Stimulus Properties of Population Density

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STIMULUS PROPERTIES OF POPULATION DENSITY

by

Robert Alan Schauerhamer

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

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Robert Alan Schauerhamer
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INTRODUCTION

Animal research on population growth in controlled environments has yielded some basic formats of analysis applicable to population growth in the natural environment. Population growth proceeds logarithmically at first in an environment with fixed or finite resources. The resources become depleted with increased population size until the amount of resources remaining can support only the organisms which are present. The population levels off at a point where deaths equal births. The sigmoid curve best represents the three phases of growth in this setting. First, there is slow growth followed by a period of increasingly rapid growth and finally a leveling off of the population density (McLaren, 1971).

Animal populations may experience a sudden, rapid decline in numbers. This has come to be called population crash. The animals which die in these crashes frequently display no ostensive pathology (Christian, 1950). Population crashes may occur in regular cycles for some species (Clarke, 1949).

A type of environmental manipulation used with animals for population growth studies is the limitation of space with unlimited resources (Calhoun, 1962). This environmental situation is typified by an early rapid population growth followed by a period of infant mortality near 100% and an increase in adult mortality. The population size slowly decreases until it reaches a point of population stability. Adult mortality equals the infant survival rate in the steady state of population stability.
Animal populations in the natural environment usually experience fluctuation intermediate to that of population crash and stability (Christian, 1950; Louch, 1958). The rise and fall of these populations do not suggest the steady state of population stability and are not as dramatic or sudden as population crashes. These fluctuations are frequently referred to as population cycles.

The anthropologist, George Mendenhall (1975), gives historical evidence suggesting that the uncontrolled growth of human populations has led to these intermediate fluctuations. The notion of a stable population in relation to human populations is confounded by the nature of the resources which man uses. Stable population could be specified if the limitation of our resources could be clearly defined. Mineral resources can be estimated, but other factors such as advances in the technology of extracting metals from poor grade ore muddle such estimates. Agricultural advances along with the vagaries of the weather make it impossible to estimate food production capabilities. Estimates of the resources available in the earth's biosphere are often used in a determination of the stable population size for humans. However, these estimates are disputed because of the various assumptions that may be made concerning their limitation.

Maximal population is another notion which has been useful in population studies, along with the notions of population crash and stability. Maximal population is defined as the greatest population size which is biologically possible in a given environment. The maximal population of the previously mentioned investigations can be simply
determined as the largest number of animals which coexisted in the given environment or the highest population density attained.

The point at which the human population will reach the maximal level is not known. The world's human population is the highest that it has ever been and growth remains rapid. The computer simulation conducted by the Club of Rome (Meadows, Meadows, Randers and Behrens, 1972) was a major advance in the direction of a sophisticated estimate of a human maximal population. They made various assumptions about environmental conditions and resource availability. Their inevitable conclusion from this computer analysis was that a maximal population size will be reached within about 150 years followed by a rapid reduction in population provided that growth remains uncontrolled.

All prior notions have been somewhat amenable to scientific determinism. The variables involved in the determination of stable population and maximal population size can be estimated with a fair confidence and agreement among scientists. Optimum population does not share this benefit. Multiple philosophical approaches have rendered it hopeless beyond scientific determinism. Nearly every author writing about optimum population promotes a different definition of the term before beginning a discussion (Singer, 1971).

An optimum level of population may be loosely defined as the "best" level of population in consideration of biological restrictions and psychological preferences. Economists have actively attempted a determination of the level of population necessary to maintain a standard of living to which we have become accustomed (Spengler, 1969).
All considerations of an optimum population level have been based on the society. The optimum level is determined by the benefits to the society or at best the individual is envisioned as a part of a homogeneous society. The diversity of individual preferences is not taken into account.

One of the arguments which Ehrlich (Ehrlich and Ehrlich, 1974) presents for a lower stable population is that it would permit great diversity in preferred population size to exist. It may become difficult for a hermit to find a desirable place to live if population growth continues. Preferred population is centered on the individual as opposed to the society.

This study is an attempt to measure individual preferences of population density using infrahuman subjects. The trend of preference with increasing density is of interest. A comparison of any preferred population size will be made with stable population size for the same controlled environment.

