Selection of Food by Size in the Chimpanzee, and Comparison with Human Judgments

Abstract. Adult chimpanzees, given access to an array of pieces of banana, select the pieces in order of size, larger pieces being taken first. Selection is mediated by perceived sizes, and the responses correspond closely to human visual judgment of size.

As evidenced by measures of learning, work, or simple choice responses, animals generally prefer a larger piece of the same food to a smaller one. This preference has usually been considered a motivational problem, and has been studied primarily in terms of motivational mechanisms. However, in situations where an animal has direct access to an array of food pieces, vision mediates selection (*1*), and so in order to understand the process of selection the perceptual as well as "purely motivational" mechanisms must be examined. The purpose of this experiment was to investigate the role of perceived size in the food-size selection of chimpanzees.

Two adult male chimpanzees (No. 43, Hal; and No. 71, Jent) were tested on a general test apparatus (*2*). On each trial they were presented an array of four pieces of banana placed 2.5 inches apart and about 2.5 inches from the cage wire. They were allowed to take one piece; then the food tray was withdrawn for 5 seconds; then the tray with the remaining pieces was presented again; and so on until all pieces had been taken. The order of selection indicated the rank order of preference.

Sixteen stimuli were used, consisting of all possible combinations of four sizes of banana and four orientations of a piece of banana. The sizes used were 0.7, 0.8, 0.9, or 1.0 inch in one dimension, and 0.5 inch in the remaining dimensions. As judged by samples of five pieces, these sizes averaged 2.8, 3.3, 3.7, and 4.1 gm in weight, respectively; variation between the pieces of any given size was no more than 7 percent. The orientations employed are shown schematically in Fig. 1. They are termed height, width, length: near cue, and length: far cue, respectively.

On each trial, only 4 of the total 16 stimuli were presented. Each of the four differed in size and in orientation. (Permuted Greco-Latin squares were used for each four trials to determine size, orientation, and location.) Twelve trials were administered each day for 8 days, thus presenting each of the 16 stimuli 24 times to each animal.

The results are shown in Fig. 2. Individual differences in performance were small; the mean ranks assigned by each of the animals to the 16 stimuli correlated .92 by Pearson product moment correlation (r). Analyses of variance indicated that each animal discriminated between the sizes used, and also that his performance was affected by the orientation of the food pieces ($p = .001$). Height and width facilitated preference to the greatest extent; by comparison length was ineffective, thus creating some reversals in ranks. For example, if a 0.9-inch piece was in a vertical orientation (height) and a 1.0-inch piece was oriented longitudinally (length), the chimpanzees tended to prefer the former, smaller piece. Thus a size-position combination overrode the size of the piece and led to the selection and eating of the objectively smaller piece of food (*3*). Selection was linearly related to the amount of reward (*4*), but only if visually mediated size errors were eliminated.

In order to demonstrate the degree to which visual factors can account for the process of food selection, a second experiment was performed. This time a direct comparison was made between chimpanzee food-size selection and human visual size judgments.

A large collection of pieces of banana served as stimuli. The experimenter attempted to make each piece unique in size, shape, or texture. They were weighed (weights ranged from 1.7 to 26.0 gm), and then eight pieces at a time were taken randomly and laid out on the test tray in random orientations. Two adult male human beings, working simultaneously but independently, estimated the rank order of size for the eight pieces. Eight such trials were conducted. After this, the same 64 stimuli in the same arrays were presented to a highly sophisticated adult female chimpanzee, No. 28, Alpha. The apparatus and procedure used in testing Alpha were the same as those used in experiment 1.

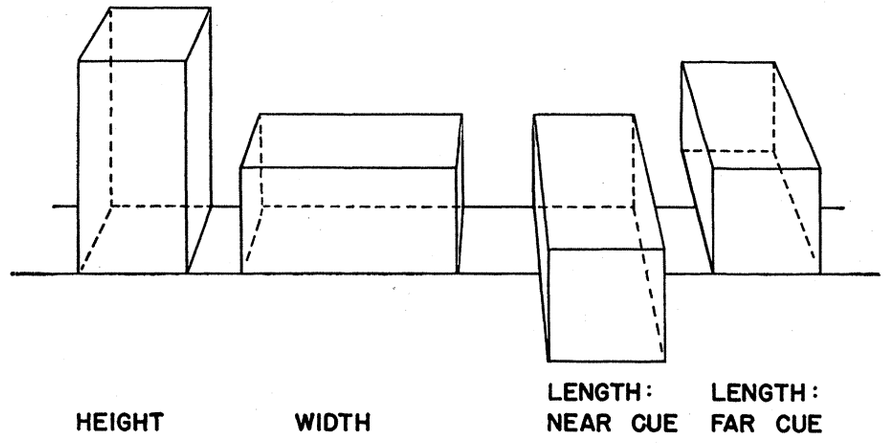

Fig. 1. The orientations of food stimuli used in experiment 1.

