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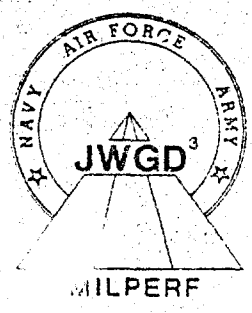

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THE EFFECTS OF 12 HOURS OF MOPP IV GEAR ON COGNITIVE PERFORMANCE UNDER NON-EXERCISE CONDITIONS

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SUMMARY

Twenty-four U. S. Marine Corps personnel performed computer controlled tasks during 12 one hour periods, with and without full chemical warfare protective gear. Decreased speed and accuracy was found in the performance of various tasks. Most of these changes were present within the first four hours of testing. Many more changes were seen than in a previous study where the M17A2 mask was used alone in a four hour protocol. The results suggest that chemical protective clothing may interfere with performance even in sedentary activities and that the predominant problem comes from factors other than the mask.

INTRODUCTION

Soldiers as well as firemen, people working with hazardous materials, and rescue workers are sometimes required to perform their duties while wearing protective clothing and masks. Because this often occurs in critical situations, it is important to know how performance is affected by such encumbrances. In the military this is known as Mission Oriented Protective Posture (MOPP), and the gear is known as MOPP gear, with MOPP IV (mask, gloves, boot covers, hood, and suit) being the highest level of protection. As part of a series of studies on the effect of protective clothing and devices on soldiers, we have looked at performance of a number of sedentary tasks during a 12 hour period of MOPP IV protection.

MATERIALS AND METHODS

Subjects and Schedule

Twenty-four volunteer male, enlisted marines were studied. Some data items are not available on every subject because of equipment failure or subjects misunderstanding. Descriptive statistics are presented in Table 1. Testing occurred over a 4 day period. On the first day subjects were familiarized with the equipment and trained in the various tasks. These tasks included: simple reaction time to a stimulus appearing in the middle of the computer screen (SRT); complex reaction time, with four buttons as possible responses to 4 stimuli (FOUR); logical reasoning (LOGIC); a test of reciprocal alternation performance (TRAP), involving rapid alternation between two buttons, with one finger, with eyes closed; alphanumeric visual vigilance (ALPHA), involving responding to certain alphanumeric stimuli but not others. Subjects also responded to a questionnaire about their mood, degree of fatigue, and symptoms (MOOD). (The results from the questionnaire will be presented elsewhere.) All tasks were computer administered and have been described in detail previously (Ryman, D.H., Naitoh, P., and Englund, C.E., 1984). Subjects completed the tasks while seated in a comfortable chair in a room with an ambient temperature of about 70°F.

Table 1

Population Characteristics

	MEAN ± SD		MIN	MAX	N
AGE (YEARS)	23	3	18	29	24
WEIGHT (KG)	75	7	64	91	24
HEIGHT (CM)	176	8	160	191	23
% BODYFAT	14	5	6	25	23
YEARS SERVICE	4	3	.5	12	24
PAY GRADE	4	1	2	6	24
HOURS EXP.	67	84	0	400	21
LOG_{10} HRS EXP.	1.5	.7	-.1	2.6	21

SD = standard deviation
MIN = minimum
MAX = maximum
N = Number of subjects with data on measurement in question
KG = kilograms
CM = centimeters
% BODYFAT = percent body fat (Hodgdon and Beckett, 1984)
HOURS EXP = hours of previous experience using MOPP gear (information not available on 3 subjects)
LOG_{10} HRS EXP = log base 10 conversion of the preceding variable using -.1 for 0 hours.

On the second day, half the subjects were randomly assigned to undergo testing while wearing MOPP IV gear (Figure 1). This gear was worn over standard battle fatigues and boots. It consisted of charcoal impregnated chemical protective pants and jacket, rubber boot covers, rubber gloves with cotton liners, the M17A2 mask, and a hood that fitted over the mask. The masks had been altered by replacement of the outlet valve with a brass tube (4.2 cm long, 2.6 cm internal diameter, see Figure 2) to allow for collection of oxygen consumption readings (manuscript in preparation). Inhalation through the modified frontpiece was prevented by attachment of a one-way