The reductivist approach to population psychology has generated some elementary stimulus-response studies. Calhoun's (1962) observations of a high density population led to his description of population density in terms suggesting an eliciting stimulus. Aggressive behaviors, such as tail biting, were observed to develop in some males with increased population density. Many abnormal sexual and eating behaviors emerged in this setting. The increased population density could be said to cause or elicit these behaviors because of their simultaneous occurrence.
The notion of the eliciting action of population density may also be used in an explanation of the reduction of some behavior. Normal maternal behaviors were lacking for some females in the high density of Calhoun's study. Some females made incomplete nests which offered inadequate protection for the pups. The lack of normal nest building may be proposed to be a result of the increase of other behaviors which would be incompatible with normal nest building or the lack of eliciting conditions.

The elicitation of behavior by population density as a stimulus which would be incompatible with other behavior has been the topic of a study on human task performance (Freedman, Klevansky and Ehrlich, 1971). This study attempted to eliminate stimuli that might accompany high population density and examine population density as a single stimulus.

We should make it clear that this research was designed to investigate the effects of high density per se, and not the effect of other factors that tend to go along with high density. We did not want to study the effects of lack of air, physical discomfort, restriction on movement, high temperature, odors, or any other typical consequences of high density among humans. Rather, we were interested in the individual's reactions to the high density itself, to their feelings of being crowded when these other variables were eliminated or controlled. (p. 13)

Although the study was discussed in somewhat different terms, the behavioral analysis of this experiment is explained as the elicitation of respondent behavior by an aversive stimulus (the crowded environment) which is incompatible with operant behaviors. The operant behaviors measured in this experiment were crossing out a specific number on a sheet of random numbers, memory tasks, forming words from
six letters, etc. The performance on these tasks served as the dependent variable.

The main independent variable was the degree of crowding under which the subjects performed these tasks. The subjects were given chairs with desk arms and placed into rooms of various sizes, thus achieving various densities of subjects per work area.

No trend of effect on the task performance was observed across densities. The authors conclude:

Thus we feel that there is good reason to interpret the present findings as demonstrating that density per se does not function as an ordinary aversive, arousing stimulus as does, say, electric shock or loud noise. Density may function this way under some as yet unspecified conditions; but it is not a simple, aversive stimulus in the usual sense. (p. 24)

The abandonment of population density as a simple stimulus is suggested by the study by Freedman, Klevansky and Ehrlich. It may be that the responses which are elicited by population density are compatible with the tasks performed in this study, but could be incompatible with other behavior. Also, the density may not have been sufficiently high to serve as an eliciting stimulus (the highest density was .14 subjects/ft.2).

Some physiological variables have also been investigated as dependent variables with population density as the independent variable. Population density has been assumed to be an aversive or "stress" stimulus. Several studies have concentrated on the change of glandular weights, adrenal and testes, with population density (Southwick and Bland, 1959). Since population density has been assumed to be
aversive, it would also be appropriate to investigate the effects of experimentally controlled aversive stimulation on fertility, sex ratio of offspring, and other physiological events. Fertility and sex ratio of rats have been shown to be significantly altered with maternal stress in the form of periodic restriction of movement (Lane and Hyde, 1973). The litter size delivered by the stressed female rats was significantly reduced and the sex ratio of offspring changed from approximately one to 36:68 males/females, or .56. The aversive stimulus used in this experiment was the same as had been used in a prior experiment which showed that this stimulus caused the development of stress ulcers in rats (Sines and McDonald, 1968).

A theory of stress has emerged from these studies on aversive stimulation and alteration of fertility. A human study has assumed that ulcer patients have been subjected to stressful environments and has compared the fertility of such patients to that of normal people from the same area (Kubickova and Vesely, 1974). They found that "patients with duodenal ulcer, regardless of sex, have a 25% lower fertility rate compared to the general population" (p. 316).

The studies thus far on population density as a stimulus have viewed it as an eliciting stimulus. Also, it has been unanimously assumed that it is an aversive or stress stimulus.

