THE MILITARY PERFORMANCE OF SOLDIERS IN CONTINUOUS OPERATIONS: EXERCISES "EARLY CALL" I AND II

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There are frequently times in defensive encounters when there is little or no opportunity for sleep. Hence, the effects of sleep loss are the object of continuing study in military psychology.

Although many experiments have been carried out to determine the effects of sleep loss, most of these have been in a laboratory setting, and the few that have been carried out in the field have been mainly of relatively short duration (up to 5 days) and have not all aimed at being militarily realistic. There was a need, therefore, to carry out a field trial of longer duration, with as much realism as possible, and with sufficient numbers to preserve this realism.

Exercise Early Call I (Haslam, Allnutt, Worsley, Dunn, Abraham, Few, Labuc, & Lawrence, 1977) was designed to meet these aims, and it was decided that Infantrymen should adopt a defensive role against a small number of 'enemy' troops, and that the tactical situation should be maintained for 9 days.

Methods

Subjects. Three Platoons, consisting of 68 members of the Parachute Regiment were the trial subjects. Their age range was 17 to 38 years, with a mean of 21 years.

For purposes of testing, the three Platoons were each divided into 2 groups, called Alpha and Beta groups, both of which consisted of Platoon Commanders, Section Commanders, and rank and file. The Platoons were so divided because it was possible to process only 36 men a day, 12 from each Platoon, on the various military, psychological and physiological tests; these were the Alpha groups. The Beta groups remained in the defensive positions for the entire trial. Subjective assessments were carried out on both Alpha and Beta groups.

Trial design. The trial was divided into 5 exercises, during each of which a defensive position was prepared and occupied. Exercises 1 (2 days) and 5 (3 days) were the control periods with 6 hours sleep per night in the field, and Exercises 2, 3, and 4 (3 days each) were the experimental or sleep-deprivation periods. After the first control period, each Platoon was randomly assigned a sleep schedule, namely 3 hours continuous sleep, 1.5 hours continuous sleep, and 0 hours sleep in 24 hours. In addition to comparing the performance of the 3 groups, it was intended to find out for how many days the 0-hours sleep group could remain in the field. Three days of training and briefing on various aspects of the trial preceded Exercise 1. The 9-day sleep-deprivation period consisted of a 3-day sequence of events which was repeated 3 times in different locations (Exercises 2, 3, and 4); thus, a defensive position was prepared and occupied for 3 days before moving to a new one. Act-

ivities undertaken in each position, apart from digging and camouflaging, included wiring, mining, patrolling, ambushing, sentry duty, and radio operating. Exercise 2 was preceded by one day of rest and preparation, and Exercise 4 was followed by 3 days of rest and recovery.

Medical and psychiatric monitoring. Considerable effort went into the provision of a strong medical team, but no untoward reactions occurred. Before the exercise began, subjects and observers were briefed on signs of exposure and of fatigue. All trial troops had the right to withdraw themselves from the exercise at any time, and they were, of course, withdrawn if they were thought by those in charge to be unfit to continue. All observers were briefed by a psychiatrist before the exercise began on the possible psychological effects of continuous operations, and were instructed to report to him any incident which gave cause for concern. The defensive positions were visited daily by the psychiatrist as a matter of routine, and further visits were made if it was thought necessary. After withdrawal from the exercise and return to the medical centre in camp, subjects were again visited by a psychiatrist.

Environment. The trial was carried out in the north of England, on the Otterburn training area, which consists mostly of open heath and moorland, intersected by gullies and streams, and with a few scattered tree plantations. Although it was summer, the climate was cool and windy with periods of quite considerable rainfall, and with relatively little sunshine. Also, the night hours were usually associated with very high relative humidity, dew point being reached on several nights.

Objective measures. To assess shooting and weapon handling, cognitive functioning, and physical fitness, the test subjects were taken from the defensive positions to testing sites. For 3.5 hours at the same time every day, between 0930 and 1630, the subjects went to the range and adjacent test site and later to a tent for these tests. During Exercises 2, 3, and 4, cognitive testing took place between 0230 and 0700, but during the control and recovery exercises (1 and 5), this was the subjects' sleep period and testing was carried out during the day.

Subjective measures. Subjective assessments were made by military observers, the Company Commander, and the subjects themselves.

Observers. One hundred military observers, drawn from all Arms, were divided into 3 shifts of 30 to cover each 24 hours, and one group of 10 who were responsible for all work carried out at the shooting and weapon-handling range.

Military Tests

Vigilance shooting. A test which combines vigilance with shooting was developed in order to study shooting performance under conditions of sleep loss. The test was of 20 minutes duration, in which time 9 rounds were fired. Portable electric targets, which were at ranges of 100 m, 200 m, and 300 m from the firing point, were exposed for 5 seconds (including the upward movement) at time intervals varying between 10 seconds and 7 minutes. Targets appeared 3 times at each distance, and 3 men were tested together. The targets were set out in such a way as to give each man an arc of fire of approximately 622 mils. In order that subjects did not learn the sequence of time intervals

and ranges, there were 3 versions of the test. The score recorded for each subject was the number of hits out of a total of 9. Subjects were told their scores.

Grouping capacity. Grouping capacity is the ability to fire 5 rounds so the shots fall in as small an area as possible. Statistical analysis of data from pilot trials indicated that if the best of 3 groups of fall of shot was taken as a subject's score, then the test had sufficient reliability to assess the effects (if any) of sleep loss. Three white cards, 295 mm X 210 mm, were placed on a board, one above the other. In the centre of the card was a black aiming mark, 25.4 mm square. Three subjects were tested together, and so there were 3 boards, which were at a distance of 25 m from the subjects. In their own time, subjects fired a group of 5 rounds at each card, starting with the one uppermost. Subjects were told their group sizes.

Weapon handling tests. The tests included filling the magazine by hand, loading rifle (standing position), unloading rifle (standing position), stripping rifle to firing pin, and assembling rifle. The tests were carried out according to the Infantry Training Manual and were scored for time and errors.

Cognitive tests. Six paper-and-pencil tests were selected, which were either meaningful to the subjects, or which examined a cognitive function of some importance. The tasks chosen for study were: encoding/decoding (Dudley, Huband, & Cox, 1972), map-plotting, short-term memory (digit span), logical reasoning (adapted from Baddeley, 1968), and the Stroop test (Jensen & Rohwer, 1966). The tests were carried out in a tent adjacent to, but out of sight of the defensive positions. The tent contained 12 booths for the subjects. Testing of the 3 Platoons during Exercises 2 to 4 was at 0200 hours (no-sleep group), 0400 and 0530 hours respectively for the 1.5 and 3 hour sleep groups, 30 minutes after being wakened from sleep.

Electroencephalography. The role of EEG recording in this study of performance during continuous operations was to provide objective physiological evidence of the amount and quality of sleep obtained and of subjects' level of awareness at particular times throughout the exercise. EEG recordings were made from 6 randomly selected subjects--as many as resources would permit. One pair was drawn from each of the 3 Platoons having 0, 1.5, and 3 hours of scheduled sleep. The recordings were made with Medilog tape recorders, running for 24 hours at a time, carried by one member of each pair on alternate days.

Visual Acuity Tests

Binocular near acuity. Binocular near acuity was measured by means of a reduced Snellen chart held by the experimenter at a distance of 37.5 cm from the subject's eyes. In order to avoid learning, there were several versions of the chart. the subject was asked to read out as many lines as he was able.

Binocular far acuity. Binocular far acuity was measured by means of a standard Snellen chart at a distance of 6 m. The illumination on the chart was 140 lux. Again, there were several versions of the chart to avoid learning, and the subject was asked to read out as many lines as he was able.

Physiological and Biochemical Measures

The physiological measures were intended in the main as background to the performance tests. Body weight and skinfold thickness were measured by regularly calibrated balance and Harpenden calipers in the standard manner. Aerobic capacity (VO_2 max) was estimated from a 6 min single-load submaximal bicycle ergometer test, using the age-corrected Astrand-Ryhming nomogram (Astrand & Ryhming, 1970). Isometric muscle strength was measured by the method of Hermansen (1974) for back flexion, back extension, left forearm flexion and extension, right forearm flexion and extension, leg extension, and hand grip.

Temperature and heart rate circadian rhythms were observed before and after the field phase by the simplest possible methods, compatible with the realism of the exercise. In addition, assessments were made of urine and blood biochemistry.

Subjective measures. As indicated earlier, subjective measures included both self-rated and observer-rated assessments. They were concerned with mood, alertness, effort, morale, effectiveness, and sleepiness.

Results

In general, the results of this trial are most easily assimilated in graphical form and they will be presented in this way in the following pages. Some specific comments will be made here as a preface.

Withdrawal from the exercise. All of the 0-hours sleep Platoon had withdrawal from the Exercise by Day 4, i.e., after 4 nights without sleep (one subject withdrew on Day 3); 39% of the 1.5 hours sleep group had left by Day 5; 48% of the latter Platoon and 91% of the 3 hours sleep Platoon completed the Exercise (Figure 1).

Although the trial was carried out in the summer, the weather was, for the most part, cold, wet, and windy. Undoubtedly the heavy rain which fell on Day 4 interacted with sleep loss, hastening the departure of the 0 hours sleep Platoon. The suddenness of this departure was probably also brought about by the early retirement of the Platoon Commander (thus saving the others from loss of face), inexperienced observers who wished to err on the side of caution, and the fact that the soldiers calculated that they had just beaten the 100 hours deprivation point, which they felt to be a significant landmark. Against all this must be set the opinion of the military observers that this Platoon had ceased to be effective by Day 3.