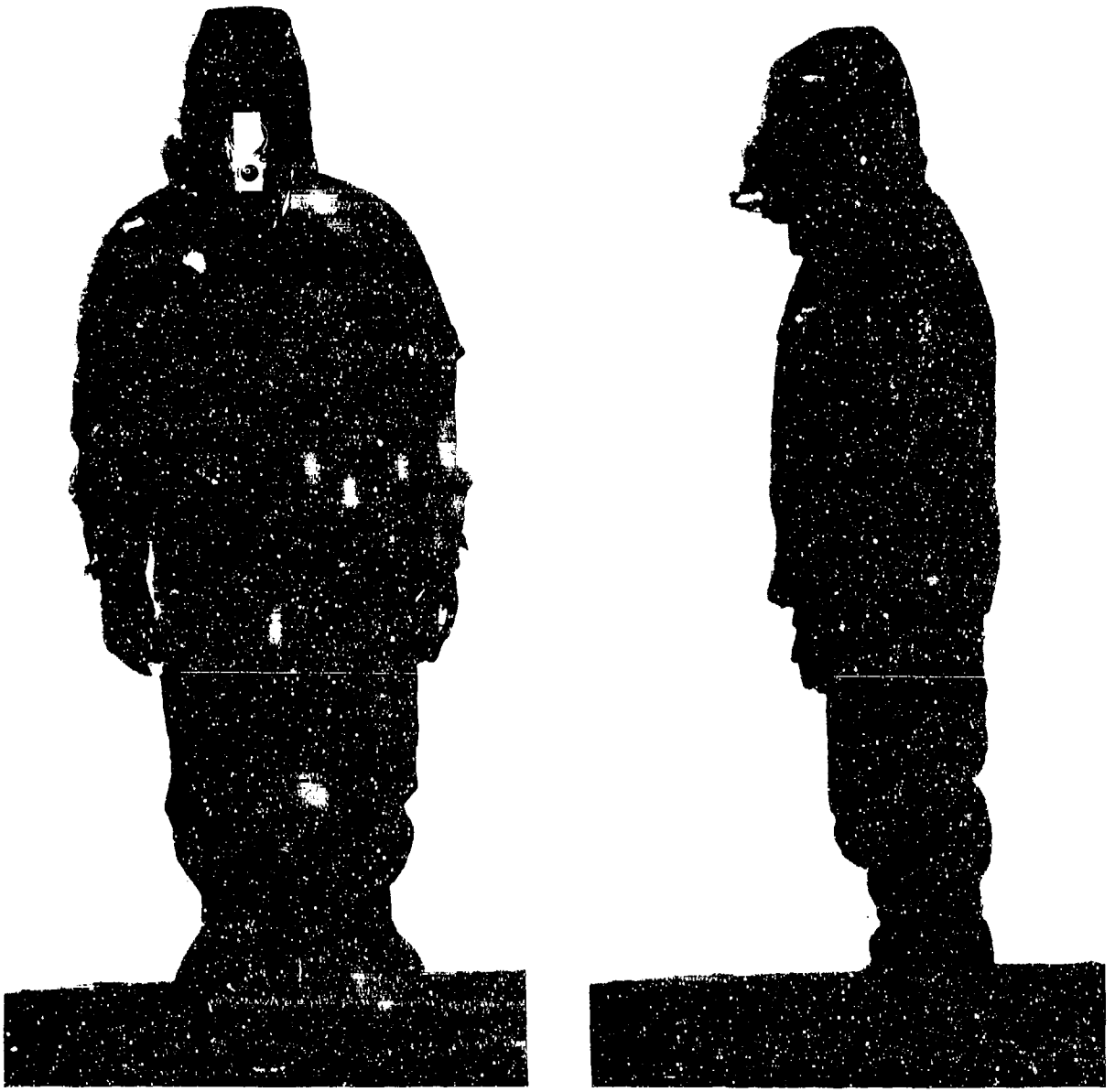


Figure 1: Subject wearing MOPP IV gear.

valve (inspiratory valve from the Rudolph 2-way mask #7900, resistance at 100 l/min flow = 4.7cm H20/l/sec). Masks were adjusted to a snug but comfortable fit. Lack of inward leakage was confirmed by having the subject inhale and hold his breath with the input filters occluded. In the control condition subjects wore standard marine battle fatigues and boots.

Figure 2: M17A2 mask with adapter.

Testing started at about 0730 after the subjects had eaten breakfast. Subjects alternated every 1/2 hour between ALPHA and combinations of the other tasks and the MOOD questionnaire. The ALPHA, SRT, and MOOD were given every hour, while the FOUR, TRAP, and LOGIC were given every other hour (6 times a day). After six hours of testing subjects were allowed a 45 minute break for lunch ("meal ready to eat" rations). The MOPP IV subject was allowed to remove the mask, hood, and gloves during the break. We avoided opening the suit at any other time except in one subject who insisted on smoking a cigarette during the afternoon, one subject who had to urinate, and brief readjustments of temperature or EKG monitoring devices. Unlimited water was available at all times (the M17A2 mask has a special attachment allowing drinking without mask removal).