The experiments which follow are, in part, a repeat investigation of some of the questions posed by the elicitations by the stimulus of population density. The elicited behavior of concern is the change in maternal behavior (as in Calhoun's study) which is reflected...
in infant mortality, fighting behavior which was measured in cause of mortality and other behaviors which were only casually observed. The second experiment is unique in its approach to the analysis of population density as a stimulus. In the second experiment, population density serves as a contingent stimulus which follows the response measured in the dependent variable, rather than preceding an elicited response. The account of contingent stimuli is derived from operant behavioral psychology. Skinner commenting on the history of operant psychology states:

Every stimulus-response or input-output formulation of behavior suffers from a serious omission. No account of the interchange between organism and environment is complete until it includes the action of the environment upon the organism after a response is made. (Skinner, 1969, p. 5)

The second experiment of this study is a rudimentary attempt to determine if population density can be considered an aversive, or punishing, stimulus or a reinforcing stimulus. These functions of stimuli are determined by the effect which they have on operant responses upon which they have been made contingent. If a response is followed by a stimulus and the response probability is reduced in the future, then the contingent stimulus is a punisher. If the response had increased in probability, then it would be defined as a reinforcing stimulus.
EXPERIMENT I

Materials and Methods

Each initial population consisted of 4 male and 4 female [Upj: TUC(CFl-1)sp] mice, 5-10 weeks old. Two populations were maintained in separate cages. Purina laboratory chow and water were given ad libitum. Sawdust and shavings were used for bedding and were changed daily.

The mice were maintained in a community cage for the duration of 250 days. The floor area of the cage was four square feet. The community cages measured 2 x 2 ft. and were 1 ft. high. The cages were constructed of wood and fiberboard. All inner surfaces were covered with fiberglass cloth and resin. A fine mesh aluminum screen was used in the cage tops. Each cage contained two food hoppers, each capable of holding a quart of food. Four water bottles hung outside of each cage and delivered water through holes in the cage sides.

Data were recorded daily. The total number of mice was recorded and classified into males, females and infants. The definition of infancy used in this experiment was from the time of birth until the time that the eyes opened which was a period of about ten to fifteen days. The sex of the new adults was recorded on the first day of open eyes. All mice were counted and categorized weekly.

Births and deaths were recorded. Deaths were categorized by adult male, adult female or infant. An attempt was made to determine the cause of adult deaths.
Results

Figure 1 shows the growth of the adult mouse populations over the 250 days of the experiment. Rapid population growth typifies the 50th to 150th experimental days for Population 1 and 50th to 180th experimental days for Population 2. Slowed population growth occurred during the period from the 150th or 130th day until the 200th day for Populations 1 or 2, respectively. After the 200th day Population 2 slowly declined in adult population, while Population 1 appeared to be stable. The stable population size for this experimental setting can be estimated to be less than 130 mice per cage or a density of less than 32.5 mice per square foot.

Birth rates declined and infant mortality increased with increasing population density. Male infant survival appears to be higher than female infant survival, with a total of 188 males and 142 females surviving until the age at which they opened their eyes. The sex ratio of births in this environment is not known; however, it is known that the sex ratio of births is approximately 1.0 in normal laboratory environments.

Fertility changes and sex ratio alteration with increasing population size were sought. The number of infants were recorded daily, but this turned out to be an unreliable measure of births. As the density of the populations increased, more infants were missed in the count. Mice were observed to have been born on several occasions, and not a trace of them remained in the morning when data recording was made. Infant mice were frequently consumed.
Figure 1: Total Adult Population for Populations 1 and 2 During 250 Days of Growth.
FIGURE 1

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No mice were observed to be born during the last 50 experimental days in Population 1. Also, all female mice were examined on the final day to determine a late stage of pregnancy. None of the 76 adult females in Population 1 were pregnant at this time. Nine out of the 59 adult females (15.25%) in Population 2 were in a noticeable stage of pregnancy.

The experiment has been divided into the first half (the first 125 experimental days) and the second half (the last 125 experimental days) to determine an effect of population density on the sex ratio of infants which survived to adulthood. The sex of the infants was determined on the first day of open eyes (the definition of adulthood used here). The adult population density for the first 125 experimental days ranged from 1.75 to 23.50 mice/ft.\(^2\) in Population 1 and from 1.25 to 13.75 mice/ft.\(^2\) in Population 2. During the last 125 experimental days, the adult population density ranged from 23.50 to 47.25 mice/ft.\(^2\) in Population 1 and from 13.75 to 37.25 mice/ft.\(^2\) in Population 2.

Eighty-one males and 61 females became adults from both populations during the first 125 experimental days. The male/female sex ratio is 1.33 for this period. The sex ratio of infants surviving to adulthood for the second half of the experiment was also 1.33, 108 males and 81 females. Therefore, there appears to be no difference with increased population density in the alteration of the sex ratio of mice living up until the time that they open their eyes in this controlled environment.
EXPERIMENT II

Materials and Methods

The subjects were 24 male and 24 female, experimentally naive [Upj:TUC(CF1-l)sps] mice, 5-10 weeks old. The subjects were caged in one of six densities, 2, 4, 8, 16, 32 or 64 mice per square foot, four days prior to the onset of the experiment. Food and water were provided ad libitum as in Experiment I.

