Sensory Deprivation: Effects upon the Functioning Human in Space Systems

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There has been a rapid development of interest in the phenomena which may be produced in the human being by a reduction in sensory input. It would appear that the work in this field was first started in the early 1950s with animals and was concerned primarily with the effects of reduction of sensory input upon the development of the animal. As in the opening up of any new field, there were precursory lines of investigation which eventually led to this area.

One of the earliest of such investigative lines was inaugurated by work done by Hebb (1) in contrasting the development of rats blinded in infancy with normal rats. The two groups were tested subsequently by a rat intelligence test. A far greater degree of intelligence was observed in maturity in the controlled rats than in the blinded animals.

A study which began to approach more closely the field of reduced sensory input was one carried out at the same time by Hebb on rats reared in small cages as contrasted with those brought up in a much wider environment.

A few years later, Hymovitch (2) studied rats reared in a setting in which demands on them for decisions and problem solving were lessened and pain was greatly reduced. He contrasted them then with controlled rats brought up where there were many problems in food seeking and in conflicts with other rats. He showed that the rats brought up in the protected environment with reduced demands revealed in adult life a lasting inferiority in problem solving.

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Even earlier than this, important studies were carried out by Mackworth (3), who was requested by the Royal Air Force towards the end of 1943 to determine the optimum length of watch in connection with radar operation in anti-submarine control. Lapses in attention had been observed in those engaged in such monotonous activities. Apparently, even before this, work had been carried out in the Middle East where the optimum duration of such watches had been recommended as one hour. The Mackworth studies served to clarify the observation that where close and prolonged attention must be given to some part of the environment in which little change is occurring, or where it is occurring at very regular intervals, there tend to occur lapses of attention despite possible serious consequences. This constituted one of the first hints of the possible effects of decreased sensory input and tied in with similar work being carried on by Sharpless and Jasper (4). They reviewed and reported that where stimulation fails to change rapidly, it loses its power to evoke response.

Still another investigation leading to the present field of decreased sensory input was instituted by myself at the Albany Medical School in 1938 (5). This was concerned with nocturnal delirium in the aged. We were interested in the number of aged individuals with marked restriction in the memory span who, during the night, passed into a confused, delirious, excited stage from which they emerged during the daylight hours. After considerable experimentation, it was found that if these individuals were placed in a quiet room during the daytime with their eyes bandaged, they would not only pass into an identical confused and extremely anxious state, but they would show some very interesting phenomena, such as a tendency (while still bandaged and asked to describe their image of the room) to state, for example, that there were four windows instead of one, three beds instead of one, four dressers instead of one. Apparently, there was a breakdown in the synthesis of the various sense impressions of the objects in the room which they had gained at the time of entry. On removal of the bandages they rapidly recovered from their delusions.

From this it was concluded at the time that, in order to maintain a time and space image, we ordinarily rely upon two major factors: (a) our continued sensory input, and (b) our memory. In these

individuals the memory span was so limited that it was impossible to retain a space-time image over the period of one hour during which they were blindfolded and kept in a quiet room, as the quietness of the room and the bandaging of the eyes cut off their only other means of maintaining their space-time image.

Considerable anxiety was provoked in these persons as their space-time image became disturbed. This is a phenomenon which—as will be reported later—quite frequently appears in states of reduced sensory input.

These were the early lines of investigation which ultimately brought us to the present field. The essential development of the concept of sensory isolation, however, took place in the psychology laboratories of Professor D. O. Hebb of McGill University. A report on the effects of decreased variation in the sensory environment in the adult human subject was published by Bexton, Heron, and Scott in 1954 (6). They reported on the effects of decreased input of stimulation on 22 male college students. These students wore translucent goggles, gloves, and cardboard cuffs and remained in a partially soundproof cubicle with a U-shaped foam rubber pillow for reclining the head. It was difficult to keep some of the subjects in the test area for more than 2 or 3 days. Since most of the categories of phenomena subsequently reported as occurring in consequence of decreased sensory input were described in this report, they will be listed here.