Military Tasks

Vigilance shooting. The average number of hits can be seen in Figure 2. Analysis of variance indicated:

(1) that for all 3 Platoons, performance on the experimental days was significantly worse than on the control days ($p < .01$ for 0 hours sleep group; $p < .001$ for the other 2 groups);
(2) there was a significant deterioration over the sleep deprivation

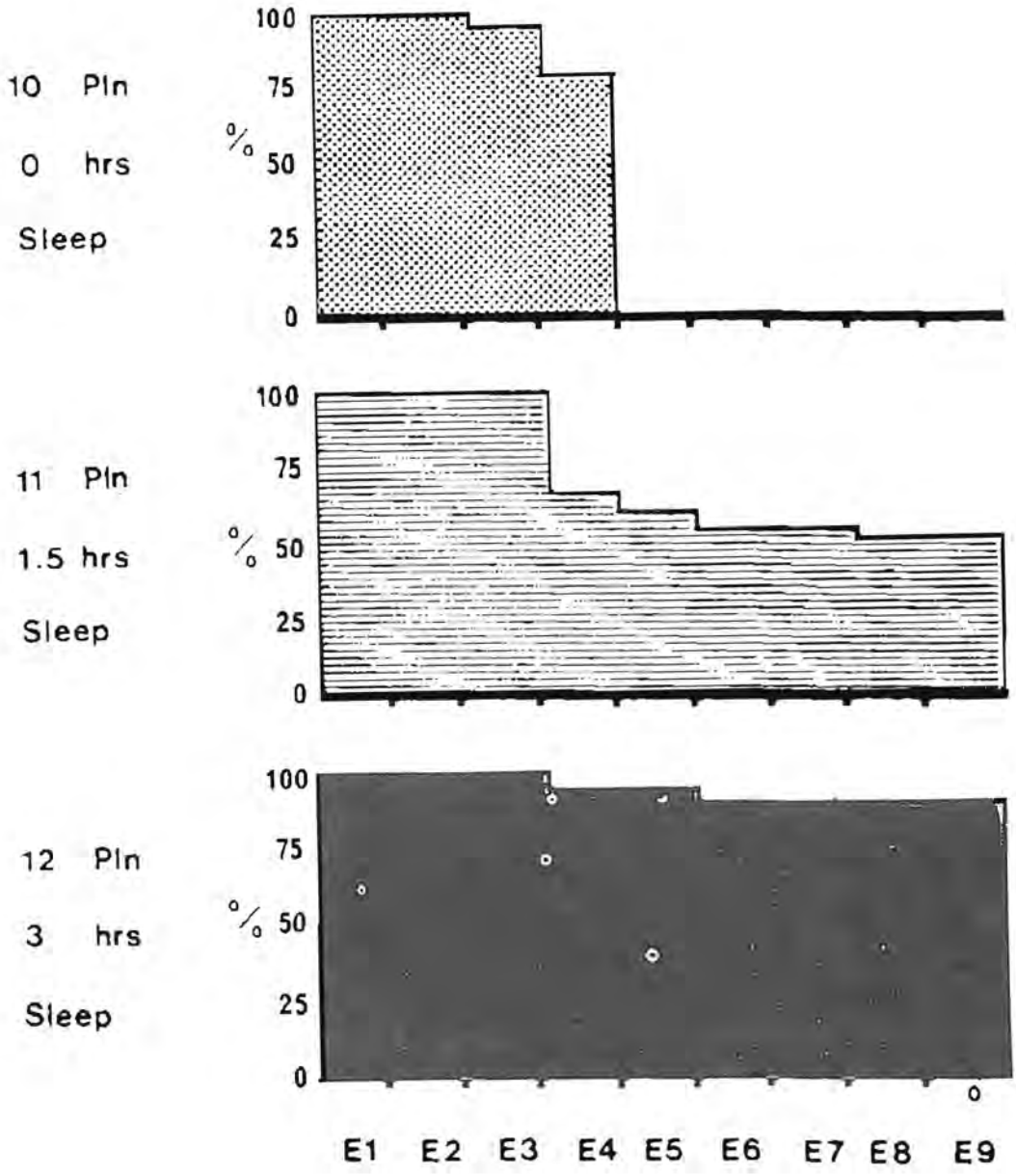

Figure 1. Percentage of soldiers in the 3 Platoons remaining in the field over experimental Days 1-9.

period for the 1.5 hours and 3 hours sleep groups ($p < .01$ in both cases);

(3) for the 0 hours sleep group, performance on Day 2 was significantly worse than on Day 1 ($p < .05$).

Grouping capacity. The average size of the best group for the 3 Platoons over the course of the trial can be seen in Figure 3. As this figure shows, there was no overall deterioration with sleep loss, and means varied between 2.00 and 2.75 inches for the entire trial.

Weapon handling tests. There was no significant difference between experimental and control days for any group. With regard to the more difficult tasks of stripping and assembling the rifle, there were larger fluctuations than in a simple task like loading the rifle. In stripping and assembling, the performance of the no sleep group was significantly worse than the other 2 groups on deprivation Days 2 and 3 ($p < .05$ and .001, respectively); but it was also significantly worse on the first post-deprivation day ($p < .05$ and .001 for stripping and assembling, respectively). There appeared to be a practice effect (C3-C5 compared with C1-C2 was significant at the .01 level) for the 3 hours group in stripping and assembling, and at the same level for the 1.5 hours group in assembling which obviously would have had most impact on the performance of the 3 hours sleep group (91% of whom remained in the field) and on half of the 1.5 group. Figures 4 and 5, which give mean times for assembling the rifle and for loading it, illustrate the above points.

Cognitive Tests

In Figure 6 can be seen the results for encoding. This figure will serve to illustrate the general pattern of performance in the cognitive tests. For the majority of these tests, there was a rapid deterioration in performance over the first 4 days of sleep loss, with an upturn on Day 5 for those subjects remaining after the night in base camp. [Because of the heavy rain which fell continuously for 24 hours, the subjects were taken into camp for a change of clothing and general drying out. The sleep regimes were adhered to.] Thereafter, there was a further decline, followed in most instances by improved performance on Day 9, the last deprivation day.

In most tests, for all 3 Platoons performance on the experimental days was significantly worse than on the control days (p varies from $< .05$ to .001), and there was a significant deterioration over the sleep deprivation days. Although in the encoding test, the performance of the no sleep group was significantly worse than the other 2 groups on Day 3 ($p < .01$), this was not the general finding. That is, the cognitive tests did not distinguish between the 3 sleep groups; in fact, in most instances, there was a non-significant trend for the performance of the 1.5 hours group to be better than that of the 3 hours group.

Electroencephalography

The proportion of reliable data recovered was gratifyingly high. Obviously there were gaps in the data from individuals on the alternate days. A more serious restriction of the amount of information obtained resulted from the fact that by Day 5 both of the 0 hours scheduled sleep pair and one each of

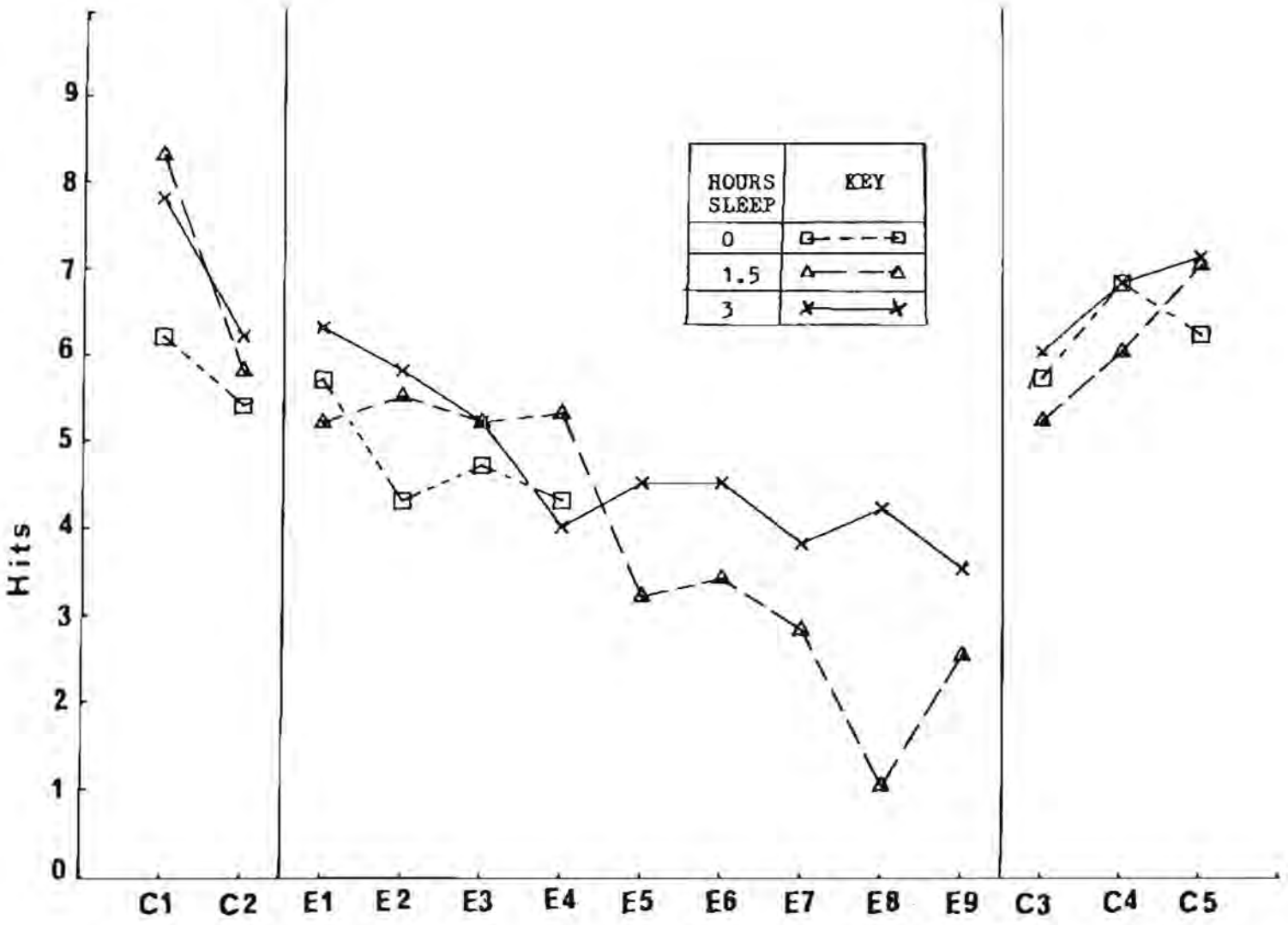

Figure 2. Vigilance Shooting. Average number of hits for the 3 Platoons.