The mice were maintained in the community cages which were described in Experiment I. Eight experimental subjects were used from each community cage, four males and four females. All eight mice in the lowest density cage were experimental subjects, and eight of the 256 mice in the highest density were experimental subjects while the remaining mice served as confederates in the experiment.

The experimental chamber measured 1 X 1 ft. on the floor and was ½ ft. high. It contained two identical sides, separated by a partition, measuring ½ X 1 ft. on the floor. A pint food hopper and water bottle nozzle was contained in each of the two sides. A square hole, 1½ X 1½ in., was cut through the partition at the floor level. Fresh food, water and shavings were maintained in the experimental chamber. Figure 2 is a diagram of the experimental chamber.

No experimental manipulations were performed on the first four days after placing the subjects into the community cages. The subjects participated in sixteen experimental sessions, one session per day. The session strategy was four sessions of baseline, eight
Figure 2: Top View Diagram of the Experimental Chamber.
sessions of acquisition and four sessions of extinction.

In each session the subject was removed from the community cage and placed into one of the sides of the chamber. The initial side was randomly predetermined. A stop watch was initiated at the beginning of each session. The response of interest in this experiment was the partition crossing response. It was defined as occurring when the torso of the mouse's body had completely crossed through the hole from one side to the other.

Baseline

The subject was taken out of the community cage where the density was 2, 4, 8, 16, 32 or 64 mice/ft.\(^2\) depending upon the experiment and placed into the experimental chamber. The mice were alone in the experimental chamber during baseline.

The time in seconds from entrance until the emission of the fifth response was recorded. The subject was removed from the experimental chamber and replaced into the community cage of original density ranging from 2-64 mice/ft.\(^2\) exactly 15 minutes after the session began. If five responses did not occur within the 15 minutes, then the number of responses which did occur was recorded.

Acquisition

The subject was taken out of the community cage where the density was 2, 4, 8, 16, 32 or 64 mice/ft.\(^2\) depending upon the experiment and placed into the experimental chamber. The mice were alone in the
experimental chamber during the acquisition sessions.

The time in seconds from entrance until the emission of the fifth response was recorded. The subject was removed from the experimental chamber and replaced into the community cage of original density ranging from 2-64 mice/ft.\(^2\) immediately contingent upon the fifth response. There was a time limit of one hour during acquisition. If five responses did not occur within the hour, then the subject was replaced into the community cage and the number of responses was recorded.

**Extinction**

The density of mice in the experimental chamber was raised to the density of the community cage for that experiment. Since the experimental cage area was one square foot, the number of mice required to accomplish equal densities of experimental chamber and community cage was exactly the numerical values of the densities of the community cages, 2, 4, 8, 16, 32 and 64. The sex ratio was maintained at one male/one female by adding the appropriate number of males and females to the experimental chamber.

The time in seconds from entrance until the emission of the fifth response was recorded. The subject was removed from the experimental chamber and replaced into the community cage immediately contingent upon the fifth response. There was a time limit of one hour during extinction. If five responses did not occur within the hour, then the number of responses was recorded.

All recorded data from the sessions were transformed into the
datum of response frequency. All recorded times in seconds were divided into 18,000 to produce the number of responses per hour.\(^1\) When the number of responses had been recorded during baseline, the number was multiplied by four to obtain the number of responses per hour. If the number of responses was recorded in either acquisition or extinction, this datum was already in the number of responses per hour.

Results

Figures 3 through 14 are graphical representations of the response frequencies of individual subjects during baseline, acquisition and extinction. The contingent stimulus of replacement into the community cage with a fixed density was determined to be a punisher for subjects demonstrating a lower acquisition than free operant baseline and extinction. A total of 2 mice, 4.17% of the total number of mice, showed response frequencies throughout the experiment characterizing punishment (Table 1).

