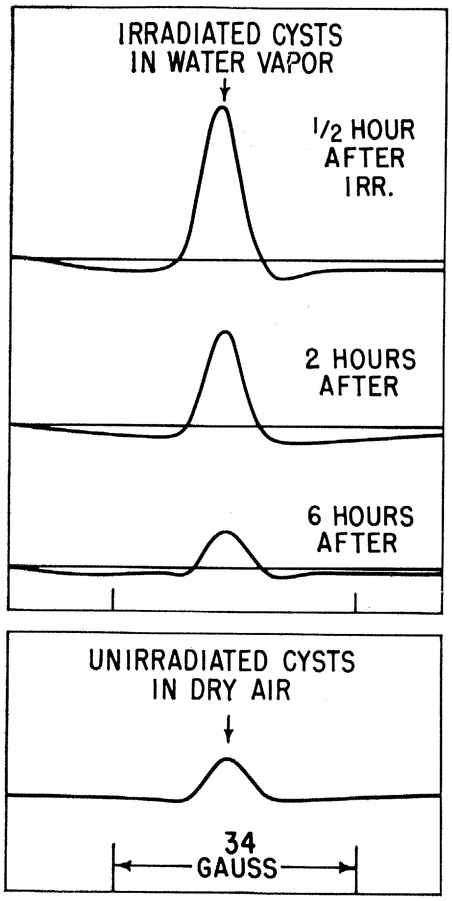

Fig. 4. The top three curves show the electron-spin resonance of *Artemia* cysts irradiated with the same dose of gamma rays and under conditions similar to those described in Fig. 3, except that they were irradiated and stored in an atmosphere of water vapor at room temperature. The bottom curve shows the natural electron-spin resonance of the unirradiated cysts.

dry air, pure O_2, NO, or in any other environment studied.

Shields and Gordy (*8*) found that moisture greatly increases the decay of the ESR patterns of the irradiated nucleic acids DNA and RNA. Furthermore, the shape and width of the DNA and RNA signals, which they obtained when the acids were irradiated in moist air, were similar to those we obtained with cysts irradiated in moist air. This suggests the possibility that the protective or healing effect of water vapor is related to its neutralizing effects on the free radicals produced by irradiation of the nucleic acids. It does not, of course, constitute a proof of such a relationship. Indeed, Shields and Gordy suggested that the water might actually be converting the free radicals to some new stable chemical species which would constitute an irreversible damage. That water vapor apparently heals or prevents biological damage caused by irradiation of the seed and cysts at the same time as the free radical signal decays, indicates the opposite—that is, that the decay in the ESR signals in the irradiated DNA and RNA caused by the moisture may result from a restoration of these acids by the water. The ESR signal in the cysts may arise, of course, neither from the nucleic acid nor from the nucleoproteins. The shells of the cysts constitute a considerable portion of the sample and may contribute to the ESR signal. Also, the healing effect of water may be an indirect one in which the water activates some other healing agent.

A study similar to that reported here has been made on grass seed, *Agrostis stolonifera*, by Sparrman *et al.* (*9*), who obtained evidence, both from ESR signals and survival rates, for the protection of the seeds by NO in water concentrations of less than 12 percent, and found that the radiation resistance of these seeds, when stored in air after irradiation, increased with water content up to about 12 percent. Powers and his associates (*10*) have found that H_2S and NO have radiation protective effects in bacterial spores, and have related these effects to the decay of the ESR patterns of free radicals produced by the irradiation. Reviews of these and related studies have been given by Zimmer (*11*), and by Kirby-Smith and Randolph (*12*).

Thus, from studies of electron-spin resonance in living organisms, evidence is accumulating that much of the biological damage caused by irradiation is associated with radiation-induced free radicals. The extent and nature of the biological damage appears to depend upon the chemicals which happen to react first with those free radicals after they are produced by the irradiation (*13*).

