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CHANGES IN EEG ALPHA FREQUENCY AND EVOKED RESPONSE LATENCY DURING SOLITARY CONFINEMENT [1]

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One week of solitary confinement of prison inmates produced significant changes in their EEG frequency and visual evoked potentials (VEP) that parallel those reported in laboratory studies of sensory deprivation. EEG frequency declined in a nonlinear manner over the period. VEP latency, which decreased with continued solitary confinement, was shorter for these *S*s than for control *S*s whose VEP latency did not change over the same period. Experimental *S*s who had been in prison longer had shorter VEP latencies than relative newcomers to the prison.

A great deal of research has been carried out on the effects of sensory deprivation (Schultz, 1965; Zubek, 1969) on humans. It has been well-established (Zubek, Bayer, Milstein, & Shephard, 1969; Zubek, Bayer, & Shephard, 1969; Zubek & Welch, 1963) that a slowing of EEG alpha frequency occurred for *S*s placed in various types of sensory deprivation situations over a 7-day period. Such results suggest that arousal level decreases with prolonged deprivation. Another question, which has received little experimental attention, concerns the effect of stimulating *S* during or immediately after deprivation. Most recently, Zuckerman (1969) has hypothesized that the arousal potential of stimulation is inversely related to the immediate level of arousal at the time of stimulation. Other theorists, notably Lindsley (1961), Schultz (1965), and Vernon (1963) have proposed similar formulations as applied to the sensory deprivation setting. Assuming that the EEG frequency decline during deprivation is an adequate indicator of lowered arousal levels (Duffy, 1957), it is possible that stimulation introduced during deprivation would have a high arousal potential. There is some evidence in support of this hypothesis. Fox (1967) sensorally deprived infant canines for 7 days and then recorded their evoked potentials. He found that the visual evoked potential (VEP) latency of deprived *S*s was shorter than for nondeprived *S*s and concluded that arousal to sensory input increased as a result of deprivation.

A sensory deprivation situation that occurs in our society from time to time is the solitary confinement of prisoners. It is quite likely that this type of confinement imposes severe sensory deprivation. The purpose of the present study was twofold. First, isolated prisoners would be predicted to show higher arousal potential because of a lower arousal level induced by the solitary confinement. It was decided to measure the latency of VEPs in these prisoners and compare them with prisoners who were not in solidary confinement. Also, it was considered advantageous to determine the rate of EEG frequency decline, if any. Such a decline would indicate whether prison confinement were producing EEG results similar to that of the Zubek

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studies and in addition whether it would be an index of adaptation of the prisoner to his confinement environment. This procedure is unique in that EEG measures were taken throughout the 7-day deprivation period. To date, Zubek and his colleagues, with one exception (Zubek, 1964), have employed cross-sectional studies and not recorded EEGs from the same *S* throughout 7 days of deprivation. Cross-sectional studies have always reported a linear decline in EEG frequency. Zubek, Shephard, and Milstein (1970) have noted that longitudinal studies of EEG decline may produce different EEG findings and have important implications for sensory deprivation research.

METHOD

Subjects

An initial pool of volunteer *S*s was obtained by advertising for inmates' services in Kingston Maximum Security Penitentiary, Kingston, Ontario. Eighty-two *S*s volunteered. Those prisoners who were medically unfit or had a previous record of psychiatric or behavior problems in prison were rejected, as were *S*s with a Beta IQ below 80. Twenty *S*s were finally selected. The age range was 18–45 yr. The *S*s were randomly assigned to solitary confinement or the control condition. There were 10 *S*s per group. No incentives were offered *S*s, that is, money or parole recommendation. The *S*s were informed that a note regarding their cooperation in the experiment would be placed on their institutional file. Otherwise, their status in the prison would be the same after the experiment as before.

Apparatus

Two identical $8 \times 8 \times 12$ ft. cells, one for experimental and one for control *S*s, served as experimental chambers. These cells were routinely used in solitary confinement and were located in the maximum security detention wing of the penitentiary. The walls were 45-cm.-thick reinforced concrete, painted flat black. Two doors led into the cell, an inner barrier of steel bars and an outer door of 7.5-cm.-thick hard maple. The outer door contained a slot measuring 15×75 cm. which was closed throughout the experiment. Furnishing in the cell was limited to a bed, a sink, and a toilet. The bed was 182.8×76 cm. and was covered by a foam rubber mattress. The usual illumination level in the cells was a constant 10 mL. for security reasons. The light source was turned off during stimulation and recording. Noise level within the cells was approximately constant at 50 db. Nearby cells were kept empty throughout the experiment. An aerial antenna was suspended parallel to the cell wall and 9 ft. from the floor. The aerial transmitted telemetered EEG and VEP information to a Beckman Type-R dynograph in an outside laboratory. In the box containing the regular light source was a Grass PS-2 photo-stimulator mounted 10 ft. from the head of *S*'s bed.

