

FAA-AM-72-19

# RESIDUAL PERFORMANCE EFFECTS OF SIMULATED SONIC BOOMS INTRODUCED DURING SLEEP

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May 1972

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Office of Aviation Medicine  
Washington, D.C. 20591

12

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-AM-72-19		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle RESIDUAL PERFORMANCE EFFECTS OF SIMULATED SONIC BOOMS INTRODUCED DURING SLEEP				5. Report Date May 1972	
				6. Performing Organization Code	
7. Author(s) W. Dean Chiles, Ph.D. Georgetta West, B.S.				8. Performing Organization Report No.	
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P. O. Box 25082 Oklahoma City, Oklahoma 73125				10. Work Unit No.	
				11. Contract or Grant No.	
				13. Type of Report and Period Covered  OAM Report	
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D. C. 20591				14. Sponsoring Agency Code	
15. Supplementary Notes  This research was performed under Tasks AM-A-70-PSY-13, AM-A-71-PSY-13, AM-B-70-PSY-24, and AM-B-71-PSY-24.					
16. Abstract  Twenty-four male subjects were tested on a complex performance device involving monitoring, mental arithmetic, and pattern discrimination. Three age-groups were used: 20 to 26, 40 to 45, and 60 to 72. Subjects were tested for 30 minutes each morning and each evening for a 21-day period. On the sixth through the 17th nights, subjects were exposed to eight simulated sonic booms with an "outdoors" overpressure level of 1.0 psf presented at 1-hour intervals during sleep.  The results provided no evidence that exposure to simulated sonic booms during sleep produced measurable consequences with respect to complex performance. A significant age effect was found for five of the ten measures. Significant differences (apparently a learning effect) were found in performance across the three phases (pre-boom, boom, and post-boom). There was also a significant interaction between age and phase for five of the measures. Analysis of the simple effects indicated there were rather large differences among the three groups at the beginning of testing with the differences decreasing in the two latter phases.  The time-of-day effect was significant for five of the measures.					
17. Key Words Complex Performance Sonic Booms Age Diurnal Variations				18. Distribution Statement Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 8	22. Price \$3.00

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### **ACKNOWLEDGMENT**

The present study was conducted as a part of a larger experiment directed by Drs. W. E. Collins and P. F. Iampietro. Their complete cooperation is gratefully acknowledged.

## RESIDUAL PERFORMANCE EFFECTS OF SIMULATED SONIC BOOMS INTRODUCED DURING SLEEP

### I. Introduction.

In June 1968, the Subcommittee on Human Response, a part of the National Academy of Sciences Committee on SST-Sonic Boom, issued a *Report on Human Response to the Sonic Boom*. In that report, the Subcommittee posed two questions which, among others relating to sonic booms, have not yet been "fully studied." One of these questions was: "Do repeated booms cause changes in the depth of sleep as judged by the electroencephalogram (EEG)?" A second question was: "Do repeated brief awakenings of normal subjects cause behavioral changes, psychological distress, or excessive fatigue?" The present study was conducted as a part of a larger experiment carried out by the Civil Aeromedical Institute to provide information bearing on these two questions.

The rationale for studying sleep effects of sonic booms derives from the fact that a significant portion of the population sleeps at times other than during the nighttime hours. Thus, the occurrence of sonic booms over populated areas at almost any time during the day or night might be expected to impinge upon sleeping individuals. During daylight hours, these people might be, for example, night workers, hospital patients, or the elderly. The specific aspect of the problem that is of concern to this report is the possibility that, if there are disturbing effects of sonic booms on sleep, the accumulation of such effects over a number of days might result in measurable changes in behavior. (Other aspects of the larger study will be reported in later OAM reports: Collins and Iampietro (1972), and Smith and Hutto (1972).)

Previous research on the effects of sleep loss suggests that complex performance involving

time sharing may provide more sensitive indices of performance deficiencies than are afforded by simpler measures (Chiles, Alluisi, and Adams, 1968). In addition, the context in which this study was formulated placed emphasis on the generation of data and findings of potential relevance to practical situations. This consideration also points toward the advisability of using complex performance in that such performance is typical of the demands placed on the worker by his job. The CAMI Multiple Task Performance Battery (MTPB) provides measures of such performance. In addition to the fact that the system is largely automated and can be used to test up to five subjects simultaneously, the MTPB permits variations in the difficulty of individual tasks over a fair range, and, more importantly, the requirement for the time-shared performance of different tasks can be imposed.

