

PRE-DECISIONAL AND POST-DECISIONAL
LATENCIES IN RATS

By

NANCY ANN MARLIN

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Thesis Approved:

Larry Hochhaus

Thesis Adviser
Robert F. Stevens

Robert Weber

Norman D. Durham
Dean of the Graduate College

997585

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CHAPTER I

INTRODUCTION

Historical Background

Philosophers have long considered man's "awareness of his own awareness" to be a characteristic unique to mankind. It has been speculated that this reflective ability separates man from the animals. While animals show awareness of their present states, and indeed past states through their behaviors, it is thought that they have no cognition of this awareness or of their memory.

Besides the representations so far considered, namely those which according to their construction could be referred to time, space, and matter, if we see them with reference to the object, or to pure sensibility and understanding [i.e., knowledge of causality] if we see them with reference to the subject, yet another faculty of knowledge has appeared in man alone of all the inhabitants of the earth; an entirely new consciousness has arisen, which with very appropriate and significant accuracy is called reflection. For it is in fact a reflected appearance, a thing derived from this knowledge of perception, yet it has assumed a fundamentally different nature and character. It is not acquainted with the forms of perception, and in its regard even the principle of sufficient reason, which rules over every object, has an entirely different form. It is only this new consciousness at a higher potential, this abstract reflex of everything intuitive in the non-perceptual conception of reason, that endows man with that thoughtfulness which so completely distinguishes his consciousness from that of the animal, and through which his whole behavior on earth turns out so differently from that of his irrational brothers (Schopenhauer, 1958, p. 36).

Frequently within science such intriguing ideas preclude experimental investigation. This occurs because such phenomena are almost

inevitably complex, and are therefore difficult to operationally relegate to a laboratory setting. The domain of scientific research is restricted by the methodologies available for making accurate measurement. Utilization of the scientific method requires public and replicable observations, thus constraining areas of research to those amenable to such procedures.

The problem seems more pronounced in the science of psychology in behavior is used as the data base. Disagreement exists as to the delineation of which areas should be included within this behavioral domain. In the behaviorist framework of psychology objective measures of overt behavior are sought. Radical behaviorists disparage any attempt to deal with subjective or internal states, interpreting these as suspect remnants of introspectionism. Yet because of the nature of psychology, stringent adherence to overt behavior may not be the most prudent or productive method for the advancement of psychological knowledge. Behaviorism ignores an important realm of available data concerning the complementary subjective behaviors that are occurring. Recent trends in cognitive psychology take issue with the rigid behavioristic approach. Neisser (1967), for example, contends that psychology is essentially concerned with the mind and its processes, not merely with behavior. Psychology employs behavior as the necessary means to gain access to the workings of the mind. This viewpoint supports active processing and transformation of information within the individual. With the development of psychology sophisticated and intricate methodologies have evolved to measure complex subjective experience. These allow for quantification of conscious private experience.

Signal Detection Theory

Recent methodological developments in signal detection theory have provided impetus for measures of processes such as "awareness of awareness" (Murdock, 1966). Signal detection theory originated in electrical engineering work with detection problems in radar, and was soon applied to the more general area of psychophysics and perception as an alternative to threshold measures of sensation (Swets, Tanner, & Birdsall, 1961). Threshold theory states that there is a sensory threshold, above which sensation is experienced, and below which the subject would simply guess. To accommodate for guessing, the traditional "correction for guessing" was utilized (Kinsch, 1970). Yet experimental studies indicated threshold measures were unreliable, both between and within subjects (Swets, 1964).

Threshold measures ignored the fact that our subjective experience is not a direct reflection of reality or of the stimulus input to the sensory receptors; more than sensory information must be involved. Signal detection theorists postulated that psychological information processing must exist in addition to the sensory processing. The idea of background interference or "noise" seemed to augment the necessity of processing other than sensory, especially when considered in light of the physiological findings of spontaneous neural activity:

Imagine some neural pulses arriving at the brain; are they due to light entering the eye, or are they merely spontaneous 'noise' in the system? The brain's problem is to 'decide' whether neural activity is representing outside events, or whether it is mere 'noise' which should be ignored (Gregory, 1973, p. 81).

Psychophysicists hypothesize an active decision-making process in addition to the sensory process which determines if the individual will

respond to the sensation. To experimentally separate these two components, that is, to obtain independent measures of sensitivity and decision processes, signal detection methods were adapted.

In signal detection theory, two different but overlapping distributions are assumed to exist: one for random noise (N), and one for signal-plus-noise (S+N), with the mean of the signal-plus-noise distribution having the higher value (see Figure 1). These distributions are usually depicted as normal, and as having equal variances. The abscissa represents the value or strength of an observation, which is the sensory data on which the decision is based. The ordinate displays the probability of the observational value occurring within each of the probability density distribution functions. Signal detection theory provides a measure of sensitivity which is uncontaminated by response bias or decision factors, and which varies along a single continuum. The distance between the means of the distributions is d' , the sensitivity measure.

