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Sleep in the M-40 mask: Sleep quality, mask fit factor
and next day performance.

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This study was designed to determine whether nighttime sleep is substantially disrupted when soldiers wear the M-40 chemical protective mask. Nine male volunteers participated. On four test nights they wore the mask while on four control nights they slept without it. During each test night the duration and fragmentation of sleep were assessed using a wrist-worn activity monitor. Total sleep time significantly declined and number and length of awakenings increased when soldiers wore the mask. There were considerable individual differences in ability to sleep while wearing the M-40 mask. Some soldiers had comparatively little difficulty sleeping in the mask while others were extremely restless throughout the night. Subjective sleep quality as measured by self-report questionnaires was also significantly degraded by the mask. Mask fit-integrity during sleep was continuously assessed using the Portacount™ mask fit-validation device. There was considerable variability in the extent of protection provided by the mask over the night. Some soldiers were protected throughout the night but others were only protected intermittently. Residual day time effects of the mask wear were present: error rates on a choice reaction time task increased and performance on the SynWork task was degraded.

INTRODUCTION

During future military operations soldiers may be required to wear chemical protective masks during sleep, as illustrated by the nighttime SCUD attacks during Operation Desert Storm. Policies and procedures for safely sleeping in the chemical protective mask need to be established. It is not known whether specific masks offer reliable protection during sustained periods of sleep or whether sleep quality is degraded under such conditions. In addition, little data are available on possible decrements in daytime mental performance following sleep while wearing a protective mask. To begin to address these issues the Joint Operational Test and

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Information Directorate (JOD), Dugway Proving Ground, requested that a study be conducted to determine the consequences associated with sleeping in the chemical protective mask.

The primary purpose of this project was to determine whether the quantity and quality of sleep were substantially disrupted by sleeping in the M40 mask. Therefore, the duration and fragmentation of sleep were assessed using unobtrusive, wrist-worn activity monitors and subjective sleep quality using self-report surveys. Because sleeping in a mask is of little value if it fails to provide effective protection against attack, mask fit-integrity was assessed using a mask fit-validation device. Similarly, there is little reason to be concerned about mask-induced changes in sleep if military performance during waking periods is unimpaired. Thus, daytime cognitive performance and mood were measured.

METHOD

Subjects

Nine healthy male soldiers, aged 19-25, (mean age \pm SEM = 20.33 \pm 0.65) volunteered to participate in the study. They were fully briefed on the purpose and requirements of the study and potential risks and benefits of participation. Before participation all subjects were medically screened.

Materials/Apparatus

Chemical protective mask. The M40 mask was developed to improve fit integrity without sacrificing comfort. It consists of a face-blank with an in-turned periphery and two rigid lenses mechanically attached to the facepiece. The air-filtering medium is a single, side-mounted, external canister that is interchangeable with those used by NATO countries.

Activity monitors. The duration and fragmentation of sleep were measured using an unobtrusive, wrist-worn activity monitor, the Motionlogger Model AAM-32. Data from these monitors have been validated with traditional EEG-based polysomnography. They were found to reliably measure the duration and pattern of sleep and to reliably distinguish between sleep and waking (Cole and Kripke, 1988; Webster et al., 1982; Sadeh et al., 1989).

Post-Sleep Evaluation. The subjective quality of each night's sleep was assessed using a 24 item post-sleep evaluation questionnaire.

Protective mask fit validation system. The Portacount device (Model 801; TSI Inc., St. Paul, MN.) is a portable, mask seal integrity tester which uses a miniature condensation nucleus counter (Laye, 1987; Mauroni and Walden, 1991). The Portacount assessed fit factor continuously in 40 second epochs.

Performance Tasks. Two computer-based, performance tasks were administered twice each day, at 0900 and 1400. Subjects practiced each task on multiple occasions before the start of mask/sleep testing. A test of four choice visual reaction time was administered on a laptop microcomputer (Grid Compass II, Model 1131) (Banderet and Lieberman, 1989; Lieberman et al., 1990.) A

"synthetic work" task (Elmore, 1991) was run on an MS-DOS compatible desktop computer equipped with a Soundblaster audio board, headphones, mouse and color monitor. The mouse was used to perform all the tasks. This desktop-computer simulation incorporates workload, resource sharing, and contingency factors that simulate a variety of military tasks. The program, SynWork, requires continuous attention to four tasks, each of which taxes a different sensory or cognitive process, while the subject is working toward a superordinate goal. During each 20 minute test session the screen was divided into four quadrants with a different task presented in each quadrant. A small window in the center of the screen displayed the subject's score. A Sternberg memory task was presented in the upper left quadrant of the screen and an arithmetic task was presented in the upper right quadrant. In the lower left quadrant a visual monitoring task was presented and an auditory vigilance task in the lower right quadrant. Instructions to the subjects emphasized the goals of maintaining vigilance, sustaining high work rates, and attaining high total scores.

