## Exteroceptive Cueing of Response Force

*Abstract.* Food pellet reinforcement for rats was made contingent upon the peak force of a bar-pressing response falling within restricted limits. Two such "bands," 5 to 10 grams and 15 to 20 grams, were established, the momentarily correct "band" indicated by one of two exteroceptive stimulus values. Peak force of response tended to conform to the reinforcement requirements, the two stimulus values setting the occasion for differentiated distributions of response force.

Following Skinner's (*1*) original distinction, the term "discrimination" has come to refer to those behavioral situations in which an organism is reinforced for making a given response only when it is emitted following exposure to a specific exteroceptive signal. The term "differentiation" is used to describe those situations in which exteroceptive stimuli customarily remain constant, and the organism is reinforced only for responses having a specific form, intensity, duration, or other preselected property.

Skinner (*1*, p. 338) suggests that many instances of behavior reflect a "double discrimination," combining the circumstances of discrimination and differentiation. This typically might involve a specific value of an exteroceptive stimulus indicating the particular intensity of response necessary for reinforcement.

The present report concerns itself with the "double discrimination" type of behavior Skinner was describing. This class of behavior has much to teach us, for it deals with a rather commonplace behavioral situation: one in which an organism maintains successive responding, but adjusts each individual response value to that "required" by the value of a varying exteroceptive cue. This type of behavior is implicit in common forms of closed-loop error detection and correction.