They are essentially an early somnolence followed in the later days by restlessness, unusual emotional lability, reduction in the capacity to concentrate on a topic for any length of time during the test, together with "blank" periods. Subjects also showed considerable decrease in ability to make words out of jumbled letters, and visual hallucinations—and occasionally auditory and somatesthetic—were noted. Reference was also made to disturbance in the body image. One subject reported that he felt as if his head were detached from the body; another reporting that his mind seemed to be a ball of cotton wool floating above his body. It was noted that subjects coming out of the area of reduced sensory input seemed at first to be dazed. There was some disturbance in vision—usually lasting not more than a minute or two and consisting in difficulty in focusing and objects appearing fuzzy—and the environment seemed to be

two-dimensional, with the colors more saturated than usual. Confusion, headaches, and a mild nausea and fatigue were also reported, but these conditions lasted no longer than 24 hours.

Hebb himself gave further structure to the concept of sensory isolation in his article published in 1955, "The Mammal and His Environment" (7), in which he points to the connection between these observations and studies carried out on brain stimulation and, particularly, the concept of cortical arousal.

Lilly in 1956 reported on a somewhat different approach (8). Part of his report consisted in a description of two human subjects suspended with all but the top of the head immersed in a tank containing slowly flowing water at 34.5° C. The subjects wore a blacked-out mask for breathing. In so far that this study was based on an extremely short period of exposure to reduction in sensory input and is characteristic of certain others which have appeared, we will report it in some degree of detail.

Lilly stated that for the first three-quarters of an hour, the ongoing thinking of the day persisted, then relaxation occurred, with feelings of being isolated in space. During the next hour there was growing tension, and hidden methods of self-stimulation developed, such as slow swimming movements. The tension rose to the point where the subject might have to leave the tank. While in the tank, the subject's thinking was directed towards fantasies of a highly personal and emotionally charged nature. Finally, there might occur a stage where there was projection of visual imagery. He also reported another approach, namely, a study of autobiographical records of individuals who suffered long periods of partial isolation, such as in shipwrecks and in the polar winter. A considerable diversity of findings were reported, such as increased passivity, an increased vividness of the inner life and a gradual loss of visual acuity. Visual hallucinations were also noted.

Since then, a considerable range of contributions has been made. The field was reviewed by Wexler *et al.* in 1958 (9), and a symposium on the subject was held in Boston in that year. Vosburg *et al.* (10) reported, in a study of 12 adult college students, that in experimental sensory deprivation there is first a stage of adaptation characterized by repeated excursions into memories, then a breakdown in adaptive behavior, and, finally, either panic or flight. These results were

obtained over a three-hour period in an anechoic chamber. Rosenzweig (11) has compared sensory deprivation and schizophrenia and states that he feels that perceptual interference produces the primary symptoms of schizophrenia more closely than does mescaline or LSD 25.

The more recent publications indicate a growing sophistication of approach. Gruenbaum *et al.* (12) suggested that the task of the investigator is to study the following three major variables: (1) experimental variables dictated by the nature of the experiment, namely, the types of interference with sensation and, in particular, whether there is a reduction in the total amount of sensation, or essentially, an interference with the pattern of sensory input; (2) variables arising from the subject's personality, his motivation, and other characteristics; and (3) variables arising from the relationship between the experimenter and the subject. They were not able to find any relationship between clinical ratings of what they termed "ego integrity" and the production of disturbances in perception. They considered that since sensory deprivation did not serve to explain the psychodynamics of personality, save in terms of reactions to loneliness, it did give an opportunity to study the interrelations of the various components of the perceptual apparatus.

Davis *et al.* (13) approached the matter from the point of view that it is not the absence of sensory stimulation which reduces the effects, but the absence of meaningful stimulation. They found that random visual stimulation was not sufficient to prevent the occurrence of aberrations and concluded that meaningful contact with the outside world is essential for normal functioning rather than the quantity of or change in sensory input.

From the survey of the literature, it is clear that we are now moving from an earlier conception of the importance of the reduction of the total quantity of sensory input to a conception that, in addition, the quality of input is also significant.

We would also like to draw attention to something which we believe to be important, namely, the concept of the individual himself concerning the duration of reduction of sensory input. In certain circumstances the duration may be entirely in his hands, hence he may structure it as he will. Secondly, it may be structured by the investigator, and the investigator may impart this to the

subject: e.g., it may be said to the subject that he must remain for three days. And, thirdly, there may be no structuring whatsoever, hence the subject may feel that there is no definite limitation to the extent of his stay in the area of reduced sensory input.