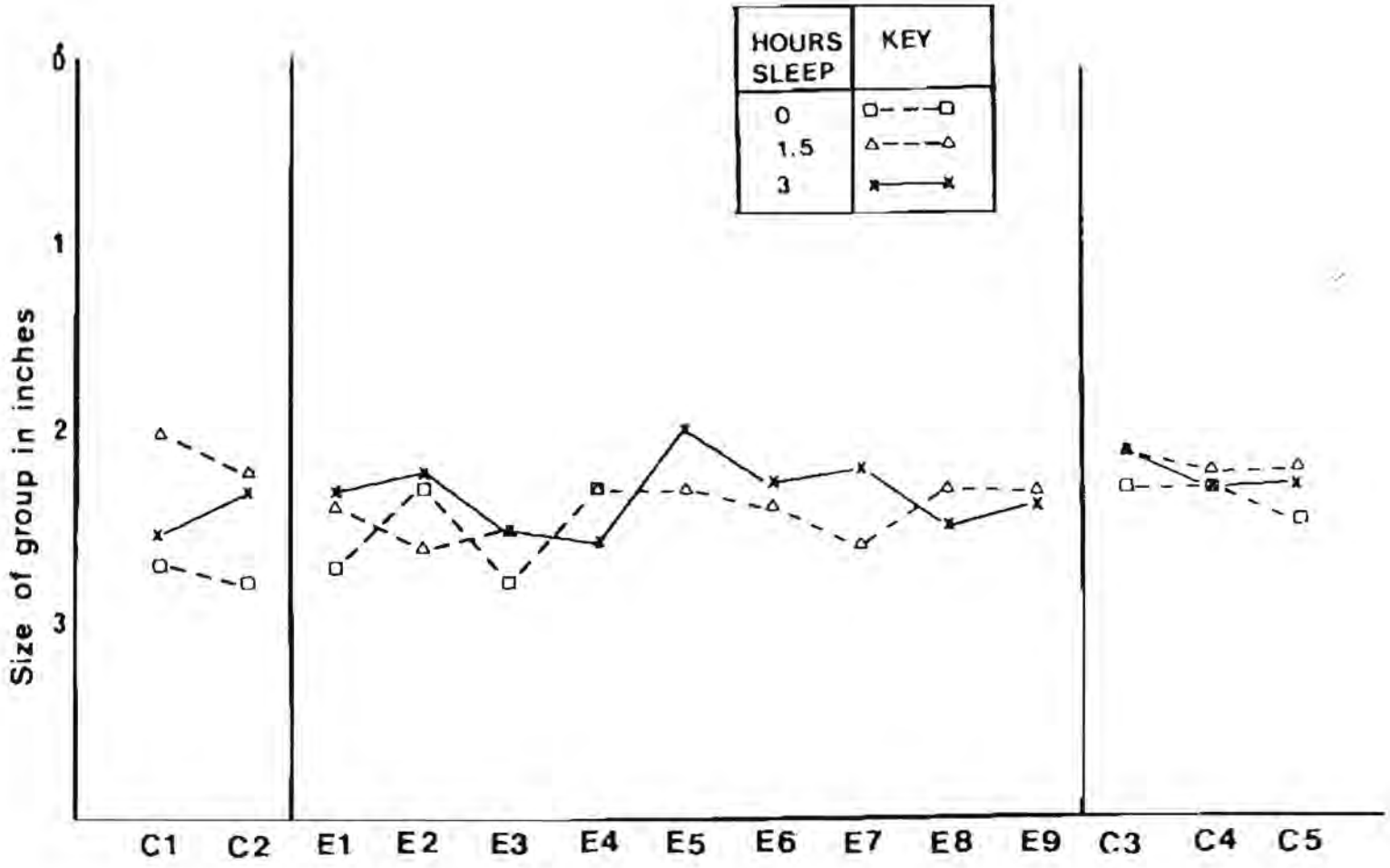

Figure 3. Grouping Capacity. Average size of best of 3 groups for the 3 Platoons.

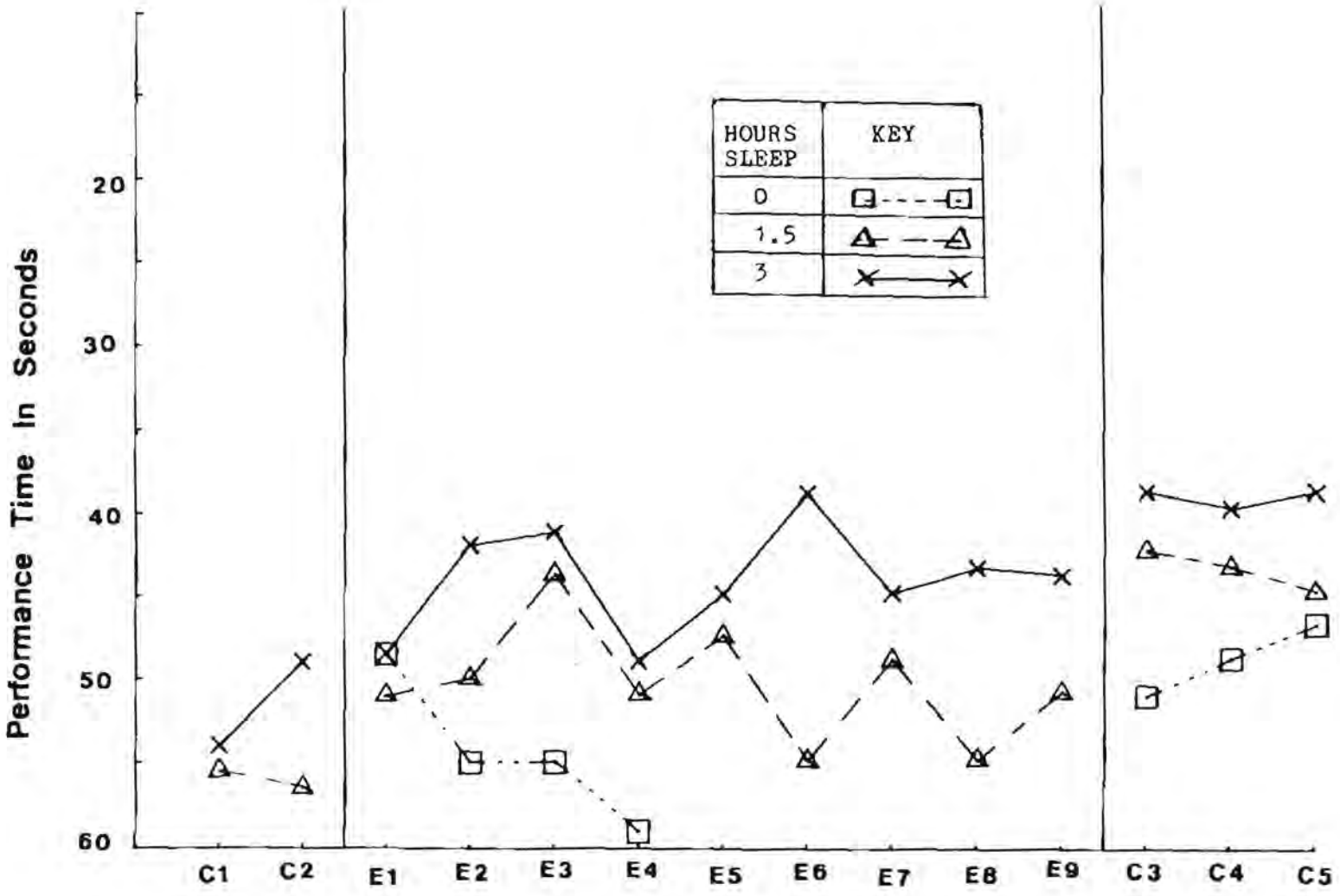

Figure 4. Assembling rifle. Average time taken by the 3 Platoons.

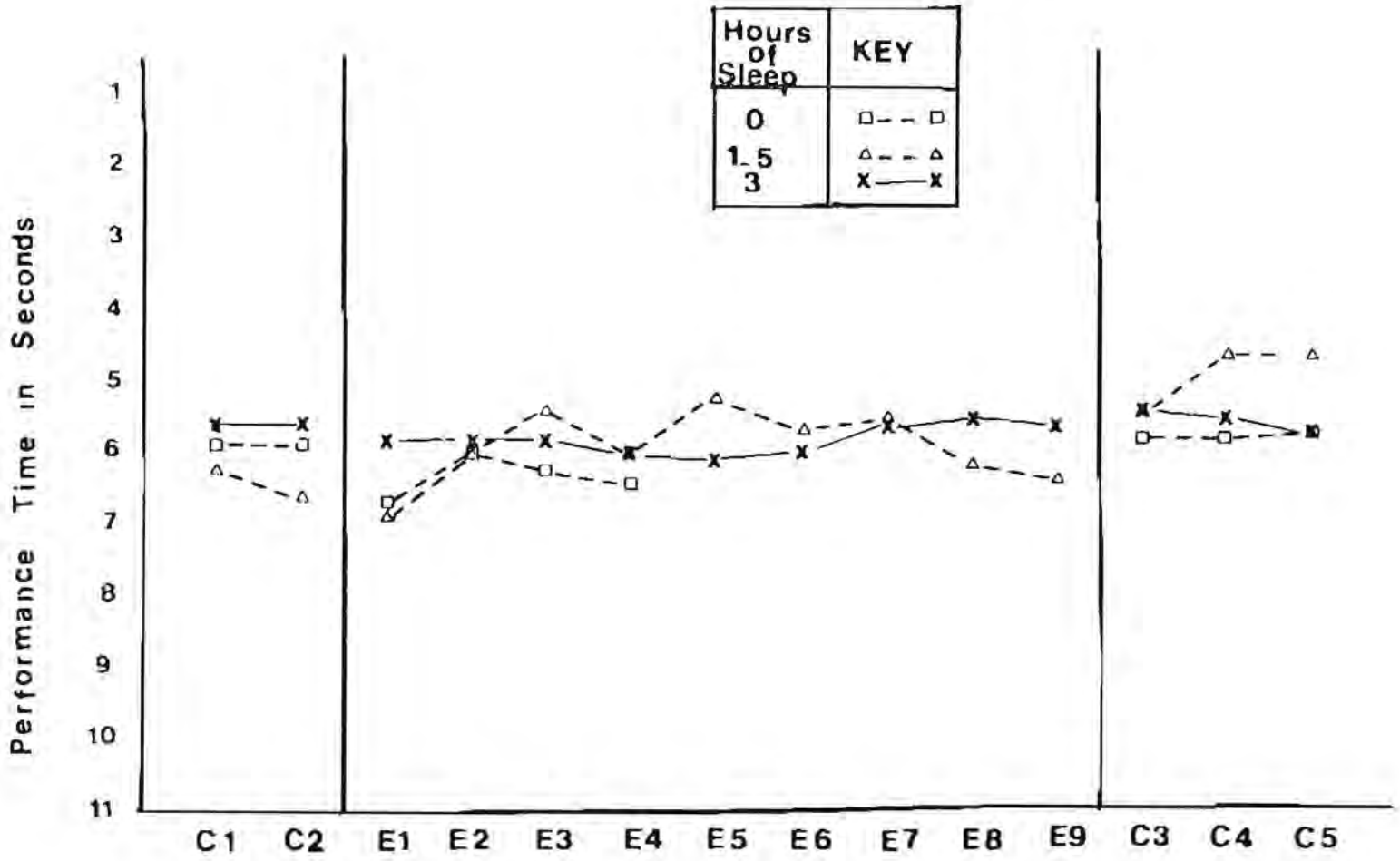

Figure 5. Loading rifle. Average time taken by the 3 Platoons.