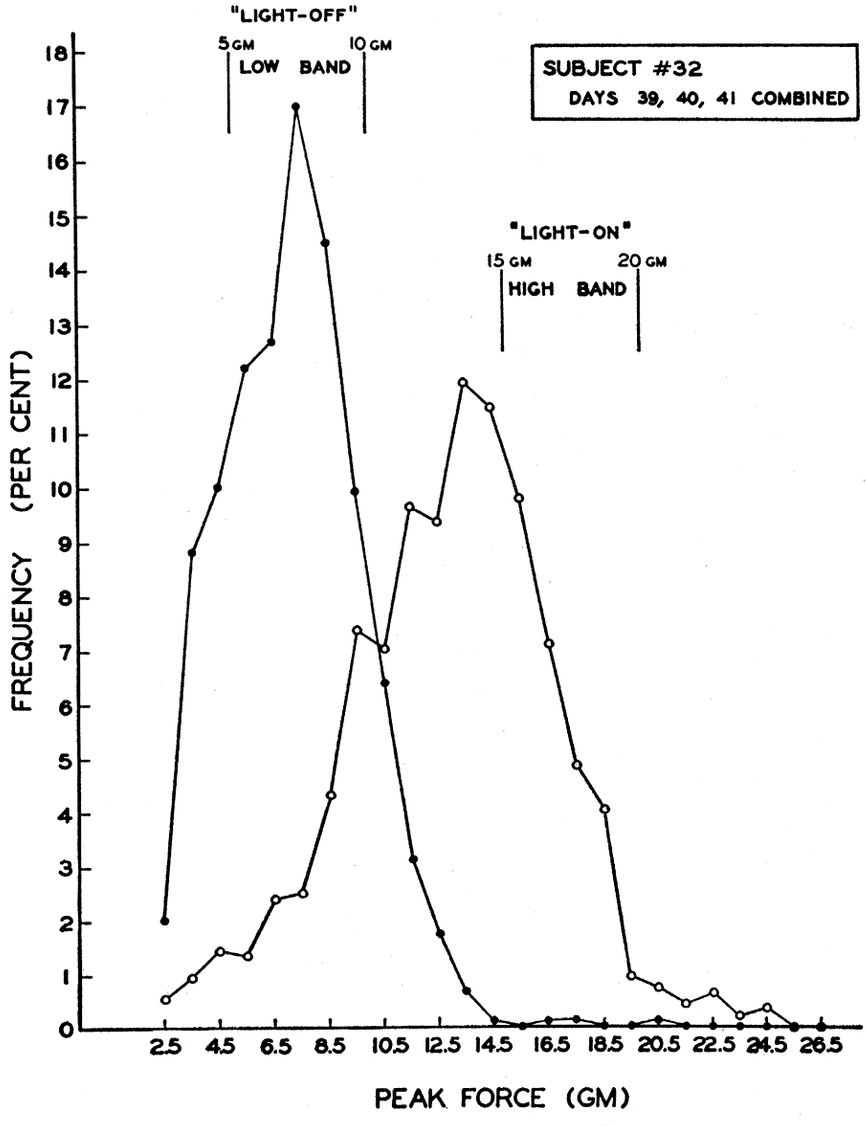


Fig. 1. Frequency distribution of peak force during "double discrimination" performance. Reinforcement occurred only for responses within the indicated bands.

The performance curves shown in Fig. 1 are frequency distributions of peak force emission for a single, male, Wistar rat, 90 days old at the start of the experiment. Under exteroceptive conditions of "darkness" or light-off, the animal was regularly reinforced with a 45-mg pellet (after 23 hours' food deprivation) for pressing a lever with a peak force between 5 and 10 g (*2*). However, when an overhead light was on (approximately 20 ft-ca at the cage floor), the same animal was reinforced only for pressing between 15 and 20 g. The points shown are percentages for specific force levels obtained for the combined data gathered over the last three of 41 sessions. Each daily session was 20 minutes and 40 seconds in duration, and was divided into random presentations of "light-on" and "light-off" periods of 10, 20, 40, 80, or 160 seconds. The cumulative time-in-the-dark and time-in-the-light was evenly divided within each session. The two curves represent the relative distribution within each stimulus condition.

Although data are shown for a single subject only, a total of eight subjects were run. For four of these, conditions were as previously described. For the other four subjects, the relation between presence of light and force level required was reversed.

All subjects developed a tendency to respond with a force level appropriate to the particular exteroceptive signal presented. This was true regardless of the specific stimulus conditions (that is, light-on or light-off) correlated with either of the bands of force required for reinforcement.

In the performance shown in Fig. 1, peaking in the low band is as might be expected; the peaking appropriate to the high band falls somewhat below the reinforcement range, with the distribution of forces being more variable than for the low band. This type of performance was characteristic of all eight subjects. Each animal's median peak force of response was within the reinforced range for the low band condition, but below the reinforcement band for the high band condition.

Variability of the high band distribution was significantly greater than for the low band distribution for each subject (F ratio, two-tailed test, 5-percent level).

For the entire group of eight subjects, the force level of the first response following each change in the exteroceptive cue was significantly altered in the appropriate direction (that is, higher or lower) from that prevalent prior to the stimulus change (two-tailed sign test, 5-percent level). In other words, "double discrimination" behavior involving emission of force appropriate to the value of a specific exteroceptive cue, was effectively established (*3*).

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**References and Notes**

1. B. F. Skinner, *Behavior of Organisms* (Appleton-Century, New York, 1938).
2. J. M. Notterman, in *J. Exptl. Psychol.* **58**, 341 (1959), provides a description of the apparatus involved in this study.
3. This research was supported by the Office of Naval Research, Physiological Psychology Branch, under contract NONR 1858 (19).

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## Strain and Sex Differences in Serum Cholesterol Levels of Mice

*Abstract.* Five inbred strains of mice differed significantly in serum cholesterol level. Cholesterol levels ranged from 128 mg/100 ml in C57B1/6 mice to 208 mg/100 ml in C3H mice. Cholesterol level was significantly higher in males than in females. The cholesterol level of 2-month-old mice did not differ from that of 1-year-old mice.

In recent years hundreds of papers have dealt with environmental, and in particular, dietary factors determining the level of serum cholesterol in man and animals (*1*). By contrast, only a handful of studies have dealt with hereditary factors influencing cholesterol level. This paper is a report on serum cholesterol levels in five inbred strains of mice. Between-strain variation in serum cholesterol was significantly higher than within-strain variation. Since all five strains were maintained under identical laboratory conditions, this finding suggests an important genetic component in the determination of serum cholesterol level in mice.

