oping during the 1-hour preavoidance interval were maintained throughout the 2-hour avoidance interval for all five dogs, as shown in Fig. 1. Changes in heart rate during the avoidance interval, however, were typically characterized by immediate and marked average increases over the preceding preavoidance levels. In four of the five dogs, these average heart rate increases during the 2-hour avoidance interval were statistically significant ($P < .01$). The patterns of blood pressure and heart rate during the post-avoidance interval were more variable between dogs, however, and require more extensive experimental analysis.

The results of this experiment show clearly that repeated exposure to behavioral conditioning can produce divergent and sustained changes in concurrently measured levels of blood pressure and heart rate. Accounts of similar divergencies observed in classically conditioned rabbits (*6*) and shock-exposed curarized dogs (*11*), limited to periods of only seconds, have called attention to homeostatic autonomic reflex mechanisms related to the maintenance of blood pressure. The extended circulatory changes persisting over the 1-hour preavoidance interval in the present study, however, suggest the participation of more enduring hormonal influences. Changes in blood catecholamine levels have been related to avoidance behavior in the monkey (*12*), for example, suggesting that increases in circulating norepinephrine levels, known to produce divergent effects upon blood pressure and heart rate (*13*), may account, at least in part, for the preavoidance cardiovascular response pattern described in the present report.

Although the relationship of these blood pressure elevations accompanied by heart rate decreases in the dog to the similarly divergent circulatory changes characteristic of essential hypertension in humans (*14*) is far from clear, chronic exposure to such behavioral conditioning has been reported to produce sustained hypertensive patterns. Herd *et al.* (*15*) and Forsyth (*16*) have described chronic blood pressure elevations developing in monkeys after prolonged, though intermittent, performance on similar shock-avoidance programs for periods up to and exceeding 1 year. Additionally, Forsyth (*16*) observed a sustained bradycardia accompanying the chronic pressure elevations in at least some animals. Under any circumstances, however, a wide range of behavioral and physiological factors, including temporal parameters, reinforcement contingencies, and hormonal processes, would seem to require further scrutiny in the experimental analysis of this unique finding.

DAVID E. ANDERSON
JOSEPH V. BRADY
Department of Psychiatry and Behavioral Science, Johns Hopkins University School of Medicine, Baltimore, Maryland 21205

References and Notes

1. R. A. Dykman and W. H. Gantt, *Bull. Johns Hopkins Hosp.* **107**, 72 (1960); S. H. Ferreira, L. R. Gollub, J. R. Vane, *J. Exp. Anal. Behav.* **12**, 623 (1969).
2. R. P. Forsyth, *Psychosom. Med.* **30**, 125 (1968); J. D. Findley and J. V. Brady, *Proc. 77th Annu. Conv. Amer. Psychol. Ass.* (1969).
3. J. V. Brady, D. Kelly, L. Plumlee, *Ann. N.Y. Acad. Sci.* (1969).
4. D. G. McDonald, J. A. Stern, W. W. Hahn, *J. Psychosom. Res.* **7**, 97 (1963); F. S. Fehr and J. A. Stern, *ibid.* **8**, 441 (1965); R. D. Fitzgerald and R. M. Vardaris, *Psychonom. Sci.* **6**, 437 (1966); W. F. Caul and R. E. Miller, *Physiol. Behav.* **3**, 865 (1968).
5. G. E. Deane, *Psychonom. Sci.* **3**, 119 (1965); N. Schneiderman, M. Smith, A. Smith, I. Gormezano, *ibid.* **6**, 241 (1966).
6. A. Yehle, G. Dauth, N. Schneiderman, *J. Comp. Physiol. Psychol.* **64**, 98 (1967).
7. D. E. Anderson, L. A. Daley, J. D. Findley, J. V. Brady, *J. Behav. Res. Instr. Meth.* **2**, 191 (1970).
8. J. Perez-Cruet, L. A. Plumlee, J. E. Newton, *Proc. Symp. Biomed. Eng.* **1**, 383 (1966).
9. M. E. T. Schwinnen, *Proc. Annu. Conf. Eng. Med. Biol.* **10**, 18.4 (1968).
10. M. Sidman, *Science* **118**, 157 (1953).
11. A. H. Katcher, R. L. Solomon, L. H. Turner, V. Lolordo, J. B. Overmeier, R. A. Rescorla, *J. Comp. Physiol. Psychol.* **68**, 163 (1969).
12. J. W. Mason, J. V. Brady, W. W Tolson, in *Endocrines and the Central Nervous System*, R. Levine, Ed. (Williams & Wilkins, Baltimore, 1966), pp. 227–248.
13. L. S. Goodman and A. Gilman, *The Pharmacological Basis of Therapeutics* (Macmillan, New York, 1955).
14. I. Page and J. W. McCubbin, in *Handbook of Physiology*, W. F. Hamilton, Ed. (American Physiological Society, Washington, D.C., 1965), sec. 2, *Circulation*, vol. 3, pp. 2163–2208.
15. J. A. Herd, W. H. Morse, R. T. Kelleher, L. G. Jones, *Amer. J. Physiol.* **217**, No. 1, 24 (1969).
16. R. P. Forsyth, *Psychosom. Med.* **31**, 300 (1969).
17. Supported by NIH grant HE-06945.