The third day was a rest day, in order to eliminate any recovery or carry over effects. Subjects were allowed to do whatever they wished but instructed not to drink alcohol and to get adequate sleep. The fourth day was the same as the second day except that the other subject wore the MOPP IV gear.

Mask Only vs Complete Gear Effects

An earlier stage in this series of studies (Kelly, T.L., Yeager, J.E., Sucec, A.A., Ryman, D.H., Englund, C.E., and Smith, D.S., 1987) involved wearing only the mask while performing these same tasks for a four hour period. The data from the twenty-four male subjects in that study were compared with the first four hours of this study to separate effects of the mask from those related to other parts of the protective clothing.

Statistical Analysis

Statistical analyses were performed using the SPSS-X statistical package on a VAX computer. MOPP vs Control mean daily performances (and mean first 4 hour performances) were compared using paired 2-tailed t-tests. Analyses of variance (SPSSX MANOVA; Norusis, 1985) were done to separate out the effects of the protective garments from possible confounding or interactive effects from whether the suit was worn the first or second test day or variation over the sessions within a day. Pearsons product moment (r_s) correlation coefficients were run between the significant changes seen when MOPP gear was worn and the amount of previous experience with such gear, age, pay grade, and years in the service, to test for any linear relationships. Spearman rank order (r_s) correlation coefficients were also calculated to confirm Pearson correlations because the Spearman is not influenced by extreme values (high low outliers) as is the Pearson and, therefore, is more robust for small samples. Since the hours of experience with chemical defense gear had an extremely positive skew, a log transformation was done on this variable. The level for significance was set at $p \leq .05$.

RESULTS

Results are summarized in Table 2. When the suit was worn, the simple reaction times were significantly slower by t-test. This was true for all

Table 2

Suit vs No Suit Results (reaction times in msec)

	SUIT		NO SUIT				
	MEAN	SD	MEAN	SD	t	p	df
SRT							
MEAN R	438	92	392	59	3.30	.003	23
FAST R	259	37	244	27	3.52	.002	23
SLOW R	1060	421	855	294	2.93	.008	23
FOUR							
MEAN R	724	93	662	60	3.95	.001	22[a]
FAST R	388	74	423	44	-2.76	.011	22
SLOW R	1482	223	1287	156	4.63	<.001	22
%CORRECT	80.5	10.7	89.6	6.8	-6.10	<.001	22
TRAP							
#PRESSES	1243	219	1334	185	1.80	NS	21[b]
FAST R	180	38	172	36	-0.82	NS	21
SLOW R	729	174	659	167	-2.33	.030	21
LOGIC							
#ATTEMPT	32.2	6.4	36.6	9.7	3.06	.006	19[c]
%CORRECT	92.1	5.0	91.6	7.0	0.42	NS	19
ALPHA							
%CORRECT	77.2	15.2	83.4	11.5	-3.19	.004	23

[a]One subject held key down constantly and overflowed data array.
[b]TRAP box disconnected from computer for one team (2 subjects)
[c]Four subjects did not understand task (chance percent correct)
ALPHA = alphanumeric visual vigilance task
#ATTEMPT = number of questions answered
%CORRECT = percent correct
p = level of significance
df = degrees of freedom
MEAN R = mean reaction time
FAST R = fastest 10% reaction time
FOUR CHOICE = four choice reaction time task
LOGIC = logical reasoning task
MEAN R = mean reaction time
#PRESSES = number of key presses
SD = standard deviation
SLOW R = slowest 10% reaction time
SRT = simple reaction time task
t = paired 2-tailed T-test
TRAP = task of response alternation performance

measures of speed (overall mean reaction time, fastest 10%, or slowest 10%). In the FOUR reaction time task, t-tests showed the mean and slowest 10% to be sloved in a similar manner. However, the top 10% responses when the suit was worn were significantly faster than the top 10% responses in fatigues. In the TRAP task, only the slowest 10% showed a significant drop. In the LOGIC test the number of questions attempted, during the 3 minutes allowed for this task, was lower in the suit condition.