Before proceeding to a review of the findings from our Institute, may I state that the field has now reached sufficient complexity that we may recognize six major areas of study and investigation. The first is with respect to reduction of sensory input during the developmental years in animals; the second refers to reduction in sensory input in fully developed animals and human beings; the third relates to reduction in sensory input incidental upon monotonous occupations; the fourth has reference to historical and anecdotal reports of individuals who have been shipwrecked, who have remained throughout the winter in lonely Arctic regions, and in other situations in which there was marked reduction in sensory input; the fifth consists in the effects of reduction in sensory input by blockage of conduction within the body of sensory stimuli; and the sixth is concerned with the effects of reduction in the responsiveness of the individual to stimulation.

At the Allan Memorial Institute, the effects of reduced sensory input upon human behavior have been studied in three different ways: (1) by reduction in the amount of stimulus coming from the environment and received by the individual through his eyes and ears, and an attempted reduction of some of the tactile stimuli by limitation of the use of his hands; (2) by reduction of input achieved through interference with the conduction of stimuli from the external receptors to the central nervous system; and (3) by reduction of the responsiveness of the individual to stimulation.

During the last several years, by far the greater amount of work at the Institute has been done with respect to the reduction of stimuli from the environment. The earliest published reports from the Institute are by Azima and Cramer-Azima (14). In their experiments, sensory isolation was achieved by covering the eyes with goggles, keeping the arms in cardboard cylinders, and reducing verbal communication to twice a day for the purposes of interviewing. The psychoneurotic and schizophrenic subjects were maintained in a darkened room and told they could terminate the study any time they wished. They remained in the room for periods ranging from

one to seven days. Feelings of depersonalization appeared in 8 of the 15 patients. It was felt by the workers that repression and aggression turned against the self led to the depersonalization syndrome. In addition, hallucinations occurred in 4 patients. There were moderate to marked changes in the body scheme of 8 patients.

Our later investigations in reduction of stimuli have depended upon a more rigorous and sustained reduction in sensory input. The patients were in a darkened room with goggles, and their ears were covered with rubber eardrums into which was led white sound. White sound was also led into the room. The arms were covered with cardboard cylinders. The patients were fed and toiletted in the rooms. The nurses had instructions to reduce all communication to a minimum, and the timing and composition of the subjects' meals were changed unpredictably; e.g., soup might be given for breakfast. The duration of stay in such sensory isolation was increased to a maximum of 16 days. We also carried out a brief duration (5 to 7 hours) exposure to reduction in sensory input using occlusion of the eyes and enclosure of the arms in cardboard cylinders. The patients were located in the soundproof room of our Sound Laboratory. (In this laboratory sound can be reduced from the low circumambient level by 50 to 60 decibels.) It can be stated categorically that an increase in the rigorousness of sensory isolation did not result in a proportionate increase in the disturbance of behavior.

We observed that subjects vary considerably in the degree to which they show changes attributable to reduction in sensory input, but it is not yet defined with precision what factors determine the extent to which individuals will be affected by sensory input. As a working hypothesis, however, we consider that it is probable that individuals who customarily are self-contained and self-dependent, rather than highly sociable and dependent upon others, are capable of withstanding the effects of reduction in sensory input for more prolonged periods of time.

A second general observation which may be made is that individuals tend to take active measures to protect themselves against the disturbing effects in the reduction of sensory input. Four of these steps may be recorded: A number of individuals develop such intense anxiety in the situation that it is necessary to remove them

from the conditions of reduced sensory input. It is also generally reported that individuals so exposed resort increasingly to reminiscence—in this way, as it were, maintaining their sensory input by drawing upon their inner world for the necessary input rather than upon the outer world. Other subjects endeavour to maintain their sensory input by purposeless movements, such as hand play or head movements—or by questioning the staff on any occasion when they are aware of the staff. The third step is apparently an increased sensory perceptiveness. For instance, one subject was able to maintain her space-time image by noting the very faint rumble which penetrated the white sound and the occluding earmuffs and which came from a plane passing overhead on its way to New York at 9 o'clock in the morning and 1 o'clock in the afternoon. It may be said that the staff was quite oblivious both of the plane passing overhead and of the fact that it did pass at these times. Other patients structured their space-time image by noting the composition of the meals, their number and intervals. By varying these intervals and by changing the menu from the expected time we were able to break up this structuring.

