ments. The procedure was modified so that the brightness of the comparison targets (rather than that of the standard pattern) was reduced. With the exception of the noted modifications, the apparatus and procedure were the same as in the previous experiments.

The results of this study confirm the findings of the previous experiments, although the patterns vary radically in number, separation, and arrangement of elements. The results of a Tukey analysis of the data are shown in Fig. 2. As can be seen, fields containing slanted *T*'s are segregated most readily, while those containing only vertical and horizontal lines require a much greater lowering of the brightness for two separate groups of elements to be seen. The × pattern again forms a bridge between these two extremes; + × and *T* × do not differ significantly from *T* and slanted *T* or + and slanted *T*, but on the other hand, they do not differ significantly from *T* + and *T* *T* either. Whether the standard pattern contained a *T* or a + only slightly affected the thresholds.

The main conclusions to be drawn from these experiments are that when elements are composed of two lines of equal length, changes in orientation or shape which maintain the vertical and horizontal lines in the element do not strongly affect grouping. If the orientation of the lines is changed to 45° and 135°, however, perceptual grouping relative to a vertical-horizontal pattern will be facilitated.

Two comments should be made about this conclusion. First, the fact that no significant differences were found in the thresholds with changes in shape does not mean that changes in the arrangement of the lines without changing their orientation has no effect whatsoever. The statistical tests employed are conservative with respect to the type 1 error. If we had not taken an error rate based on the whole experiment, more of the differences would have been significant. In fact, it is important to point out that the results indicate that there are variables other than the orientation of the lines which affect the tendency to group. This is illustrated by the fact that the × has the same slant as the slanted *T* and *V*, yet it groups less readily. All we wish to conclude at the present time is that changes which alter the direction of the component lines from vertical or horizontal to diagonal, proved to be more effective in facilitating grouping than changes which left the component lines in the same direction.

It should be noted that the similarity of the figures does not appear to be a good predictor of grouping. In an independent study, ten observers judged the slanted *T* as more similar to the upright *T* than either a backward *L* or a *V*. The threshold for segregation of the slanted *T*'s, however, is more similar to the threshold of the *V*, while the threshold of the backward *L* is more similar to the threshold of an upright *T*. This suggests that an analysis of grouping in terms of the similarity of the figures is not feasible. It should be noted in this connection that informational analysis of grouping based on redundancy of figures (*6*) cannot be used to explain the results, as there are always two kinds of elements whose position and number remain constant.

The results of the experiments indicate that it is necessary to examine the specific properties involved in accounting for segregation. Of the variables studied in the present experiments, the orientation of the lines proved to be the most powerful. Gibson (*7*) has suggested that the direction of a line is a basic element in the perception of a pattern. It is suggestive in this connection, that Hubel and Wiesel (*8*) found specific receptors for line orientation when studying the cortical neurons in area 17. This would suggest that relatively simple pattern properties are the most powerful in pattern segregation. However, since changes in orientation change the horizontal and vertical dimensions of the figures, the result of the experiments could also be interpreted in terms of these variables. Further experimentation is necessary to separate the effects of orientation from the dimensions of the figures.

It should be noted that the most effective variable appears to be brightness. It has been found that a number of different shapes in a number of different displays could be presented which would not segregate into groups as long as the brightness was equal for the elements in both patterns. Again, the overall similarity was not a reliable predictor of their tendency to segregate into groups. This suggests that the judged similarity of two figures is based on properties of the shapes which do not necessarily influence their separation into groups. Demonstrations which have shown the importance of more complex properties (such as shape similarity) in perceptual grouping, should be considered carefully, as they often involve changes in orientation and size of the lines composing the figures.

JACOB BECK
Department of Psychology, Harvard University, Cambridge, Massachusetts

References and Notes

1. M. Wertheimer, *Psychol. Forsch.* **4**, 301 (1923).
2. B. Julesz, *IRE Trans. PGIT, IT*-8, 1 (1962).
3. Although an attempt was made to equate the brightness of the two lines composing a figure, they were not always identical. That the results were not due to this fact was shown by a further study in which the lines for all elements were equated. The results obtained confirm the present findings.
4. T. A. Ryan, *Psychol. Bull.* **56**, 46 (1959).
5. Dunnett has derived a test for use when we compare each condition to a control. The test may be found in B. J. Winer, *Statistical Principles in Experimental Design* (McGraw Hill, New York, 1962), p. 89. As in the Tukey test, Dunnet's test controls the error rate of the experiment as a whole. Since the Dunnett test was designed to compare each condition with a control rather than to compare all possible conditions, it is more sensitive than the Tukey test.
6. F. Attneave, *Psychol. Rev.* **61**, 183 (1954).
7. J. Gibson, *The Perception of the Visual World* (Riverside Press, Cambridge, 1950), p. 195.
8. D. H. Hubel and T. N. Wiesel, *J. Physiol.* **160**, 106 (1962).
9. Supported by NSF grant GB-2901 and a grant from the Carnegie Corporation.