The above-referenced research on sleep loss also showed that differences in the levels of performance of even highly trained subjects can be expected as a function of time of day, with performance in the evening being superior to that in the morning. Thus, it is possible that any accumulative effects of the sleep disturbance might be more readily revealed when performance is already at a lower point on the continuum. Therefore, measurement periods in both morning and evening hours were deemed necessary. Although a third, mid-day session would have been desirable, the logistics of testing subjects who held regular jobs militated against such additional testing.

One of the facets of the problem identified by the Subcommittee concerned the widely held belief that there are important differences across age-groups in the average quality of sleep; the implication was that middle and older age-groups generally experience more difficulty sleeping and are more susceptible to arousal by

Assistance in data collection by Blair Fennell, Cynthia Mitchell, Karen Lewis and RuthAnn Parvin is gratefully acknowledged.

disturbing auditory stimuli. Thus, age was considered to be an important parameter of such an investigation.

The purpose of the study, then, was to examine complex performance as it might be affected by the introduction of sonic booms during sleep. Other factors considered in the research design concerned the time of day at which measures were to be made, the age of the subjects, and the specific tasks and task combinations to be performed.

## II. Method.

A. *Subjects.* Twenty-four male subjects were tested in this study; they were paid for their services. The subjects were selected to provide three different age-groups. The youngest age-group consisted of eight subjects ranging from 21-26 years of age; their median education level was two years of college. The middle age-group contained eight subjects with an age range of 40-45 years; their median education level was three years of college. The oldest age-group ranged from 60-72 years of age with a median education level of 2.5 years of college.

B. *Experimental Tasks.* The Multiple Task Performance Battery used in this study has been described in detail in an earlier report (Chiles, Alluisi, and Adams, 1968) and, therefore, will not be fully described here. The apparatus presented two passive and two active tasks. The passive tasks consisted of monitoring warning lights and probability meters; the active tasks consisted of mental arithmetic and pattern discrimination.

There were two different aspects of the warning lights task. The subjects were to monitor five normally illuminated green lights which were located one in each corner of the panel and one in the center. If any one of these lights were to go out, the subject was to push a button directly below that light to turn it back on. A red light, which was normally not illuminated, was paired with each of the green lights. If one of these lights were to come on, the subject was to push the button directly below that light to turn it off. If no response was made to a warning-light signal, the light automatically returned to its normal state after 15 seconds. The mean inter-signal interval for the warning-lights task was 30 seconds. Response time was measured

separately for the red and green lights; for each of these, the mean correct response time for each of two 15-minute test intervals was treated separately.

The second passive task involved monitoring four meters located across the top of the panel. The pointer of each meter fluctuated in a random manner about the zero (12 o'clock) position. A signal on this task consisted of a shift of the pointer of one of the meters from an average position of zero to an average position of plus or minus 25 (1 o'clock or 11 o'clock). The subject responded by pushing a lever switch immediately below the appropriate meter in the direction of the deflection thereby returning the pointer to its normal state. If no response was made, the signal would remain until the next signal was introduced. The mean intersignal interval on the probability task was 30 seconds. The performance measure was the mean correct response time for each 15-minute interval; in case no response was made to a given signal, the response time was determined by the total lapsed time until a response was made to a subsequent signal.

For the two youngest age-groups, the mental arithmetic task required the subject to solve problems by adding two 2-digit numbers and subtracting a third 2-digit number from the resultant sum, e.g.,  $55+28-49$ . The subject recorded his answer by actuation of a set of push buttons located above the panel; he then pushed a lever switch located to the right of the arithmetic display to "set his answer into the machine." The problems were presented at a rate of one every 20 seconds. The performance measures on this task were the mean response time and the mean percentage correct. For the oldest age-group, the individual problem elements were 1-digit rather than 2-digit numbers, e.g.,  $8+7-6$ . The reason for this change was the apparent inability of one of the first two subjects trained in the oldest age-group to master the 2-digit problems.