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References and Notes

1. Z. M. Bacq and P. Alexander, *Fundamentals of Radiology* (Academic Press, New York, 1955).
2. R. S. Caldecott, *Science* **120**, 809 (1954).
3. H. J. Curtis, N. Delihas, R. S. Caldecott, C. F. Konzak, *Radiation Res.* **8**, 526 (1958).
4. A. D. Conger, *J. Cell. Comp. Physiol.* **58**, Suppl. 1, 27 (1961).
5. D. W. Engel and D. J. Fluke, *Radiation Res.* **16**, 173 (1962).
6. These results were reported at the Milwaukee meeting of the Radiation Research Society. See abstract, *Radiation Res.* **19**, 211 (1963).
7. A. D. Conger and M. L. Randolph, *Radiation Res.* **11**, 54 (1959).
8. H. Shields and W. Gordy, *Proc. Natl. Acad. Sci. U.S.* **45**, 269 (1959).
9. B. Sparrman, L. Ehrenberg, A. Ehrenberg, *Acta Chem. Scand.* **13**, 199 (1959).
10. E. L. Powers and B. F. Kaleta, *Science* **132**, 959 (1960); E. L. Powers, C. F. Ehret, B. Smaller, in *Free Radicals in Biological Systems* (Academic Press, New York, 1961), pp. 351–366.
11. K. G. Zimmer, *Studies on Quantitative Radiation Biology* (Oliver and Boyd, Edinburgh, 1961).
12. J. S. Kirby-Smith and M. L. Randolph, *J. Cell. Comp. Physiol.* **58**, Suppl. 1, 1 (1961).
13. We thank Donald J. Fluke for his helpful suggestions. Research was supported by the Air Force Office of Scientific Research, grant No. AF-AFOSR-62-327, and by the Army Research Office (Durham, N.C.).

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Counteracting Effects of Physical Exercises Performed during Prolonged Perceptual Deprivation

Abstract. *Subjects who were required to perform physical exercises during a week's exposure to unpatterned light and white noise showed fewer impairments on 15 behavioral measures than did subjects who were not required to exercise during the same period in an isolation chamber. Furthermore, fewer hallucinatory phenomena and fewer disturbances of the electroencephalogram were observed.*

Research at this laboratory has shown that perceptual deprivation of a week's duration can produce widespread impairments of intellectual and perceptual-motor processes. Hallucinatory phenomena, to a limited degree, are also present. Furthermore, these behavioral deficits are accompanied by significant changes in the electrical activity of the brain (*1, 2*). The purpose of this experiment was to determine whether the introduction of physical exercises during prolonged perceptual deprivation could minimize or even eliminate these behavioral and physiological impairments. Various lines of evidence indicate that physical activity may have beneficial or counteracting effects. Reports of explorers and prisoners of war occasionally mention that performance of calisthenics has proved helpful in combating some of the effects of isolation (*3*). There is also some experimental evidence. Freedman and Greenblatt (*4*), in a review of the literature on sensory deprivation, observed that hallucinatory and delusional experiences seem to occur less frequently during isolation if motor activity is permitted than if it is not.

Fewer post-isolation distortions of the perceptual field are also present (*5*). Finally, Goldstone (*6*) reported that hallucinations induced by lysergic acid diethylamide can be eliminated by having the subjects "actively participating in the organism-environment adaptation via appropriate kinesthetic adjustments." Counteracting effects of physical activity are, therefore, possible.

