ)

Six hens responded under equal independent multiple concurrent variable-interval schedules of reinforcement with an overlaid sound associated with one key. The key that the sound was associated with was alternated between components. In the first condition there was no sound, and the sound used over the following conditions was varied over conditions. In Experiment 2, hens will respond under a modified concurrent-chain variable-interval schedule of reinforcement procedure with the various sounds turned on in only one of the two fixed-interval terminal links. Both procedures give measures of the bias resulting from the presence of the various sounds and so both should provide quantitative measures of preference. The obtained results from the two methods will be compared and discussed in relation to their applicability in identifying sounds that can be used in field situations, such as in conservation and pest control effort.

Speeding up the Internal Clock with Visual Flickering Stimuli

Laura Ortega Torres & Florente López Rodríguez

Universidad Nacional Autónoma de México (México)

Scalar Expectancy Theory proposes an internal clock that emits pulses at a constant rate. However, there is evidence showing that the pulse rate can be accelerated by preceding the time-sample stimuli with a flickering light. We tested the possibility that the same effect can be obtained in a bisection task when the flickering stimuli were presented during the training or the test phase. In the first experiment, visual stimuli indicating duration during the training phase flickered at a rate of ten per sec in one group but remained constant in a second group. A third group received similar treatments but during the testing phase. Two duration ranges were presented (200-800ms and 400-1600ms). Obtained bisection points and psychophysical functions suggested that visual flickering in the test phase produces overestimations of the presented durations, while visual flickering in the training phase yields an underestimation. Flickering stimuli did not affect neither Weber fraction, Difference Limen nor Scalar Property. These results were replicated in a second experiment when a flickering background was tested instead of the stimuli themselves. These results are discussed in the context of the memory components of the scalar expectancy theory

$$f(k; p) = \begin{cases} p & \text{if } k = 1, \\ 1 - p & \text{if } k = 0, \\ 0 & \text{otherwise.} \end{cases}$$

The Ideal Free Distribution in Humans: A New Tool for Research or Teaching

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Universite de Picardie & University of Guadalajara (France & Mexico)

The ideal free distribution (Fretwell & Lucas, 1970) predicts how individuals with equal competitive weights should distribute themselves in the environment when resources are patchily distributed. If free to move from one patch to another, foragers should distribute themselves among patches until, at the equilibrium, all sites provide the same gain per individual. Little experimental work on the ideal free distribution has been done with humans. Here, we propose a new tool for testing the predictions of the ideal free distribution in a human analogue of foraging. Nine subjects were seated in front of the screen of a video projector with a gamepad in their hands. On each trial of the experiment, each subject used the gamepad to set the hue (red or green) of his or her coloured disc shown on the screen. This choice was the analogue of a patch choice. All disks were shown on the screen, hence everybody could see everybody's choice. After the choices stabilized, the computer chose randomly a number of winners in each colour and incremented their score. This was the analogue of resources in patches. The number of winning subjects, which varied across blocks of ten trials, was announced through a speech synthesizer. Thus, the game was equivalent to a continuous-input foraging experiment with complete information. The observed distribution of subjects was close to the predictions of the ideal free distribution. However, we observed deviations in some conditions. To explain these deviations we suggest that subjects used two extreme strategies in some conditions and a mix of them in other conditions.

Learning to Count: Acquisition of Responding in a Numerical Reproduction Task with Pigeons

Lavinia Tan & Randolph C. Grace
University of Canterbury (NZ)

We studied acquisition of responding in the the numerical reproduction task introduced by Tan et al. (submitted). Subjects were trained to respond to a series of 2, 4, or 6 keylight flashes in a sample phase, and then make the same number of keypecks on the center key followed by a single response to the right key. The reliability of temporal cues in predicting response requirement was degraded through the randomization of the total sample phase duration and the individual inter-stimulus intervals (ISIs). Three pigeons received approximately 210 sessions of baseline training, and then tested with novel numbers (1, 3, 5 and 7) in 10 sessions of transfer testing. Across sessions, the correlation between stimulus and response number increased, even when controlling for temporal cues such as overall sample duration and flash rate. Multiple regression analyses revealed an increase across sessions in total variance in response accounted for by numerical and temporal cues, and variance in response number explained uniquely by stimulus number. Additional analyses of response variability were performed to investigate possible processes underlying the development of counting behavior in this procedure.