Accuracy was also lower in the suit condition. In the FOUR reaction time task, those wearing the suit obtained a lower percent correct. This was due to a reduced number of correct responses (434 vs 507, $t=7.45$, $df=22$, $p<.001$), along with an increase in errors of commission (109 vs 57, $t=-5.36$, $df=22$, $p<.001$) and a slight increase in errors of omission (2.7 vs 1.8, $t=-2.46$, $df=22$, $p=.022$). The ALPHA vigilance task also showed a lower percent correct in the suit condition. However, accuracy in the LOGIC task was similar in both conditions. The number of correct answers did decrease (29.8 vs 33.7, $t=2.66$, $df=19$, $p=.015$), but this was in proportion to the decrease in the total number of questions attempted.

When just the data from the first four hours of each day were analyzed, all of these differences remained significant except for the increase in the slowest reaction time on the TRAP test. Most of the differences were present immediately (in the first hour of testing). The decreased accuracy on ALPHA and the increased 10% slowest response times on SRT were not significant in the first hour. An additional difference, an increase in the number of button presses on TRAP in the suit condition, was present in the first hour but not when the day's performances were averaged.

The analyses of variance demonstrated some interactive and sessions effects. On the FOUR task there was an interactive or confounding effect from day of testing on the fastest response times. (Subjects were faster on the second day, 392 vs 419 msec, $F(21,1)=5.14$, $p=.034$). The percent correct on the ALPHA showed a significant sessions effect ($F(11,12)=3.76$, $p=.016$). The most significant trend was quadratic ($F(1,21)=35.63$, $p=.001$), with best performances at the start and end of testing and most errors in the middle sessions. The slowest button presses on the TRAP showed a similar pattern

($F_{sess}(5,17)=4.06$, p=.013; $F_{quad}(1,21)=16.62$, p=.001), with slowest performances in the middle sessions. There were linear patterns on FOUR mean ($F_{sess}(5,17)=4.21$, p=.011; $F_{lin}(1,21)=15.1$, p=.001) and slow ($F_{sess}(5,17)=5.79$, p=.003; $F_{lin}(1,21)=16.95$, p=.001) reaction times. These performances deteriorated over the 12 hour testing day. The number of correct responses on LOGIC, in contrast, showed an upward linear trend ($F_{sess}(5,13)=8.29$, p=.001; $F_{lin}(1,17)=26.9$, p<.001), with best performances at the end of the day. Percent correct was unchanged as number attempted went up correspondingly. All of these trends were similar in the MOPP and the no-MOPP conditions.