The problems on the pattern discrimination task involved the successive presentation of a standard pattern for five seconds and two comparison patterns for two seconds each. These patterns were presented on a 36-cell, square display in the lower left corner of the panel. Each pattern consisted of six vertical bars, ranging in height from one to six squares. The subject

had to determine if the first, second, or neither comparison pattern was exactly the same as the standard pattern. The subject responded to this task by pushing one of three buttons marked "1," "2," and "X" (neither).

The task was complicated for the subjects in the youngest and the middle age-group by introducing random distortions of the comparison images (see Chiles, Alluisi, and Adams, 1968, p. 156). The distortion involved four randomly selected "noise" cells; if a noise cell should have been illuminated as part of a comparison pattern, the light would fail to come on and vice versa. The oldest age-group was tested without the distortion; it was feared that difficulties similar to those experienced with arithmetic might be encountered on this task if it were made too complex. Problems were presented at the rate of one every 30 seconds. Performance was measured in terms of the percentage of correct responses.

*C. Procedure.* The subjects were trained and tested in two-man teams, each member of a team being from the same age-group. Each team was given a 1-hour training session, usually, the day before their first actual test session. The first 30 minutes of training involved familiarizing the subjects with the various tasks and the appropriate responses. Each man was urged to do his

best on all of the tasks. During the second 30 minutes of training, the subjects experienced a test session that was the same as those given during the test proper. The first 15 minutes consisted of monitoring and mental arithmetic and the last 15 minutes consisted of monitoring and pattern discrimination. Thereafter, each group was tested for 30 minutes each morning at approximately 0700 hours and 30 minutes each evening at approximately 2000 hours for a 21-day period. The data collected during the first two days (four test sessions) were not used in the statistical analysis. This was considered a leveling-off period for the subjects.

The subjects spent the first five nights (Phase I) sleeping in the boom room and getting adjusted to the experimental situation. For the next 12 consecutive nights (Phase II), eight simulated sonic booms were presented each night. They were presented hourly beginning at 2300 hours and ending at 0600 hours. The "outside" overpressure level of the booms was 1 psf (measured in the pressure chamber adjacent to the subject's sleeping quarters) and 0.1 psf inside the sleeping quarters. Rise time of the boom recorded in the sleeping quarters was 12 msec with a boom duration of approximately 284 msec. The last four nights (Phase III) were set aside for a recovery period. Between the

TABLE I.—F Ratios for Analyses of Variance

	RO	R15	GO	G15	MO	M15	A%	AT	T%	Comp
<b>A</b> (Morn vs Even) d.f.=1, 21	7.78*	.01	5.69*	1.58	.01	.07	8.46*	8.01*	3.17	4.32*
<b>B</b> (Pre-Boom-Post) d.f.=2, 42	3.51*	.89	13.43***	28.14***	3.83*	2.91	9.40***	39.68***	31.80***	19.18***
<b>C</b> (Age-Groups) d.f.=2, 21	4.21*	2.69	13.23**	9.58**	.03	.24	.26	.66	7.74**	4.06*
<b>AB</b> d.f.=2, 42	.00	.00	.00	.60	.00	.03	.00	.00	.00	.00
<b>AC</b> d.f.=2, 21	.39	.69	1.53	1.10	2.05	2.30	5.08*	1.01	.80	2.25
<b>BC</b> d.f.=4, 42	3.17*	6.48***	4.02**	44.51***	1.10	.75	1.51	1.96	.45	8.34***
<b>ABC</b> d.f.=4, 42	.00	.00	.00	.60	.00	.03	.00	.00	.00	.00
*p < .05	**p < .01	***p < .001								

morning and evening test sessions, the subjects carried out their regular daily activities. Five of the subjects in the youngest age-group were students and three had regular jobs. Seven of the subjects in the middle age-group were employed in various occupations and one was a student. Seven of the subjects in the oldest age-group were retired and one had a professional job.

### III. Results.

Each of the nine performance measures and a composite measure of monitoring performance were subjected to analyses of variance (Lindquist Type VI design). The monitoring composite was the sum of the linear transformation of the red-lights measures, green-lights measures, and meter measures; for this composite measure, a larger number reflects better performance. The variables entered in each analysis were: experiment phases (Phase I, pre-boom; Phase II, boom; and Phase III, post-boom), age-groups (the youngest—21-26 year olds, the middle age-group—40-45 year olds, and the oldest group—60-72 year olds), time of day (morning and evening), and subjects (within groups). The results of these analyses are shown in Table 1.