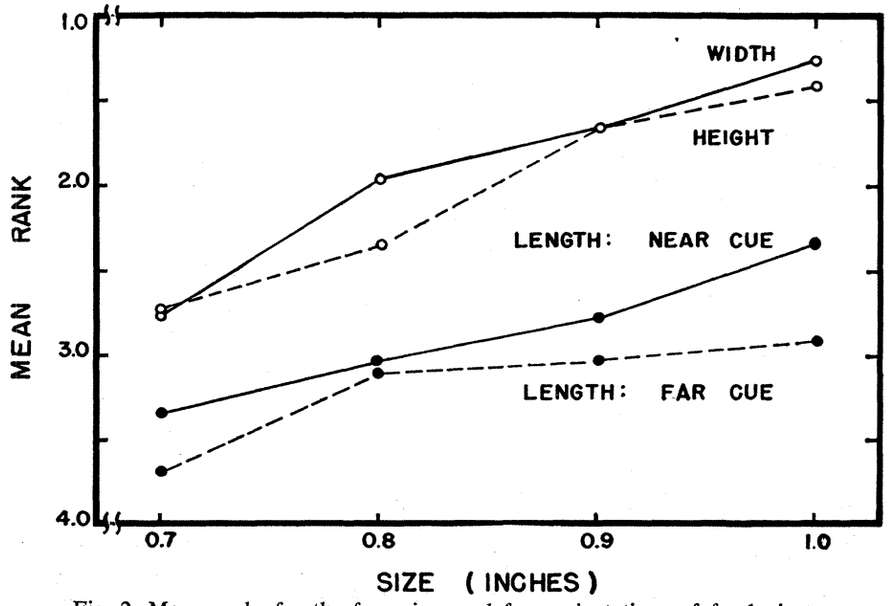

Fig. 2. Mean ranks for the four sizes and four orientations of food pieces.

The discriminations involved in this test were quite difficult, according to the reports of the human subjects, and as shown by the fact that all subjects including the chimpanzee made a number of errors.

Product moment correlations were computed between the ranking of each subject and (i) the weight of the stimuli (ranked within each trial-array), and (ii) the ranks assigned by the other subjects. The chimpanzee's order of food selection correlated almost as highly with the actual size (weight) of the stimuli as did the humans' rank ordering ($r = .87$ for Alpha; .93 and .96 for the humans). Furthermore, Alpha's scores had high agreement with the humans'. Her scores agreed with the human scores as well ($r = .89$ and .86) as these agreed with each other ($r = .90$). Alpha's correlations with the judgments of humans were as high as the correlation between her own preferences and the weight of the food.

Clearly, then, chimpanzee selection of larger sizes of food-pieces in a direct choice situation is mediated by visual size perception. The mechanisms of selection appear to be similar to human perception of the same stimulus objects (*5*).

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References and Notes

1. J. G. Yoshioka, *J. Genet. Psychol.* **37**, 427 (1930).
2. Pictured in G. Gray, *Sci. American* **192**, 73 (1955).
3. I have found no indication that errors of this sort are overcome with training. In the course of other experiments chimpanzee No. 5, Bokar, was tested a total of 35 days, making over 2000 choices. The nature of his errors remained unchanged throughout.
4. H. F. Harlow and D. R. Meyer, *J. Comp. and Physiol. Psychol.* **45**, 73 (1952).
5. This work was supported in part by grant M-1005 from the National Institute of Mental Health, U.S. Public Health Service.

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Synchronous Division in Chlamydomonas moewusii

Abstract. Mass cultures of *Chlamydomonas moewusii* have been synchronized by means of light-dark shifts. Division of at least 91 percent of the population was made to occur in 1/24 of the life cycle of the cells. The advantages of working with synchronized cultures of obligate autotrophs are discussed.