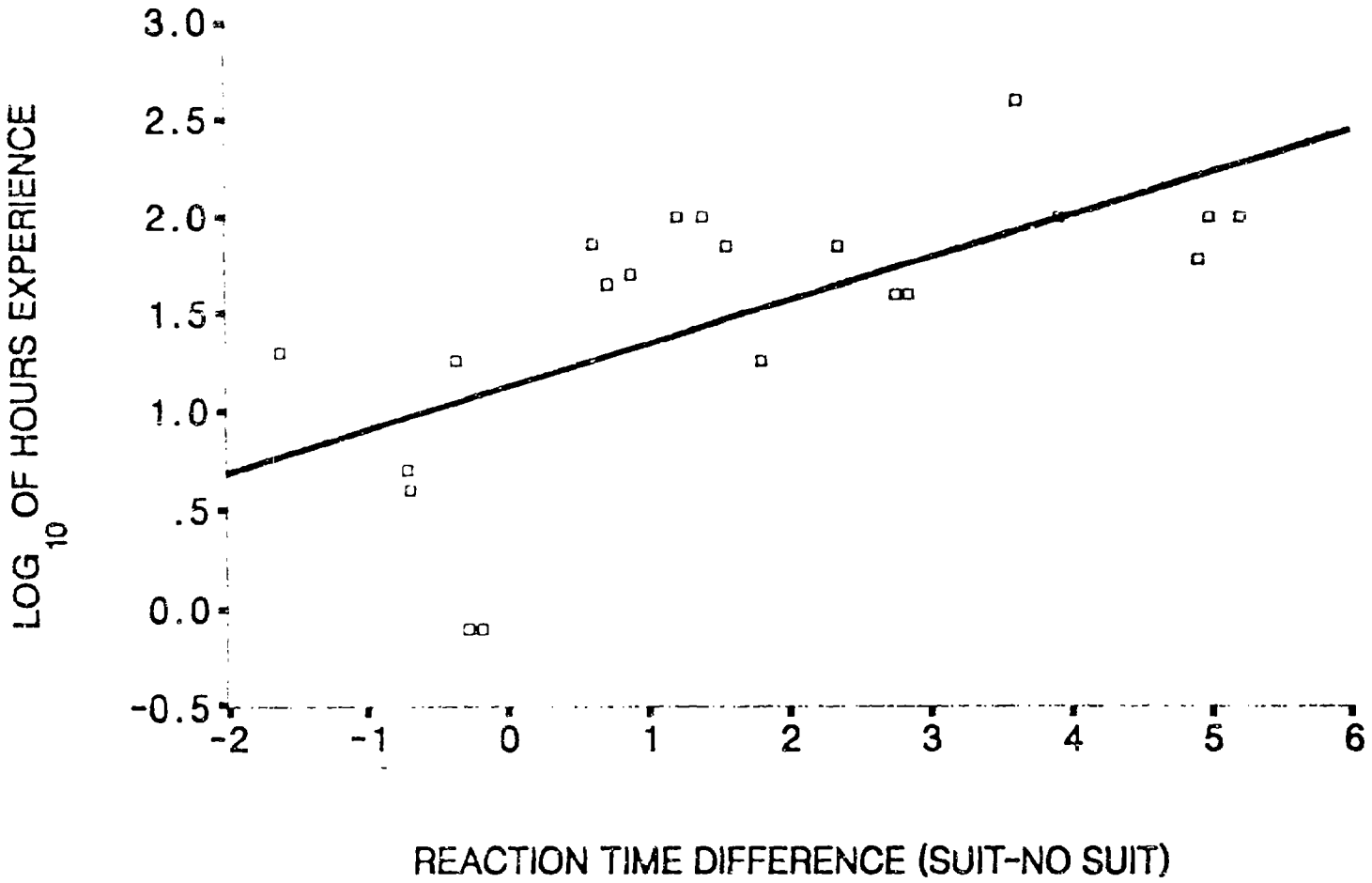
The amount of slowing on the SRT when the suit was worn correlated significantly with the hours of previous experience with the gear for both the mean response speed (r_p=.45, p=.04; r_s=.53, p=.01) and the fastest responses (r_p=.49, p=.03; r_s=.64, p=.002). These findings were confirmed using the log base 10 transformation of the experience variable (for the mean r_s=.47, p=.03; for the fastest r_s=.68, p=.001) (see Figure 3). The only other significant correlation was between years in the service and the amount of decrement in MOPP gear for the slowest 10% button presses on the TRAP task (r_p=.45, p=.03; r_s=.43, p=.05). Partial correlations were done to further clarify these relationships. When age or years in service were controlled for, the SRT mean and 10% fastest response times continued to show a significant correlation with amount of previous experience with chemical defense gear. However, when age was controlled for the relationship between years service and the 10% slowest button presses on the TRAP task was no longer significant (p=.183).

DISCUSSION

Speed of Performance

Most previous reports have found the chemical protective clothing tends to slow response or increase task performance time as was found in the present study. Rauch, Witt, and Banderet (1986) studied subjects solving paper and pencil tests of cognitive performance while wearing various levels of chemical protective clothing. Detrimental effects were only seen at the

Figure 3. HOURS CHEMICAL DEFENSE EXPERIENCE vs CHANGE IN FASTEST 10% REACTION TIMES ON SRT



MOPP IV level (similar to ours but using a different mask). They attributed the decrement to the clumsy gloves interfering with use of a pencil. A MOPP II condition, consisting of battle dress worn with an overgarment and boot covers but no mask or gloves, did not affect performance.

McGinnis, Bensel, and Lockhart (1973) studied three protective glove assemblies including butyl rubber gloves. While the butyl gloves performed best of the three, they still significantly slowed performance of four dexterity tasks. Bensel (1980) studied four protective glove assemblies including butyl rubber gloves. The same tasks were used as in the preceding study with the addition of a rifle disassembly/assembly task. Significant decrements were not seen with the butyl glove.

Johnson and Sleeper (1986) studied soldiers performing one (O'Connor finger dexterity test) and two (Purdue pegboard manual dexterity test) handed tests of manual dexterity with and without the M17A1 gas mask and hood and/or standard butyl rubber gloves. They found the gloves but not the mask had significant detrimental effects on how fast the tasks could be performed. Similar results were found by Rauch (unpublished) in subjects performing math computations while wearing a mask and/or gloves.

Kobrick and Sleeper (1986) had soldiers perform a visual signal detection task while wearing fatigues, MOPP IV gear, or MOPP IV gear plus the added stress of a hot (91^{o}F) humid (61% RH) environment. They found that the MOPP and MOPP plus heat conditions caused progressive highly significant increases in response time to all signals. The decrements in this case were thought to be primarily related to visual impairment from the mask.