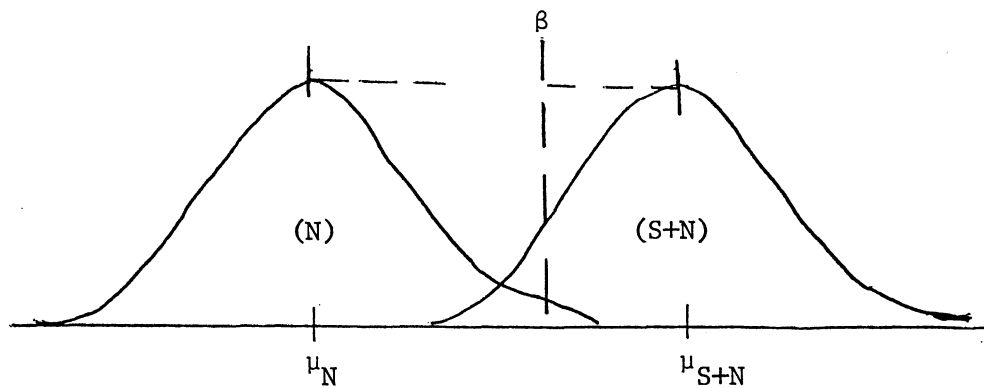


Figure 1. Hypothesized Distributions of Signal Detection Theory

For observational values where the distributions overlap, perfect discrimination is impossible. The subject must decide between the two distributions. For this decision process, the subject adopts a criterion, β , which is essentially a cutoff point on the observational scale. For values above the criterion the subject reports experiencing a signal, and below the criterion reports no signal. Thus, assuming there is some overlap in the two underlying distributions, there are four interdependent conditional probabilities which can be obtained from this binary decision process. They are: the hit rate $\{HR = P(S+N|S+N)\}$, the false alarm rate $\{FAR = P(S+N|N)\}$, and their complements, the miss rate $\{MR = P(N|S+N)\}$, and the correct rejection rate $\{CRR = P(N|N)\}$. The relationship between the hit rate and false alarm rate is depicted in the receiver operating characteristic (ROC) curve.

The signal detection view sounds deceptively similar to threshold theory. In signal detection theory, however, the criterion is set by the subject, and is not a function of sensory processes, but depends on motives, values, and expectations regarding noise and signal-plus-noise events (Swets, Tanner, & Birdsall, 1961). The criterion describes a response or decision threshold rather than a sensory threshold; in signal detection theory sensation is represented by a continuous process. Signal detection theory and threshold theory also differ in the shapes assumed for the noise and signal-plus-noise distributions. In threshold theory the distributions are traditionally rectangular, thus all values occur with equal frequency.

Rectangular distributions are certainly atypical in psychology, and it appears counterintuitive that extreme and mean observational values would occur with equal frequency. Nonetheless, because signal

detection theory hypothesizes a sensory continuum instead of two discrete states, these different distributions make testable predictions.

According to threshold theory, the relationship between the hit rate and false alarm rate should increase linearly as the subject moves his criterion along the observational axis. Signal detection theory predicts that as the subject moves the criterion from right to left the rate of change will first be greater for the hit rate, and then greater for the false alarm rate, producing a smoothly arched ROC curve.

Prior to the work of Egan, Shulman and Greenberg (1959), the experimental manipulation of the criterion required many experiments under varying conditions of payoff or instructions, each of which produced one point on the ROC curve. Egan et al. developed the now common methodology of having the subject report responses on a confidence rating scale. The use of this method assumes the confidence ratings reflect the multiple criteria subjects must maintain on each trial. The frequency of responses for each confidence rating within each of the two response categories (e.g., "old" and "new" in a recognition task) are recorded, and the hit rates and false alarm rates are then calculated by moving the criteria along the divisions between these multiple ratings. The confidence rating technique allowed great economy in the generation of ROC curves as the ROC curve could now be obtained after a single experiment. The resulting ROC curves were smoothly arched, supporting signal detection theory (Bernbach, 1967; Donaldson & Murdock, 1968; Murdock, 1965; Swets et al., 1961).

This procedure has been generalized so that it can be employed with animal as well as human subjects. In such instances the confidence ratings are operationally defined by response latencies (Hack, 1963,

1966). Experiments with human subjects in which dependent measures of both confidence ratings and response latency were made have also empirically demonstrated this relationship (Murdock, 1968; Norman & Wickelgren, 1969). The extreme confidence ratings (e.g., very certain) were quick responses, while the less extreme confidence ratings had longer response latencies.

In experiments with human observers latency measures have generally been supplementary to confidence ratings, and it has often been considered that they convey similar information. Both confidence and response speed are assumed to be inverted U-shaped functions of response strength, the longest latencies and lowest confidence ratings being near the criterion. Norman and Wickelgren (1969, p. 195) state "response latency is related to trace strength in exactly the same way that confidence judgements are related to trace strength." The basic theoretical interpretation is that very strong or very weak observational values, being distant from the criterion, are easy to respond to quickly, and the subjects will be most certain of these responses. But observational values near the criterion are more difficult to discriminate, and therefore receive lower confidence ratings (Murdock, 1974). Studies done with infrahumans using response latency also substantiate signal detection theory assumptions by their resultant ROC curves (Hack, 1963, 1966; Hume, 1974; Yager & Duncan, 1971).

The implications of the confidence rating method go beyond simple verification of the assumptions of equal variance and normal distributions. Confidence ratings demonstrate that subjects can maintain multiple subjective decision criteria. Subjects can evaluate and compare their single observation against other subjective observations and

determine within which confidence range the observation falls. Subjects can accurately rate their confidence of an observation. In a recall memory paradigm using confidence ratings, Murdock reports that subjects "give highest ratings when they are nearly always correct, when they give lowest judgements they are nearly always wrong, and intermediate judgements are ordered accordingly" (Murdock, 1966, p. 320). Confidence ratings and response latencies demonstrate the complexity and accuracy of processing information concerned with man's awareness of observational information.

A second type of confidence rating can be given, which suggests an even more cognitive level of information processing in the individual. This deals with the process earlier referred to as "awareness of awareness". Rather than give a confidence rating of his certainty of the observation (the stimulus), the subject gives a confidence rating based on his judgement of the correctness of his own response. This measure has been labeled Type II d' (Clarke, Birdsall, & Tanner, 1959).

Type II d' differs from Type I d' in several respects (Clarke, Birdsall, & Tanner, 1959; Healey & Jones, 1973; Murdock, 1974). The major distinction is that Type I d' is stimulus conditional; what is given by the subject is a rating based on his confidence of the presence or absence of the stimulus signal. The a priori probability of the signal is determined by the experimenter. The confidence rating is an expanded response which generates several points (as opposed to just one point generated by a Yes-No response) to be plotted on the ROC curve.