*A. Composite Monitoring Measure.* Analysis of this measure revealed a significant difference in performance across phases and a significant difference between the performances of the different age-groups along with a significant interaction between the two variables (Table 1). The cell means for this interaction are shown in Table 2. The data were further evaluated by "t" tests (as outlined by Lindquist (1956, p. 272)) between individual means to clarify the effects of the two variables involved. The oldest age-group's performance improved significantly in comparing Phase II with Phase I ( $t=3.78$ , d.f.=42;  $p<.01$ ) and likewise in comparing Phase III with Phase I ( $t=5.41$ , d.f.=42;  $p<.01$ ). The other two groups showed no such improvement. In comparing groups, the oldest age-group performed significantly poorer than the youngest ( $t=3.81$ ;  $p<.05$ ) and middle age-group ( $t=2.51$ ;  $p<.01$ ) only during the first phase of testing.

Performance for this measure was significantly better in the evening than in the morning (Table 3).

TABLE 2.—Cell Means for Age-Phase Interaction for All Measures.

		Age		
		20	40	60
RArith	I	1.08	1.36	2.15
	II	1.02	1.32	1.79
	III	1.12	1.37	1.74
RTID	I	1.05	1.44	1.86
	II	1.04	1.60	1.49
	III	1.23	1.53	1.37
GArith	I	2.31	3.75	5.97
	II	2.12	3.28	4.94
	III	2.23	3.05	4.34
GTID	I	2.16	3.53	5.81
	II	1.89	3.23	4.14
	III	2.13	3.02	3.49
MArith	I	13.71	10.20	12.68
	II	8.26	11.77	10.49
	III	8.59	7.36	9.04
MTID	I	10.50	12.69	12.52
	II	8.00	15.59	10.54
	III	7.61	8.81	7.78
A%	I	86.04	91.20	90.40
	II	95.43	94.77	91.81
	III	95.97	95.94	93.70
ATime	I	7.96	9.01	8.12
	II	7.64	8.11	7.64
	III	7.13	7.62	7.35
T%	I	80.08	79.37	91.56
	II	88.09	85.13	96.69
	III	87.83	85.47	97.67
Comp.	I	40.46	37.90	32.95
	II	41.72	37.83	36.26
	III	40.91	39.16	37.68

TABLE 3.—Means for Measures that Showed a Significant Time-of-Day Effect.

	Morning	Evening
RArith	1.48	1.40
GArith	3.69	3.42
ATime	7.99	7.70
Comp. Score	38.10	38.55

$p < .05$  for the difference between morning and evening for each measure.

*B. Red-Lights Measures.* The red-lights measures for the first 15-minute test interval showed significant differences in performance across

phases and across age-groups (Table 1). The data for the second 15-minute interval showed no such differences. However, both measures showed a significant interaction between experiment phase and age as seen in the cell means for those measures in Table 2. Further analysis showed that the performance of the oldest age-group improved significantly from Phase I to Phase II during the first interval ( $t=2.42$ ,  $d.f.=42$ ;  $p<.05$ ) and likewise for the second interval ( $t=2.42$ ,  $d.f.=42$ ;  $p<.05$ ). Performance also improved from Phase I to Phase III for the first interval ( $t=2.76$ ,  $d.f.=42$ ;  $p<.01$ ) and for the second interval ( $t=3.20$ ,  $d.f.=42$ ;  $p<.01$ ). Neither of the other groups showed significant changes across phases. During Phase I, the youngest age-group performed significantly better than the oldest for the first-interval ( $t=3.67$ ;  $p<.05$ ) and the second-interval ( $t=3.42$ ;  $p<.05$ ) measures. The middle age-group responded significantly faster to the red lights than did the oldest age-group during Phase I for the first 15-minute interval ( $t=2.64$ ;  $p<.05$ ). For Phase II, only the first-interval measure showed significant differences between groups: the youngest age-group responded more quickly than the oldest ( $t=2.57$ ;  $p<.05$ ).