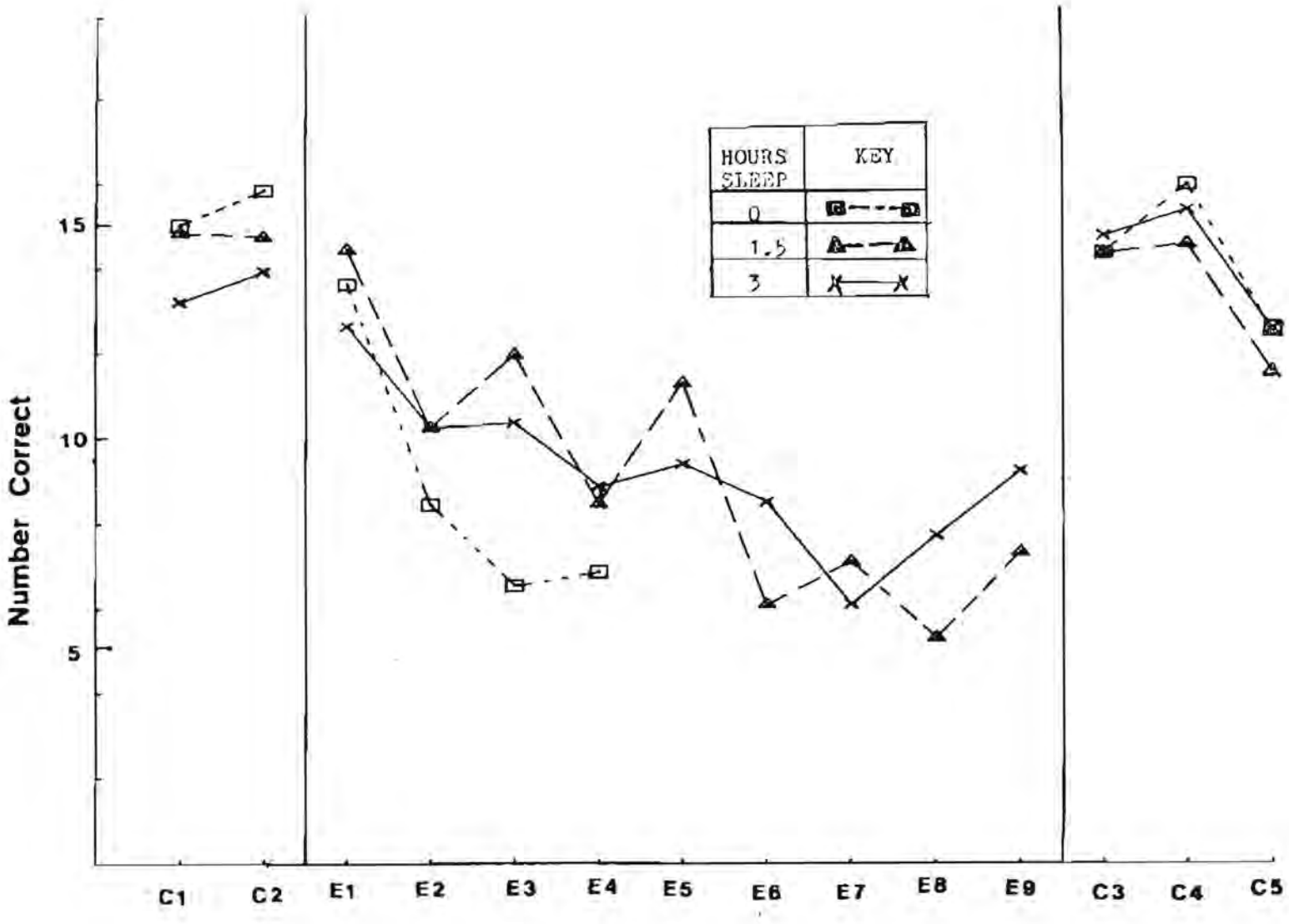

Figure 6. Encoding. Average number correct for the 3 Platoons.

the 1.5 hours and 3 hours sleep pairs had withdrawn or been withdrawn. Nevertheless, it was possible to build up a picture of the changing pattern of consciousness. The picture that emerges is as follows:

(1) Despite the efforts of the observers, there was unscheduled sleep, which increased progressively both in terms of depth and duration, over the sleep deprivation period;
(2) The unscheduled sleep was principally in the form of light sleep, the major part of which was Stage 2 sleep;
(3) During the sleep deprivation period, there was an increase in activity that was mainly alpha, without eye movement, and with reduced muscle tonus.

During the post-deprivation phase, EEG records for 2 subjects, one from the 1.5 hours and the other from the 3 hours sleep group, both of whom had completed the 9 days, suggested that after only one recovery day, the sleep pattern on the second night was little different from their baseline pattern. The amount of "recovery" sleep on the first day was 17.47 and 12.44 hours, respectively.

Visual Acuity

There was no deterioration in near and far acuity; it is unlikely, therefore, that these aspects of visual functioning contributed to the observed decrement in cognitive tasks and vigilance shooting.

Physiological and Biochemical Measures

The results indicated that the subjects' survival times were not determined by physiological factors.

While many measures did not reveal anything of physiological significance, there were 2 exceptions, namely, back extensor muscle strength and circadian rhythms. There was a deterioration of the former, significant only for the 1.5 hour sleep groups, and a flattening of the latter, especially body temperature, roughly proportional to the 3 sleep schedules.

Subjective Measures

As expected, sleepiness increased, alertness decreased, and there was a deterioration in mood and effort. Figure 7 shows mean scores for the 3 groups on a 5-point scale of alertness, rated by the military observers. This will serve to give the general picture of subjective measures, except for group morale which remained high. At the de-brief session, several non-commissioned officers reported that they had found a more relaxed style of leadership to be apposite and, particularly in the later stages of the exercise, exhortation to be better than order.

Discussion

Military Tasks

Vigilance shooting and grouping capacity. These 2 sets of results confirm

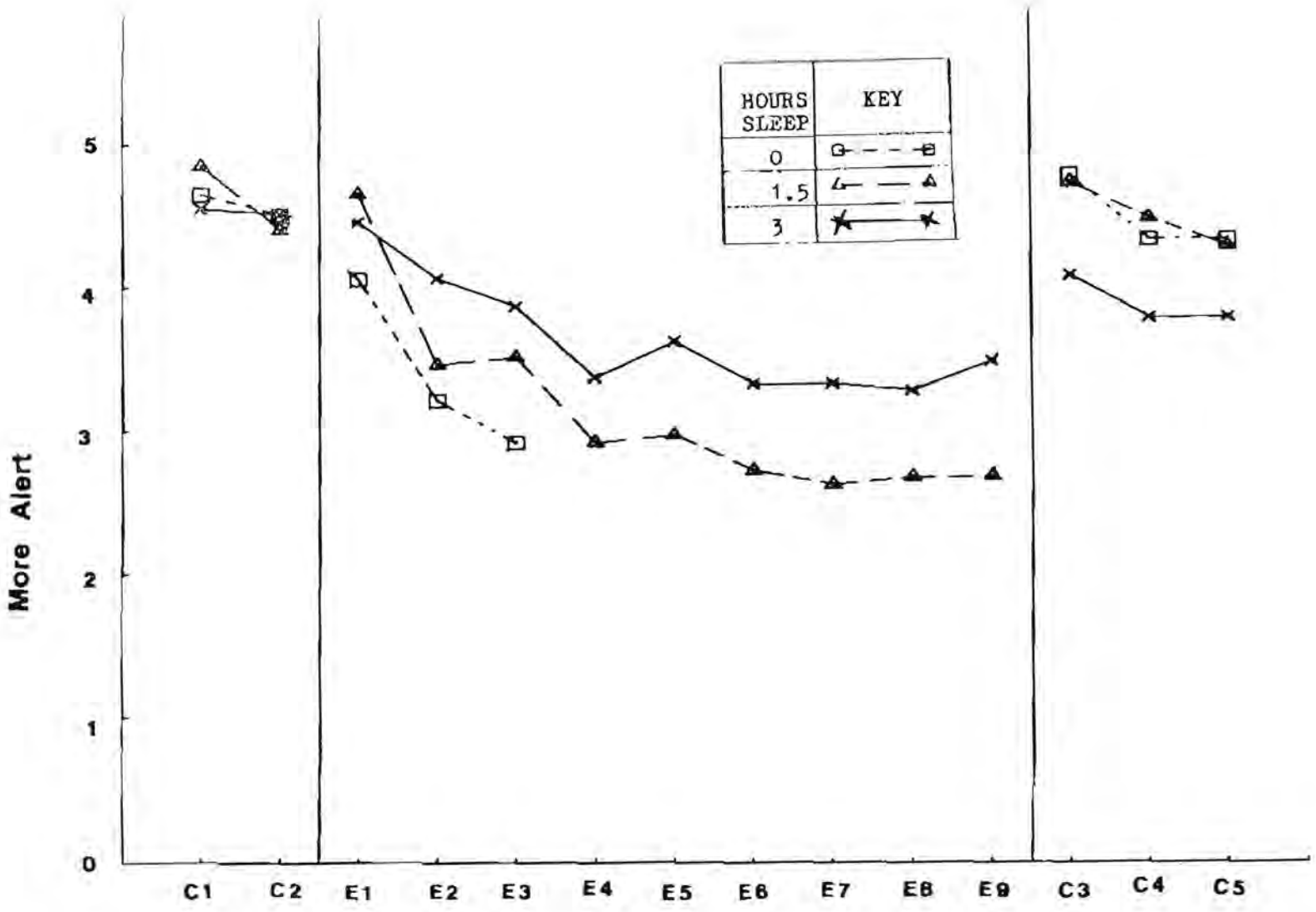

Figure 7. Average level of alertness for the 3 Platoons.

other sleep loss results in that grouping is a self-paced task and is therefore less likely to deteriorate than an experimenter-paced task with a high vigilance component (Johnson & Naitoh, 1974). Vigilance, of course, is extremely sensitive to sleep loss (Wilkinson, 1964). Also, grouping is a well-learned task and thus resistant to sleep loss effects (Johnson & Naitoh, 1974). These 2 sets of results together indicate that shooting skill per se does not deteriorate but that attention does. This was confirmed in a de-brief session when subjects said that their eyes had wandered from the target locations. In the event of war, motivation to see and kill the enemy will be high, but, nonetheless, vigilance in any situation, and especially under conditions of sleep loss, will almost certainly deteriorate over time.

Weapon handling tests. The observed practice effect, which only became manifest when subjects were less tired, presumably nullified any effect of sleep deprivation over the experimental days. However, weapon handling is, of course, a well-practised skill, and in this respect should be resistant to sleep loss effects. Nevertheless, stripping and assembling the rifle are somewhat "fiddling" tasks (especially assembling), and might be expected to show some effect (Johnson & Naitoh, 1974); to the extent that these tests differentiated between the Platoons, this expectation was borne out.

Cognitive Tests

There are several indications from the results of these tests that amount of sleep loss was not the only influence upon performance, and that morale and motivation played their part. One indication is the improved performance after the night in base camp, when the sleep regimes were adhered to but the subjects were warm and dry; a second indication is the upswing in performance on the last day of sleep deprivation, and the third is the overall performance of the 1.5 hours Platoon. Throughout the exercise, it appeared that this Platoon was very highly motivated, perhaps because they had the greatest challenge. Clearly, the Platoon with no scheduled sleep could not keep going for the 9-day period of the exercise, and for the 3 hours group, the challenge was not prodigious.

Electroencephalography

It has been shown that monitoring of brain activity by continuous tape recording is feasible under the conditions of a military exercise. Such recordings give the best available objective indication of a subject's state of alertness at any given time, and provide the only complete information concerning the duration and depth of sleep acquired each day. Processing the information is, however, likely to remain a tedious task until the advent of reliable computer methods.

Physiological and Biochemical Measures

It has been accepted from the outset that the study of physiological aspects would be subsidiary to the main aims of the trial, and that the test programme would, of necessity, proceed under a certain number of constraints lest it exert undue influence on the performance of the subjects by the very nature of the tests employed. Also, it was important that the Alpha Groups should not be placed at a disadvantage as compared with the Beta Groups.

Back extensor muscle strength. A reduction in back muscle strength is cited by Simonson (1972) as a result of sleep deprivation. In the present trial, sleep deprivation was associated with maintenance of the erect posture, with consequent demands upon the back extensors. The observed deterioration was thought unlikely to be of military significance, however.

Circadian rhythms. The military significance of the observed changes in circadian rhythms is debatable; previous British Army studies (Adam, Brown, Colquhoun, Hamilton, Orsborn, Thomas, & Worsley, 1972) produced inconclusive results, although here the disturbances were induced by time-zone transition. More recent analysis of the data (Colquhoun, 1976) demonstrates relationships between the degree of circadian rhythm disturbance and performance in psychological tests, coupled with personality characteristics. The link between these observations and combat effectiveness will depend in part upon studies involving the military 'decision makers', but could also be usefully examined in studies involving the rifleman to find out the length of time, coupled with degree of sleep loss, in continuous operations before circadian rhythms are disturbed.