Mood Questionnaires. Three standardized mood questionnaires were administered on a laptop computer following performance testing: the Profile of Mood States (POMS) (McNair et al., 1971), the Stanford Sleepiness Scale (SSS) (Hoddes et al., 1972), and the Environmental Symptoms Questionnaire (ESQ) (Sampson and Kozbrick, 1980).

Procedures

Prior to the start of the test every subject was individually fitted with his own M40 mask by trained technicians. Adequacy of fit for every subject's mask was assessed using the Portacount fit tester. On the first three days of the study, before the start of testing, subjects wore the mask, without the hood, for a total of approximately three hours, to familiarize them with mask wear. Upon completion of training and accommodation to the experimental sleeping conditions, subjects slept in the mask, without the hood, for a total of four nights over a two week period. On each week of testing a subject slept in the mask for two consecutive nights and was also tested on two consecutive control nights without the mask. Sleep/mask and behavioral testing were conducted in a climate controlled test suite that provided a barracks-like sleeping environment.

RESULTS

Data were analyzed by repeated measures ANOVA. The fit factor data from the Portacount were initially averaged into 10 min. time blocks. Then an average nighttime mask penetration per subject was derived. All data are expressed as mean (\pm SEM) in the text and figures. Statistical significance was defined for each specific factor of each ANOVA performed as $p < .05$.

Mask Tolerance

Subjects were able to tolerate wearing the mask for most or

all of the night. However, upon request, several subjects, largely due to discomfort, were permitted to remove the mask for varying periods of time.

Sleep

Subjects' rest was significantly disturbed by sleeping in the mask as assessed by the wrist worn activity monitors (Fig. 1). Minutes of waking significantly increased on average, from 25 ± 2.1 to 86 ± 8.5 per night ($p < .001$) and number of awakenings rose from $8 \pm .59$ to $20 \pm .87$ ($p < .0001$). There was little significant evidence of adaptation to mask wear over the course of the study. There were considerable individual differences in ability to sleep while wearing the M40 mask.

The subjects' subjective evaluation of sleep in the M40 mask corroborated the activity monitor data. Subjects reported it took significantly longer and was more difficult to fall asleep when wearing the mask (Fig. 2). They also reported they woke more often, had difficulty falling back asleep when awakened, slept less soundly and were more restless when sleeping in the mask. They also felt considerably less rested upon awakening and less awake.

Mask Fit

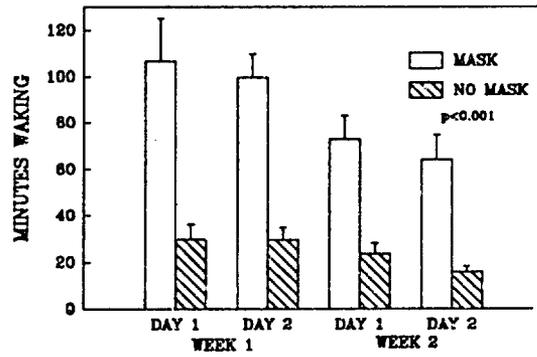
Although fit adequacy was verified each night prior to the start of the sleep period, mean fit factor varied greatly across subjects, indicative of considerable variability in the extent of protection provided by the mask over the night (Fig. 3). In general, fit factor decreased over successive nights of mask wear (Fig. 3).