10 December 1970

Free Recall and Abstractness of Stimuli

Abstract. *The relation of abstractness of stimuli to efficiency of free recall was studied in college and fourth-grade students. Groups were shown a sequence of objects, pictures, and object names and were asked to recall what they had seen. Recall tests were conducted either immediately after presentation of the stimulus-sequence, after 24 hours, or after 1 week. Objects were recalled more frequently than pictures, and pictures more frequently than words. Adults performed better than children, except in the case of objects.*

In order to examine the relation of abstractness of meaningful stimuli to the efficiency of their free recall, we have compared free-recall performance when the stimuli to be recalled were actual objects, full-scale black-and-white photographs of these same objects, and their printed object names. The data indicate that ease of recall is inversely related to abstractness of stimuli. Recall for objects was best; for pictures, poorer; and for object names, poorest. Furthermore, adults performed the experimental task better than children except when the stimuli to be recalled were objects.

Among more than a score of studies that constitute the literature on memory as a function of stimulus abstractness, 17 have dealt with memory for pictures and words, 5 with objects and words, and 1 with objects and pictures. None has examined memory across the full dimension of stimulus abstractness under a single set of experimental conditions. In 13 experiments, the subjects were adults, and in 6 experiments they were children. Only four of the studies have been comparative: two involved normal adults and normal children; one, normal adults and adults with memory defects; and one, normal children and mental retardates. Brief discussions of these findings are found in recent reviews (*1, 2*).

Subjects were 90 adults (students at the State University of New York at Albany with a mean of 19 years of age) and 90 were fourth-grade children (students with a mean of 9 years and 5 months of age, in two public school districts in the Albany metropolitan area). Each sample of 90 subjects was randomly divided into three groups of 30 subjects each. Each group received a different counterbalanced sequence in which a third (that is, seven) of the stimuli were objects, a third were pictures, and a third were words. The three orders were constructed in such a manner that individual stimuli occurred in a different version (either object, picture, or word) in each order and with only one version in a particular order. Each group was further ran-

domly divided into three subgroups of ten subjects each. One subgroup was tested with an immediate-recall test; one was tested 24 hours after presentation of the stimuli; and one was tested after 1 week.

