posed at stations along the Chilibre River, where sentinel hamsters had recently died of VEE virus infection. Collections were made daily, between the hours of 6:30 p.m. and 8:45 p.m., from 19 August through 13 September. Immediately after each collecting period all live mosquitoes were identified by species at the Juan Mina field station of the Gorgas Memorial Laboratory. All specimens of *C. aikenii* were subsequently liberated in groups of 80 or less inside Barraud-type cloth cages. Laboratory-bred hamsters were exposed individually to the bites of the mosquitoes held in the cloth cages. Special precautions were taken to prevent possible contamination of normal hamsters held at the field station with VEE virus from infected hamsters and mosquitoes. Each morning after exposure of the hamsters, engorged mosquitoes were separated and transferred from the cages to glass jars lined with plaster of Paris, in which they were held for 24 hours before being stored in liquid nitrogen. Mosquitoes that were not engorged were maintained in similar glass jars during the day and given access to the same hamster in the evening; additional females captured that evening were added to make a total of 80 specimens. With the exception of a few missing specimens from every group, presumably eaten or destroyed by the hamsters, all mosquitoes used in these experiments were frozen in liquid nitrogen along with tissue samples from hamsters which became ill or died after exposure to the bites of wild-caught *C. aikenii.*

Attempts to isolate virus from hamsters and mosquitoes were made at the central laboratory by inoculation of suckling mice. Each sample of serum or plasma was diluted in four volumes of phosphate-buffered saline solution containing antibiotics. Bovine albumin was included in the diluent used for the trituration of hamster tissues and mosquitoes. Specimens from sick or dead hamsters were processed individually, whereas mosquitoes were pooled in groups of ten or less. We made a preliminary identification of viral isolates by testing crude mouse brain antigens with reference antiserum prepared against the No. 3880 strain of VEE virus (*3*), by means of the complement-fixation technique.

Table 1 summarizes results of exposures of hamsters to the bites of wild-caught *C. aikenii* females. A total of 4227 *C. aikenii* were given access to 11 hamsters, and 1203 (28 percent) became engorged. Six of the 11 hamsters exposed came down with VEE infections. In the case of two of the positive hamsters, VEE virus was isolated from one of several pools of mosquitoes which fed on these hamsters 2 to 4 days before death. Processing of mosquitoes allowed to feed on the other four hamsters which developed infections has not yet been completed.

In order to determine the vector potential of the species, 30 wild-caught *C. aikenii*, which had engorged on the blood of three infected hamsters, were held at ambient temperatures (24° to 28°C) for 8 to 16 days, after which they were each given access to a single clean hamster. Twelve of the 30 mosquitoes transmitted VEE virus for an overall transmission rate of 40 percent. The infection rate in 25 of these mosquitoes tested individually for presence of virus was 92 percent.

Results of these experiments show that *C. aikenii* was responsible for at least some of the VEE being transmitted in the study area. This conclusion is reached from the fact that VEE virus was isolated from clean laboratory-bred hamsters after exposure to wild-caught mosquitoes captured along the Chilibre River and, in some cases, from mosquitoes which engorged on their host 2 to 4 days before its death, the period of time which corresponds to the usual incubation of the virus in hamsters. The high rate of VEE transmission obtained in these experiments suggests that this species is a very efficient vector of the virus in nature. The high population density of *C. aikenii* as compared with other mosquito species, coupled with epidemiological information gathered in the study area but not pertinent to this report, indicates that this culicine species was the most important, if not the only, mosquito vector of VEE virus in this endemic area during the study period.