A group of 27 male university students were placed individually in a dome-shaped isolation chamber, 7 ft (2.1 m) high, 9 ft (2.7 m) at its widest point, and 7½ ft (2.3 m) at the base, for 7 days. Of these, 18 endured the full week. Washroom facilities, a food chamber, and an air-conditioning unit were provided within the chamber, making it unnecessary for the subject to leave for any reason during the isolation period. The only piece of furniture was a mattress. The behavior of the subjects was monitored at all times by means of an intercommunication and closed-circuit television system. The subject wore a pair of translucent goggles which reduced the level of ambient illumination from 90 to 20 ft-ca (990 to 220 lu/m^2) under the goggles. The goggles permitted diffuse light but eliminated all pattern vision. The subject also wore a set of earmuffs through which white noise, somewhat above the threshold of hearing, was constantly presented. No gloves were worn. Singing, humming, or any other vocal activity was not permitted. No restrictions, however, were placed on the subject's motor activity. He was free to move about the chamber. Furthermore, six 5-minute exercise periods, consisting of such activities as head rotation, touching toes, and push-ups, were introduced at irregular intervals each day. These exercises were rehearsed prior to isolation and subsequently were initiated by an auditory signal. They could be repeated at times other than those prescribed if the subject so desired. The total incidence of exercise periods was recorded.

The subjects were given two batteries of tests, intellectual and perceptual-motor. These were identical with those used in an earlier perceptual deprivation experiment (*1*). The intellectual tests, measuring 12 different abilities, were administered before isolation and at six intervals during the week (actual intervals might range from 18 to 30 hours). No intellectual tests were given immediately after isolation. Seven equivalent forms of each test were used. Some of the tests measured fairly simple abilities involving overlearned material, while others appraised more complex abilities requiring deliberation and manipulation of ideas. The tests were all short, of several minutes' duration each, and consisted of the following: simple arithmetic problems, numerical reasoning, abstract reasoning, verbal fluency, verbal reasoning, space visualization, digit span, rote learning, recall, recognition, cancellation, and dexterity. The total testing time was approximately an hour. Two of 12 tests, digit span and rote learning, were given over the intercom system. The remainder were presented visually, that is, the subject lifted the goggles, completed the tests and then readjusted the goggles. The battery of three perceptual-motor tests was given only before and immediately after the week of deprivation. It consisted of the Farnsworth-Munsell 100-hue test of color discrimination, Necker reversible figures, and pain sensitivity (Hardy, Wolff, and Goodell dolorimeter).

In addition to the 15 behavioral measures, electroencephalograms were taken from 10 of the 18 subjects before and after the week of deprivation. These subjects were placed on a fixed feeding schedule, and records were taken after a meal and after completion of the behavioral tests. An interval of approximately 3 hours elapsed between the last exercise period and recording time. Precautions were also taken to eliminate any drowsiness. The mean occipital lobe frequency was then determined by the method of Engel *et al.* (*7*). This involved counting the number of waves occurring in each of 200 one-second samples of artifact-free occipital lobe tracings.

The pre-isolation scores of the 18 subjects, on the 15 behavioral tests, were matched with the initial scores of 18 out of 29 experimental subjects from an earlier study (*1*) employing *identical* conditions and duration of perceptual deprivation. These subjects, however, were not allowed to exercise. Furthermore, they were required to lie quietly on the mattress. They were allowed to sit up only when eating and to stand up only when going to the washroom facilities a few feet away. Since the subjects for the present and the earlier study (*1*) were drawn from a homogeneous population of students, it was possible to select 18 subjects from the earlier study whose "pre"-scores were almost identical with those of the present experimental group. The pre-scores of those 18 subjects were also matched with the initial scores of 18 out of 40 ambulatory control subjects. These subjects received the same battery of tests, and at the same time intervals, as the experimentals, but they were never isolated. An additional group of recumbent controls was not used, since we have already shown that the recumbent position, maintained for a week, exerts no significant effect on our behavioral measures or on the electroencephalogram (*1, 2*).