In contrast to Type I d' , Type II d' is a response conditional discrimination. Whereas in Type I d' the distributions between which

the subject must decide represent noise and signal-plus-noise, in Type II d' the two distributions represent incorrect and correct responses. "Type II is more complicated as it deals with the receiver's rating of confidence in his identification response" (Clarke et al., 1959, p. 629). Type II d' confidence ratings are ratings of the subject's confidence in the correctness of the response, and are given after the first response or decision is made. "The subject first gives a forced response . . . then evaluates this response by giving a confidence judgement to indicate how sure he is that this response is correct" (Murdock, 1974, p. 118).

Type II d' appears to be a second-order mode of behavior, corresponding to "awareness of awareness", in which the observer's conscious experience is evaluated. The fascinating aspect of this research is that subjects can accurately evaluate their own responses. In short, they know when they are right and know when they are wrong. Positive values of Type II d' have been empirically demonstrated in a variety of studies (Bernbach, 1967, 1971; Donaldson & Glathe, 1970; Murdock, 1966). Throughout trials subjects gave accurate evaluations of the correctness or incorrectness of their own responses. Such data attest to the complexity of cognitive processing in man. Type II d' is a tool which may enable researchers to objectively grasp this type of information processing.

Statement of the Problem

One of the purposes of the present experiment was to investigate whether the data of human memory studies can be generalized to infra-humans. The present experiment measured Type I d' and Type II d' of

rats using response latencies before and after a two-choice decision.

The decision-making processes and discriminative abilities of rats have been studied under a wide variety of circumstances. It has been shown that signal detection analysis can be applied to the decision behavior of rats (Blough, 1967; Hack, 1963, 1966; Hume, 1974). In the present study, Type I d' was computed from the rats' pre-decisional running latencies and Type II d' was computed from post-decisional running latencies. If Type II d' data from human subjects will generalize to rats, the rat's running speed should be faster after correct responses than after incorrect responses.

The methodology and design can be viewed as a learning or memory paradigm in which the correct and incorrect responses represent the two overlapping distributions of signal detection analysis. The present attempt to relate post-discrimination latencies to correct and incorrect responses should not be confused with earlier attempts to measure Type I processing in animals, although pre-decisional latencies, yielding a measure of Type I d' were also recorded. Type II d' is thought to measure the evaluative or response editing processes of cognitive functions such as memory, learning, and perception. These areas are themselves interrelated on methodological grounds; for this reason the more inclusive term of awareness has been used.

In a broader sense, the present investigation is a comparative study that raises speculation as to the commonality of such information processing between species. The traditional Thorndikian approach presumes that the behavioral differences between species are only of a quantitative nature. More recent comparative analyses suggest that "suspicion has lingered that there are qualitative differences as

well . . . 'qualitative' in the sense that phenomena of learning characteristic to some animals fail entirely to occur in others" (Bitterman, 1975, p. 700).

The present experiment examines running latency prior to and following a two-alternative forced-choice discrimination in a modified T-maze. Resultant d' values were obtained from the recorded latencies and the correctness of direction choice. A Type I d' significantly different from zero would replicate previous findings in the animal psychophysical literature (Blough, 1967; Hack, 1966; Hume, 1976), while findings of Type II values significantly different from zero would support the idea that Type II processes can be generalized to other species through this method.

CHAPTER II

METHOD

Design

The design of the present experiment was a successive conditional discrimination (Mackintosh, 1974). The discriminative stimulus was a light at the decision point in the maze. For example, when the light was on the correct response was to turn right; when the light was off the correct response was to turn left. The correct direction for the presence or absence of the discriminative stimulus was counterbalanced across subjects, and the discriminative stimulus' absence or presence (light on or off) was randomized across trials.

On each trial, the direction of the subject's choice, either correct or incorrect, as well as the pre-decisional and post-decisional latencies were recorded. The pre-decisional latency was defined as the time from when the subject entered the choice point area until it passed the decision point; the post-decisional latency was defined as the time from when the subject passed the decision point until the subject reached a goal box.

Subjects

The subjects were four adult female hooded rats. All subjects were experimentally naive and approximately 150 days old at the time of

testing. They were adapted to handling and were individually housed in plastic cages. Subjects were food deprived for 48 hours prior to Session One, and were maintained on a restricted diet of approximately 12 grams of Purina Laboratory Chow per day following each session. Water was available ad libitum throughout the experiment. A diurnal cycle of approximately 10 hours dark - 14 hours light was maintained in the animal colony room.

Procedure

Several shaping trials, in which food was placed in the food cups of both goal boxes, were used to familiarize the subjects with the apparatus. For each trial during the experiment the discriminative stimulus (the light) was turned on or off with a probability of .5 on each trial according to a random pattern, two food pellets (Noyes Precision Food Pellet, 4.5 mg) was placed in the correct goal box, and the subject was placed in the start box. After reaching a goal box the subject was removed from the maze and returned to its home cage, and the latencies and response direction were recorded. The four subjects were given each trial sequentially (i.e, Trial 1, Subject 1; Trial 1; Subject 2; Trial 1, Subject 3; Trial 1, Subject 4; Trial 2, Subject 1, . . .) generating a mean intertrial interval for each subject of approximately five minutes. This procedure continued until the subject reached a criterion of ten successive correct trials.

A ceiling of 60 seconds for the pre-decisional and post-decisional latencies, as well as for the animal to leave the start box, was imposed. Subjects exceeding this value were returned to their home cage and it was considered as one trial for the subject although no data was

recorded for that trial. Water was available at all times in the home cage during the intertrial interval and the room was dimly illuminated during all sessions.

Due to the observation that subjects were demonstrating a strong position preference, a rerun correction procedure was introduced for incorrect responses from Trial 125 - Trial 185. Under this procedure each subject was returned to the start box following an incorrect decision until a correct choice was made.

