encephogr. Clin. Neurophysiol. **19**, 75 (1965).

17. The physiological activity may be related, in part, to the response characteristics required of the animal; in this case, it is withdrawal and suppression of the natural tendency to step down from a platform. This disruption may take the form of simultaneous activation of SNC and other fiber pathways, such as those which we have described from the lateral hypothalamus [Y. Huang and A. Routtenberg, *Physiol. Behav.* **7**, 419 (1971)], which perforate through the SNC. The disruption could occur because simultaneous activation of SNC and descending lateral hypothalamic fibers normally does not occur. Another possibility is that the efferent nigral outflow to the ipsilateral midbrain tegmentum and tectum [R. Y. Moore, R. K. Bhatnager, A. Heller, *Brain Res.* **30**, 119 (1971)] is responsible for the disruption, since Glickman (*3*) showed that direct stimulation of midbrain tegmentum could cause impairments in performance in a passive avoidance task.
18. A. Routtenberg, *Physiol. Behav.* **6**, 589 (1971); *Ann. N.Y. Acad. Sci.* **193**, 159 (1972).
19. J. F. R. König and R. A. Klippel, *The Rat Brain* (Williams & Wilkins, Baltimore, 1963).
20. Supported by the Alfred P. Sloan Foundation.

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Hibernation: Effects on Memory or Performance?

McNamara and Riedesel (*1*) report that ground squirrels which hibernate during an 11-day period of exposure to cold perform better on a test designed to measure retention of a previously learned visual discrimination than do animals which do not hibernate during the cold retention interval. They interpret this result in terms of an alteration in memory. This interpretation is interesting because it extends previous research indicating that in some cases exposure to cold facilitates retention of learning in poikilotherms (*2*). However, there are deficiencies in McNamara and Riedesel's experimental design which make alternative interpretations possible.

After an initial 2-week period of adaptation to the experimental situation and a 1-week rest, all animals were trained on a visual discrimination for 7 weeks, after which they received 8 weeks of reversal training before being subjected to the first of two 11-day periods of exposure to cold. Thus, all the animals received exactly the same amount of training. However, equivalent amounts of training do not guarantee equivalent amounts of learning. If the animals that subsequently hibernated learned the reversed discrimination more thoroughly than those that did not hibernate, the observed difference in retention performance could be interpreted more parsimoniously in terms of this initial difference than in terms of any supposed effect upon memory. McNamara and Riedesel state that "before the cold-exposure periods there were no differences between those animals that later hibernated and those that did not hibernate ($F = 4.49$, d.f. = 1,16, $P > .05$)." This conclusion is apparently erroneous, since the stated value of the F statistic is equal to the critical value for rejection of the null hypothesis at the .05 level of significance (*3, 4*). Thus, it is quite likely that the difference in retention-test performance can be accounted for by a difference in degree of learning.

However, even if there were no difference in performance at the end of training, it would still be unsafe to assume that the hibernators and nonhibernators had learned the task equally. For example, if the hibernators had learned more rapidly than the nonhibernators, they would have been overtrained to a greater degree than the nonhibernators; and this differential overtraining could account for the observed difference in retention-test performance (*5*). To ensure equivalent degrees of initial learning and to avoid differential overtraining, McNamara and Riedesel should have trained each of their animals to the same criterion of initial correct performance. For example, training for each animal might have been discontinued when it first reached the criterion of eight correct responses in ten successive trials.

Another uncontrolled variable is the differential effect of exposure to cold upon the general physical condition of hibernators and nonhibernators and possibly upon their level of motivation (*6*). "All animals spent the same amount of time in the cold. For the first few days the animals had free access to food. Subsequently, food was withdrawn in varying amounts to encourage hibernation. Some animals hibernated while others did not." Since hibernation reduces metabolic rates and conserves bodily stores of nutrients and since the nonhibernators were not fed for some unspecified but apparently significant portion of the cold 11-day retention interval, it seems certain that during the retention test the nonhibernators must have been thinner and generally in poorer physical condition than the hibernators. Indeed, McNamara and Riedesel themselves recognize that "the cold environment acted as a stressful situation to awake animals." The differential stress to which hibernators and nonhibernators were subjected may have left them unequally able to perform the discrimination. Alternatively, the two groups of animals may have been unequally motivated to escape from the mixture of water and detergent which was their "reward" for correct performance. Clearly, a control experiment is needed to determine whether the general aftereffects of their stressful experience could have produced the relatively poor retention-test performance of the nonhibernators before differences in memory are posited as an explanation. The necessary control experiment would be a comparison of acquisition of the visual discrimination by previously untrained hibernators and nonhibernators that had just been exposed to cold for 11 days.

Finally, even if the other necessary control procedures had been followed and it was clear that some kind of memory effect had been found, the fact that McNamara and Riedesel's animals were tested for retention of a reversed discrimination would make the effect difficult to interpret. When animals make errors on a reversed discrimination, they do so by responding in the fashion that was correct in original learning. Thus, unless a control group of animals is tested for retention of the unreversed discrimination and comparisons are made between the performance of these controls and that of the reversed animals, it is impossible to tell whether animals that make errors in reversed discrimination have forgotten both of their training experiences or only the second one.