Subjective Measures

Mood and behavioural changes can appear after one night of sleep loss, and are present, to some degree, in all subjects following 2 nights without sleep (Johnson & Naitoh, 1974). The results of the Exercise reported here support these general observations. However, the morale of the Company remained good, and this was probably attributable to the fact that they were a well-integrated group. Another factor was that the Company knew the scheduled end of the exercise, and the survivors were able to gear themselves to the known time limit. Particularly for the 3 hours sleep Platoon, this is manifest in the end-of-trial spurt in performance on some tests.

Conclusions

Thus, to sum up, it can be said that even small amounts of scheduled sleep are beneficial; compared with a survival time of 4 days for the 0 hours sleep Platoon, 48% of the 1.5 hours sleep Platoon and 91% of the 3 hours sleep Platoon survived for the full 9 days. Tasks with a mainly physical content suffered least, and those with a cognitive and vigilance component suffered most, deteriorating to about 50% of control values over the first 4 days of sleep loss. Experienced military observers considered that physical tasks were carried out at an acceptable level by the 0 hours sleep Platoon for 3 days, by the 1.5 hours sleep Platoon for 6 days, and by the 3 hours sleep Platoon for 9 days.

Exercise Early Call II

A militarily realistic regime, but one previously unstudied in the field, is one which demands, without remission, several days of continuous activity, followed by a period of less intense activity, during which short periods of rest are possible. With this in mind, and based on the results for Early Call I, the design of Early Call II (Haslam, 1978) was for 3.75 days of continuous activity followed by 6 days when there was limited opportunity for sleep.

With regard to recovery, it was found in Early Call I that after 3 days rest in camp following the 9-day sleep deprivation period, performance was restored to its initial level. As stated earlier, during the recovery period, EEG records for 2 subjects suggested that after only one day, the sleep patterns on the second night were little different from base line patterns. This raised the question as to whether 2 days, or even one, would be sufficient to restore efficiency to its initial level. It was decided, therefore, in Early Call II to examine the effect of 1.25 days of rest following the 9-day exercise.

Methods

Subjects. Ten members of the APRE Trials Team, formed into a Rifle Section of 2 non-commissioned officers and 8 other ranks, were the trial subjects. They were all trained Infantrymen, with an average age of 23.9 years, range 21-26.

Subject briefing. Before the trial began, the subjects were briefed about the sleep regimes and the duration of the trial; they were also briefed on the nature of the medical and physiological activities in the Exercise period. All were required to declare any current illness, disability or medication. At that time, all were fit. In addition to the above, subjects were briefed on signs of hypothermia. Further, they were told that they would be withdrawn from the trial by the Senior Medical Officer-in-Charge if he thought they were unfit to continue.

Trial design. During the first 90 hours of the trial (Exercise 1) there was no scheduled sleep, after which there was a schedule of 4 hours block sleep in every 24 hours for the following 6 days (Exercise 2). This 9-day period was preceded and followed by a 2-day control period when 6 hours block sleep per 24 hours was allowed; the first of the control periods was preceded by one day of training, and the second by 30 hours of rest. Twenty four hour medical coverage was provided during all phases.

Military aspects of the trial. The trial took the form of a tactical exercise, and a full Section defensive position was dug, camouflaged and occupied. Surprise attacks by "enemy" troops were countered and other activities included, for example, mine-laying, mine-clearing, First Aid, and "casualty" evacuation. In order to prevent sleep occurring, there were many other activities throughout each 24 hours; tests and assessments took up much of the day and night.

Environment. The trial took place in the south of England, during winter months. Basic meteorological data were collected; these included rainfall, air temperature, and windspeed.

Objective measures. In order to assess shooting, cognitive functioning, and physical fitness, subjects were taken daily to various ranges and test sites. This entailed traveling 26 miles per day in a 4-ton vehicle.

Subjective measures. In addition to the above objective measures, subjective assessments were made by military observers of the subjects' military effectiveness or "fitness to fight" and also of their morale; the subjects

assessed their own mood daily by means of a questionnaire.

Observers. Throughout the trial, military and civilian staff observed the subjects for 24 hours a day. In addition to assessing the various activities carried out during their shift, their duty was to ensure that subjects had no unscheduled sleep, for example, while in the defensive position or traveling to and from the ranges.

Military Tests

Vigilance shooting. The same test was used as in Early Call I, but it was carried out on an electronic target range (ETR), and all 10 subjects were tested together.

Grouping capacity. Although in Early Call I no overall deterioration was found, it was decided that, while using grouping for zeroing purposes, a measurement would be made of the group. This assessment, therefore, had less reliability than the earlier test.

One group of 5 rounds was fired at a range of 100 m and measurements were made to the nearest quarter-inch. Greater variation would, of course, be expected than in Early Call I because of the shorter range in that trial.

Cognitive Tests

The 2 most sensitive tests used in Early Call I were selected and lengthened: a 20-minute Logical Reasoning Test modified from Baddeley (1968) and a 10-minute decoding test (Dudley et al., 1972). On the experimental days, test sessions were at 1300 hours, 0100 hours, and 0545 hours. During the control days there was only one session daily at 1300 hours because subjects slept from 0045-0700 hours. Due to a circadian effect, performance would be expected to be better at 1300 hours than at the other 2 times of testing. During Exercise 2, performance on awakening was assessed.

Electroencephalography

During this trial, the EEG activity of all 10 subjects was continuously monitored for the 15 days of the trial, again using Medilog recorders.

Physiological and Biochemical Measures

The aim of these assessments was to detect and measure any change in physiological state during the exercise, with particular reference to physical fitness. The following methods were used:

(1) Anthropometry: Height, weight, and skinfold thickness at 4 sites;
(2) Electrocardiography: 12 leads (resting; supine);
(3) Blood pressure measurement: 3 automatic reading at 120 second intervals after a period of rest (supine) during electrocardiography;
(4) Pulmonary assessment: Total expired volume and forced expiratory volume 1 second (Vitalograph);
(5) Isometric muscle strength (static);
(6) Estimated maximum oxygen uptake: 12-minute, 4-load sub-maximal bi-

cycle ergometer test;
(7) Haematological and biochemical assessment of venous blood on 8 control and exercise days;
(8) Six-hourly urine collections;
(9) Rectal temperatures for 24 hours with leads connected at 15-minute intervals during 2 control days, the first during the week preceding the exercise, and the second during the Recovery Day.

Assessments (1)-(6) were made between 2000 and 2330 daily. Each subject was involved in testing for approximately one hour. Subjects were put through the assessment battery in pairs in the same order each night; the requirement to combine physiological assessment with 2 other activities sharing the same block of time precluded random processing.

The order of testing, with the exception of 2 interchangeable parallel blocks of activity, was constant. This was determined by the need to achieve the maximum relaxation for electrocardiography and blood pressure measurement and to retain bicycle ergometry and venepuncture as the last activity.

Subjective Measures

In order to assess mood, subjects completed daily at 1230 hours the 'Profile of Mood States' (McNair, Lorr, & Droppleman, 1971). This questionnaire includes the factors of tension, depression, anger, confusion, fatigue and vigour; these can be summed, with vigour weighted negatively, to give a Total Mood Disturbance score. In addition, and as stated above, the military observers assessed the subjects' overall effectiveness and morale.

Results

Subjects. In spite of a few minor complaints such as colds and headaches, all 10 subjects completed the trial in good order. Three factors probably contributed to this:

(1) each evening they spent 3 hours in a warm building for physical fitness tests and servicing of EEG recorders;
(2) the amount of physical exercise was moderate, especially after the initial digging-in period;
(3) they were protected from wind and rain by rainproof overgarments.

Weather. The weather was typical for the time of year. During the sleep deprivation days, maximum and minimum temperatures ranged from 10.7°C to -3.2°C. On 5 of these days, there was rainfall, the amount ranging from 0.71 mm to 24.79 mm.

Military Tasks

Vigilance shooting. As can be seen in Figure 8, the general trend of performance was U-shaped. The visit of a VIP to the range on the third day of sleep loss may have affected alertness, leading to the observed upswing in scores on that day. Overall, performance deteriorated 20% from a mean control value of 68% of targets being hit. Recovery to this value had occurred by Day 6 (i.e., after 3 nights with 4 hours block sleep per night).

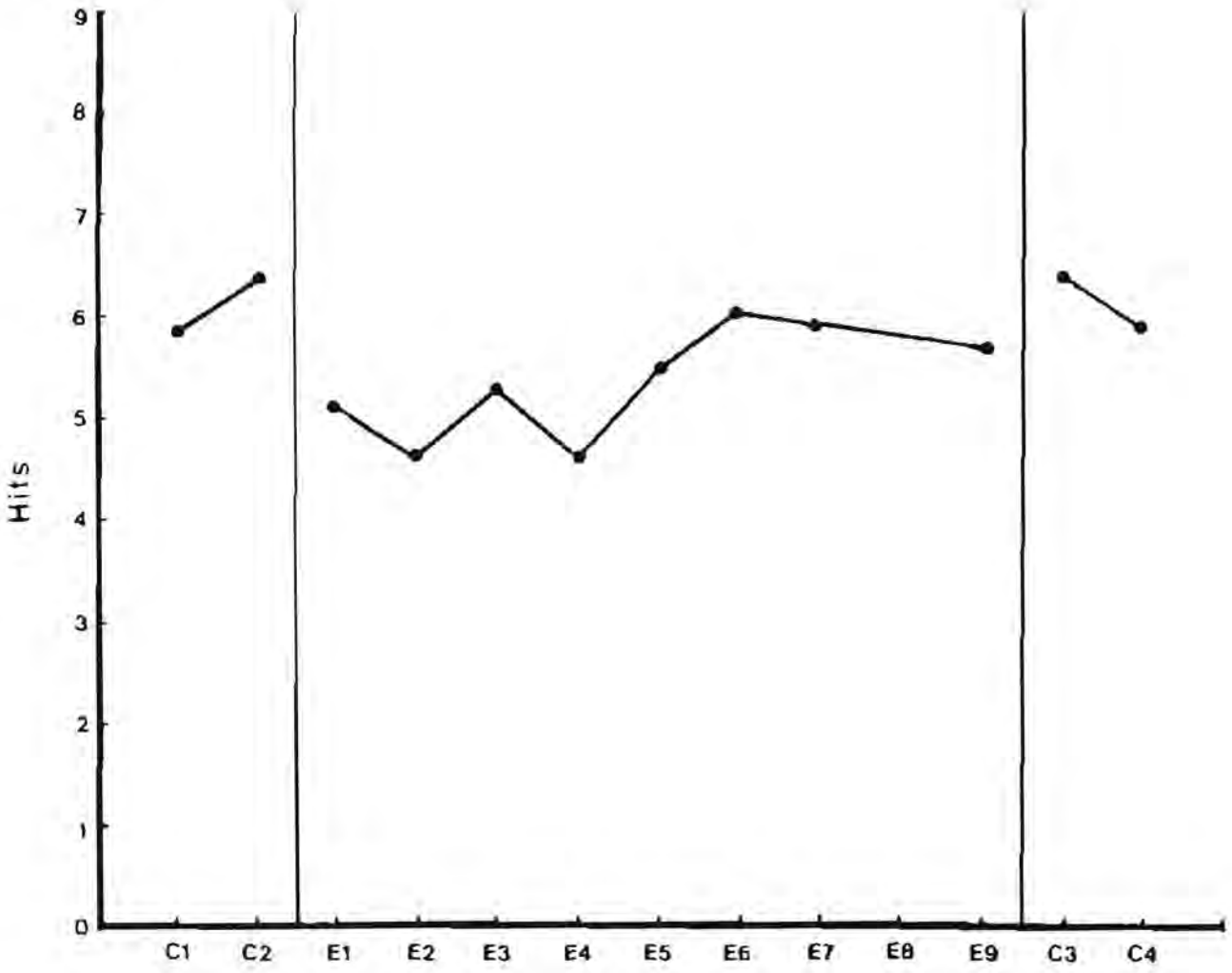

Figure 8. Vigilance Shooting. Average number of hits.