Moreover, once the effects of reduced sensory input were clearly observable in our subjects, we initiated another experiment based on an attempt to change the personality characteristics of the individual by running in a series of verbal signals designed to produce change. We noted that the subjects at once became dependent on these signals and would call the staff at once with considerable distress if the apparatus broke down. In addition, this dependence upon this form of sensory input persisted—although in lesser form—for days and weeks after the patient was removed from the conditions of reduced sensory input.

When we turn from consideration of these steps taken by the subject to maintain his space-time image to other effects produced by reduction in sensory input, we may note increased passivity, relaxation, and dependence, which appear within the first few days. There is increased introspection and fantasy production, sometimes with increased physical concern about the body. Auditory and visual hallucinations we found to be quite rare, even though the subject was on one occasion kept under such conditions for as long as 16 days.

When reduced sensory input was ended, there was in a few cases a degree of what was apparently a reactive euphoria, lasting in one or two instances for several days. There was some tendency to see objects as being rather flat and two-dimensional; this lasted, however, for only a few hours. We also noted what has been recorded by others: some measure of inability to speak with normal volume and some feelings of inadequacy. These findings were, however, not striking.

We now pass over to the second category of experiments, namely, the attempt to reduce sensory conduction within the body.[1]

It should be noted that we are on much surer ground in assessing the reduction of sensory input in the first category of experiments, where we directly reduce the amount of stimulus from the environment. When we attempt to reduce sensory conduction within the body, we are faced with the problem of the side effects of the agents which we use. And when we attempt to understand the effects of reduced sensory input by reducing the responsiveness of the individual to stimulation, we are faced with the still more complex problem of the considerable disturbance which we produce in thinking by the agents which we use for this purpose.

Sernyl appears to exert its action by the release of adrenaline and noradrenaline in association with the depression of the availability of serotonin in the brain (15). This is consistent with Brodie's hypothesis (16) that serotonin and noradrenaline are antagonistic chemical mediators regulating the central nervous system. Because of the importance of the kinesthetic input and the preservation of the body image, it was felt that Sernyl might throw valuable information upon the problem of the effects of the reduction in sensory input.

With our psychoneurotic subjects Sernyl produced apathy, then anxiety, followed by disturbance of body image, feelings of unreality and depersonalization. There were also thought disorder and disorganization of intellectual processes and difficulty in comprehension.

One patient experienced auditory hallucinations; two patients

[1] In this second category of experiments we used preparations furnished by Parke, Davis & Co. Ltd.: Cl 395 (Sernyl) and Cl 400. These substances were developed for their possible anaesthetic properties.

became hostile and paranoid. The body image disturbances which occurred in all patients were well recalled after the effects of Sernyl had disappeared. Feelings of floating in outer space were frequently described. There was a tendency for patients to maintain catatonic limb postures. This was not present under administration of Cl 400.

Our third set of experiments consisted in an attempt to reduce the activity of the individual. These studies, which also were carried out on psychoneurotic and schizophrenic subjects, involved the use of massive electroshock to a point where marked degrees of confusion occur. One finding which may be reported with some confidence, in that it is present in the other two sets of experiments where we studied the effects of reduction in sensory input, is that at the point where electroshock is beginning to interfere with the maintenance of the space-time image there occurs marked anxiety, and often hostility. The deeper levels of disorganization which occur as electroshock is continued are so greatly affected by disturbances in the whole process of thinking that very little information concerning interference with sensory input can be learned. In these deep states of confusion, which we term states of "complete depatterning," the individual's span of awareness is usually limited to the immediate present. He is concerned only with whether he is hot or cold or hungry. He communicates in very simple terms—quite unaffected by memories or by anticipations.