The stimuli were 21 small, common objects previously scaled for familiarity. Scale values were obtained through a multiple-stage procedure. (i) Approximately 200 college students were asked to list the names of 200 common, small objects (none larger than 25 by 25 by 15 cm) with which they frequently had come into contact. (ii) From these responses, the 50 object names most frequently listed were chosen. (iii) These object names were presented to an additional 50 students for rating. An 11-category scale varying from very frequently contacted (category 1) to very infrequently contacted (category 11) was used for this purpose. (iv) The 27 stimuli with the highest rated frequency of contact (average 4.74 out of 11) were selected. Finally, this list was reduced to 21 object names because 6 of the object names could not reliably be recognized by a group of children comparable to those chosen for the experiment. The stimulus list consisted of the following items: apple, book, bottle, coin, cup, eraser, flower, fork, key, light bulb, match, matchbook, pencil, radio, ring, safety razor, scissors, shoe, soap, toothbrush, and wallet.

As indicated above, each stimulus was prepared in three versions. The full-scale photographs of the objects on a white background were black-and-white glossy prints (19 by 25 cm). The object names were printed in black lower-case letters on 20 white cards (20 by 27 cm). Stimuli were presented in alternate sections of an eight-section platform that rotated behind a screen with a viewing aperture. The arrangement for presentation was such that only one stimulus could be seen at a time. The rotating platform and screen were painted neutral gray.

The subjects were tested in groups in the classroom setting. They were told only that they were to watch the window in the screen before them. After announcing that he was about to start, the experimenter presented stimuli one at a time in random order. Each was presented only once for 5 seconds with 5 seconds between presentations. Groups under the immediate-recall condition were then given a sheet of paper and asked to list the names of all the stimuli they had seen. The same

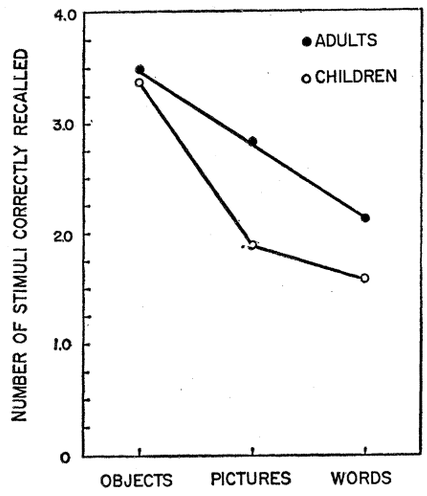

Fig. 1. Free recall as a function of level of abstractness of stimuli in university and fourth-grade students.

procedure was also followed in the 24-hour and the 1-week recall groups.

In statistically evaluating the data, we have assumed that all effects were fixed effects. A series of analyses of variance were first performed; then a mean separation test with the least significant difference set at $P = .05$ was used to evaluate paired means (*3*).

The data on the time of recall are essentially uncomplicated. For both adults and children, performance was poorer as time between exposure to the stimuli and administration of the free-recall test was increased. For the adults, neither the level of abstractness represented by the individual stimuli nor the stimulus sequence used had any differential effect upon this temporal variable. Among the children's groups, there was a significant interaction involving recall period, sequence, and version produced by the unexplained performance of one of the nine subgroups. In this group, which trained with one of the three sequences and was tested 24 hours after presentation of the stimuli, recall for pictures and words proved to be equally poor when compared with recall for objects. In all other groups, recall for words was poorest, for pictures next poorest, and for objects best.

Figure 1 indicates that there is a monotonic relation between abstractness and success in free recall. This is confirmed by significant F ratios between levels of abstractness for both adults and children [adults: $F(2, 243) = 30.83$, $P < .001$; children: $F(2, 243) = 18.08$, $P < .001$]. Performance was best for objects, somewhat poorer for pictures, and poorest for words. In the case of the adult subjects, mean separation tests invariably bore out this conclusion. In contrast, children's recall for words was not reliably poorer than for pictures: difference = .31; least significant difference at .05 level = .32. However, this failure at statistical significance reflects, as noted above, the atypical behavior of one of the nine subgroups. For the remaining eight subgroups, behavior was consistent with the conclusion. Furthermore, the superiority of recall for pictures over that for words under these same conditions was confirmed by data more recently obtained in the laboratory of one of us (W.B.).