21 July 1966

Underwater Vocalization by Sea Lions: Social and Mirror Stimuli

Abstract. *Underwater vocal response of three sea lions* (Zalophus californianus) *increased under conditions of social interaction. When confronted by their mirror images, two animals increased their number of vocalizations, which included "whinny" sounds, barks, buzzing, and varying patterns of click trains. Click vocalizations showed habituation and recovery when the animals were in the presence of the mirror stimulus.*

Vocalization by an animal often appears related to alertness or increased activity; presumably during activated states, physiologic arousal is great (*1*). Among seals and sea lions, vocalizations in air (sounds often having a pulsed structure) are valuable in communication and are frequently associated with stress, social play, fighting or sparring, increased sexual activity, and disturbance from a resting state (*2*). It has been suggested (*3*) that underwater click vocalizations by the sea lion *Zalophus californianus* may be related to a general arousal phenomenon (*1*) as well as to a specific or focused arousal such as the "questioning reaction" or "orienting reflex" (*4*). Since click vocalizations are likely to convey information concerning the moods of the animal, these sounds may function as part of its underwater-communication system.

Social and novel stimuli strongly induce behavioral and physiologic arousal, and the concept of arousal is useful in the interpretation of investigative behavior (*5*) and of patterns of social behavior (*6*). If clicking vocalizations underwater are related to the emotional character of *Zalophus*, they may be expected to play a prominent role in its behavior in situations considered arousal-producing. To test this hypothesis, three sea lions in a tank were presented with a social stimulus (another sea lion) and novel stimulus (a mirror) (*7*).

The amounts and types of underwater vocalization (*8*) were compared in the presence and absence of the stimuli. Underwater vocal behavior and investigative behavior were quantified by means of a time-ruled check list; frequency was recorded by 30-second intervals. Two experimenters observed the animals from the testing platform: one monitored and scored the occurrence of underwater vocalizations; the other observed the animals, activating a stop-watch only when an animal's head was submerged, scoring behavioral categories, and making qualitative notes on the behavior of each animal. Vocalizations were scored only during "running time," that is, when at least one animal had its head underwater.

We used a male (Sam) and two females (Bibi and Cathy), 3 to 4 years old; all had been captive for at least 1 to 2 years. Previously, in different types of visual-discrimination tasks, Bibi (*3*) and Sam had spontaneously produced clicking sounds under water, and Cathy had been conditioned to emit these sounds (*9*).

Each animal was paired with each of the other two on separate occasions. One pair was tested each day and all three pairs initially received a total of four test sessions, with one animal of each pair alternately introduced into the tank individually or as a "partner." The procedure was as follows: (i) an animal was introduced into the tank and swam freely for 1 hour, observations being made during the first 10 minutes of this period; (ii) the underwater vocalization of the single free-swimming animal was recorded for 20 minutes; (iii) a second animal, the "partner," was introduced into the tank and underwater vocalizations by both animals were recorded for 20 minutes; and (iv) the partner was removed from the tank and recording of underwater vocalizations by the first animal was resumed. One session was run daily for 12 days.

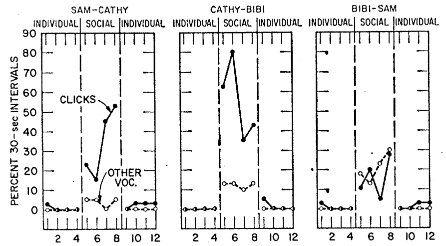

Fig. 1. Amount of clicking and other underwater vocalizations by sea lions tested individually and in pairs.

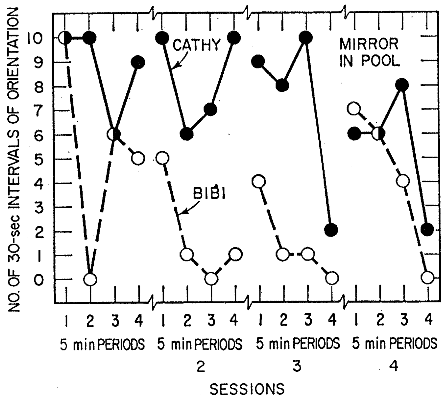

Fig. 2. The course of intra- and intersession visual orientation toward back-to-back mirrors.