Daytime Performance

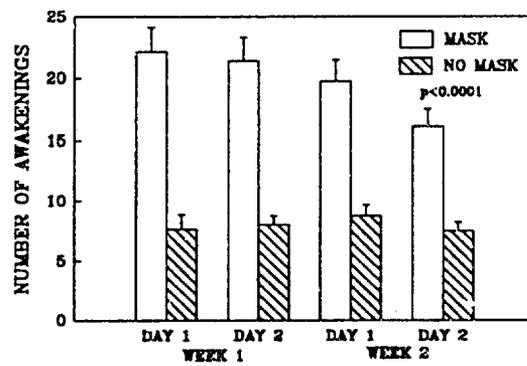
Performance on the four choice RT task was significantly impaired by sleeping in the mask the preceding night. Number of premature errors increased from a mean of $1.50 \pm .17$ when subjects did not wear the mask to $2.89 \pm .56$ ($p < .04$) when they did (Fig. 4). Similarly, number of time out errors (taking too long to respond) increased from $0.06 \pm .04$ when subjects did not wear the mask to $0.26 \pm .09$ ($p < .03$) when they did (Fig. 4). The SynWork program provides a number of measures of performance. Soldiers were told that the visual monitoring sub-task had the highest priority. Not surprisingly, high levels of performance were maintained on this task and performance showed little variability across days. In contrast, the most difficult sub-task, addition, was consistently degraded by mask wear, as was total score on the SynWork task (Fig. 5). Both total points and response rate were influenced by circadian fluctuations in performance. During the second week of the study, response rates were higher in the afternoon, while total score was lower, indicating compromised efficiency during the afternoon circadian trough.