Apparatus

The maze used was a wooden modified T maze (Figure 2). The runway measured 3 feet (.9144 meters) from the start box to the choice point, and each arm had a total cumulative length of 5 feet (1.524 meters). A 15-watt light bulb and socket were mounted to the maze at the choice point. The maze alleys were 4 inches (10.16 cm.) wide, with at least 4 inch (10.16 cm.) high walls throughout. After the choice point the two alleys were made discriminable by the presence of .75 inch (1.90 mm.) white textured rubber strips in the left alley. With the exception of the white food cups in each goal box and the white textured strips in the left alley, the entire maze was painted flat black. Three sets of Lafayette Photoelectric Cells, Model PC-45, were connected to relays to two Hunter Klockcounters, calibrated to thousandths of a second, were used to record pre-decisional and post-decisional running latencies.

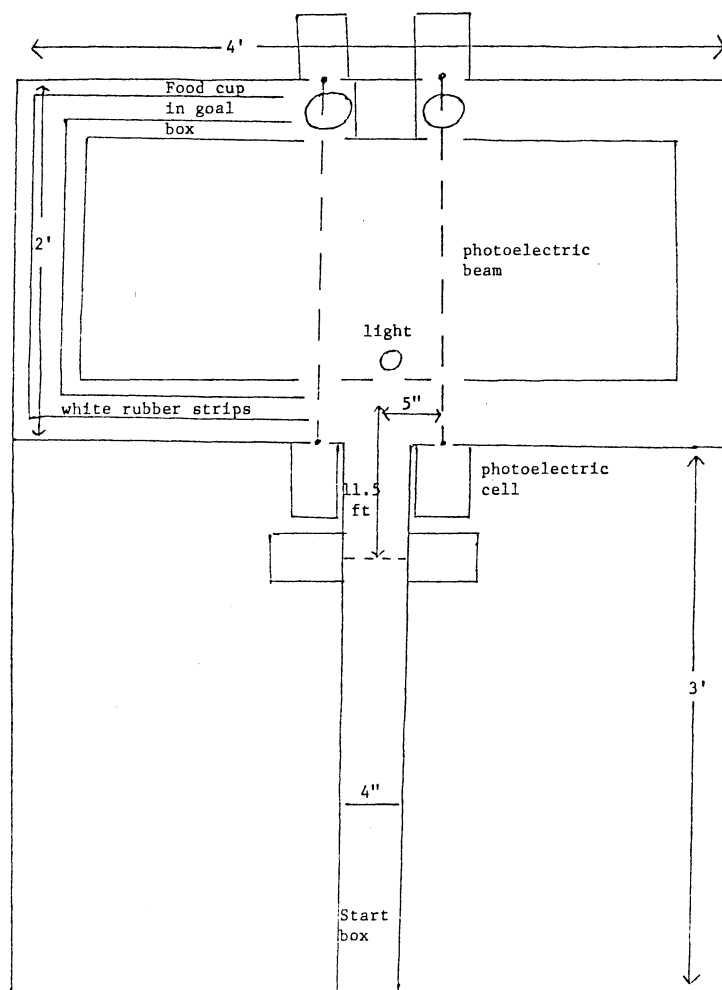


Figure 2. Diagram of Maze Drawn to Proportion

CHAPTER III

RESULTS

Each of the four subjects was able to learn the discrimination to the criterion of ten correct successive trials of correct responses. A mean of 175.2 trials ($\sigma = 24.8$) was required to reach the criterion excluding rerun correction trials and including the ten criterion trials. Subject 4 reached criterion during Session 7; Subjects 1, 2, and 3 reached criterion during Session 10. The rate of learning was somewhat erratic as shown by the acquisition data in Figure 3.

Performance was particularly close to the chance level of 50% during the middle sessions. This was due to the position habits subjects developed, commonly observed in discrimination learning. By always choosing to run to one arm of the apparatus, animals were effective on a Variable Ratio-2 Schedule of Reinforcement. Responding was maintained by the fact that animals were reinforced for this response on the average of every other trial. This strategy of always running in the same direction is presumably less difficult for the animal than the successive conditional discrimination. The correction rerun trials, in which the animal was given as many subsequent trials as necessary to make the correct response of choosing the opposite arm of the maze and obtaining the reinforcement, were successful in extinguishing these habits. On correction rerun trials the probability of reinforcement on