Fine and Kobrick (1985) studied soldiers performing sedentary tasks patterned after those performed by a fire direction center. Tasks were performed with and without MOPP IV protective clothing and with and without a hot (91^{o}F) humid (61% RH) environment. MOPP gear plus heat caused marked and persistent deterioration within 4 to 5 hours. Subjects in MOPP gear without heat showed significant decrements after 5 hours but had improved back to baseline after 7 hours. King and Frelin (1984) had military medical specialists perform a series of basic medical tasks while wearing fatigues

or MOPP gear. MOPP gear slowed performance of all tasks. While practicing for 6 days improved performance, MOPP performance remained slower than that in fatigues. Spioch, Kobza, and Rump (1962) studied the effects of a protective mask without other protective garments. He found that performance of the Bourdan psychotechnical test, "a test based on the accuracy and time required for a patient to strike out certain letters, numbers, or words" (Dorland, 1981) was slowed when subjects wore the mask.

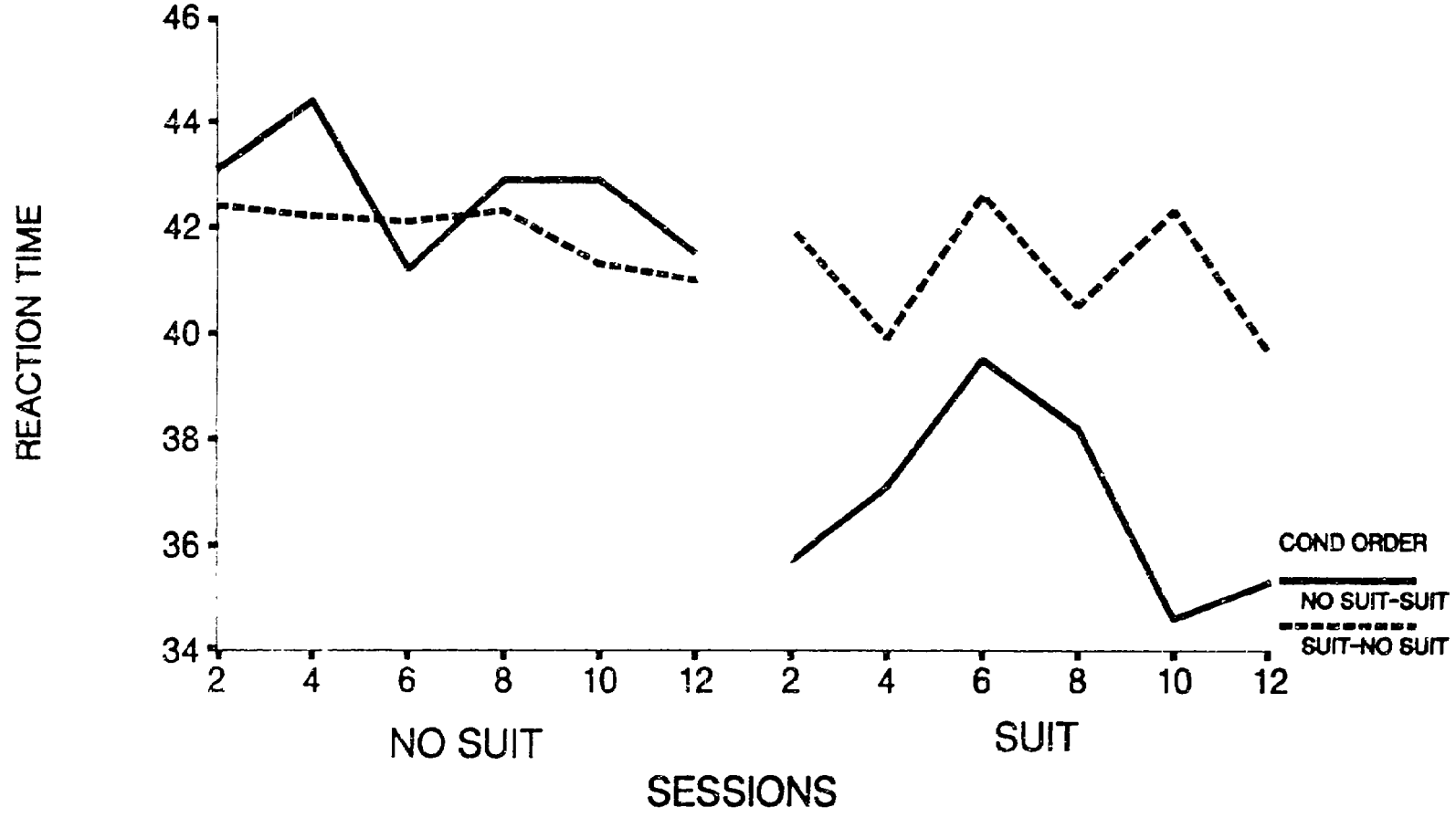
The improvement in the 10% fastest response times on the 4-choice task conflicts with the studies just discussed. The design of this task makes it possible that this is an artifact. The subject makes his choice among 4 buttons closely placed in a 2x2 square. The fingers of the gloves are rather wide and floppy. The finger in the glove could easily overlap 2 buttons at once, and cause them to be depressed in rapid succession. Twenty-five percent of such accidental responses would be correct by chance and thus could make up many or all of the 10% fastest responses. The fact that the percent correct decreased with the glove supports this possibility. Additionally, there is a confounding effect from whether testing in the MOPP gear occurred on the first or the second day. Subjects were faster on the second day of testing, and this practice effect was greater on MOPP performance than on performance in fatigues (interaction of condition with order $F=5.14$, $df=1,125$, $p=.034$) (see Figure 4).