Analysis of variance indicated that scores on sleep deprivation days 1-3 and also on 4-6 were significantly worse than on control days ($p < .01$ and .05, respectively). However, performance on Day 7 and Day 9 was not significantly different from that on control days.

Grouping capacity. In spite of only one group being fired, the basic stability of the measure is indicated by mean scores for the control days which varied little. As can be seen in Figure 9, there was a small amount of variation in average performance over the sleep deprivation days, and an increase in group size of 4.3 inches on Day 5 compared with Day 4. Analysis of variance with selected contrasts indicated that performance on Days 4-6 was significantly worse than on Days 7 and 9 ($p < .05$) and also than on the control days ($p < .001$); it was not, however, significantly different from Days 1-3.

Cognitive Tests

Logical reasoning. During the 0545 hours test sessions in Exercise II i.e., Days 4-9), it was apparent that most of the subjects were unable to start the Logical Reasoning test within 5 minutes of awakening. Scores, therefore, were derived from a 15-minute test, and in order that all sessions should yield scores from tests of comparable length, the first 5 minutes were excluded from the statistical analysis for the other 2 sessions. The mean number of correct responses per page of the test for the 3 sessions can be seen in Figure 10.

By the third day without scheduled sleep, the average score of the 3 sessions (1300, 0100 and 0545 hours) was approximately 35% of the control value. With 4 hours scheduled sleep per night, performance during 1300 hours and 0100 hours sessions showed an overall improvement to a mean value of approximately 80% of the control value on Day 6; 60% of the control value was reached on Day 4, i.e., after 4 hours sleep. On Days 7-9 performance evened out at approximately 83%. However, at 0545 hours it remained at an average level of approximately 35% of the control value for the remainder of the exercise. Part (about 5-10%) of this decrement was presumably due to a circadian effect and a further part to an awakening effect. An unexpected finding was that performance at 0100 hours was better than at 1300 hours. [It should be remembered that on Day 4 at 0100 hours, subjects had not had their 4 hours scheduled sleep.]

Decoding. Figure 12 gives mean scores for the 3 sessions. By Day 3, the average score for the 3 sessions was approximately 50% of the control value. By Day 6, the mean performance level of the 1300 and 0100 hours sessions had recovered to approximately 85% of the control value; after only 4 hours sleep it had recovered to 80%. On Days 7-9, performance leveled out at approximately 90%. At 0545 hours, however, the average level was approximately 66% for the remainder of the trial.

Electroencephalography

At the time of writing, the EEG analysis is incomplete, and covers the second control day, the first 4 days of sleep loss, and also the last day of the deprivation phase. So far as they go, the results support those of Early Call I in as much as there were increasing amounts of unscheduled sleep over

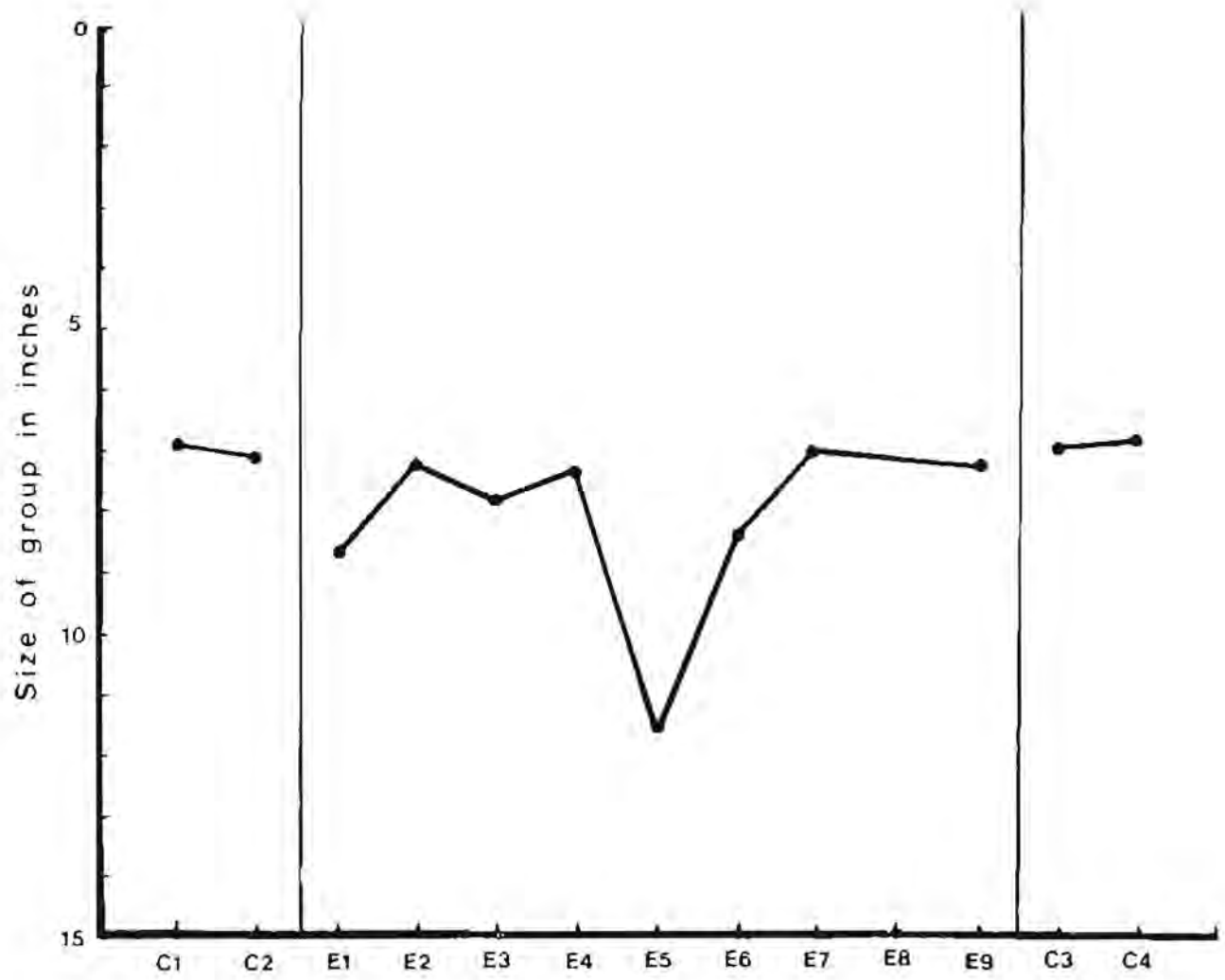

Figure 9. Grouping Capacity. Average size of group in inches.

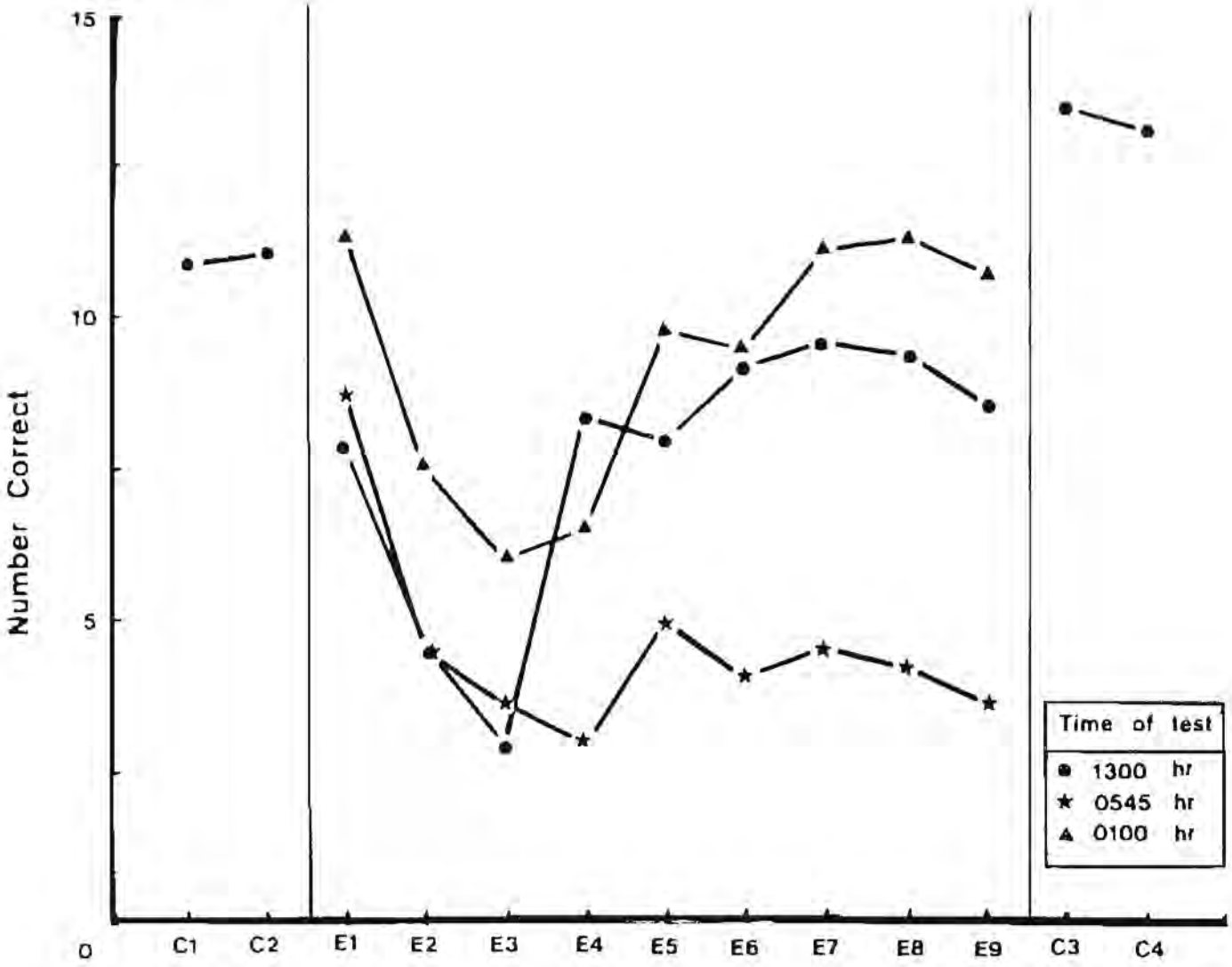

Figure 10. Logical Reasoning. Average number correct per page at different times of day.