Pigeons' Timing but not Choice Adapts Rapidly to Suddenly Equivalent Terminal Links

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University of Canterbury (NZ)

Evidence from studies using rapid acquisition procedures demonstrates that pigeons' choice and timing behavior is capable of adapting to dynamic environments. In the present experiment we asked how choice and timing behavior that had adapted to frequently-changing terminal links would be affected by a sudden switch to constant and equal terminal links. Pigeons received extensive training in concurrent chains with FI 10 and FI 20 terminal link delays where the location of the shorter terminal link varied according to a 31-step pseudorandom binary sequence, followed by 11 sessions where both terminal link delays were FI 15 s. Baseline performance was consistent with that reported in prior research (Kyonka & Grace, submitted). When terminal links were changed to FI 15 FI 15, pigeons continued to demonstrate strong preferences for either terminal link in each of the 11 test sessions. By contrast, measures of temporal control over terminal-link responding showed an immediate adjustment to the new schedule values, after only a few reinforcers had been delivered in the first test session. This surprising result provides evidence that choice and timing behavior can be dissociated under some circumstances.

The Effects of Negative Contingencies on Human Choice Behavior in Simple and Complex Decision-Making Tasks

Celia Lie & Brent Alsop
University of Otago (NZ)

Previous research on the generalized matching law (Baum, 1974) has largely focused on the effects of positive contingencies on choice behavior. There has been less attention paid to the effects of negative contingencies, particularly in conditional discrimination tasks. Here, we present a series of experiments that investigated the effects of different types of punishers on human choice behavior using a simple conditional discrimination task, and a more complex decision-making task. In the simple discrimination task, participants judged whether various stimulus arrays contained more items of one color or another. In the complex task, participants were presented with various statements, and judged whether each statement was "true" or "false". The relative frequency or magnitude of the punishers was manipulated across conditions. Results showed systematic negative relations between response bias and the punisher contingencies. This provides further evidence for the symmetric effects of reinforcers and punishers in choice procedures.

Stay and Switch Reinforcement and Bouts of Responding

James S. MacDonall

Fordham University (USA)

Recently, several investigators reported that responding maintained by variable-interval schedules of reinforcement occurred in bouts (Killeen, Hall, Reilly, & Kettle 2002; Shull, Gaynor & Grimes, 2001). Initiating bouts and responding in a bout each occurred randomly in time. Interresponse times (IRTs) were described by a double exponential equation, where one exponential described the rate of initiating bouts and the other described the rate of responding in bouts. The purpose of this analysis was to begin to apply this approach to responding maintained by concurrent schedules. I analyzed the IRTs, which were not included in the published report (MacDonall, 2006), from responding maintained by one pair of stay and switch schedules. Run lengths and visit durations were a joint function of the ratio of the stay to switch reinforcers earned per visit and the sum of the stay and switch reinforcers earned per visit (MacDonall, 2006). For these rats, responding only occurred randomly in time but not in bouts. The decay (rate) parameter in the exponential equation also was a function of these variables. Whether a more punctuate response, like nose poking, would produce bouts remains to be determined.

Do Rats Time Filled and Empty Intervals of Equal Duration Differently?