These results, however, may not be an artifact. A study by Hamilton and Zapata (1983) found trends for decreased response times and more problems attempted, along with decreased accuracy, when U.S. aircrew chemical defense gear was worn for a 6 hour period. While one of the tasks used in that study was similar or identical to FOUR in the current report, other tasks would not have been susceptible to this sort of artifact. Possibly the difficulty of working in the gloves caused subjects to pay closer attention.

Accuracy

A few researchers have looked for changes in accuracy, rather than just speed. Spioch et. al. (1962) found an increase in errors of commission along with the slowing in performance seen in subjects wearing a mask. King

Figure 4. FOUR CHOICE 10% FASTEST REACTION TIMES BY CONDITION ORDER GROUPS



and Frelin's 1984 study of performance of basic medical tasks found few errors in general, with no apparent effect from the MOPP IV protective clothing on error number. Neither the mask or the gloves affected accuracy on Rauch et. al.'s (1986) paper and pencil cognitive tests. Performance of math computations (Rauch, unpublished) was also unaffected. Fine and Kobrick (1985) found MOPP gear with or without a hot environment tended to increase errors in some of the tasks used. These appeared to be predominantly errors of omission, which occurred intermittently during the 7 hour testing sessions. Hamilton and Zapata (1983) also found decreased accuracy on serial math problems, target detection, and four-choice reaction time. They found a slight increase in accuracy on logical reasoning. It appears from their report that none of these effects achieved the standard level of significance.

Our study goes along with these varying results in showing effects on some tasks but not others. Percent correct decreased in the ALPHA vigilance task and on the FOUR task. The LOGIC task showed only speed and not accuracy decrements. The two response buttons for this task are far enough apart on the keyboard that any lack of dexterity caused by the gloves would be unlikely to generate errors. The FOUR task has closely positioned buttons such that the wide glove finger tip could easily hit the wrong button. However, the Alpha task involved only one button so the gloves should not have increased errors.

Hamilton, Simmons, and Kimball (1983) looked at the performance effects of heat stress from wearing various protective gear while flying a helicopter during hot weather. They found that those who suffered only slight heat stress (neither heart rate or core temperature consistently elevated) showed improved performances while those with more severe stress showed deterioration. Our subjects experienced at most slight stress by this definition. Thus, the deterioration in performance conflicts with Hamilton et al.'s results. However, that study compared performance after the heat stress with that after being isolated in a room all day with nothing to do. We compared performance during the heat stress with performance during a day of testing without that stress.

Effects of the M17A2 Mask vs the Other Protective Garments

The 24 male subjects in the earlier mask-only study had similar characteristics to those in this study (mean ± sd: age, 24.7 ± 4.4 years; height, 174.8 ± 6.1 cm; weight, 76.7 ± 9.0 kg). There have been few previous reports of significant mask effects on sedentary performance. Spioch et al. (1962) did show a reduction of both speed and accuracy in subjects wearing a mask without other protective gear. Kobrick and Sleeper (1986) attributed some of the deterioration they found in response speed to visual impairment, from the mask, but they did not confirm this by testing subjects in the mask without the other gear. Johnson and Sleeper (1986) and Rauch (unpublished) found no performance decrements when a mask was worn without gloves.