FIGURE 1

SLEEP IN THE M-40 MASK
MINUTES OF WAKING: ACTIVITY MONITOR



SLEEP IN THE M-40 MASK
NUMBER OF AWAKENINGS: ACTIVITY MONITOR



SLEEP IN THE M-40 MASK
LENGTH OF AWAKENINGS: ACTIVITY MONITOR

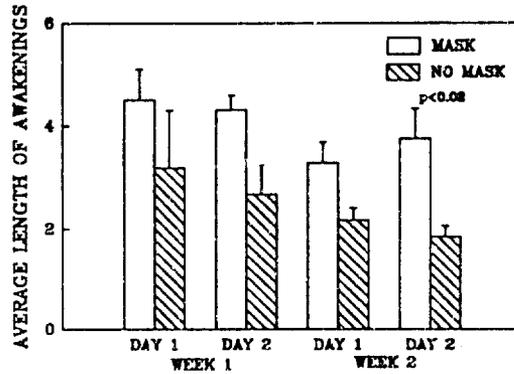
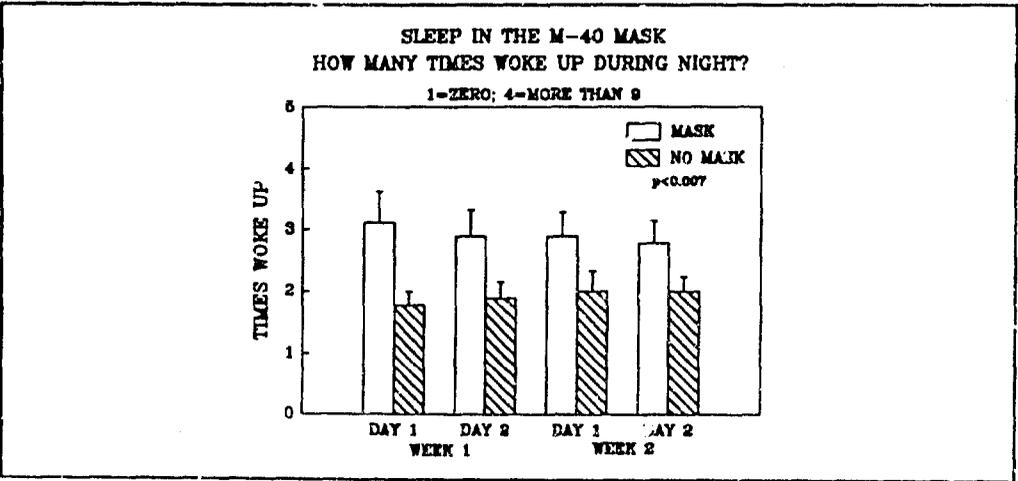
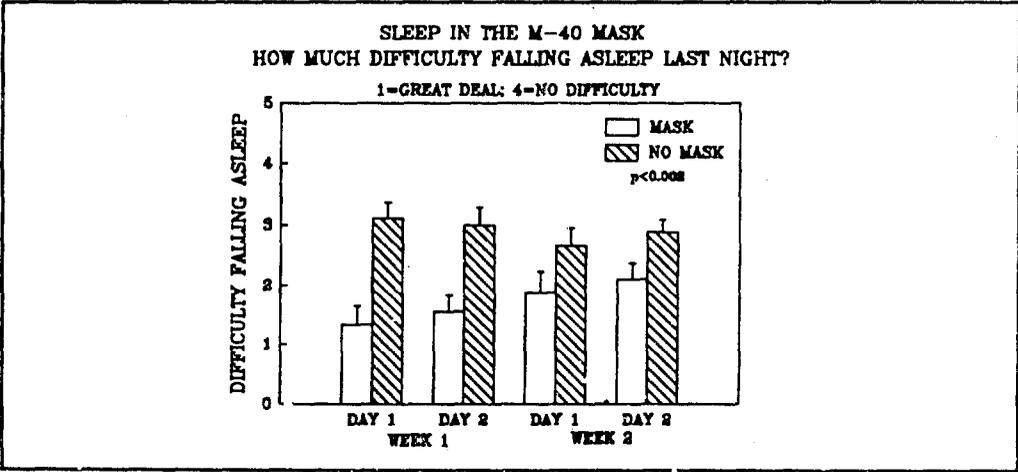
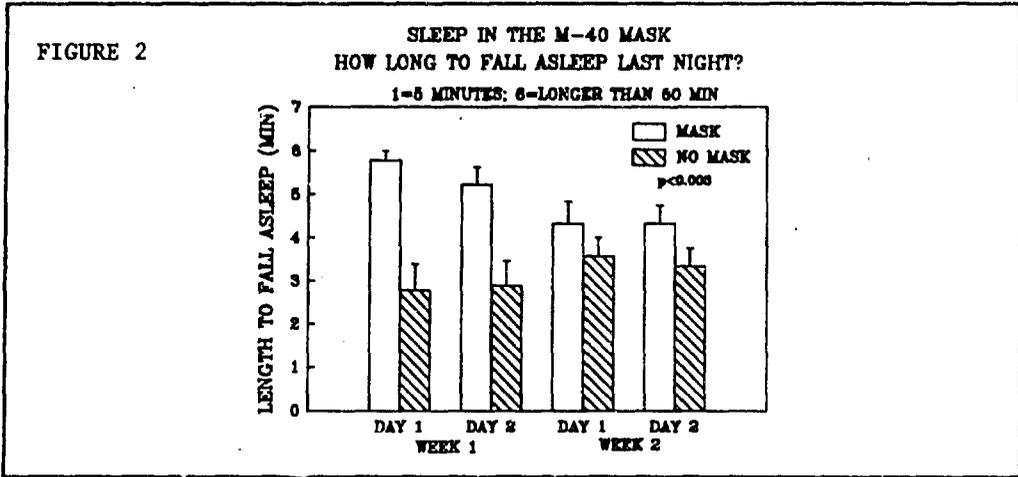
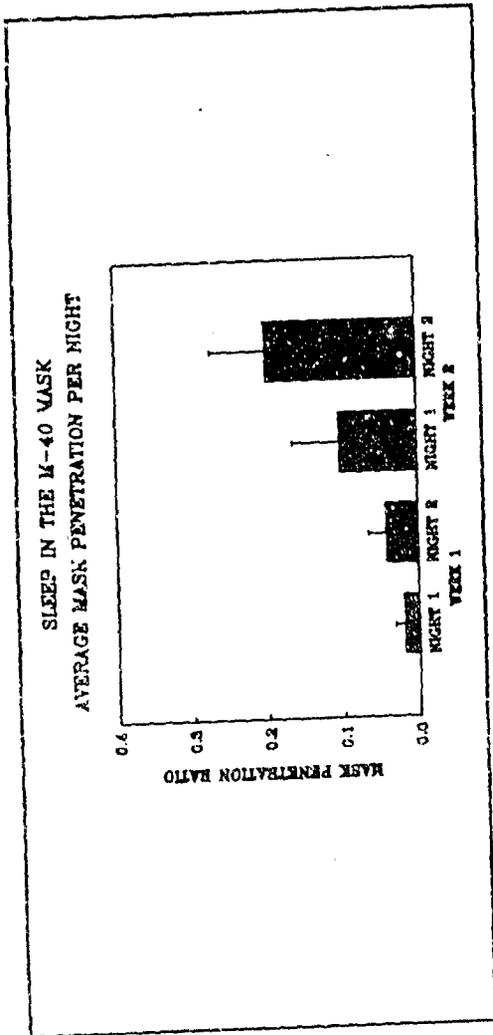