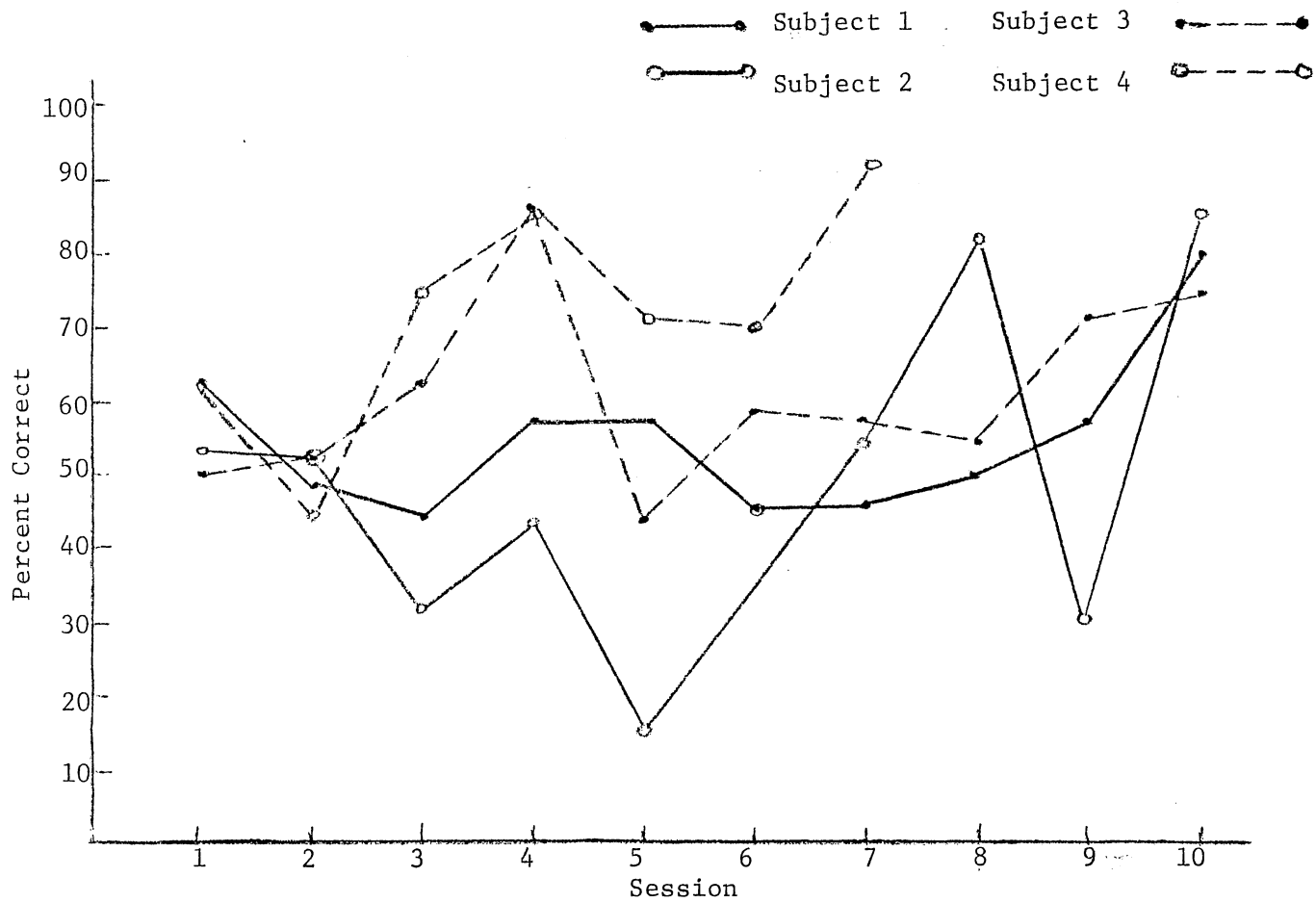


Figure 3. Percent of Correct Responses During Each Session of Individual Subjects

the preferred but incorrect side was reduced to zero.

On many trials, particularly during the first few sessions but to a larger extent throughout the entire experiment, data was lost due to rats reaching the imposed 60 second ceiling or attempting to climb out of the maze or onto the photoelectric cells.

In analyzing the data to obtain values of d' for pre-decisional and post-decisional latencies it is desirable to eliminate prelearning, chance performance in order not to overshadow any differences after the animal has begun to learn the discrimination. Due to the great variability in the learning curves (Figure 3), the last 20 trials of each subject prior to reaching the learning criterion were used as data points in the signal detection analysis. This number of trials was selected as being a reasonable sample size from which to estimate values of d' . The last 20 trials were selected as it is the data immediately prior to criterion which should be most sensitive to differences, if any, which exist between correct and incorrect latencies. These data have the additional advantage of having complete data for almost all of these trials as the above-mentioned problems resulting in loss of data were very infrequent by this point in the experiment.

The pre-decisional latencies for the last 20 trials prior to criterion for all four subjects (a total of 55 correct and 25 incorrect responses) were combined for analysis as no significant differences were found between subjects, $F(3,76) = .88, p > .25$. The pre-decisional latencies were grouped into decile categories (cf. Yager & Duncan, 1971) and then divided into correct and incorrect responses within each decile category. The frequency, cumulative frequency, and proportions of responses within each of these divisions is shown in Table I. The

TABLE I

PRE-DECISIONAL LATENCY CATEGORIES, CONDITIONALIZED UPON CORRECT AND INCORRECT
RESPONSES FOR THE LAST 20 TRIALS FOR ALL SUBJECTS PRIOR TO CRITERIA

Latency in Milliseconds		≤ 300	≤ 350	≤ 400	≤ 450	≤ 500	≤ 550	≤ 600	≤ 650	≤ 700	≤ 2500
Cumulative Frequency	Correct	1	20	33	39	45	47	50	50	51	55
	Incorrect	1	3	7	12	15	19	20	23	23	25
Cumulative Proportion	Correct	.018	.364	.600	.709	.818	.854	.909	.909	.927	1.00
	Incorrect	.040	.120	.280	.480	.600	.760	.800	.920	.920	1.00
Cumulative Probability	Correct	1.8	36.4	60.0	70.9	81.8	85.4	90.9	90.9	92.7	1.00
	Incorrect	4.0	12.0	28.0	48.0	60.0	76.0	80.0	92.0	92.0	1.00

resultant ROC curve from these data is shown on linear coordinates in Figure 4 and on normal deviate (z-score) coordinates in Figure 5.

As predicted by signal detection theory, the ROC curve on linear coordinates is smoothly arched, although the obtained curve is not symmetrical. On normal deviate coordinates, the ROC curve approximates a linear function. The value of d' was obtained from this graph by multiplying $\sqrt{2}$ by the distance along the minor diagonal between the origin of the normal deviate graph (zero detectability) and the ROC function according to the graphical method of signal detection theory (Simpson & Fitter, 1973). For the pre-decisional latency data, d' is equal to .65. This value of d' is significantly greater than zero as compared by the G-test (Gourevitch & Galanter, 1967), $G = 2.09$, $p < .04$. For the last 20 trials prior to reaching criteria subjects' pre-decisional latencies reflected a discrimination between correct and incorrect choices. Fast pre-decisional choice times were associated with correct responses.