The data from the male subjects in our previous mask only study were consistent with these reports. We found small effects from the mask only on the mean SRT scores (mask 252 msec, no mask 237 msec, $t=-2.10$, $p=.047$) and the number of presses per session in the TRAP (mask 1284, no mask 1358, $t=2.82$, $p=.010$). There were no effects on accuracy. Thus, most of the performance changes seen in the subjects wearing MOPP IV gear must be attributed to equipment other than the mask. Judging by the results of previous studies the clumsy gloves may be a major detrimental factor. If a better fitting but still durable glove could be designed, performance while wearing the suit might be improved. King and Frelin (1984) tried out a prototype glove designed to enhance tactile sensitivity. These gloves did improve performance but they tended to develope flaws which could make them unsafe. An alternative mode of compensation is to adapt tasks to be performed to the need for gloves. An example of this is a simplified keyboard with larger keys for computer type tasks.

It is difficult to attribute the decreased accuracy in the ALPHA vigilance task to the gloves. This task employed a single hand held button and speed of response was not important. Possibly the discomfort or increased warmth from the MOPP suit made subjects less attentive.

Sessions Effects

Previous studies in this lab have used some of these cognitive tests over extended periods of time. No change was found in SRT or FOUR performance during the first 12 hours of a 20 hour continuous work session (Naitoh and Ryman, 1985). The present findings of progressive deterioration in mean and 10% slowest response times on FOUR conflict with those results. This cannot be attributed to the MOPP gear as the trend was the same in the no-MOPP condition. Another study showed a peak in LOGIC performance in the evening during the 10th session of a 17 hour work period (Englund, C.E., Ryman, D.H., Naitoh, P., and Hodgdon, J.A., 1984). As the present study's workday ended in the evening, the upward trend in LOGIC corresponds somewhat with the evening peak in the earlier study. This is the most difficult task to understand. and it is possible that a prolonged learning effect could account for the upward trend. The quadratic trend on ALPHA, with worst performances in the middle sessions, is a new finding for which there is no obvious explanation.

Other Factors

It is unclear why subjects with more previous experience with MOPP gear would show greater decrements in SRT performance, or why those with more years in the service would show greater slowing on button pressing in the TRAP task when the MOPP gear was worn. Those with more years in the service were generally older and had more previous experience with the protective clothing. However, partial correlations controlling for age or years in service did not change the SRT findings. Correcting for age reduced the correlation between the MOPP effects on the speed of the slowest button presses and number of years in the service to r_p=.3473 (p=.070). This is not surprising as age showed a low grade relationship to that variable (r_p= .3597, p=.100) and a stronger correlation with years in service (r_p=.5445, p=.002). It should be noted that previous experience was a fairly inaccurate variable, based on estimates made by the subjects which we had no records to confirm.

CONCLUSION

Subjects wearing full MOPP IV gear showed decrements in both speed and accuracy in performance of sedentary tasks during a 12 hour experimental session. Almost all of these changes were present within the first 4 hours of testing and most within the first hour, indicating that prolonged wearing is not required for performance deterioration. Since previous investigation found that wearing the M17A2 Mask alone had only minimal effects, other aspects of the gear (most likely the clumsy gloves) must be responsible for most of the decrements. When tasks are required to be performed while wearing such gear more time should be allowed for task completion and compensatory changes, such as avoiding closely spaced control buttons, should be made. Increased practice using MOPP IV gear does not appear to reduce the decremental effects on performance.

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(U) THE EFFECTS OF 12 HOURS OF MOPP IV GEAR ON COGNITIVE PERFORMANCE UNDER NON-EXERCISE CONDITIONS

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Twenty-four volunteer male Marines participated in a randomized crossover design experiment involving performance of computer controlled tasks during two 12 hour days, one day in Army fatigues and one in complete chemical protective gear. These tasks included the following: simple response time (SRT), complex (4-choice) response time (FOUR), logical reasoning (LOGIC), a task of response alternation performance (TRAP), an alphanumeric visual vigilance task (ALPHA), and a questionnaire on mood, fatigue, and symptoms. Subjects showed decreased speed in performing the SRT (mean response time 438 vs 392 msec, p=.003) and the FOUR (mean response time 724 vs 662 msec, p=.001) tasks, decreased speed on the slowest button presses in the TRAP task, decreased number attempted in the LOGIC task (32 vs 37 per session, p=.006) and decreased percent correct in the FOUR (81 vs 90%, p<.001) and ALPHA (77 vs 83%, p=.004) tasks. All these differences, except for those in the TRAP task, were also significant if only the data from the first four hours of each day were analyzed. The male subjects in a previous study similar to this one, except that just the M17A2 mask was worn and testing lasted only four hours, showed changes only in the SRT and TRAP tasks. Therefore, the (over)

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19. ABSTRACT (continued)

changes seen in the more complex FOUR, LOGIC, and ALPHA tasks must be attributed to other aspects of the gear, most likely the gloves.