Both measures showed better performance in the evening than in the morning, but the difference was significant only for the first-interval measure (Table 3).

*C. Green-Lights Measures.* Both green-lights measures showed significant differences across phases and between groups, and there was a significant interaction between the two variables (Table 1). Analysis of the simple effects (cell means for those measures in Table 2) showed that the performance of the oldest age-group improved significantly from Phase I to Phase II for the first-interval measure ( $t=2.63$ ,  $d.f.=42$ ;  $p<.01$ ) and also for the second-interval measure ( $t=5.14$ ,  $d.f.=42$ ;  $p<.01$ ). The improvement of the oldest age-group from Phase I to Phase III was also significant for the first-interval measure ( $t=4.16$ ,  $d.f.=42$ ;  $p<.01$ ) and the second-interval measure ( $t=7.14$ ,  $d.f.=42$ ;  $p<.01$ ). No other groups showed significant improvement across phases. For the measures during both intervals, a significant difference across age groups was found during all three phases. The largest differences between groups were found during Phase I. For the first 15-

minute interval, the youngest age-group's responses were significantly faster than those of the middle age-group ( $t=2.38$ ;  $p<.05$ ) and the oldest age-group ( $t=6.06$ ;  $p<.05$ ); and the middle age-group responded significantly faster than the oldest age-group ( $t=3.68$ ;  $p<.05$ ). During the second 15-minute interval, the responses of the youngest age-group were significantly faster than those of the middle age-group ( $t=2.35$ ;  $p<.05$ ) and the oldest age-group ( $t=6.25$ ;  $p<.05$ ) and, as with the first-interval measure, the middle age-group responded significantly faster than the oldest age-group ( $t=3.91$ ;  $p<.05$ ). During Phase II, the first-interval measure showed significant differences between the middle and the oldest age-groups ( $t=2.75$ ;  $p<.05$ ) and between the youngest and oldest age-groups ( $t=4.67$ ;  $p<.05$ ) with the oldest age-group having the poorer performance in each case. The second-interval measure showed significant differences between the youngest and the middle age-groups ( $t=2.30$ ;  $p<.05$ ) and between the youngest and the oldest age-groups ( $t=3.85$ ;  $p<.05$ ) with the youngest age-group having the better performance in each case. During Phase III, the youngest age-group performed significantly better than the oldest age-group for both the first 15-minute interval ( $t=3.49$ ;  $p<.05$ ) and the second interval ( $t=2.33$ ;  $p<.05$ ); and the middle age-group performed significantly better than the oldest age-group on the first-interval measure ( $t=2.14$ ;  $p<.05$ ).

As with the red lights, both green-lights measures showed better performance during the evening but only with the first-interval measure was the difference between morning and evening performance significant (Table 3).

*D. Probability Monitoring.* None of the variables had a significant effect on the second-interval probability measure. The only significant effect on the first-interval measure was a significant difference across phases (Table 1). The performance of the groups during Phase I was significantly poorer than their Phase-III performance (Table 2). As seen in Table 2, although the age by phase interaction was not significant, only the oldest age-group showed continuous improvement across phases.

*E. Arithmetic Measures.* Neither arithmetic measure showed significant differences between

groups. For the arithmetic percentage-correct measure there was significant improvement from Phase I to Phase II ( $t=6.56$ ,  $d.f.=42$ ;  $p<.01$ ) and from Phase I to Phase III ( $t=8.20$ ,  $d.f.=42$ ;  $p<.01$ ). Since there was a significant interaction between time of day and age-groups, further analyses were performed. No differences were found between groups for either morning or evening sessions; and only the oldest age-group performed significantly better in the evening than in the morning on this task (Table 4). For the arithmetic response-time measure, Phase I performance was significantly poorer than that of Phase II ( $t=10.16$ ,  $d.f.=42$ ;  $p<.01$ ) or Phase III ( $t=17.82$ ,  $d.f.=42$ ;  $p<.01$ ); and Phase II performance was significantly poorer than that of Phase III ( $t=7.66$ ,  $d.f.=42$ ;  $p<.01$ ).

The response times of the subjects in the evening were significantly faster than for morning performance (Table 3).

TABLE 4.—Cell Means for Arithmetic Percentage (Age and Time-of-Day Interaction).