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References and Notes

1. P. Galindo, S. Srihongse, E. de Rodaniche, M. A. Grayson, *Amer. J. Trop. Med. Hyg.* **15**, 385 (1966); T. H. G. Aitken, L. Spence, A. H. Jonkers, W. G. Downs, *J. Med. Entomol.* **6**, 207 (1969); R. W. Chamberlain, W. D. Sudia, T. H. Work, P. H. Coleman, V. F. Newhouse, J. G. Johnston, *Amer. J. Epidemiol.* **89**, 197 (1969).
2. At present this group of mosquitoes poses a taxonomic problem. J. N. Belkin [*Mosquito Syst. Newsl.* **2**, 59 (1970)] relegated the name *Culex* (*Melanoconion*) *aikenii* (Aiken and Rowland), 1906, to the status of a *nomen dubium* and resurrected the names *ocossa* Dyar and Knab and *panocossa* Dyar from the synonymy of *aikenii* to designate two closely related forms which he considered distinct species. Work being carried out at Gorgas Memorial Laboratory has shown that systematic relationships between the two forms and their taxonomic status need further clarification. For this reason we decided to continue the use of the old, well-established name of *Culex aikenii*, until the above-mentioned studies are completed.
3. K. M. Johnson, A. Shelokov, P. H. Peralta, G. J. Dammin, N. A. Young, *Amer. J. Trop. Med. Hyg.* **17**, 432 (1968).
4. Supported by PHS grant AI-02984.

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Preavoidance Blood Pressure Elevations Accompanied by Heart Rate Decreases in the Dog

Abstract. *Blood pressure and heart rate were monitored continuously in five dogs for 1 hour before performance on a free-operant shock-avoidance task. Cardiovascular changes during the preavoidance hour were characterized by sustained and significant* increases *in blood pressure, and sustained and significant* decreases *in heart rate.*

Previous reports of cardiovascular responses to behavioral conditioning with laboratory animals have generally described parallel changes in blood pressure and heart rate. Typically, concurrent elevations in both pressure and rate measures have been associated with the development and maintenance of Pavlovian conditional reflexes in both dogs and monkeys (*1*), instrumental escape and avoidance behavior in monkeys and baboons (*2*), and conditioned suppression of operant behavior in monkeys (*3*). Decreases in heart rate during Pavlovian conditioning with rats (*4*) and rabbits (*5*) have also been described in experiments without blood pressure measurements, and one study (*6*) has suggested that divergent, if transient, changes in blood pressure and heart rate may occur during Pavlovian conditioning in rabbits.

The present report describes divergent and sustained blood pressure and heart rate changes in dogs related to the perfomance of an operant shock-

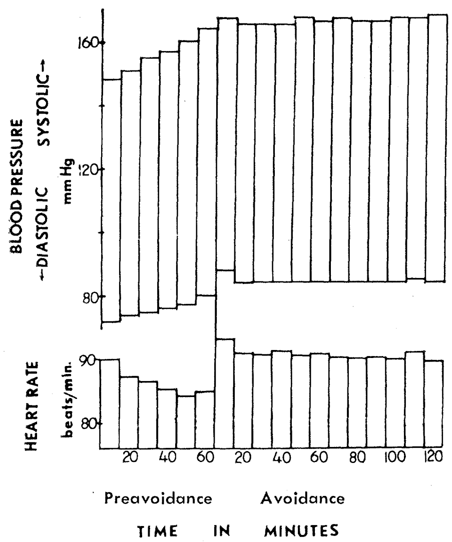

Fig. 1. Blood pressure and heart rate averages over successive 10 minute intervals during the preavoidance and avoidance periods for 44 terminal experimental sessions.

avoidance task. Specifically, progressive elevations in both systolic and diastolic pressure have been observed concurrently with progressive decreases in heart rate during a fixed 1-hour interval immediately and systematically preceding a required 2-hour shock-avoidance task. Additionally, elevations in both pressure and rate were recorded during the 2-hour avoidance, and more complex variations were observed in the course of a 1-hour postavoidance interval.

Five adult male dogs (two beagles and three mongrels), each weighing approximately 25 lb (11 kg), served as subjects. The animals were confined in a specially designed flexible restraint harness and experimental isolation chamber (*7*) which provided freedom of movement in a number of standing, sitting, or lying positions. The harness served the purpose of affording protection for indwelling arterial catheters, associated strain-gage transducers, and shock electrodes. A translucent nose key (13 by 8 by 0.5 mm), mounted on the front chamber wall immediately in front of the dog's head, activated a microswitch adjusted to approximately 15 g of inward pressure and provided the recorded operant for shock avoidance. Transillumination of the response key from behind provided visual stimuli for performance discrimination. Electric shock was administered through stainless steel electrodes applied with electrode paste to the shaved rear leg of the dog. An indwelling 18-gage polyvinyl catheter, implanted in a femoral artery (*8*), exited from the skin at the nape of the neck under the restraint collar and connected to a Statham strain-gage transducer (P23de) secured to the harness support. A Harvard peristaltic pump, attached to the transducer through a polyethylene tube and stopcock valve, provided continuous infusion of lightly heparinized saline (7000 USP units per liter) at a constant rate of approximately 12 ml/hr. Pressure signals from strain-gage transducer were amplified and analyzed by an electronic averager (*9*) which provided on-line printout of blood pressure (both systolic and diastolic in millimeters of mercury) and heart rate (in beats per minute) over consecutive 10-minute intervals.