Post-decisional response latencies of the last 20 trials for each subject were also analyzed using the graphical method of signal detection theory. Latencies were combined over subjects for analysis as no significant differences between subjects were present, $F(3,76) = 1.08$, $p > .25$. The decile categories for post-decisional latencies, conditionalized upon correct and incorrect responses, are given in Table II. The untransformed response probabilities are graphed on linear coordinates in Figure 6 and the same data is plotted in terms of normal z-scores in Figure 7. As can be clearly seen from the graphs, the Type II d' value of .07 does not significantly differ from chance, $G = .23$,

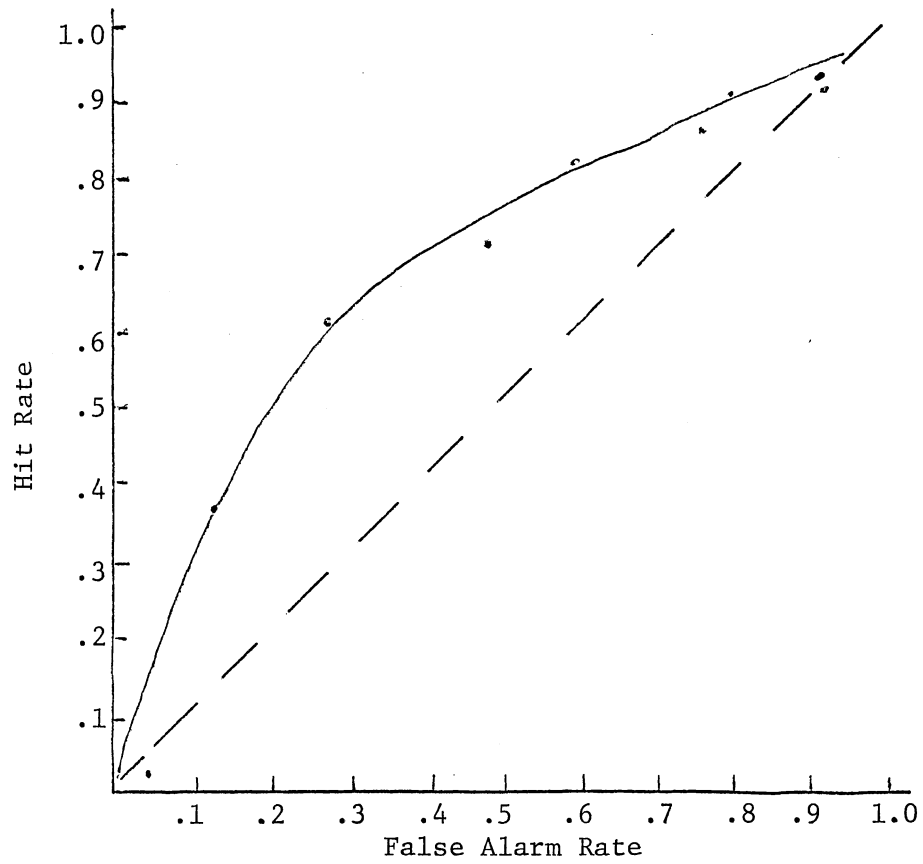


Figure 4. ROC Curve for Pre-Decisional Latencies

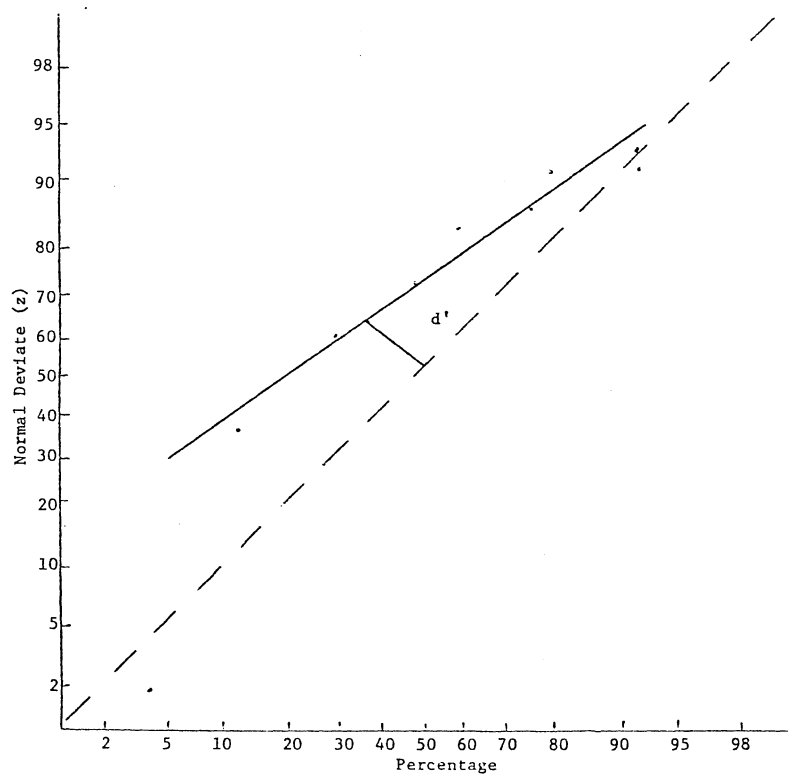


Figure 5. ROC Curve for Pre-Decisional Latencies

TABLE II

POST-DECISIONAL LATENCY CATEGORIES, CONDITIONALIZED UPON CORRECT AND INCORRECT
RESPONSES FOR THE LAST 20 TRIALS FOR ALL SUBJECTS PRIOR TO CRITERIA

Latency in Seconds		≤ 1.7	≤ 1.8	≤ 1.9	≤ 2.0	≤ 2.1	≤ 2.2	≤ 2.3	≤ 2.4	≤ 2.5	≤ 16.0
Cumulative Frequency	Correct	1	6	15	22	31	33	37	42	46	56
	Incorrect	0	1	8	11	13	13	19	20	20	24
Cumulative Proportion	Correct	.018	.017	.268	.393	.554	.589	.661	.750	.821	1.00
	Incorrect	.000	.042	.333	.458	.542	.542	.792	.833	.833	1.00
Cumulative Probability	Correct	1.8	10.7	26.8	39.3	55.4	58.9	66.1	75.0	82.1	1.00
	Incorrect	0.0	4.2	33.3	45.8	54.2	54.2	79.2	83.3	83.3	1.00