	Age		
	20	40	60
Morning.....	92.74	93.11	89.36
Evening.....	92.23	94.85	94.59

F. *Pattern Discrimination.* As shown in Table 1, the oldest age-group (which was presented problems without distortion of the comparison patterns) performed significantly better than both the youngest age-group ( $t=3.06$ ,  $d.f.=21$ ;  $p<.01$ ) and the middle age-group ( $t=3.67$ ,  $d.f.=21$ ;  $p<.01$ ). Performance on this task improved from Phase I to Phase II ( $t=6.71$ ,  $d.f.=42$ ;  $p<.05$ ) and from Phase I to Phase III ( $t=7.08$ ,  $d.f.=42$ ;  $p<.05$ ).

#### IV. Discussion.

The mechanism through which the sonic booms might have been expected to produce performance decrements would presumably have been a reduction in the amount of sleep and/or a deterioration in the "quality" of sleep during Phase II. This would have been expected to be revealed in the form of decrements during Phase II relative to Phase I; and, on the assumption that learning was complete before the beginning

of Phase I, performance during Phase II would have been poorer than Phase I. However, the data reflecting the main effect of phases look very much like a learning effect. There were no decrements during Phase II relative to either the pre- or post-boom phases. Thus, there is no evidence that any possible sleep interference produced by the simulated sonic booms of 1 psf (0.1 psf inside the sleeping quarters) had a residual effect on the performance of any of the age-groups. The lack of a performance effect of the booms is clearly compatible with the results of the analyses of the sleep behavior of the subjects. Namely, the results of those analyses indicated that, on the average, sleep during the boom phase of the experiment did not differ from that during the preceding or succeeding phases (Collins and Iampietro, 1972).

Despite the fact that the experimental design did not provide a very powerful test of the effects of age as a variable, significant differences between age-groups were found. The primary reason for the relatively low power of the design was that, although eight subjects per group gave adequate power for assessing the effects of the boom, this was a rather small number for the main effect of age. In addition, the apparent necessity of giving easier problems to the oldest subjects on the arithmetic and pattern discrimination tasks would be expected to attenuate any real differences between that group and the other two groups. Clearly, the differences in problem difficulty would be expected to have direct effects on the performance of the arithmetic and pattern discrimination tasks, and, because of the time sharing requirements, we might expect indirect effects on the performance of the other tasks. Thus, the significant differences across age-groups on the pattern discrimination task are properly attributed to the fact that the oldest age-group had easier problems. It could be argued that the lack of a significant age effect on the arithmetic task is, in fact, evidence that there *was* an age effect. Specifically, as regards the percentage-correct measure, the 1-digit problems were so easy that, if age were not a factor, the oldest age-group should have performed significantly better than the other two groups, but they actually performed (non-significantly) poorer. The argument is even clearer in the case of the response-time measure. In another study using the same tasks with college-age sub-

jects, we found a mean response time of 5.34 seconds for the same 1-digit problems after only two 15-minute practice sessions (Jennings, Chiles, and West, 1972). However, direct substantiating evidence for these arguments is not available, and, therefore, they must be regarded as inferences.

The most prominent age effect was observed in the prolongation of the learning process in the oldest age-group as compared to the other two age-groups in the performance of the warning-lights monitoring task. The general picture presented by these measures was that of rather large differences in response times between the oldest and the other age-groups during Phase I, with reductions in the magnitudes of the differences in Phase II and III. More direct evidence of the slower learning rate of the oldest age-group is seen in the interaction between age-groups and phases on the monitoring tasks. Specifically, significant improvements across phases were found only in the case of the oldest age-group. The pattern of significant differences between the middle and youngest age-groups, e.g., differences in Phase I and Phase II but not in Phase III, is *suggestive* of a difference in the learning rates of those two groups. The finding of differential learning rates, which is clearest in the comparison of the oldest and the youngest age-groups, is directly compatible with previous findings such as those of Welford and Birren (1965) who reported age-related impairments in ability to learn simple tasks.