A great deal of attention has been paid to the subject of synchronous division of cell populations in recent years (*1*, *2*). The principal reason for this interest has been to provide the investigator with a large amount of cellular material with most, if not all, of that material existing in the same morphological and physiological condition. In addition, an often overlooked reason for producing such cultures is that the endeavor to induce synchrony often reveals fundamental information about cellular mechanisms (*3*). This paper is concerned primarily with the methods used to induce synchronized division in *Chlamydomonas* and with a brief discussion of their importance.

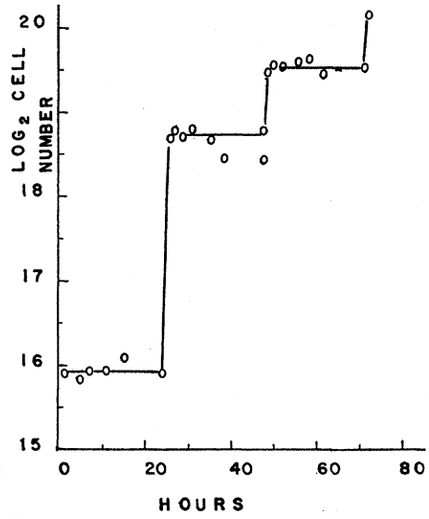

Fig. 1. Growth curve of *Chlamydomonas moewusii* showing synchronous division as a function of a light-dark cycle.

The minus strain of the heterothallic, obligately photosynthetic protist, *Chlamydomonas moewusii* (Burkholder and Provasoli strain) was used. The cells were cultured in 2 liters of liquid medium (*4*) buffered at *p*H 6.8 in 4-liter Pyrex bottles. The cultures were maintained at 25°C and were aerated continuously with a mixture of 95 percent air and 5 percent carbon dioxide. The cells were stirred gently at 10-minute intervals for 30 seconds with a magnetic stirrer. Illumination was provided by six 15-watt, cool white, fluorescent lamps. The light intensity was approximately 800 ft-ca incident on one surface of the growth vessel.

As a result of previous experiments concerned with the investigation of the behavior of the cells in constant light (*3*, *5*), a regimen of a 12-hour light, 12-hour dark cycle was chosen in order to synchronize the growth and division of the culture. All the experiments reported here were performed with cultures inoculated with cells previously grown on the same light-dark cycle. However, other experiments have shown that this treatment of the stock culture is not a requirement for the induction of synchrony. The results of this choice are plotted in Fig. 1. All population curves were prepared by counting fixed cells directly in a hemocytometer. Below 250,000 cells/ml, the error of this counting method did not exceed 15 percent; the average error was 12 percent. Above 250,000 cells/ml, the error did not exceed 8 percent. When the population was determined in cultures containing fewer than 50,000 cells/ml, samples were concentrated by centrifugation before counts were made. No attempt was made to correlate hemocytometer counts with viable counts. However, the cytological observations, presented below, concerning the abundance of eight-celled mother cells would preclude the presence of large numbers of nonviable cells.

The curve indicates an eightfold increase in the population above the initial number of inoculated cells during the first cycle. The smaller increases (less than complete doublings) in cell number during the second and third cycles are due to the limiting conditions for population growth imposed upon the medium by the large number of cells produced during the first cycle. Optimum growth, as determined by eightfold increases of about 90 percent of the population during a single cycle, ceases after the population has reached a density of about 400,000 to 480,000 cells/ml, which represents an inoculum of about 50,000 to 60,000 cells/ml. Measurements made on cultures begun with very small inocula (10, 25, and 100 cells/ml) indicated eightfold increases occurred during each cycle until the limiting number was reached. Twenty experiments performed both with cultures begun with small and large inocula produced the same results reported here.

True synchronization of growth and division is believed to have occurred because of the following evidence. (i) Examination of the curve reveals no increase in cell number between 0 and 23 hours. The cells were exposed to light during the first 12 hours and to darkness the second 12 hours. The entire increase in population then, as revealed by the curve, occurred during the 23rd and 24th hour (that is, the 12th hour of darkness). In 2 experiments out of 12 in which the inoculum was large (about 50,000 cells/ml), an increase in cell number occurred until the 25th rather than the 24th hour. Thus, "cytokinesis" usually occupied only 1/24 of the entire life cycle. (ii) Examination of the cells throughout the growth cycle revealed a steady shift in cell types from the true flagellated, ellipsoid, vegetative cell, through the nonflagellated spherical cell, to the multinucleated sphere ("mother cell") which gave rise to the eight independent, flagellated, vegetative cells.

Analysis and evaluation of the data reveal both the highest percentage and the highest degree of synchrony (that is, the shortest amount of time during which division occurs) yet obtained for