Remainder of the apparatus was contained in a trailer laboratory located just outside the cell block. Antenna lead-in wire connected the laboratory to the experimental rooms. EEG and VEPs were recorded on two channels of the dynograph from an Onyx telemetry receiver. The transmitter was located in a specially designed cap worn by *S*s throughout the experiment. The cap also served to hold the EEG electrodes in place. An Ampex SP-300 four-channel magnetic tape recorder stored the VEP information and trigger impulses. The VEPs were analyzed on a Memnetron 400 computer of average transients.

Procedure

When experimental *S*s started their confinement, bipolar Beckman biopotential skin electrodes were attached to the shaved parieto-occipital region (O_2-P_4). Confined *S*s remained in the cell continuously for 7 days. Control *S*s entered their testing cell just prior to EEG and VEP recordings and were removed after. All *S*s were prone on their beds for recording and instructed to remain very still. The EEG leads were always in a fixed position and the telemetry transmitter a fixed 10 ft. from the antennae. A 25-min. dark-adaptation period occurred before recording of EEG and VEP. EEG samples were recorded on Days 1, 4, and 7 at 12:00 a.m. and from these three hundred 1-sec. artifact-free samples were selected for scoring. Research assistants who did not know which treatment *S* had received hand counted the number of waves in each 1-sec. sample (Engle, Romano, Ferris, Webb, & Stevens, 1944; Zubek & Welch, 1963) which is directly convertible to cycles per second. Frequency histograms were then determined for each *S* by calculating the percentage of 1-sec. samples at each 1-cps class interval between 7.5 and 12.5 cps as well as the average frequency for all samples. VEP samples to 50 photic stimuli (with an average of one flash per second) at maximum PS-2 intensity were gathered daily at 9:00 a.m. Interflash interval was random and varied from 5 to 20 sec. Peak-to-trough amplitude and the latency of the large negative peak at approximately 130 msec. after stimulus onset were selected for analysis.

After testing, control *S*s were returned to their living quarters where they were free to do as they wished except for engaging in very strenuous sports activities; experimental *S*s remained in their confined cells. Testing and routine maintenance procedures took up less than 2% of the total time spent by the experimental *S*s in solitary confinement.

The scores used for VEP analysis, the percentage latency and amplitude, were based on the latency and amplitude of the VEP recorded on Day 1 (approximately 30 min. after entering confinement), taken as base rates. For example, if the latency of an *S*'s major negative VEP peak were 120 msec. on Day 1 and 115 msec. on Day 2, the percentage score recorded on Day 2 was 96%, that is, a decrease of 4%. The statistical analysis used was trend analysis of variance (Edwards, 1958, p. 271).

RESULTS

EEG

Table 1 contains average EEG alpha frequencies of solitary-confined and nonconfined *Ss* for Days 1, 4, and 7. Alpha frequency significantly declined for solitary-confined *Ss* over days (Treatment × Trial) but remained stable for the nonconfined prisoners, $F = 40.0$, $df = 2/36$, $p < .01$. Figure 1 shows the distributions of EEG frequency in two representative solitary-confined prisoners on Days 1, 4, and 7 of confinement. Quite clearly, the distributions shifted to a lower frequency in these *Ss*.

The rate of frequency decline was not linear. Although EEG frequency declined on an average of .97 Hz. after 7 days of monotonous confinement, 77% of the total decline occurred within the first 4 days of confinement. This quadratic trend was significant, $F = 10.8$, $df = 1/36$, $p < .03$.

VEP

The introduction of visual input into monotonous confinement differentially affected *Ss*.