\(^1\)Original datum = x seconds; desired datum = number of responses per hour. The transformation performed is

\[
\frac{5 \text{ responses}}{x \text{ seconds}} \times \frac{3600 \text{ seconds}}{\text{hour}} \quad \text{or} \quad \frac{18,000 \text{ responses}}{x \text{ hour}}
\]
Figure 3: Response Frequencies for Four Males from a Community Cage Density of 2 Mice/Ft.$^2$. 
**Figure 3**

Graphs depicting response frequency over sessions for four different individuals labeled as male 1, male 2, male 3, and male 4. The x-axis represents sessions labeled as baseline, acquisition, and extinction. The y-axis shows response frequency ranging from 0 to 600. Each individual's data shows variations in response frequency across the sessions.
Figure 4: Response Frequencies for Four Females from a Community Cage Density of 2 Mice/Ft.².
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Figure 5: Response Frequencies for Four Males from a Community Cage Density of 4 Mice/Ft.$^2$. 

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FIGURE 5
Figure 6: Response Frequencies for Four Females from a Community Cage Density of 4 Mice/Ft.$^2$. 
Figure 7: Response Frequencies for Four Males from a Community Cage Density of 8 Mice/Ft.$^2$. 

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FIGURE 7

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Figure 8: Response Frequencies for Four Females from a Community Cage Density of 8 Mice/Ft.$^2$. 

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FIGURE 8
Figure 9: Response Frequencies for Four Males from a Community Cage Density of 16 Mice/Ft.$^2$.
Figure 10: Response Frequencies for Four Females from a Community Cage Density of 16 Mice/Ft.².
Figure 11: Response Frequencies for Four Males from a Community Cage Density of 32 Mice/Ft.$^2$. 

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FIGURE 11
Figure 12: Response Frequencies for Four Females from a Community Cage Density of 32 Mice/Ft.².
FIGURE 12

RESPONSE FREQUENCY

female 1

female 2

female 3

female 4

baseline acquisition extinction

SESSIONS

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Figure 13: Response Frequencies for Four Males from a Community Cage Density of 64 Mice/Ft.$^2$. 

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FIGURE 13
Figure 14: Response Frequencies for Four Females from a Community Cage Density of 64 Mice/Ft.$^2$.
**TABLE 1**

**MICE DEMONSTRATING GRAPHICAL EVIDENCE OF PUNISHMENT OR REINFORCEMENT WITH POPULATION DENSITY AS A CONTINGENT STIMULUS**

<table>
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<th>Density (mice/ft.²)</th>
<th>Subject</th>
<th>Behavioral Effect</th>
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<tr>
<td>4</td>
<td>female 4</td>
<td>punishment</td>
</tr>
<tr>
<td>8</td>
<td>female 3</td>
<td>reinforcement</td>
</tr>
<tr>
<td>16</td>
<td>male 3</td>
<td>punishment</td>
</tr>
</tbody>
</table>

One mouse demonstrated an increase in response frequency during acquisition which is indicative of reinforcement. This is 2.08% of the total number of subjects who were reinforced by the contingency (Table 1).

There appears to be a lack of a trend in punishment or reinforcement of replacement into the community cage when the density varied from 2 to 64 mice/ft.². Only 3 of the 48 subjects, 12.50%, demonstrated any behavioral effect with population density as a contingent stimulus. This small number suggests random variation rather than any systematic effect.
COMMENTS

Population Density as a Stimulus

Increased population density in the natural environment has been noted to be accompanied by several environmental changes. The cumulative behavioral effects of the environmental changes accompanying population density increase has been studied. It has been more difficult to eliminate or control the various accompanying changes to investigate population density as an isolated stimulus. Some of the environmental changes which have been observed to accompany increased population density with rodents include a scarcity of food, inadequate cover, and increased wounding by fights (Christian, 1950).

The distinction between unconditioned and conditioned stimuli has not been made in prior behavioral analyses of population density. An unconditioned eliciting stimulus requires no prior training to elicit the respondent behavior. Electric shock is frequently used as an unconditioned eliciting stimulus in laboratory settings. Some of the environmental changes observed to accompany increased population density in the natural environment are unconditioned eliciting stimuli. Examples are increased exposure to hot and cold due to a lack of adequate shelter and wounding caused by increased fighting (Calhoun, 1949) derived from animal studies.

A conditioned eliciting stimulus achieves its effect on respondent behavior by the repeated pairing of a previously neutral stimulus with an unconditioned eliciting stimulus. Pavlov's experiment
was to repeatedly pair the neutral stimulus of a bell with the unconditioned stimulus of food presentation which elicited the response of salivation. The bell eventually came to elicit the response by itself.