The avoidance procedure required the animals to postpone shock by pressing the response key within a specified interval following a previous response (*10*). Brief 60-hertz electric shocks (5 ma for 0.3 second) were programed every 20 seconds unless the dog pressed the nose key within that interval and postponed the shock another 20 seconds. This procedure quickly generated stable key-pressing in all animals at a rate well above the required three per minute, thus avoiding all but a few shocks during the experimental sessions. The avoidance requirement was programed daily during a 2-hour interval signaled by illumination of the translucent nose key with a white light. A 1-hour interval immediately before and a 1-hour interval immediately after the 2-hour avoidance session were programed for each dog in the experimental chamber without stimulus lights or shocks. Measures of blood pressure and heart rate averaged over successive 10-minute intervals were obtained throughout the entire 4-hour experimental period. All programing of the experimental procedures and recording of the animal's behavior, blood pressure, and heart rate were accomplished remotely and automatically by a system of timers, counters, transducers, amplifiers, cumulative work recorders, and associated electromechanical and electronic circuitry.

Figure 1 shows the concurrent changes in blood pressure and heart rate during the preavoidance and avoidance periods, in form of averages for 44 terminal experimental sessions (ten terminal sessions for each of three dogs, and seven terminal sessions for the other two dogs). The figure shows consecutive 10-minute interval averages, and summarizes the stable response pattern which developed after each dog had participated in at least ten daily 4-hour experimental sessions. Characteristically, progressive elevations in both systolic and diastolic pressure accompanied by progressive decelerations in heart rate were observed during the preavoidance hour. Statistically significant ($P < .05$) increases in systolic pressure between the first and last 10-minute intervals of the preavoidance period were observed in all five dogs, as shown in Table 1. Statistically significant ($P < .05$) increases in diastolic pressure during the same interval were observed in four of the five dogs, the elevation in diastolic pressure for the fifth dog being significant between the .10 and .05 level. As indicated in Table 1, however, four of the five dogs showed significant ($P < .05$) decreases in heart rate during the preavoidance hour. Preavoidance increases in systolic pressure were observed during all 44 sessions included in this analysis, diastolic increases occurred during 39 of the 44 sessions, and heart rate decreases were recorded during 35 of the 44 experimental sessions. Additionally, increases in pulse pressure (difference between systolic and diastolic pressure), averaging more than 12 mm-Hg, were observed during 41 of the 44 preavoidance intervals.

Table 1. Mean differences in average heart rate, and both systolic and diastolic blood pressure, between the first and last 10-minute intervals of the preavoidance hour for each dog. N = number of terminal sessions for each dog; N.S., not significant.

Item	Blood pressure (mm-Hg)		Heart rate (beats/min)
	Systolic	Diastolic	
	Dog No. 1 (N = 10)		
Mean	+12.75	+9.78	−15.58
S.E.M.	3.70	3.61	4.38
P	.01	.03	.01
	Dog No. 2 (N = 10)		
Mean	+19.86	+12.29	−8.29
S.E.M.	6.25	3.97	3.36
P	.02	.02	.05
	Dog No. 3 (N = 7)		
Mean	+12.40	+4.50	0.00
S.E.M.	1.75	1.09	1.62
P	.01	.01	N.S.
	Dog No. 4 (N = 10)		
Mean	+13.10	+4.40	−11.40
S.E.M.	4.63	2.67	9.73
P	.01	.01	.01
	Dog No. 5 (N = 7)		
Mean	+10.43	+5.57	−9.57
S.E.M.	9.90	7.75	5.66
P	.01	.07	.01

Elevations in blood pressure developing 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 postavoidance 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.

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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.

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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-