Mika L. M. MacInnis

Brown University (USA)

The goal was to determine whether rats time empty and filled intervals of equal duration differently. Each of five rats was trained for 50 sessions on an instrumental appetitive head entry procedure in which food was available (primed) every 120 s. On "empty" cycles, 30 s prior to the next food prime a 0.5-s pulse of white noise was presented. On "filled" cycles, 30 s prior to the next food prime white noise came on and stayed on until food was delivered. The two types of cycles were presented with equal probability. The results showed that the rats timed both the food-to-food interval and the stimulus-to-food interval. A comparison of the response gradients on filled and empty cycles following stimulus presentation showed better temporal discrimination on filled cycles. The results were modeled using a Packet theory of timing, with a linear averaging rule to combine the temporal information provided by the stimulus and food. A comparison of the combination rule parameters between cycle types reflected the superior temporal discrimination on filled cycles. The model fits to the individual response gradients were evaluated using a Turing test.

$$f(k; N, q, s) = \frac{1/(k+q)^s}{H_{N,q,s}}$$

Psychophysical Thresholds: How many Probe Sessions are Enough?

Renee Railton

University of Waikato (NZ)

Within psychometrics, probe sessions are often only conducted once in order to determine a particular psychophysical threshold for an organism. However, by only conducting one probe session, the researcher may underestimate or overestimate the threshold that they are measuring. In this experiment, six hens were trained to discriminate between a flickering and a still light in order to determine their critical flicker fusion frequency (CFF) threshold. The probe sessions consisted of increasing the flicker rate by 5Hz over blocks of trials for a total of 10 sessions each in order to determine the CFF of these hens. It was found that the first 2-3 probe sessions tended to underestimate the CFF thresholds, i.e., early probe sessions were lower than the remaining sessions which remained fairly stable. As a result, more than one probe session may be required in order to gain a more accurate picture of an organism's psychophysical threshold. The results of this study will be presented in light of their implications for assessing the psychophysical abilities of hens.

Is Reaction Time a Measure of Complexity of Choices in Delay Discounting Tasks?

Elias Robles & Jeffrey Anastasi

Arizona State University (USA)

Delay discounting (DD) rate has emerged as a robust measure of impulsivity. Procedural variations in estimating DD have not been fully characterized, and may lead to important differences in the subjects' behavior. In this study, participants were administered a computerized DD task where 8 delay values were presented in ascending order, and 30 immediate hypothetical reward values were presented in descending order. A second group of participants was exposed to the delay values in descending order, and to the immediate rewards in ascending order. In addition, all participants were assessed with a DD task with the same 240 choice trials presented in a random order. Each trial was followed by a 3 s intertrial interval during which no choices were available. Systematic changes in reaction time were observed with the 3 tasks. Reaction times increased gradually as choice options approximated indifference points, with the indifference point choice associated with the longest reaction time. Reaction time decreased abruptly following the indifference point for the ascending and descending sequences but gradually decreased for the random sequence. These data suggest that in most cases, reaction time parallels the complexity involved in making individual choices in DD tasks.

$$H(x) = \sum_{i=1}^n p(i) \log_2 \left(\frac{1}{p(i)} \right) = - \sum_{i=1}^n p(i) \log_2 p(i).$$

Some Quantitative Properties of Terrorism

John A. (Tony) Nevin

University of New Hampshire (USA)

Some quantitative properties of terrorism are common to very different terror campaigns. Consider lethal terror attacks and retaliations within Northern Ireland from 1971 through 1976, a regional campaign with clear political goals, and international terror attacks by Al Qaeda from 1993 through 2005, a global campaign with unclear political goals. For both Republicans and Loyalists in Northern Ireland, and for Al Qaeda (excluding Iraq): 1) Times between lethal attacks were exponentially distributed, suggesting a constant probability of attack over time. 2) The proportion of attacks with at least N deaths was a negative power function of N, as in other relations between severity and frequency (e.g., earthquakes). Although the forms of the functions characterizing these terror campaigns are the same, their parameters differ: Al Qaeda attacks occurred far less often and were far more deadly than attacks and retaliations in Northern Ireland.