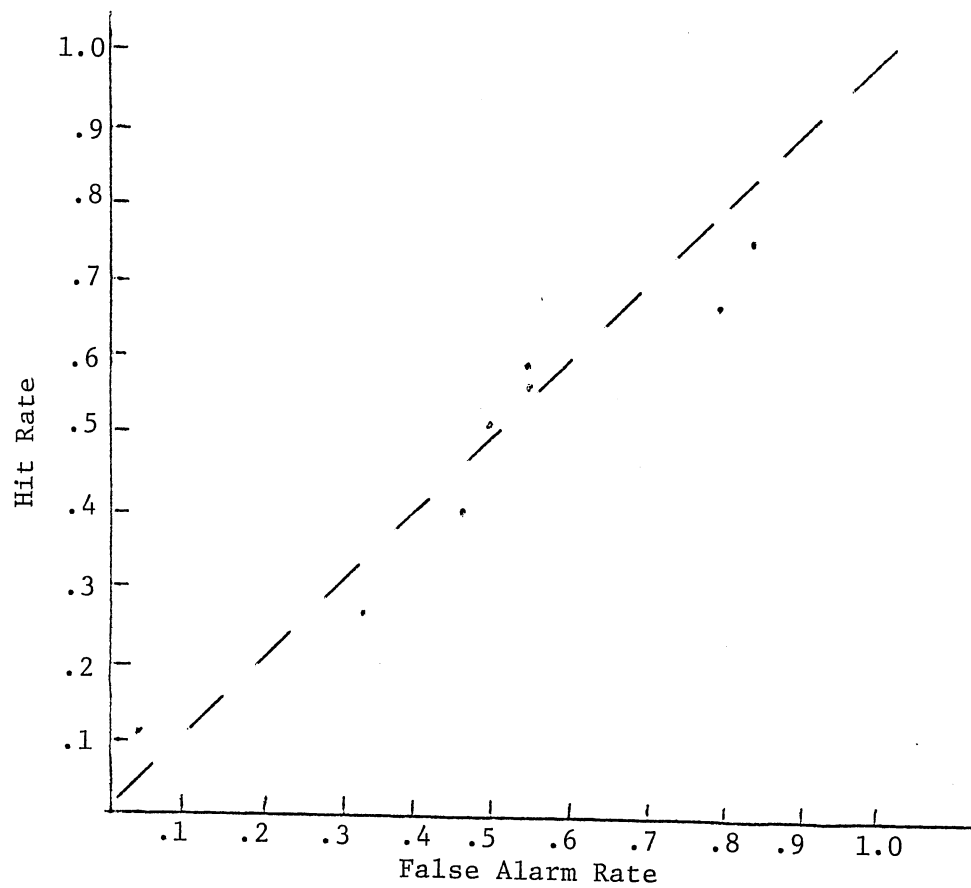


Figure 6. ROC Curve for Post-Decisional Latencies

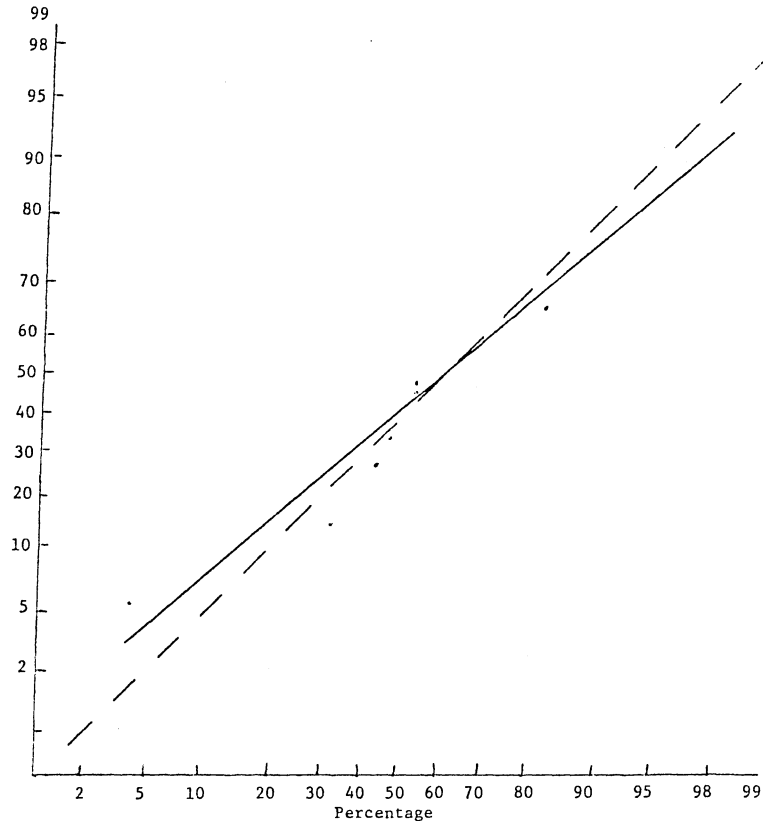


Figure 7. ROC Curve for Post-Decisional Latencies

$p > .50$. This finding of a nonsignificant Type II d' indicates that the post-decisional response latencies failed to discriminate between correct and incorrect responses.