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References and Notes

1. M. C. McNamara and M. L. Riedesel, *Science* **179**, 92 (1973).
2. T. M. Alloway and A. Routtenberg, *ibid.* **158**, 1066 (1967); T. M. Alloway, *J. Comp. Physiol. Psychol.* **69**, 1 (1968); *ibid.* **72**, 311 (1970); J. W. French, *J. Exp. Psychol.* **31**, 78 (1942).
3. A. L. Edwards, *Experimental Design in Psychological Research* (Holt, Rinehart and Winston, New York, 1960); Q. McNemar, *Psychological Statistics* (Wiley, New York, 1962).
4. All the F values reported by McNamara and Riedesel are exactly equal to the critical values for the .05 level of significance with the corresponding degrees of freedom. Moreover, the inconsistency with which they interpret these F values is also puzzling. Some are interpreted as giving $P > .05$, as in the instance cited; others are interpreted as giving $P < .05$. Since McNamara and Riedesel list critical values labeled

as such in their table 1, perhaps they meant to be reporting critical values throughout their report and erred in giving some of them in the form appropriate for F values computed from data.

5. B. J. Underwood, *Psychological Research* (Appleton-Century-Crofts, New York, 1957).
6. N. Mrosovsky, in *Mammalian Hibernation*, K. C. Fisher, A. R. Dawe, C. P. Lyman, E. Schonbaum, F. E. South, Eds. (Oliver & Boyd, London, 1967), vol. 3, pp. 152–174.

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The reporting of the critical value without the calculated F ratio, noted by Alloway, was an oversight for which we apologize. The data in Table 1 correct the error and provide supplemental information requested by Alloway.

His request to prove no difference in amount of learning in all animals is difficult. We reported reversal training continued until all animals had attained the criterion of 85 percent correct responses. We accepted the null hypothesis. By the methods employed, there was no difference between the performance of the two experimental groups. The data on rate of learning (*1*) is difficult to reduce to a reasonable amount for publication here.

By the statistical analyses used, no differences ($P > .05$) were found between the hibernation and no-hibernation groups during the discrimination and reversal training for (i) number of trials to criterion, (ii) number of correct discriminations per week, and (iii) number of errors per week. In addition, all animals were making 70 to 80 percent correct responses 7 days before the end of reversal training. The procedure he suggests for ensuring uniform learning would give each animal a different total experience and could result in impractical timing for the investigator. There were many advantages in having the exposure to the cold on the same dates for all animals.

There was no evidence of physical disability among the animals. Mean weight of all animals was 220 g prior to cold exposure and 214 g at the end of the experiment. The animals that did not hibernate lost as much as 40 g during the cold exposure, and their mean weight at the end of the second cold exposure was 190 g, within the normal range for these animals under laboratory conditions. The animals were clearly capable of swimming.

Table 1. One-way analysis of variance on retention 48 hours after the first cold exposure (A), 48 hours after the second cold exposure (B), and 21 days after the second cold exposure (C). Abbreviations: d.f., degrees of freedom; H, hibernation; NH, no hibernation; ♂, male; and ♀, female.

Groups compared	d.f.	F ratio	Critical value	P
		Test A		
H (♂♀), NH (♂♀)	1, 14	10.02	4.60	$< .05$
H (♂), NH (♂)	1, 7	31.18	5.59	$< .05$
H (♀), NH (♀)	1, 7	15.90	5.59	$< .05$
H (♂), H (♀)	1, 8	0.00	5.32	$> .05$
NH (♂), NH (♀)	1, 6	0.56	5.99	$> .05$
		Test B		
H (♂♀), NH (♂♀)	1, 16	4.49	4.49	$< .05$
H (♂), NH (♂)	1. 7	1.67	5.59	$> .05$
H (♀), NH (♀)	1, 5	40.23	4.68	$< .05$
H (♂), H (♂)	1, 9	1.14	5.12	$> .05$
NH (♂), NH (♀)	1, 13	0.56	4.67	$> .05$
		Test C		
H (♂♀), NH (♂♀)	1, 16	57.18	4.49	$< .05$
H (♂), NH (♂)	1, 7	34.71	5.59	$< .05$
H (♀), NH (♀)	1, 5	26.13	4.68	$< .05$
H (♂), H (♂)	1, 9	0.19	5.12	$> .05$
NH (♂), NH (♀)	1, 13	0.16	4.67	$> .05$
		Tests B and C		
Test B NH (♂♀), test C H (♂♀)	1, 14	0.58	4.60	$> .05$

The additional experiment Alloway suggests, comparison of acquisition of the visual discrimination by previously untrained hibernators and nonhibernators that had just been exposed to cold for 11 days, is a reasonable control. However, he suggests this control apparently out of concern about the capacity of the animals to perform after cold exposure without hibernation. In our opinion, this is not a critical factor, as indicated by the moderate weight losses of the animals during cold exposure. Furthermore, as noted in the report, animals that did not hibernate had similar poor performance 21 days after the second cold exposure. There are other control and experimental groups we would like to use: (i) A group of animals housed at room temperature throughout the experiment would indicate a control rate of memory loss without cold exposure or hibernation. (ii) An experimental group that hibernated within 48 hours after onset of cold exposure could be compared with a group of animals that hibernated 5 or 6 days after the start of cold exposure. (iii) Future studies would include field work to identify learned behavior among these animals. Retention of essential learned behavior during hibernation may be the cause for the evolution of hibernation in widely diverse mammals.

The last paragraph in Alloway's comment is interesting but irrelevant. In a similar vein we may be asked to test for memory of behavior learned during the 2-week acquisition period.

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References and Notes

1. M. C. McNamara, thesis, University of New Mexico (1972).
2. Throughout the development and performance of these studies, Dennis Feeney and Maura Cashion have contributed confidence, insight, and suggestions.

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