Sixteen mice from each of the five inbred strains listed in Table 1 were tested. Information about these strains is contained in a report of the Committee on Standardized Genetic Nomenclature for Mice (*2*). Within each strain two age groups were formed, one of young animals (mean age, 66 days) and the other of old animals (mean age, 377 days); both groups contained four males and four females. This resulted in a factorial design of 5 strains × 2 sexes × 2 age levels. All mice were raised and maintained on Purina mouse breeder chow with free access to food and water. Five hours before a blood sample was taken, the food was removed from the cages. A sample of 0.2 ml of blood was drawn by retrobulbar cavernous sinus puncture. Serum cholesterol was determined colorimetrically by an adaptation of the method of Caraway and Fanger (*3*) by means of a Beckman/Spinco ultramicro analytical system (*4*).

Table 1. Serum cholesterol levels in five strains of mice.

| Strains | Serum cholesterol (mg/100 ml) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Females | | Males | | Age groups pooled ($N$ = 8) | | | |
| | | | | | Means | | S.D. | |
| | Young | Old | Young | Old | F | M | F | M |
| C57B1/6JLs–a$^t$a | 115 | 107 | 144 | 144 | 111 | 144 | 29.2 | 29.6 |
| DBA/1 | 134 | 120 | 210 | 184 | 127 | 197 | 18.9 | 20.2 |
| SEC/1GnLs–Sese | 133 | 162 | 199 | 235 | 148 | 217 | 29.4 | 27.2 |
| SEC/2Gn–Dse/dse | 149 | 144 | 235 | 213 | 146 | 224 | 10.6 | 22.9 |
| C3H | 179 | 183 | 223 | 247 | 181 | 235 | 32.4 | 20.6 |
| Overall means | 142 | 143 | 202 | 205 | 143 | 203 | 24.1 | 24.1 |

To determine the reliability of the colorimetric method used, each blood sample was divided in two and each half was analyzed separately. The reliability coefficient was .98. In analyzing variance, the two samples obtained from each mouse were averaged. Of the three main factors (strain, sex, age), only strain and sex contributed significantly to total variation. Neither age nor any of the interaction terms reached significance at the 5-percent level.

Mean values for the various groups are presented in Table 1. A significant separation of mean values for certain strains is apparent. This separation is clearest for C57B1/6 and C3H, the two extreme strains of this study. Table 1 also shows consistent and significant ($P < .001$) differences between females and males. In each of the five strains tested cholesterol level was higher in males than in females.

Strain differences in cholesterol level have previously been reported by Mayer and Jones (*5*) and by Zomzely and Mayer (*6*). Mayer and his co-workers were primarily interested in cholesterol levels in obese mice. They compared obese strains of mice with various nonobese control strains and found cholesterol levels ranging from 160 to 200 mg/100 ml in obese mice, and levels of 70 to 140 mg/100 ml in control animals. Because of their primary interest in problems of obesity, Mayer and his collaborators failed to compare control strains among each other. Mayer's work centered around strains with known metabolic defects. We selected randomly five strains from 13 strains maintained in our colony. Yet, within these randomly chosen strains we detected a range of cholesterol levels comparable to that found by Mayer. It can be expected that if more strains of mice were screened, cholesterol levels would be found to be normally distributed among strains.

The almost identical cholesterol levels in the SEC/1 and SEC/2 strains, two sublines of the SEC strain, will be noted. As such, similarity of sublines is expected, and it supports the argument for a genetic determination of the trait under investigation. It should be mentioned, however, that these particular sublines were reproductively isolated for more than 56 generations (*2*). Apparently the genes determining cholesterol level were in homozygous condition before these two sublines of the SEC strain were formed.

One of our most striking findings is that the cholesterol level is significantly higher in males than in females. Yet, in our search of the literature we did not find any reference to such a sex difference in mice. To be sure, Carpenter and Mayer (*7*) and Zomzely and Mayer (*6*) mention a sex difference in yellow mice. But in their case the situation was reversed: obese yellow females showed higher cholesterol levels than males.

Two-month-old and one-year-old groups of mice were included in our design because we expected to detect age-related changes in cholesterol level