The question may now be posed as to the application of this distinction to population density as a stimulus. It may be either that population density is an unconditioned eliciting stimulus or it may be conditioned as an eliciting stimulus by the repeated pairings with all the other stimuli which accompany increased population density. The tremendous variability of results from studies on population density as an eliciting stimulus suggest that it is not a universal unconditioned eliciting stimulus, and lend credence to viewing population density as, at best, a conditioned eliciting stimulus.

Experiment II of this study was designed to investigate the effects of population density as a contingent stimulus on operant response frequency. The distinction between unconditioned and conditioned was not applied in this experiment.

An unconditioned reinforcer or punisher should have a uniform effect on the probability of behavior upon which it has been made contingent. The effect should be observed across all normal individuals within a particular species. The fact that only 4.17% of the mice demonstrated punishment and only 2.08% of the mice demonstrated reinforcement suggests random variability and not an effect of the contingent stimulus.

Population density probably exists as a neutral stimulus to the
naive organism. There is no evidence exhibited by this experiment that would lead to a belief that a change from a low to a high density environment affects a mouse as a stimulus at all.

The investigation of the stimulus properties of population density has not been exhausted. A third type of stimulus is the discriminative stimulus which is "a stimulus in whose presence a particular bit of operant behavior is highly probably because the behavior has previously been reinforced in the presence of that stimulus" (Reynolds, 1968, p. 36).

Stimulus control, or the probability of behavior associated with a particular discriminative stimulus, may be used in a further investigation of population density. Studies of stimulus control exerted by population density could be used to determine the least difference between densities that animals could discriminate under ideal conditions. This information would be helpful to further studies of population density as a contingent stimulus. If, say mice, are unable to discriminate between a density of 2 and 16 mice/ft.\(^2\), then it would be pointless to use more than one intermediate of this range as a contingent stimulus.

A simple method to generate stimulus control would be to reinforce a response made in the presence of one density and not reinforce any response made when the specified density was not present. An experiment may be conducted using the same fixed densities that were used in this study. It might be possible to bring a response under the stimulus control of a specific population density if that...
response was reinforced with a conditioned reinforcer in the presence of 16 mice/ft.$^2$ and extinguished in the presence of all other densities. It would then be possible to determine the degree of stimulus generalization about the stimulus of 16 mice/ft.$^2$ (the gradient of response probability with distance from the stimulus of original conditioning).

A General Extinction Due to Design

A less noticeable trend in the response frequencies was a continual reduction throughout the experiment, i.e., the acquisition response frequency was less than that for baseline and extinction was less than acquisition. A continual trend in the decrease of response frequency can not be interpreted as either punishment or reinforcement due to the contingent stimulus of the specified population density. The change observed from baseline to acquisition would not be continued when a change from acquisition to extinction is made.

The larger than would be expected number displaying this continual reduction might be explained by the nature of the experimental manipulation. The only way to get the mice from one cage to the other was to pick them up by the tail and place them into the other cage. This could have been a punishing experience for them, but by no means has any connection with the contingent stimulus of the change in population density. It is merely speculation that the transferring may explain this general decrease in response frequency, if the transferring itself is aversive.
The Response Class

Operant experiments with animals traditionally use a response which is compatible with some sort of automatic recording device. The bar press of mammals and the key peck of birds are frequently used and may be recorded electrically with microswitches as a part of the operanda.

A dilemma presented by the use of this sort of automatically recorded response is that it is rarely very high in free operant baseline. The bar press and key peck are shaped by successive approximations before other experimental manipulations are performed. The nature of the preferred population experiment necessitated a response with a relatively high baseline so that either reinforcement or punishment by the contingent stimulus could be demonstrated.

It might have been possible to automatically record the partition crossing response used in this experiment with a slight change in the definition of the response class. The class could have been broadened to include any entrance into the partition hole. Then a light-beam switch could have been used. The mice did go halfway through the hole in the partition, stand for a few seconds and then back up into the side from which they had come. An automatic recording device would have recorded this occurrence, but with an observer these instances were not counted. The only occasion that a response was recorded was when the entire torso had moved from one side of the experimental chamber to the other.
The response used in this experiment had two major problems, both of which were determined in a pilot study. The density of the experimental cage varied during extinction with the density of the community cage. The pilot study showed that the response was reduced even without prior contingencies when the experimental cage was very dense with mice. Sometimes three or four mice would lodge themselves in the hole of the partition and fall asleep, rendering the crossing-over response impossible. The response was used anyway because the highest density (64 mice/ft.\(^2\)) was not originally planned as a part of the experiment and this was the point at which serious distortion occurred. The highest density was added to the experiment only after the stable populations showed a higher than expected maximal population size. One of the intentions of this study was to compare stable population size with preferred population size so that the fixed densities of the preferred population size experiment had to include the stable population size.