This superiority of recall for objects over that for pictures over that for words may be interpreted in several ways. We may think, for example, in terms of the amount of information encoded in the memory trace. Memory is for the individual event, not for the general case. And ease of recall, as both Helson and Gibson have emphasized (*4*), depends upon the distinctiveness of the individual event, that is, the extent to which it is differentiated from the general or normative case. Distinctiveness, in turn, depends not only on the extent to which the individual event departs from the norm on some relevant dimension (*5*) or dimensions but also on the number of relevant dimensions involved (*6*). Objects may be remembered better than pictures because they are, in this latter sense, more distinctive. Similarly, pictures are more distinctive than object names (*7*).

Paivio has recently advanced an encoding hypothesis to account for outcomes of the kind reported here (*1*). In a series of experiments he observed that pictures are recalled better than object names and that concrete words are recalled better than abstract nouns, results he attributes to multiple as contrasted to single memory codes. Pictures, for example, can be stored both as images and in coded verbal form whereas object names are more likely to be stored only in verbal form. Posner (*8*) has expressed a similar view. The encoding hypothesis, however, does not readily accommodate the present difference in recall for objects and pictures since, presumably, multiple-coded storage would be involved in both instances unless we assume that the trace for images of objects stores more information than that for pictures. Two properties present in the objects but not in the pictures are color and three-dimensionality. Paivio, Rogers, and

Smythe (*9*) report that color is not a variable that is significant for the recall of either pictures or words. Meanwhile, it has been demonstrated, with both human subjects and monkeys (*10*), that discrimination learning is more efficient for three-dimensional objects as compared to flat patterns.

The assumption that stimulus abstractness is inversely related to the amount of information in the stimulus display suggests that subjects should recall objects with the greatest frequency, pictures with the next greatest frequency, and words with the least frequency throughout the period of free recall. A random selection was made of the response sheets of 30 of our subjects: 5 adults and 5 children from the subgroups tested immediately after the initial presentation of the stimulus response, 5 adults and 5 children from the 24-hour subgroups, and 5 adults and 5 children from the 1-week subgroups. A tabulation was made of the kind of stimuli identified on successive responses. As their initial response, 12 of the 30 subjects mentioned an object, 11 a picture, and 7 a word. This rank order of object-picture-word tended to manifest itself with occasional variation throughout the entire series of responses. For example, on the sixth response, 12 subjects responded with objects, 5 with pictures, and 4 with an object name. The subjects not only tended to respond with objects but these responses also tended to persist as other forms of response dropped out. Thus by the 12th response, two subjects responded with objects, one with a picture, and all other responses were exhausted. Only one subject gave as many as 14 responses, and his last response identified an object. In other words, the relative strength of responsive modes tended to display itself early and to persist throughout the response period. This pattern evidenced itself with equal clarity in the immediate, 24-hour, and 1-week recall data.

Although the stimulus encoding hypothesis is attractive, we cannot, at this point, eliminate the possibility that objects, and to lesser extent pictures, have greater motivating properties than words as stimuli for recall. At the same time that they are more distinct they are also more interesting and vivid.

The superiority of adult performance over that of children (Fig. 1) was confirmed by statistical test [between age groups: $F(1, 513) = 28.52$, $P < .001$]. However, the responses of the two age groups to the several versions of stimuli differed with time of recall [time of test: $F(26, 513) = 14.91$, $P < .001$]. Further analysis indicated that there were initially only slight differences between adults and children in the recall of objects and these had disappeared by the time of the 1-week recall test (difference between age groups at 1 week = .20, least significant difference at .05 level = .25). In contrast, adults were clearly superior to children in their recall of pictures throughout all test periods. Finally, the anticipated superiority of adults in the recall of words did not assert itself until there had been a 1-week delay in recall (difference between age groups at 1 week = 1.51, least significant difference at .05 level = .25).