There appear to be three mechanisms underlying the differences in age-groups. The three possibilities are clearly not mutually exclusive and it is quite likely that all contributed. First, the differences could have been a repetition of the findings of previous reaction time studies though only in part. For example, the largest difference found by Goldfarb (1941) between a group ranging in age from 18 to 24 and a group ranging in age from 55 to 64 was with a 5-choice reaction time task; the actual magnitude of the difference was less than 0.1 seconds. If we use this figure as an estimate of the contribution of reaction time to the difference between our youngest and oldest subjects, then reaction time would account for less than 20% of the difference in the case of red-lights monitoring (with arithmetic) and less than 5% in the case of green lights (also with arithmetic). The second likely

contributor is efficiency of scanning habits. Clearly, the rate at which the subject could *effectively* scan the various monitoring displays and the frequency with which he did so would be important determiners of response times. This would be especially true of the green lights as compared to the red lights in that the onset of a red light was much more likely to be seen "out of the corner of the subject's eye." Another aspect of the efficiency of scanning is the flexibility of the subject in shifting, for example, from working an arithmetic problem to scanning the monitoring displays. Closely related to the flexibility factor is the breadth of the subject's attention with respect to perceiving a monitoring signal when his vision is focused on the displays for one of the two active tasks. The findings reported by Wallace (1956) lend support to the proposition that flexibility and/or breadth of attention were important contributors. He found that subjects in their sixties required tachistoscopic exposures about six times as long as did those in their twenties in the identification of very simple pictures and designs; they required up to 20 times as long for more complicated material. The third possible contributor to the production of performance differences as a function of age is differential motivation. However, the observations of the experimenters gave them the clear impression that the oldest age-group took the experiment the most seriously; the middle age-group was next; and the youngest subjects, although their continued application to the tasks was above our expectations, took the experiment the least seriously. Since the apparent differences in motivation were most pronounced toward the end of Phase III, any bias present should have tended to favor the performance of the older age-groups and, thus, would tend to underestimate age effects. Therefore, we consider the best explanation of the results with respect to age to be that the biggest contribution was made by differences in time-sharing skills such as scanning habits and flexibility of attention. Reaction time *per se* undoubtedly made a contribution, but it was probably relatively small.

The obtained differences between morning and evening performance are clearly compatible with the findings of previous research reviewed by Ray, Martin, and Alluisi (1961) and Trumbull (1966) as well as the research reported by Chiles,

Alluisi, and Adams (1968). An important methodological implication of this finding is that the multiple task performance approach used in this study yields relatively sensitive measures. Generally, we would not consider time of day to be one of the more powerful laboratory variables. It should also be remembered that the difference favoring evening performance was present despite the fact that a full day of activity intervened between the morning and evening sessions. On the other hand, an average time of only about 30 minutes elapsed from the time the subjects were aroused from sleep until they reported to the laboratory for testing. Thus, the pace of events prior to the morning test session may have been rather slow with respect to bringing them to a full level of performance alertness. The obtained interaction between time of day and age-group in the case of the percentage-correct arithmetic measure, when analyzed for simple effects, suggests that the oldest age-group may have had more difficulty "getting up to speed" in the morning than did the youngest age-group. However, this was the only measure that yielded a significant interaction between these two variables. Therefore, this finding should probably be considered as an isolated case since we can offer no good rationale as to why the effect should be peculiar to the accuracy of arithmetic computation.

## V. Conclusions.

The simulated sonic booms introduced during sleep did not have measurable consequences with respect to complex performance. The fact that significant effects were found as a function of age and as a function of the time of day at which performance was measured suggests that the measures were sensitive to meaningful variables. Thus, it is concluded that the sleep effects of the booms did not contribute significant variance with respect to performance.

Age appears to make a large contribution to the level of complex performance to be expected under these conditions. The most prominent feature is the difference in the rate at which skill is acquired, but, even after extensive practice differences between the oldest subjects (60 to 72) and youngest subjects (21 to 26) are still evident. Earlier in learning, significant differences are also seen between middle age-group subjects (40 to 45) and the oldest subjects. And, at the beginning of learning, differences are seen between the youngest and middle age-group subjects.

The time of day at which testing is carried out was found to be a significant contributor to the level of performance exhibited by the subjects. Thus, further support is given to the generally held conclusion that diurnal variations in performance must be considered both as a part of the methodology of performance measurement and in establishing operating procedures.

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