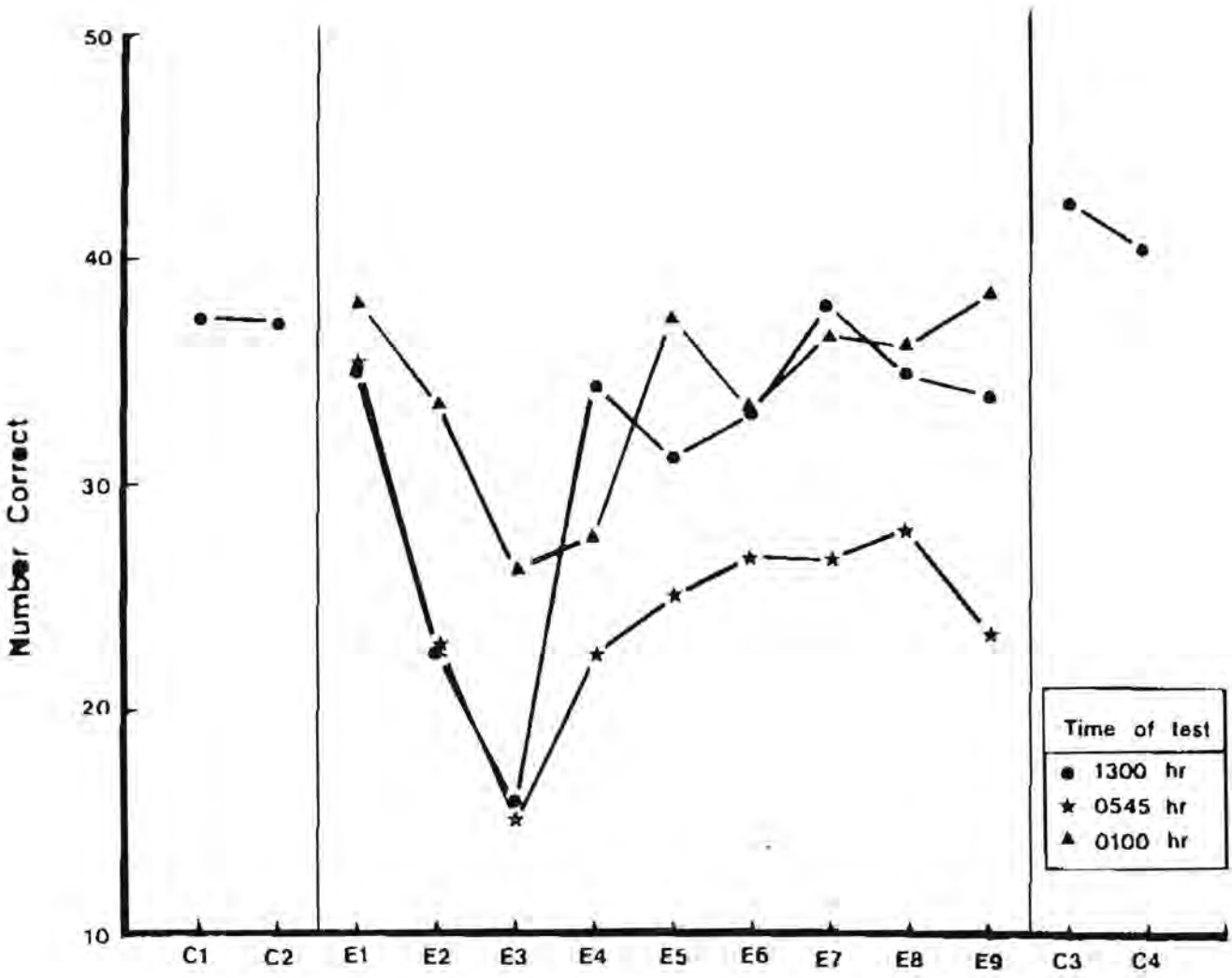

Figure 11. Decoding. Average number correct at different times of day.

Day 1 to Day 3, that is, until the first period of 4 hour scheduled sleep, and there were also increasing amounts of alpha activity. The average amount of unscheduled sleep during the whole of this period was approximately one hour.

It is of interest that one period of 4 hours sleep was enough to reverse the trend of increasing unscheduled sleep and increasing amounts of alpha activity although not enough to abolish them altogether.

Physiological and Biochemical Measures

No change in physiological status or physical fitness, defined here as strength and stamina, was observed, except that which lies within the limits of experimental error. No trend within the limits of experimental error was demonstrated.

With regard to rectal temperatures, the lack of change in the circadian pattern in the 2 control periods does not exclude the possibility of a shift having occurred at some point during the 10 intervening days with complete subsequent reversion to the former pattern. In addition, no adverse effects to the imposed regime were detected by the simple biochemical methods used.

Subjective Measures

Profile of mood states. Analysis of variance indicated that for all measures scores were significantly worse on the experimental days than on the control days ($p < .01$ or .001 in all cases). With the exception of fatigue, all scores were lowest on Day 5 (after 2 nights with 4 hours sleep), with gradual partial recovery to Day 8 or 9. Figures 12 and 13 show mean scores for Total Mood Disturbance and Fatigue. As can be seen in these figures, mood did not fully recover to pre-deprivation levels until after the Recovery Day, during which an approximate average amount of 19.5 hours (range 17-22) sleep was taken.

Military effectiveness. By Day 2, the subjects' movements, reactions, and speech were becoming slower. Four hours sleep, however, had a marked effect in that on Day 4, subjects were much more alert.

In response to simulated attacks by the "enemy" in the early hours of the morning, weapon handling deteriorated over the sleep deprivation days. It was not possible to observe the soldiers' defensive tactics on the nights of Day 4 to Day 9 because on these nights they slept from 0145-0545 hours. As in Early Call I, morale remained high (except for Day 5), and a relaxed leadership style was found to be effective when dealing with tired soldiers.

Discussion

Military Tasks

Vigilance shooting. Although with no scheduled sleep, performance decrement was only 20% compared with control values, this test was an indicator first of the effect of total sleep deprivation, and then of the effect of 4 hours sleep per 24 hours. The recovery which had occurred by Day 6 was maintained to Day 9.

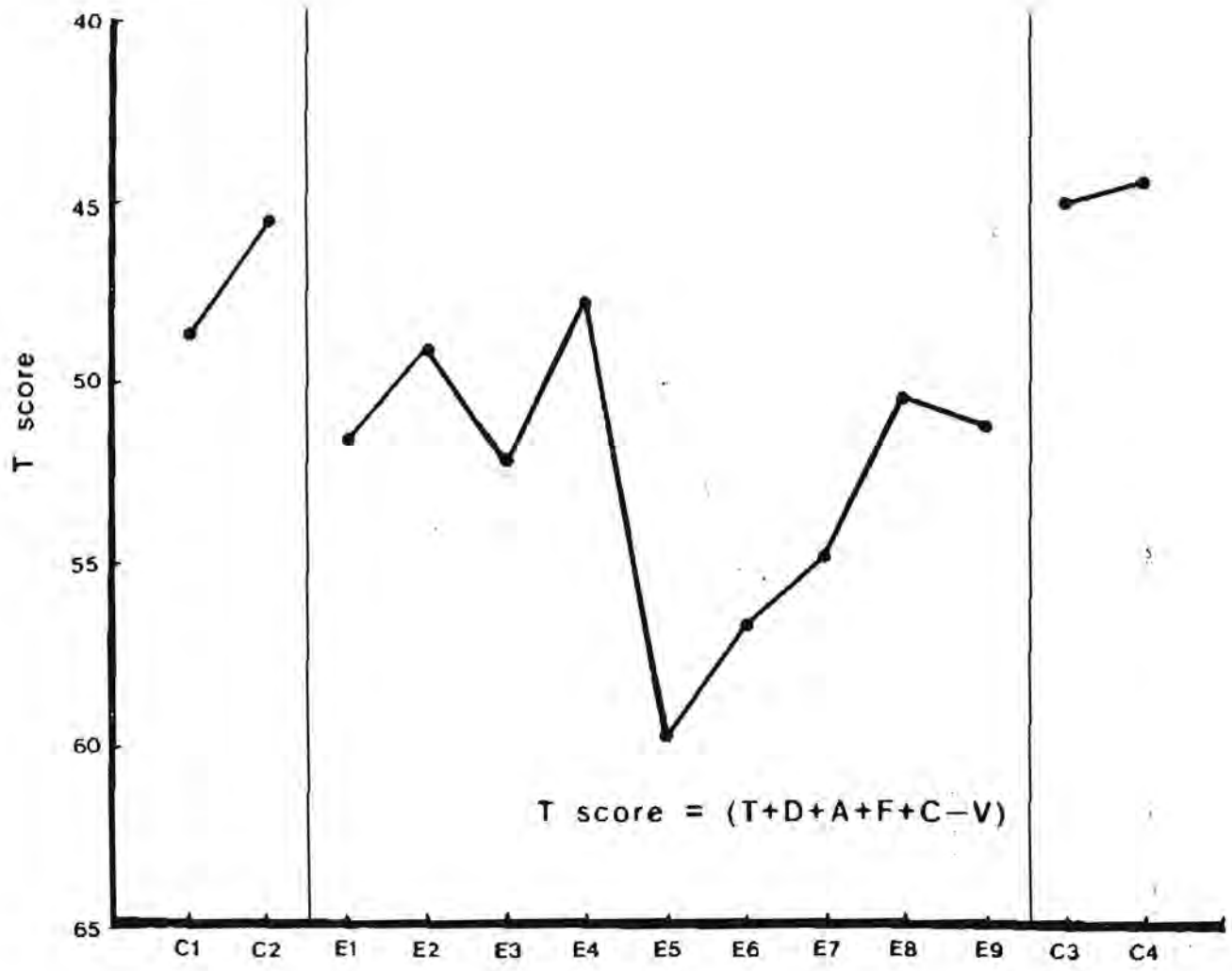

Figure 12. Profile of Mood States: Total Mood Disturbance average score.