TABLE 1

EEG FREQUENCIES OF SOLITARY-CONFINED AND NONCONFINED SUBJECTS

Group	*S*	Days		
		1	4	7
Solitary confined	1	10.4	9.7	9.6
	2	11.4	10.6	10.4
	3	11.1	10.0	9.7
	4	11.0	10.4	10.3
	5	10.5	9.5	9.2
	6	10.7	9.6	9.3
	7	10.6	10.1	9.9
	8	10.0	9.8	9.5
	9	9.6	9.3	9.0
	10	12.2	11.0	10.9
$\bar{X}$		10.75	10.00	9.78
Nonconfined	11	11.0	11.0	10.7
	12	10.6	10.5	10.7
	13	10.5	10.7	10.4
	14	11.0	10.7	10.9
	15	10.4	10.6	10.5
	16	10.3	10.3	10.3
	17	9.4	9.6	9.6
	18	11.2	11.2	11.1
	19	11.1	11.1	11.2
	20	10.3	10.2	10.4
$\bar{X}$		10.58	10.59	10.58

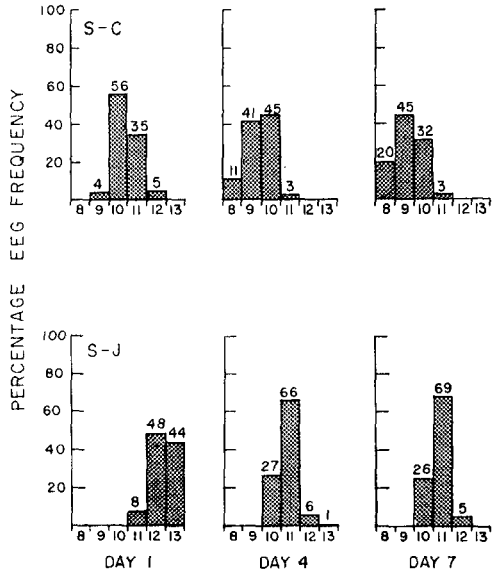

FIG. 1. The percentage of EEG alpha frequencies appearing in two confined *Ss* protocols during time in solitary confinement.

As can be seen from inspection of Figure 2, the mean VEP latencies for both groups were quite similar (approximately 1 msec.) over the first 48 hr. From Hour 72 on, the solitary-confined-*Ss*' VEP latency decreased while the VEP latency of the controls increased slightly. This change over days (Treatment × Trial effect) of the VEP for solitary-confined *Ss*, compared to the controls, was statistically significant, $F = 4.2$, $df = 5/90$, $p < .01$. Figure 2 illustrates the major negative peak latencies for both groups.

Of the 10 confined *Ss*, 4 had been in prison an average of 4 yr. while the other 6 were relative newcomers (6 mo. on the average). The VEPs of this first group of confined inmates were of a shorter latency during treatment, $F = 8.0$, $df = 1/8$, $p < .05$, than that of newcomer prisoners even though both groups had approximately the same Day 1 VEP latencies. Of the control group, 4 *Ss* had spent 4 yr. in prison on the average and 6 were classed as newcomers. There were no differences in their major negative peak latencies ($F < 1$). Although the confined *Ss*' VEP amplitude was slightly greater, the differences were not significant, $F = 1.9$,

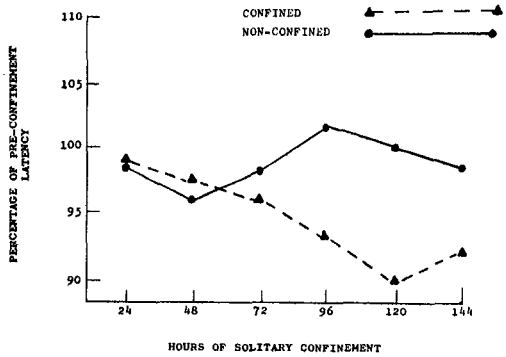

FIG. 2. Percentage latency of major VEP negative peak for confined and nonconfined *S*s.

$df = 1/18$, $p > .05$ (Treatment) and $F = 1.2$, $df = 5/90$, $p > .05$ (Treatment × Trials).

DISCUSSION

The present experiment confirms that a slowing in EEG frequency occurs during solitary confinement of prisoners. Zubek and Welch (1963) previously demonstrated that the EEG had declined by .85 Hz. upon termination of 7 days' sensory deprivation, 1.21 Hz. after 7 days' perceptual deprivation, and 1.42 Hz. as a result of immobilization plus perceptual deprivation (Zubek, Bayer, Milstein, & Shephard, 1969). The present study shows a slowing of .97 Hz. after 7 days' prison solitary confinement, indicating that prison solitary produces quite similar EEG frequency slowing effects to those reported by Zubek and his colleagues on normals in his laboratory sensory and perceptual deprivation settings.