An analysis of variance revealed significant F ratios for 7 out of the 12 intellectual tests, namely, cancellation, numerical reasoning, space visualization, arithmetic problems, abstract reasoning, dexterity, and recall. Subsequent two-tailed t-tests showed that the "no exercise" group performed significantly worse than did the matched controls on all seven tests (p's $< .02$). On the other hand, the experimentals with exercises did not differ significantly from the controls on any of the tests except cancellation ($p < .01$). Furthermore, even on this test their performance tended to be better than that of the "no exercise" group. Although the F ratios for five tests were not significant, there was a tendency for the "exercise" group to perform better than the "no exercise" subjects on three of these tests. An analysis of variance of scores on the perceptual-motor tests revealed significant F ratios for all three tests. Subsequent t-tests showed that both the "exercise" and "no exercise" subjects were less sensitive to pain (p's $< .05$) and made more errors on color discrimination (p's $< .05$) than the controls. However, on neither test was there a significant difference between the two experimental groups. Finally, on the reversible figures both experimental groups experienced fewer reversals per minute than did the controls. However, only in the case of the "no exercise" subjects was this difference significant ($p < .02$).

Table 1 shows the mean difference in occipital lobe frequencies of ten "exercise" subjects before and after a week of perceptual deprivation. For comparative purposes, results are also given for ten "no exercise" and ten control subjects employed in an earlier study (*2*) involving identical conditions of deprivation and testing procedure. It can be seen that all 20 experimental subjects show a post-isolation decrease in mean frequency. However,

Table 1. Mean "pre-post" differences in occipital lobe frequencies before and after two experimental and one control condition (30 subjects, ten in each group).

	Perceptual deprivation subjects		Controls
	No-exercises	Exercises	
	−1.74	−1.28	−0.26
	−1.64	−0.78	−0.25
	−1.47	−0.61	−0.06
	−1.26	−0.56	−0.03
	−1.23	−0.50	+0.01
	−1.16	−0.33	+0.03
	−1.10	−0.31	+0.10
	−1.07	−0.27	+0.12
	−1.06	−0.15	+0.13
	−0.41	−0.01	+0.28
Mean	−1.21	−0.48	+0.01

the decrease in frequency is greater for the "no exercise" than for the "exercise" group. Of the former group, nine out of ten subjects show a decrease greater than 1 cy/sec, whereas only one of the latter group does so. The mean "pre-post" difference for the control group is almost zero. An analysis of variance yielded a highly significant F ratio ($p < .001$). Subsequent t-tests showed that both experimental groups differed significantly from the controls p's $< .01$). Furthermore, the mean decrease in frequency of the "exercise" group was significantly less than that of the "no exercise" group ($p < .001$). It is unlikely that this result can be attributed to differences in sleep patterns of the two groups, since none appeared to exist. No relation existed between decrease in frequency and the total number of exercise periods engaged in by a particular subject. This is probably owing to the fact that most of the subjects did not exercise more often than was prescribed.

Hallucinatory phenomena were almost totally lacking with only 2 out of 27 subjects reporting them. One subject saw "a snow-covered road bordered by spruce trees," while the other heard someone "whistling the same tune on a number of occasions—a tune which I heard only when hungry." On the other hand, deprivation subjects whose activity is restricted show a somewhat higher incidence of these phenomena. For example, in an earlier study (*1*) we observed that 7 out of 42 subjects reported visual and auditory hallucinations. Upon emerging from isolation none of the subjects reported any "profound and prolonged disturbances of visual perception" of the type mentioned in one of the McGill 6-day studies (*8*), for example, warping and curving of lines, walls moving in and out, and gross changes in the size and shape of objects. Similar results were also reported by our "no exercise" subjects. In view of the facilitating effects of physical activity, more of the exercising subjects might be expected to endure a week of perceptual deprivation. This did not appear to be the case. Regardless of activity level, the failure rate was approximately a third. Furthermore, the mean endurance time of the unsuccessful "exercise" and "no exercise" subjects was about the same (46.2 and 47.4 hours, respectively).

This study has demonstrated that performance of exercises can obliterate many of the impairments produced by perceptual deprivation. With exercise, only three behavioral measures were impaired, in contrast to 10 out of 15 measures impaired under a condition of restricted motor activity. Furthermore, fewer hallucinatory phenomena and less disturbance of the electrical activity of the brain were observed. It is possible that the counteracting effects would have been even greater if the subjects had exercised more frequently and actively. Generally speaking, most of them were not too interested in exercising more often than prescribed. This was particularly the case toward the end of the experimental period when some of the subjects performed the exercises in a somewhat lethargic fashion.