FIGURE 2





MASK FIT FACTOR RATIO
(DATA ABOVE LINE AT 1667 INDICATES PASS)

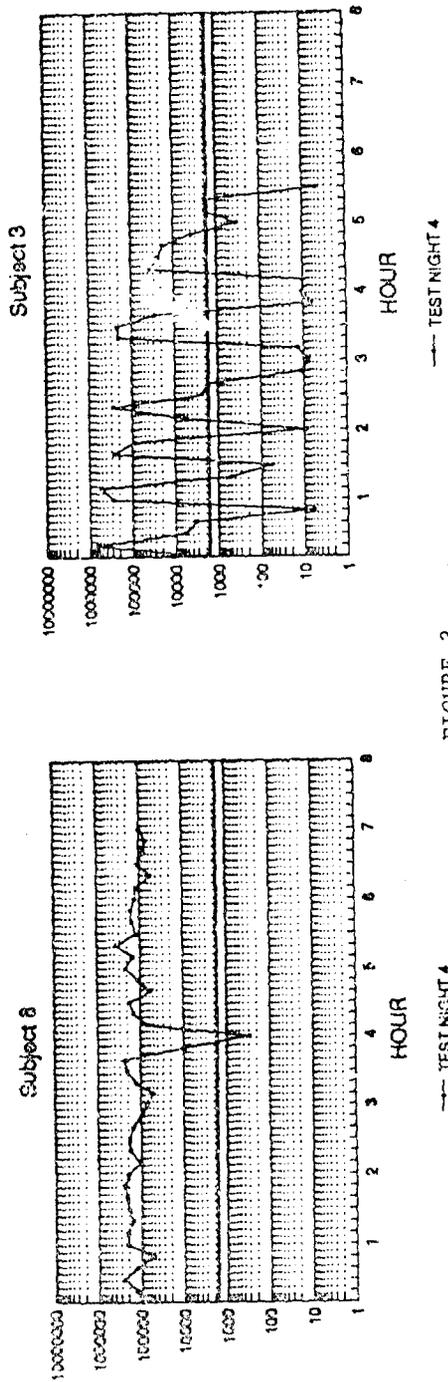
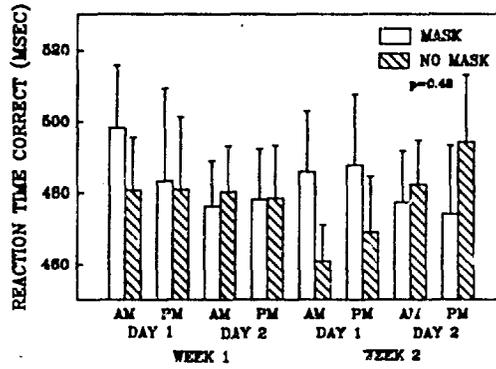