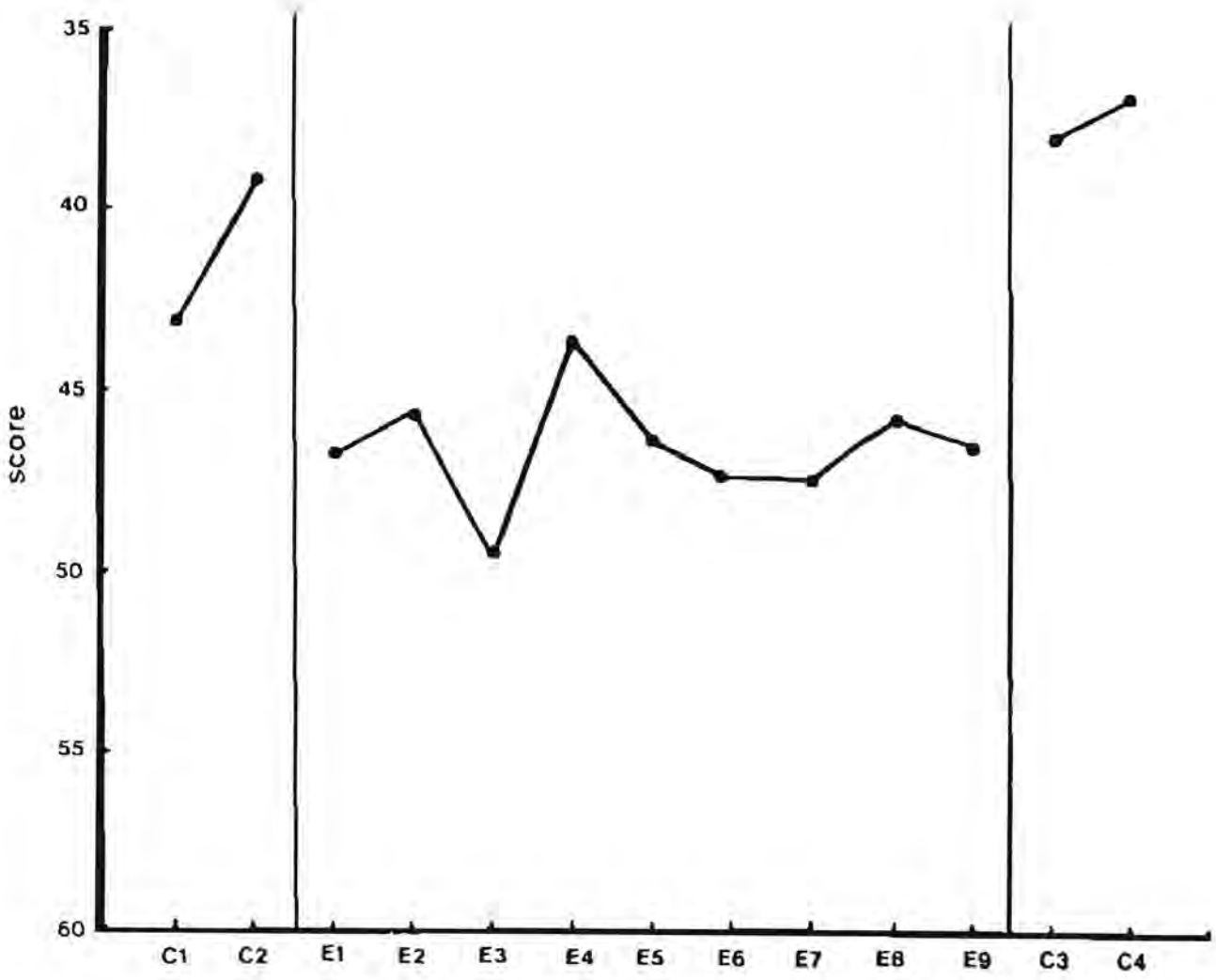

Figure 13. Profile of Mood States: Fatigue average score.

When the present results are compared with those for Early Call I, it can be seen that approximately the same percentage decrement was observed for the Platoon who had no scheduled sleep for 3 days. For the other 2 Platoons, one of which had 3 hours and the other 1.5 hours scheduled sleep in 24 hours, performance on the ninth day of sleep deprivation had deteriorated to the level where 37% and 28%, respectively, of the targets were hit.

Over the 9-day sleep deprivation period, the 1.5 hours sleep Platoon had a total of 13.5 hours scheduled sleep and the 3 hours sleep Platoon had a total of 27 hours scheduled sleep; these amounts span the Early Call II quota when subjects had a total of 24 hours scheduled sleep in 9 days.

Although it is interesting to make these comparisons, no further comment is justified because of the different conditions of the 2 trials.

In any event, 4 hours block sleep was found to have recuperative value for vigilance shooting performance, following a decrement when there was no scheduled sleep.

Grouping capacity. The drop in performance on some tasks on Day 5 was probably due less to sleep loss than to weather conditions, because a cold wind blowing in the subjects' faces that morning. The biggest fall in mood was also on Day 5. On that day, there was a change for the worse in the washing facilities and the subjects were told about this at midday by the military advisor to the trial. Grouping was carried out at 0900 hours; poor performance on Day 5 cannot, therefore, be attributed to the above. Apart from this drop, there was no statistically significant variation over the trial, and in this way the results are similar to those for Early Call I.

The results confirmed expectations that no overall deterioration would be found in grouping, a self-paced, well-learned task which was carried out under as controlled conditions as possible.

Cognitive Tests

Logical reasoning and decoding. The unexpected finding that performance in the Logical Reasoning test, and on Days 1-3 in the Decoding test also, was better at 0100 hours than at 1300 hours is probably attributable to the fact that subjects had recently been in a warm, dry building for 3 to 4 hours while carrying out the Physical Fitness tests. [It will be remembered that in Early Call I there was a marked improvement in nearly all tests after one night in camp, which subjects left immediately prior to their cognitive test session.]

The results indicate a drop in Logical Reasoning performance after one night without sleep, and in Decoding, a more mechanical task, after 2 nights without sleep. As little as 4 hours sleep clearly had a marked beneficial effect, except for Logical Reasoning at 0545 hours. This is the time of day when performance is usually at its worst (Colquhoun, Blake, & Edwards, 1968), and also when there is maximum interaction between sleep loss and circadian effects (Johnson & Naitoh, 1974). However, in this trial, there was an added effect, attributable to awakening. This effect has been shown to impair performance, with drowsiness persisting for at least 15 minutes in non-sleep-deprived subjects (Wilkinson & Stretton, 1971). For subjects suffering from

loss of sleep, the effect may well last longer than this, and in this case would account for the less marked improvement at 0545 hours in the Decoding test compared with performance at the other two times of testing.

When considering these results, it should be remembered that in this trial there was no real spur to awakening, such as a threatening or demanding situation, to provide an arousing stimulus.

To sum up, it can be said that cognitive functioning began to deteriorate following one night without sleep, and on the third day of sleep loss was considerably impaired.

Four hours sleep per 24 hours had a beneficial effect which was less marked at 0545 hours than at 1300 and 0100 hours.

Electroencephalography

Physical activity. Quantifiable changes in physical activity, indicated by eye movements, movement artifact, and muscle activity, were recorded by the EEG, although no change in physical fitness was detected by a battery of 8 other physiological assessments. The EEG changes were in accordance with the qualitative observations made by directing staff, and corresponded closely with self-rated fluctuations in fatigue and vigour.

Sleep. One of the difficulties encountered in an exercise of this kind is that of ensuring that the amounts of sleep obtained coincide with the amounts planned and observed. In Early Call II, the tape recorders showed that:

(1) in the day in which 90 hours without sleep was reached, the average amount of unscheduled sleep was only 47 minutes;
(2) in the day following the first 4 hour sleep period, this amount was reduced to 17 minutes;
(3) the amounts of unscheduled sleep recorded agreed closely with those noted by observers.

Alpha Activity. In Early Call I, alpha activity was most prominent in the subjects on the "no sleep" schedule, and increased as sleeplessness accumulated in parallel with unscheduled sleep. This pattern was confirmed in Early Call II in a larger and more completely recorded group.

The general trend was for amounts of alpha activity to increase with sleeplessness and amounts of adventitious sleep in the group. To this extent, alpha activity could be regarded as akin to sleep, perhaps a half-awake state. Although some of the alpha activity was indeed "paradoxical alpha", i.e., alpha occurring in response to stimulation in a drowsy or lightly asleep subject, the greater part of it was not.

To sum up, it can be said that:

(1) There was a clearly demonstrable and quantifiable impairment of cerebral function as well as military performance in the absence of sleep for more than 48 hours;

(2) The effect could be offset to a limited but useful extent by as little as 4 hours sleep per day;
(3) It is felt, for various reasons that cannot be discussed here in the interests of brevity, that the stimulus of battle is unlikely to be sufficient to offset the impairment adequately.

Physiological and Biochemical Measures

The results show no change in physical fitness or in any other aspect of physiological status of any statistical significance or military importance. However, there remain a number of factors relating to experimental method and the nature of the trial which must be discussed before any predictions concerning operational performance can be considered valid.

The subjects were assessed in dry, well-lit and relatively warm conditions; this may have affected their physical status and performance to such a degree that the results may not reflect their condition as it was during the same period in the field. This hypothesis would, however, require a systematic difference in results between those who were consistently assessed at the beginning of the 3-hour period and those who consistently entered the physiological battery at the end of the 3-hour block. There was no such difference.

The lack of change in physical fitness, as measured, must be interpreted within the pattern of work rate demanded by trial tasks. With the exception of the early stages of establishing the defensive position and some of the military tasks, the trial was not physically demanding. It cannot be assumed that stability of stamina and strength would have been sustained had a greater level of physical demand been imposed within the same type of continuous operations scenario.

With regard to the absence of adverse biochemical findings, the psychological concomitants of an emergency cannot be reproduced during a controlled exercise, and it is emergency or threatening situations that are likely to induce biochemical changes.

Subjective Measures

Profile of mood states. The biggest fall was also on Day 5. On that day, there was a change for the worse in the washing facilities, and the subjects were told about this at midday [Grouping was carried out at 0900 hours; poor performance on Day 5 cannot, therefore, be attributed to the above.] by the military advisor to the trial. It is worth noting that the withdrawal of a privilege from tired soldiers can result in a deterioration in mood far greater than that induced by sleep-loss itself.

On the first control day following the rest day, subjects reported that they felt completely recovered. This was supported by the observers' accounts of boisterous and cheerful behaviour, and was reflected in the Mood Profile scores.

Military effectiveness. These results for weapon-handling can be compared with those for Early Call I when little deterioration was observed in the formal weapon-handling tests. Probable reasons for this discrepancy are

that in Early Call I, the tests were carried out during the day in a situation in which there was no other activity whereas, in Early Call II, weapons were handled in the early hours of the morning in a tactical situation which, judging by their reactions, the subjects found stressful.

Thus, even well-learned skills have been found to break down in sleep-deprived subjects under stress at a time of day when performance has been shown to be at its worst (Colquhoun et al., 1968).

Conclusions

In summary, it can be said that cognitive and vigilance tasks began to deteriorate after one night without sleep, and, after 3 nights without sleep, performance on these tasks was considerably impaired. The introduction of 4 hours block sleep following 90 hours in which there was no scheduled sleep (and very little unscheduled sleep) had a marked beneficial effect upon performance and mood, and an average amount of 19.5 hours sleep at the end of the 9-day trial eliminated any remaining decrement.

Throughout the exercise, in which the amount of physical activity was moderate, there was no physiological evidence of deterioration in physical fitness; there was EEG evidence of alterations in cerebral function.

General Conslusions

To summarize, in exercises without combat stress,

(1) the effects of sleep loss are psychological rather than physiological;
(2) even small amounts of sleep are beneficial;
(3) with increasing sleep deprivation, there is an increasing likelihood of physiological sleep patterns developing in the brain;
(4) a hostile climate interacts with sleep loss and influences "survival" times.

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PROCEEDINGS

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Public Health Service
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THE TWENTY-FOUR HOUR WORKDAY: PROCEEDINGS OF A SYMPOSIUM ON VARIATIONS IN WORK-SLEEP SCHEDULES

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