DISCUSSION

In opening the discussion on this review of the effects of markedly reduced sensory input upon performance, effectiveness, and general integrity of the functioning human being, it is necessary to state a fundamental working hypothesis: that a basic activity of all human beings is to maintain and extend control over their internal and external environments. Where this control is interfered with, as, for instance, in loss of control over body equilibrium, in disorientation, in amnesia, in organic brain disease, or where the individual is forced to operate in a dangerous situation without adequate means of control, anxiety constantly appears.

Control over the environment requires the integrity of an interlocking series of images. It is necessary, for successful interaction

with the environment (both internal and external), that there should be, intact, a self image. States where this is interfered with, and which we commonly call states of "depersonalization," are almost always associated with a great sense of insecurity and anxiety on the part of the individual.

Interlocking with this image of the self, there is a body image. And, here again, disturbances in the body image are of serious consequence, as where, subsequent to temporal lobe damage, there is difficulty in locating the position of a given arm or leg. And then again there is the space-time image; and interference here, as in certain toxic and organic states, creates much apprehension and anxiety for the individual, leading, as it quite clearly does, to considerable frustration in his attempts to control his world.

These images are customarily maintained by our memorial processes. When our memorial processes are intact we can, for instance, awaken in a darkened room and immediately grasp the disposition of ourselves in time and space. Where the memorial processes are intact, the amount of sensory input necessary to maintain these images at their full effectiveness is quite limited.

Hence, for this reason, I should be inclined to raise the question whether the disturbances reported as resulting from very short periods of reduction in sensory input—namely, a few hours—are really valid manifestations; or whether it might be more accurate to say they are manifestations of (a) increased introspection, which commonly arises in solitude; (b) a decrease in sensory threshold resulting from such introspection; and (c) anticipation—a placebo effect, as it were.

It would appear that we are now at the end of the period of preliminary exploration of the phenomena brought about by reduction of sensory input and from here onwards progress is likely to be made only by the most closely controlled experiments. Variables to be studied are: (1) the degree of reduction of sensory input; (2) the pattern of reduction (cf. Davis *et al.* [13] and their comments concerning disturbance in the meaning of sensory input as contrasted with the amount); (3) anticipations of the subject with regard to what is to happen; (4) the effects of simple drowsiness upon thinking and upon experiencing in general; (5) the effects of the recumbent position maintained over many days; and (6) different ways of

strengthening the duration of stay for the patient in a situation of reduced sensory input.

Thus far we are on soundest ground in demonstrating the effects of reduction of sensory input where we report on studies of reduced sensory input upon the development of animals, and where we carry out the reduction over prolonged periods of time.

The many analogous but not planned situations which occur may give leads but these cannot give definitive answers. Among these are anecdotal reports of deprivation of human relationship, solitary confinement in jail, religious retreats, experiences in an iron lung, the break-off phenomena in high flying, and kayak sickness.

CONCLUSIONS

Behavioral changes can be produced in adult human subjects by exposure to reduction of sensory input.

There is some reason to consider that changes may also be produced in such subjects by exposure to marked changes in the meaning of the sensory input.

Reduction in input can be achieved by: (a) interference with reception of environmental stimuli; (b) less certainly, by blocking of conduction within the body; and (c) still less certainly, by interference with reception by the brain.

There is variation from person to person in susceptibility to reduction in input. The factors controlling the variability are as yet unknown.

There is no definite evidence that extending the duration of exposure to reduction in sensory input or increasing the reduction in input beyond a given level increases the extent or range of change.

Periods of exposure of less than one day probably do not produce changes properly attributable to reduction in input. Such changes as do occur after a few hours may well be due to (a) changes in behavior which normally occur when people are by themselves—i.e., there is an increased amount of reminiscence and introspection; (b) lowering of the sensory threshold; this lowering being part of the means which the individual adopts to protect himself against the effects of sensory deprivation; and (c) anticipation—i.e., a placebo-like effect.

These possibilities can only be tested effectively where controls are used.

All changes in the intact person are of a low order of intensity relative to those commonly produced by the application of drugs, physical agents or by potent physiological factors.

In brain-damaged persons, the changes are likely to be considerably more severe.

Changes tend to disappear within about a day after removal from the area of reduced input.

Persistent and extensive changes are reported in animals exposed during their developmental period to prolonged reduction in sensory input.

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