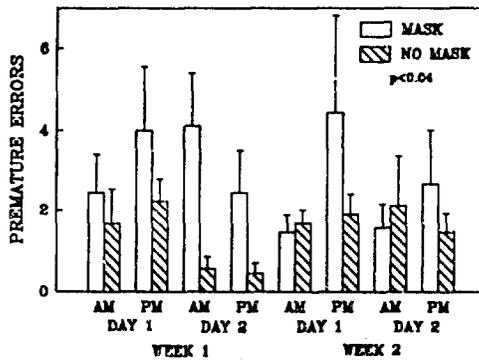
FIGURE 3

FIGURE 4

SLEEP IN THE M-40 MASK
CORRECT RT: FOUR-CHOICE REACTION TIME



SLEEP IN THE M-40 MASK
PREMATURE ERRORS: FOUR-CHOICE REACTION TIME



SLEEP IN THE M-40 MASK
TIME OUT ERRORS: FOUR-CHOICE REACTION TIME

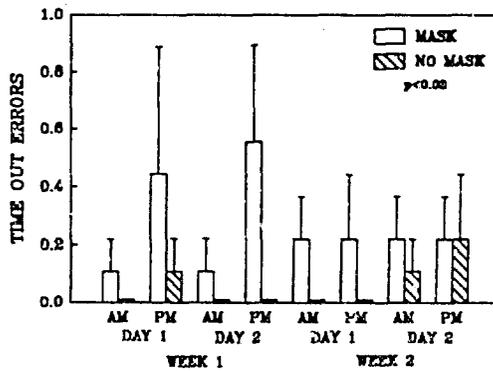
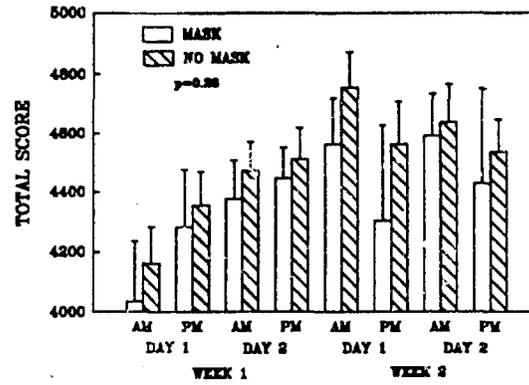
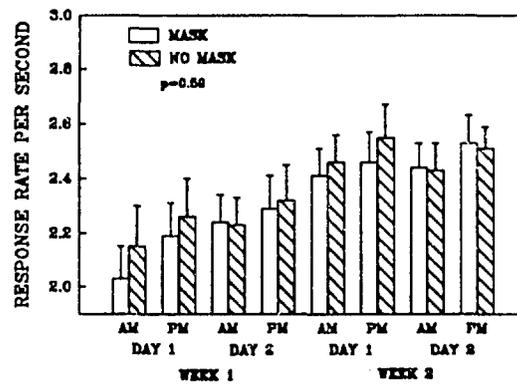


FIGURE 5

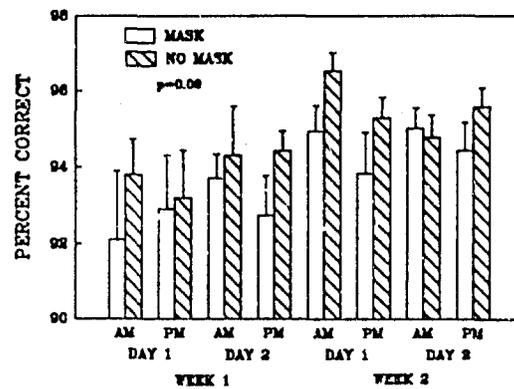
SLEEP IN THE M-40 MASK
SYNWORK: TOTAL SCORE



SLEEP IN THE M-40 MASK
SYNWORK: RESPONSE RATE



SLEEP IN THE M-40 MASK
SYNWORK: ADDITION



Daytime Mood

A variety of undesirable daytime alterations in mood state were apparent as a consequence of mask wear the previous night. On the POMS, the Fatigue and Vigor subscales were adversely affected by sleep in the M40 mask. Increased daytime sleepiness as assessed by the SSS was also a consequence of mask wear the prior night. On the ESQ, the subscales of Alert, Distress, and Fatigue were similarly altered.

DISCUSSION

A wide variety of behavioral consequences of sleeping in the M40 were observed in this study. Significant effects of mask wear on sleep quality and quantity were detected. Total sleep time, number and duration of awakenings and latency to fall asleep were all significantly impacted by sleeping in the M40 mask. The substantial increase in number of awakenings may be especially significant since moderate sleep loss appears to be less critical than frequency of sleep interruptions in inducing adverse daytime consequences (Bonnet, 1985). Of particular importance were the subjective reports of poor sleep quality, such as reduced soundness of sleep, difficulty falling back to sleep if woken and restlessness during sleep. Protection afforded by the M-40 mask was highly variable across subjects and significantly decreased over the course of the study.

The interrupted nature of sleep when soldiers wore the mask and its other adverse effects on sleep are consistent with the significant changes in mood and performance observed the next day. Subjects reported more fatigue and sleepiness, and less vigor, on self-report mood questionnaires administered in the morning and afternoon. Critical elements of cognitive performance were also disrupted during the day. Increased number of errors on the four choice RT task, especially lapses (too long errors), are considered to be classic symptoms of sleep disruption (Dinges, 1992; Wilkinson, 1992). The impaired ability to sustain work on divided attention tasks, coupled with increased circadian fluctuation in performance shown on the SynWork task, are also typical of substantial sleep disruption.

The results of this study, in particular the measurable decrements in next day performance associated with mask wear and the variability of protection offered by the M-40 mask, argue against mask wear at night unless NBC attack is highly probable.

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