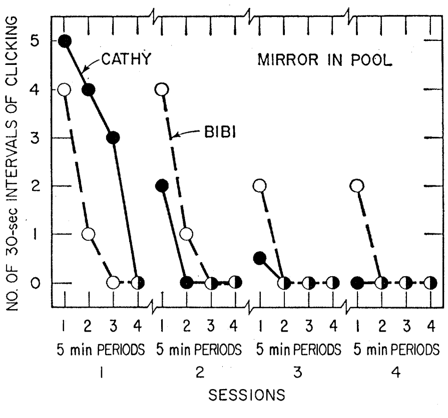

Fig. 3. The course of intra- and intersession clicking vocalization in the presence of back-to-back mirrors.

Underwater vocalizations during this experiment included "whinny" sounds, barks, and a buzzing sound, as well as varying patterns of click trains (*10*). Since there was little change in the amount or type of vocalization for each pair over the four test sessions, the results from each of the sessions were combined (Fig. 1). Clicks and other vocalizations were far more prevalent for each pair during social testing than for individuals before and after the social tests.

Clicking was the predominant vocalization by all animals, but Bibi frequently whinnied, especially when interacting with Sam; Sam and Cathy never emitted this sound. Play-fighting (characterized by chasing, gentle biting and pushing, and "porpoising" together and over one another) was the most frequent social activity. Although clicking was frequent during a social encounter, especially during an extensive chase, it was equally frequent when the animals were not swimming close to each other. Barking and Bibi's whinny were specific to social encounters, usually occurring when play appeared to shift to aggression (consisting of hard biting and lunging).

The effects of a mirror on underwater vocal and investigative behavior were determined; a mirror may be thought of as a novel stimulus having to some extent the properties of a social stimulus. Reflected self-images elicit intense interest and investigation in chimpanzees (*11*), and Tinbergen (*12*) reports that a sexually active male stickleback assumes a threatening posture when it sees itself in a mirror.

Two mirrors, each 41 by 51 cm, were hung vertically back-to-back over the center of the tank and 71 cm below the surface. Vocalizations and visual orientation to the mirror were scored. Orientation was recorded when an animal looked at either mirror for at least 3 seconds from within 0.9 to 1.2 m. The experimental design and procedure resembled those of the previous study except that the mirror replaced the partner during the test phase.

No animal vocalized underwater before or after the test periods, but all immediately oriented and produced underwater clicks upon initial exposure to the mirrors. After the initial burst of clicks while approaching the mirror, Sam remained silent and showed no further interest. The results for the other two sea lions (Figs. 2 and 3) indicate that both orientation and clicking: (i) decreased within each test session, (ii) recovered between sessions, and (iii) generally declined over sessions. In addition to clicking, Bibi emitted sharp cracks and whinnies. Both animals frequently swam 3 to 4 m from the mirror before swinging about to make a rapid "run" at it while vocalizing; they either paused a few centimeters in front of it or made a sharp turn away. In many of these excursions the animals moved their heads back and forth spasmodically in front of the mirror as if threatening; they pushed it with their noses, bit it, and occasionally slapped and clasped it with the front flippers.

Our results generally confirm the notion that clicking and other underwater vocalizations by *Zalophus* are associated with its social and investigative response and are therefore related to increased behavioral and presumably physiologic arousal. Furthermore, social facilitation of clicking and other vocalizations, and their frequent association with aggressive behavior patterns, indicate that vocalization does play a role in the underwater-communication system. Since the most vocal animal in the experiments (Cathy) had been the least vocal of the three before it was conditioned to vocalize, the threshold for elicitation of underwater vocalization may decrease as a function of previous learning.

Welker (*5*) lists prominent features that tend to characterize play and investigative behavior: response to novelty, habituation, and recovery; all have been demonstrated in connection with *Zalophus*'s investigative behavior as reflected by measures of visual orientation, and the underwater click vocalizations also conform to these principles. In fact, the curves for underwater clicks (Fig. 3) resemble those of object-contact curves obtained with chimpanzees (*13*). Moreover, the frequency and type of investigative behavior displayed by *Zalophus* appear to resemble those of other modern Carnivora (*14*).