CHAPTER IV

DISCUSSION

The pre-decisional running latencies of subjects in the present study, when analyzed according to the graphical method of signal detection theory, displayed a d' value significantly greater than zero. This finding is congruent with previous animal physiophysical research employing response latency (Hack, 1966; Yager & Duncan, 1971) or response frequency (Blough, 1967) as the dependent variable in a multiple criterion paradigm. It should be noted that in the present design pre-decisional latencies were recorded from when the rat entered the choice area, that is, after the subject had already begun to respond, until it passed the choice point. As the discriminative stimulus was presumably visible from the start box, the recorded pre-decisional latency is in fact only the latter part of the total pre-decisional latency. The significant effect of the pre-decisional choice times may have even been more robust if the total pre-decisional latencies had been recorded.

The significant value of d' for the pre-decisional running latencies indicates that these latencies reflect a discrimination between correct and incorrect choices, with subjects generally deciding faster on trials when they made correct responses. Such a discrimination implies that animals are able to edit their responses to choice situations, in this

case in terms of running latency, in a manner analogous to human memory confidence rating responses. There appears to be a memorial process occurring prior to the choice by which the subjects' pre-decisional response accurately reflects the probability of making a correct or incorrect decision.

The ROC or isosensitivity curves shown in Figures 5 and 6 for pre-decisional choice times differ from idealized functions as they are not symmetrical and have a non-unity slope. Within the present context, this could be interpreted as slower pre-decisional latencies providing less information concerning the discrimination between correct and incorrect responses as compared with the more rapid response latencies. However, this result of a non-unity slope is not typical of empirically obtained ROC curves with human (see Tulving & Madigan, 1970) or animal subjects (Blough, 1967). It has been hypothesized that this prevalent finding of ROC curves with slopes less than one may result from the underlying variables being other than normally distributed.

The primary purpose of this study was to investigate Type II d' as measured by the post-decisional response latencies. The obtained Type II d' did not significantly differ from zero, the chance detectability of d' . Rats' running latencies from after a decision was made until they reached the goal box did not reflect a discrimination between correct and incorrect choices.

This apparent lack of editing of responses by subjects in this particular task certainly does not prove that editing of post-decisional responses in animals does not occur. In this case, as always, a finding of no significant difference has two viable explanations:

(1) there is, in fact, no significant difference in the value of d' for post-decisional running latencies suggesting that response editing does not occur in this phase of the response; or (2) the present measure was insensitive to any differences that may have been present. The present measure, that of running latency as the dependent variable, does appear appropriate based on the pre-decisional latency results and the assumption that such response editing processes would manifest themselves in the same behavior; an assumption which appears to be justified at least in terms of human memory data measuring Type II d' .

A less cognitive interpretation of the post-decisional latency results can be found within traditional stimulus-response learning theories. It has often been postulated that running latencies themselves can be considered part of the learned response. Thus, if an animal runs fast and is frequently reinforced it may continue to run fast independently of whether the response was correct or incorrect.

Although this interpretation could possibly serve as an explanatory mechanism for the lack of difference between correct and incorrect post-decisional latencies, it is contrary to the result of a significant d' value in the pre-decisional latencies. This apparent discrepancy can be resolved by assuming, at least in the present task, that the processes controlling behavior before a decision is made are different from those controlling behavior after a decision is made. Prior to the choice point, the animal runs quickly when it is relatively certain of the correctness of its response, and more slowly as it is less certain. Thus, subjects are reinforced more often for running quickly than for running slowly. This is shown empirically in Table I. Perhaps the animal, realizing that the decision has been made, runs quickly as

running quickly has been reinforced more frequently. The reason why this does not occur in experiments using human subjects may be due to the very different motivational factors involved.

This mechanistic explanation does not allow for manifestations of "awareness of awareness" and is certainly inconsistent with human memory data. Rather than reflecting differences in cognitive processing between humans and infrahuman species, the results may be better understood by examining the differences between the experimental tasks in which Type II d' values are obtained in humans and the task in the present experiment. In human studies, subjects are typically asked to make a response, and then to rate their confidence in their response, usually along some given scale. The actual response is clearly dissociated from the subsequent confidence rating which is a totally different type of response. In the present experiment, the pre-decisional and post-decisional running latencies do not appear as distinct responses, but rather as different parts of the same response. The results of a significant d' value for the pre-decisional phase, but a nonsignificant value for the post-decisional phase may be accounted for in terms of the paradigm used. A more appropriate design for use in animal psychophysical research concerning Type II d' might involve two distinct responses, for example, running through the choice point and then having animals bar press in the goal box for the reinforcement, with the rate of bar pressing being used as the dependent variable for obtaining values of Type II d' .

These latter suggestions lean more toward the interpretation of no significant difference as being the result of the parameters utilized rather than as a result of radical differences in cognitive processes

between humans and other animals. As previously mentioned, the data could be interpreted as providing support for either of these two possibilities. It does, however, seem parsimonious to hypothesize that the underlying processes of Type II d' are present in other species besides man. Type II d' is a type of "second order" retrieval process, and other aspects of retrieval have been shown to be similar between man and other species. It certainly appears adaptative for animals, as well as man, to be able to behave differentially to situations as a function of the confidence in their response.

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VITA²

Nancy Ann Marlin

Candidate for the Degree of

Master of Science

Thesis: PRE-DECISIONAL AND POST-DECISIONAL LATENCIES IN RATS

Major Field: Psychology

Biographical:

Personal Data: Born in New York City, November 10, 1952, the daughter of Lawrence J. and Evelyn M. Marlin, married Brian P. Cysewski, April 24, 1976.

Education: Graduated from Floral Park Memorial High School, Floral Park, New York, in June, 1970; received the Bachelor of Arts degree from the State University of New York-Binghamton in June, 1974; completed the requirements for the Master of Science degree at Oklahoma State University, Stillwater, Oklahoma, in December, 1977.

Professional Experience: Graduate Teaching Assistant, Department of Psychology, Oklahoma State University, 1974-75; Statistics Tutor, Bureau of Indian Affairs, 1975.

Professional Affiliations: Member of the Association of Women in Psychology, the Midwestern Psychological Association, and Phi Kappa Phi.