The gradual EEG shift to lower frequencies may represent a tendency toward increased theta activity (4–7 Hz.)—see *S* S-C in Figure 1 in the confined *S*s. Mundy-Castle (1951) suggested that increasing theta occurs with frustration and stress,[3] which may be elements common to 7-day deprivation situations (Zubek, Bayer, & Shephard, 1969). In order to provide a more conclusive answer on this issue, future research should incorporate movement monitoring. Hippocampal theta has been found to relate to movement (Vanderwolfe, 1969) in infrahumans, and possibly *S*s were moving more during the later stages of confinement due to tension, anxiety, and stress, or perhaps in an attempt to provide at least proprioceptive stimulation. Autocorrelation and power density spectrum analyses of EEG frequency are additional techniques offering a more detailed assessment of the trend toward increased theta in confined prisoners.

The EEG frequency slowing may also be interpreted as an index of adaptation to isolation (Schultz, 1965; Zubek, 1969). In the present experiment, the EEG frequency decreased most markedly (.75 Hz) after 4 days of solitary confinement, suggesting that adaptation to isolation occurred primarily during the first 4 days. The present study employed a longitudinal design, that is, the EEGs were taken from the same *S*s at periodic intervals. The Zubek studies have usually employed a cross-sectional approach. In order to account for this nonlinear rate of EEG decline, Zubek, Shephard, and Milstein (1970) suggested that experimental *S*s may have developed a specific set toward the experiment.

Their hypothesis received some support in that many criminals have had experience with solitary confinement, some to a considerable degree, and would be expected to develop unique strategies (Walters, Callagan, & Newman, 1963), likely different from college *S*s, for coping with confinement. In fact, 3 of the 10 experimental prisoners had little previous experience with prison solitary confinement and their rate of EEG decline was almost linear (.33 Hz. for Days 1–4, .27 Hz. for Days 4–7). The other 7 *S*s had previously spent time in solitary confinement in other prisons. Their average EEG decline for Days 1–4 was .93 Hz., and for Days 4–7 it was .20 Hz.

In the present study, the momentary arousal level denoted by the EEG frequency decline is certainly inversely related to the arousal indicated by shorter latency-evoked responses. The major VEP negative peak latency of nonconfined *S*s was fairly stable (Dustman &

[3] Corticosteroids were taken on all *S*s. Due to complications, the corticosteroid analysis was completed for only six *S*s (three of each group). The steroids were taken at 7:00 a.m. and 6:00 p.m., and there was a trend toward higher corticosteroid levels occurring on Days 6–7 of confinement and 1–3 after confinement for the experimental *S*s compared to the three control *S*s. These incomplete data may be indicative of raised stress levels of solitary confined *S*s.

Beck, 1963) and tended to slow after repeated photic stimulation (Garcia-Ausst, Bogacz, & Vanzulli, 1964). In contrast to this habituation tendency, the major VEP negative peak latency of confined *S*s became shorter as isolation lengthened. This may represent an increased readiness to respond to external stimulation as solitary confinement progresses. This result is in line with some of the views expressed by Lindsley (1961), Schultz (1965), Vernon (1963), and in particular Zuckerman (1969), who postulated an inverse relationship between the arousal potential of stimulation and the immediate level of arousal of *S* at the time of stimulation. Zuckerman (1969, p. 413) has reviewed the literature indicating that an inverse relationship exists between EEG measures and GSR, heart rate, body movement, and blood pressure. To this list can be added the inverse relationship reported in the present study between EEG frequency and the VEP, at least as applied to the solitary confinement setting.

An institutionally imposed individual difference factor was suggested in the VEP analysis, although these data should be interpreted with caution as a very small n was invoked in these post hoc comparisons. Prisoners who had spent an average of 4 yr. in prison before the experiment produced shorter latency VEPs when in solitary confinement than did newcomer inmates. The two groups did not markedly differ as to age, IQ, or type of criminal background. (These long-term prisoners also had a slightly lower EEG frequency, 10.5–10.8 Hz., than did the newcomer prisoners.) It may be that the length of prison experience iteself affects, to a degree, reaction to solitary confinement. Fenz (1971), for example, has noted that the degree of institutionalization may be directly related to physiological reactivity. At the extreme end of the institutionalization dimension is solitary confinement. More studies examining the nature and degree of prison institutionalization are warranted.

Finally, the solitary confinement period of 7 days was chosen as part as it afforded comparison to several studies by Zubek (e.g., 1969) of the same length. This time period, however, was not atypical of solitary confinement served by prisoners in the institution where the research was carried out. The experimental situation was similar in several aspects to the "real-life" solitary confinement existent in the prison. It is entirely possible that the results obtained in the present study apply to some extent to the regular prison solitary confinement. It is also of interest that while many prisoners now spend only 1 or 2 days in confinement, the authors have noted that inmates have remained in solitary confinement for durations considerably longer than those employed in the present study.

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