RONALD J. SCHUSTERMAN
ROGER GENTRY
JAMES SCHMOOK
Stanford Research Institute,
Menlo Park, California 94025

References and Notes

1. E. Duffy, *Psychol. Rev.* **64**, 265 (1957); D. Bindra, *Motivation: A Systematic Reinterpretation* (Ronald Press, New York, 1959); D. E. Berlyne, *Conflict, Arousal and Curiosity* (McGraw-Hill, New York, 1960).
2. G. A. Bartholomew and H. E. Collias, *Anim. Behav.* **10**, 7 (1962).
3. R. J. Schusterman, *Psychol. Record* **16**, 129 (1966).
4. I. P. Pavlov, *Conditioned Reflexes* (Oxford Univ. Press, London, 1927); E. N. Sokolov, in *The Central Nervous System and Behavior: Transactions of the Third Conference*, M. Brazier, Ed. (Josiah Macy Jr., Foundation, New York, 1960), p. 187.
5. W. I. Welker, in *Functions of Varied Experience*, D. W. Fiske and S. R. Maddi, Eds. (Dorsey Press, Hollywood, Ill., 1961), p. 175.
6. W. A. Mason, in *Behavior of Nonhuman Primates*, A. M. Schrier, H. F. Harlow, F. Stollnitz, Eds. (Academic Press, New York, 1965), p. 335.
7. The interior of the oval redwood tank (4.6 by 9.1 by 1.8 m deep) was painted white; it was filled with 82 kl of fresh water, and six windows in the walls permitted observation and photography.
8. Underwater vocalizations were continuously monitored by a Channel Industries–275 hydrophone (20 cy/sec to 150 kc/sec) and an Ampex-2044 amplifier-speaker system (65 cy/sec to 13 kc/sec). Vocal signals were periodically recorded with a Uher-4000S tape recorder at 20 cm/sec (40 cy/sec to 20 kc/sec) and were analyzed with a Kay-661 spectrum analyzer.
9. R. J. Schusterman and S. H. Feinstein, *Science* **150**, 1743 (1965).
10. Copies of sonograms of these sounds are available from R.J.S.
11. W. Köhler, *The Mentality of Apes* (Vintage Books, New York, rev. ed., 1959).
12. N. Tinbergen, *The Study of Instinct* (Oxford Univ. Press, London, 1951).
13. W. I. Welker, *J. Comp. Physiol. Psychol.* **49**, 84 (1956).
14. S. E. Glickman and R. W. Stroges, *Behaviour* **26**, 141 (1966).
15. Supported by NSF grant GB-4349.

8 September 1966

Superconductivity of Alpha Uranium

The report (*1*) entitled "Superconductivity of β-uranium" shows that the β-uranium structure, when retained to low temperatures by quenching uranium alloyed with β-stabilizing elements, is a bulk superconductor with a transition temperature of about 0.8°K. However, the authors go on to suggest: "The reported superconducting behavior of α-uranium may be due only to superconducting filaments of retained stabilized α-, β-, and γ-phases, or perhaps even filaments of superconducting compounds."

I would like to point out that in the α-uranium which has been examined for superconductivity there is no metallurgical reason to find retained β- or, still less likely, γ-phases or filaments of superconducting compounds.

Investigations (*2*) based on magnetic measurements of the highest purity uranium yet produced, the Argonne uranium, have suggested that α-uranium is a superconductor. However, investigations of the specific heat (*3*) reveal no anomaly suggesting that the superconductivity is due to a filamentary structure of some sort rather than to the bulk sample.

In order to stabilize the β-phase to room temperature and below, the $\beta \rightarrow \alpha$ transformation, which occurs at 667.7° ± 1.3°C in the Argonne uranium (*4*), has to be suppressed. For a given cooling rate this occurs if the solute content of the alloy exceeds a critical value. This critical value has a lower limit of about 0.1 atom percent for the most effective solutes but is higher for most other elements. For the Argonne uranium all the solute will be in solution in the β-phase and in the high-temperature end of the α-phase, with the exception of the nonmetallic impurities, oxygen, nitrogen, and carbon. These have no stabilizing influence on the β-phase, as is shown by the similar behavior of reactor-grade uranium and Argonne uranium during the $\beta \rightarrow \alpha$ transformation. There is thus no mechanism whereby any significant enrichment of the grain boundaries can take place while the uranium is maintained in the β-phase, or during the transformation from β- $\rightarrow$ α-phase. The same argument also applies to the γ-phase and the $\gamma \rightarrow \beta$ transformation.

Even if β-phase were retained to room temperature, in low-alloy material the rate of $\beta \rightarrow \alpha$ transformation at room temperature is rapid, and only a few hours or a few days are needed to complete the transformation.

Normal metallographic examination with the light microscope of high-purity uranium (*5*, *6*), such as the Argonne uranium, which has been cooled slowly from the γ-phase field, reveals typically a very few isolated particles of U(CNO) (*5*) (the solid solution which forms between UC, UN, and UO) and UO_2 and occasionally U_6Fe and UAl_2 together with a fine eutectoidal network also of U(CNO) all in an α-phase matrix. This network does not coincide with the grain boundaries of the α-phase. It is probably at sites where there once were the grain boundaries of the prior β-structure and results from precipitation from the β-phase. Annealing in the α-phase after slow cooling does not modify the networks appreciably. It is possible to modify