The second problem was that the response was easily elicited. Handling the mice and the noise of the placement of the cage tops often elicited a few partition crossing responses early in the session. To avoid this embarrassment, the contingency was made upon the fifth response instead of a continuous reinforcement which would have been more effective in acquisition had the response been solely operant. A pilot study determined that no response frequency change occurred when the replacement into the community cage was contingent upon the first response. The first response always occurred within
the first few seconds of the session. This was presumably because of a high degree of respondent characteristic which the contingent stimulus could not affect (at least readily).

Population Density and Accompanying Stimuli

Many studies, including this one, have treated population density as a single stimulus. The validity of this approach is not readily apparent from the findings of these studies. The contingent stimulus used in this experiment was replacement into a community cage. Few of the mice demonstrated response frequency change with this contingency, and there was also no detectable trend with higher density; it appears that density alone is not a stimulus of interest.

Calhoun (1962) attributed his findings of increased fighting behavior and disrupted maternal behaviors to the high density which developed in his rat community. Some other stimuli were introduced by the design of Calhoun's cage. An electrically charged wire surrounded the inside rim of the cage. If a rat tried to escape from the cage, it was discouraged by the deliverance of a shock. In the populations of mice in the present study, it was frequently observed that the mice would crawl or jump to the top of the cage walls which were one foot high. If Calhoun's rats engaged in the same behavior, they would have come in contact with the electric shock quite frequently.

Electric shock is an aversive stimulus which is known to elicit aggressive behaviors. Furthermore, it is known to increase biting
behavior in animals and humans (Hutchinson, 1975). An increase in fighting behavior would certainly be expected with Calhoun's cage design due to the introduction of shock.

There may be stimulation which accompanies population density which account for some of the observations on high density populations. This seems to be especially true for the experimental populations which achieve densities which far exceed that which could be supported in the natural environment.

Fighting behavior was not very frequent in the mouse populations of this experiment. When a fight broke out, it usually involved four or fewer mice and did not last for more than a few seconds. A few mice died from massive wounds sustained in fights. One morning the mice in one cage were engaged in an enormous fight, females included, and it did not cease. The mice seemed to have wet fur and many had open bleeding wounds. The density of the cage with the unusual fighting was 64 mice/ft.$^2$. Two other community cages were present in the same room at that time. The densities of these cages were 46 and 35 mice/ft.$^2$ (the last two cages were the stable populations). None of the mice were fighting in the latter two cages. There seemed to be no explanation either for the sudden burst of fighting or for the difference between the populations. The problem was discovered only when the experimenter became warm and irritated during the course of cleaning the cages.

The air conditioner had been inadvertently shut off by a janitor, and the temperature of the laboratory was at least ten degrees higher.
than normal. The fact that only the highest density cage engaged in the fighting may be accounted for by the local rise in temperature from body heat. Two hundred and fifty six mice collectively give off a considerable heat and could raise the temperature of a small four cubic foot cage appreciably. The excessive heat may have served as an aversive stimulus eliciting the aggressive behaviors, and this could be an accompaniment of higher population density unless the temperature was cautiously controlled.

The fighting in the highest degree cage ceased in a few minutes after the air conditioner was turned on and the windows opened for a short period. Fighting was not observed en masse at any other time.

Fighting between two rats or two monkeys was not found to be elicited by increased temperature and humidity in a study by Gonick (1970). Shock elicited aggression was also shown to not be facilitated by increased temperature and humidity. It seems that the local temperature and humidity which accompanied the air conditioner shut off cannot, by itself, explain the en masse fighting. There seems to be a discrepancy between Gonick's data and the observation of fighting in this experiment. Gonick's environmental conditions were under much tighter control than that of the current experiment, and systematic observations used in Gonick's experiment are much more credible than the casual observations of the en masse fighting in this experiment.

It could be that fighting is facilitated in high density populations by increased temperature and humidity, but a more direct method
of measuring such an effect would be needed to make this statement. Possibly fighting could be measured as a dependent variable, and density, temperature and humidity varied independently in a regression analysis framework.
BIBLIOGRAPHY


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