Reinforcer Quality and Resistance to Change

Christopher A. Podlesnik & Timothy A. Shahan

Utah State University (USA)

Resistance to change across multiple-schedule components is a positive function of increases in reinforcer rate and magnitude. Relatively little is known, however, about how differences in reinforcer quality affect resistance to change. In the present investigation, rats responded on a two-component multiple schedule with equal VI 60-s schedules in both components. One component presented food pellets and the other component presented a sucrose solution. A range of resistance-to-change tests were conducted, including extinction, free access to food pellets or sucrose prior to the session, response-independent presentations of food pellets or sucrose during the intercomponent interval, and the availability of food pellets or sucrose throughout the entire session (i.e., contrafreeloading). Baseline response rates were higher in the component presenting food pellets for 2 out of 4 rats, similar across components for one rat, and slightly higher in the sucrose component for one rat. Resistance to extinction in the food component tended to be greater relative to the sucrose component to the degree that baseline response rates in the food component were greater than in the sucrose component. Resistance to the other disrupters typically was greater in the component when the reinforcer in the other component had been devalued (e.g., resistance to contrafreeloading with food pellets was greater in the sucrose component). These results suggest: a) Resistance to extinction with reinforcers that differ in quality may be a function of relative reinforcer efficacy, as indexed by baseline response rates; and b) Disruptions are greater when the particular reinforcer maintaining responding in a component is devalued.

$$f(k) = \frac{-1}{\ln(1-p)} \frac{p^k}{k}$$

Choice in a Somewhat Variable Environment: Modest Sensitivity to Reinforcement Amount

David R. Maguire, Christine E. Hughes & Raymond C. Pitts

University of North Carolina - Wilmington (USA)

Effects of reinforcement amount on choice were investigated in 4 pigeons. Responding was maintained under concurrent VI 30-s schedules, and reinforcer amount was manipulated by varying the number of 1.2-s hopper presentations. In Phase 1, amount ratios associated with the 2 alternatives were varied within sessions using a "variable-environment" procedure similar to that described by Davison and Baum (2003); a 5-component mixed schedule with an unpredictable component order was used here. After over 60 sessions, responding for all subjects remained relatively insensitive to reinforcer amount. In Phase 2, relative reinforcement amount (1 or 7 hopper presentation(s)) was held constant within and across sessions. Once responding became stable, the amounts arranged for each alternative were reversed. After 6 sessions in each condition, all subjects showed an appreciable shift in preference toward the larger alternative. In Phase 3, the reinforcer amounts (1 or 7) associated with each option changed from session to session according to a 31-step pseudorandom binary sequence (cf. Hunter & Davison, 1985). After one cycle through the sequence, response ratios for all subjects began to track the reinforcer ratios (i.e., subjects showed moderate sensitivity to reinforcement amount). These results suggest that sensitivity to reinforcer characteristics in a rapidly changing environment may depend on a specific behavioral history.

Species Differences between Rats and Pigeons in Choices with Probabilistic and Delayed Reinforcers

James E. Mazur

Southern Connecticut State University (USA)

An adjusting-delay procedure was used to study rats' choices with probabilistic and delayed reinforcers, and to compare them with previous results from pigeons. A left lever press led to a 5-s delay signaled by a light and a tone, followed by a food pellet on 50% of the trials. A right lever press led to an adjusting delay signaled by a light followed by a food pellet on 100% of the trials. In some conditions, the light and tone for the probabilistic reinforcer were present only on trials that delivered food. In other conditions, the light and tone were present on all trials that the left lever was chosen. Similar studies with pigeons (e.g., Mazur, 1989, 1995) found that choice of the probabilistic reinforcer increased dramatically when the delay-interval stimuli were omitted on no-food trials, but this study found no such effect with the rats. In other phases of the experiment, the probability of food was varied, and comparisons to previous studies with pigeons indicated that rats showed greater sensitivity to decreasing reinforcer probabilities. The results suggest that there are both quantitative and qualitative differences in how these two species make choices that involve probabilistic reinforcers.