These facilitatory effects are probably mediated by the ascending reticular activating system whose disturbance, by a decrease in the level and variability of sensory input, is believed to produce the classical deprivation phenomena (*9*). The introduction of exercises may provide sufficient variability of kinesthetic and proprioceptive stimulation to counteract most of the effects of unvarying stimulation from the visual and auditory sense modalities. This explanation is supported by several reports pointing to the "powerful excitatory influence of somatic sensory excitation upon the reticular activating system" (*10*). In addition to this nonspecific system, it is possible that the specific sensory systems may also be involved in these facilitatory effects (*11*). Finally, the possibility exists that psychological, rather than physiological, factors are responsible for some of the effects. For example, it is known that the subjects' expectancies, attitudes, and set are important variables in deprivation results, particularly for self-reported subjective experiences (*12*). It is doubtful that these suggestion factors played any significant role in our results, in view of the precautions taken against them. Furthermore, even if present, it is unlikely that they would affect such measures as the EEG's.

These results, together with those derived from our immobilization studies (*13*), indicate that the degree of motor activity permitted during isolation is perhaps one of the most important variables operating in sensory and perceptual deprivation experiments. Furthermore, they suggest that some of the apparently contradictory results in this area of research (*14*) may be related to differences in motor activity. These findings also indicate that exercises may prove beneficial in combating some of the effects of isolation occurring in such settings as the Arctic, prisons, and space flight. They may also be useful in the treatment of certain psychiatric patients, particularly those possessing hallucinatory and delusional symptoms (*15*).

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References and Notes

1. J. P. Zubek *et al.*, *Perceptual and Motor Skills* **15**, 171 (1962).
2. J. P. Zubek and G. Welch, *Science* **139**, 1209 1963).
3. P. Solomon *et al.*, *Am. J. Psychiat.* **114**, 357 (1957); G. A. Kimble and N. Garmezy, *Principles of General Psychology* (Ronald, New York, 1963), p. 367.
4. S. J. Freedman and M. Greenblatt, "Studies in human isolation," *Tech. Rept. 59-266, Wright-Patterson Air Force Base, Ohio* (1959).
5. J. Courtney, J. M. Davis, P. Solomon, *Perceptual and Motor Skills* **13**, 191 (1961).
6. S. Goldstone, in *Hallucinations*, L. J. West, Ed. (Grune and Stratton, New York, 1962), p. 267.
7. G. L. Engel *et al.*, *Arch. Neurol. Psychiat.* **51**, 134 (1944).
8. W. Heron *et al.*, *Can. J. Psychol.* **10**, 13 (1956).
9. D. B. Lindsley, in *Sensory Deprivation*, P. Solomon *et al.*, Eds. (Harvard Univ. Press, Cambridge, Mass., 1961), p. 174; W. Heron, *ibid.*, p. 6.
10. J. D. French, in *Handbook of Physiology*, sect. 1, *Neurophysiology*, vol. 2, J. Field, Ed. (Williams and Wilkins, Baltimore, 1960), p. 1281; H. Bernhaut *et al.*, *J. Neurophysiol.* **16**, 21 (1953).
11. J. M. Sprague *et al.*, *Science* **133**, 165 (1961).
12. C. W. Jackson and J. C. Pollard, *Behavioral Sci.* **7**, 332 (1962).
13. J. P. Zubek and L. Wilgosh, *Science* **140**, 306 (1963); J. P. Zubek *et al.*, *Can. J. Psychol.* **17**, 118 (1963).
14. D. W. Fiske, in *Functions of Varied Experience*, D. W. Fiske and S. R. Maddi, Eds. (Dorsey, Homewood, Ill., 1961), p. 106.
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