Bruner (*11*) has described the representation of past experience in memory as involving different modes, depending on the individual's level of cognitive development. Memory at the earliest stage of life is characterized by the enactive mode, that is, by the retrieval of past events through appropriate motor responses. Later on, the child is capable of the iconic mode, that is, the ability to organize and use images as the vehicle of retrieval. The last mode to appear is the symbolic mode in which language or some similarly abstract coding system is used to represent experience. Psychologists have been aware of these modes for some time and in describing them have been inclined to view one or the other as dominant at a particular age with the further important assumption that the others were undeveloped, unused, or alternatively deteriorated. Thus, whereas children use images, adults use language, and these different modes represent characteristically different cognitive styles.

Our results suggest a rather different interpretation. Adult behavior is more versatile than that of the child not simply because the adult has a more versatile cognitive style in his well-developed language skills but because he has a richer, and probably more thoroughly integrated, repertory of multiple cognitive modes. Indeed, he appears to do as well as the child in handling the iconic mode, that is, his recall of objects appears to be as good as, if not better than, that of the child. The adult's clear superiority in the recall of pictures is consistent with Paivio's hypothesis that he has integrated iconic and symbolic modes.

WILLIAM BEVAN
Department of Psychology, Johns Hopkins University, Baltimore, Maryland 21218
JOSEPH A. STEGER
Department of Psychology, State University of New York at Albany, Albany 12205

References and Notes

1. A. Paivio, *Psychol. Rev.* **76**, 241 (1969); see also *ibid.*, pp. 254–256.
2. E. Tulving and S. A. Madigan, *Annu. Rev. Psychol.* **21**, 437 (1970); see also *ibid.*, pp. 451–453.
3. H. C. Fryer, *Concepts and Methods of Experimental Statistics* (Allyn & Bacon, Boston, 1966).
4. H. Helson, *Adaptation-Level Theory* (Harper & Row, New York, 1964), p. 228; E. J. Gibson, *Principles of Perceptual Learning and Development* (Appleton-Century-Crofts, New York, 1969), pp. 152–154.
5. H. Helson, *Psychol. Rev.* **55**, 297 (1948).
6. C. W. Eriksen and H. W. Hake, *J. Exp. Psychol.* **50**, 155 (1955).
7. K. G. Scott, *J. Verb. Learning Verb. Behav.* **6**, 864 (1967).
8. M. Posner, in *The Psychology of Learning and Motivation*, G. H. Bower and J. T. Spence, Eds. (Academic Press, New York, 1969), pp. 44–100.
9. A. Paivo, T. B. Rogers, P. C. Smythe, *Psychonom. Sci.* **11**, 137 (1968).
10. H. F. Harlow, *J. Gen. Psychol.* **32**, 213 (1948); H. W. Stevenson and G. McBee, *J. Comp. Physiol. Psychol.* **51**, 752 (1958).
11. J. S. Bruner, *Amer. Psychol.* **19**, 1 (1964).
12. Supported jointly by contract N00014-67-A-0163-0001 between the Office of Naval Research and Johns Hopkins University, and by a State University of New York summer research fellowship award to J.A.S. We thank A. Downer and the North Colonie School District for their cooperation in those aspects of the study involving children.

8 February 1971

Differential Cerebral Processing of Noise and Verbal Stimuli

Abstract. *Psychophysiological measurements have indicated that the right cerebral hemisphere processes noises and other nonverbal data and that the left cerebral hemisphere processes verbal material. Direct physiological measurements, as expressed in summated auditory evoked cortical responses, unequivocally demonstrate that click noises show a greater amplitude of initial output over the right brain, and that verbal stimuli produce either equal or higher amplitudes of output over the left cerebral hemisphere.*

By the psychophysiological technique of simultaneous application of different auditory stimuli to the two ears, Kimura (*1*) showed that the left brain had a predilection for processing verbal symbols and that melodic or nonverbal symbols were processed predominantly by the right cerebral hemisphere (*2*).