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THE EFFECT OF NOISE AND VIBRATION ON CERTAIN PSYCHOMOTOR RESPONSES

by

Don Lewis

A report on research conducted at The State University of Iowa, Iowa City, Iowa, by means of a grant-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration.

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

January 16, 1943

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

It has been suggested that the efficiency of pilots is reduced by exposure to the noise and vibration characteristic of military aircraft. This problem has been investigated by Dr. Don Lewis. His findings are presented in the attached report entitled The Effect of Noise and Vibration on Certain Psychomotor Responses, which is submitted with the approval of the Committee on Selection and Training of Aircraft Pilots.

According to the results of this experiment, noise and vibration similar to those experienced in the operation of military aircraft show no measurable effect on psychomotor responses, including responses analogous to those involved in flying, even when subjects were exposed to such conditions for as long as four and one half hours.

The results reported from this investigation should be viewed in the light of other investigations of performance under similar conditions. For example, in studies of typing and of other industrial jobs, it has been found that workers are able to perform with no great loss of efficiency even under conditions which they describe as very annoying. However, there is also evidence that they maintain this efficiency only by putting forth extra effort.

Such energy expenditure may produce adverse effects over a period of days or weeks even though it does not appear under test conditions. The negative results of such experiments as are reported here should therefore not be taken to prove that noise and vibration have no effect on pilot performance or health over a long period of time.

It has been noted that service personnel often report annoyance and feel that their work suffers from exposure to noise and vibration in the airplane. The author reports that almost without exception the subjects found the experimental conditions annoying. Many of them commented weeks later on the unpleasantness of the experience. Such annoyance might, over a period of time, result in a loss of interest in the task. This aspect of the situation is one which may be of considerable importance both in civilian and military aviation.

Very truly yours,

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

MSV:rm

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THE EFFECT OF NOISE AND VIBRATION ON CERTAIN PSYCHOMOTOR RESPONSES

Summary

The noise and vibration of airplanes are widely thought to reduce the efficiency of aviators. Service personnel often report annoyance and feel that their work suffers. The present experiments were undertaken to learn if there is actually a decrement in work under noise and vibration conditions similar to those characterizing military aircraft.

The experiments were performed at the University of Iowa with 80 male college students, C.P.T. applicants, and trainees as subjects. The subjects performed on a Mashburn apparatus. The Mashburn involves a control stick and rudder bar which are manipulated by the subject in response to changes in three banks of stimulus lights. As soon as the subject has responded to one set of lights, a new combination appears. For the present study the Mashburn apparatus was modified so that the platform could be made to vibrate. In the first series of experiments, performance in randomly selected groups was studied under six conditions:

A Silence
B Noise - 85 db*
C Noise - 110 db
D Vibration - 4 to 6 mils**
E Noise - 85 db; vibration - 4 to 6 mils
F Noise - 110 db; vibration - 4 to 6 mils

Effects of noise and vibration, respectively, on heart rate, breathing, tilt perception, brain waves, and hearing acuity were also studied. In addition, the design of the experiment allowed an evaluation of interaction effects of noise and vibration.

Exposure to loud noise for as much as one hour raised the threshold for hearing somewhat, and there was an indication that breathing rate was accelerated during some of the experimental conditions. On the whole, however, the results were negative in the sense that they revealed no consistently significant differences between reactions when noise, vibration, or both were present and when these supposedly disturbing factors were absent.

It appeared that the lack of positive results in the first experiments might have been due to the fact that none of the exposures was longer than an hour. A second series of experiments was therefore performed, in which 36 C.P.T. primary course applicants spent 4½ hours each in the testing situation. Four conditions were used:

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*db = decibel, "a logarithmic unit, equal to 1/10 bel, expressing relative levels of intensity of sounds...." (From: Warren, H. C. Dictionary of Psychology. Boston: Houghton Mifflin, 1934.)

**Mil = 0.001 inch; employed here as the unit for measuring the amount of displacement of a contact point on the top of the subject's skull. (See pp. 5-6.)

A Silence
B Noise - 110 db
C Vibration - 4 to 6 mils
D Noise - 110 db; vibration - 4 to 6 mils

Measurements were made of Mashburn performance, heart and breathing rates, tilt perception, and brain waves. Here again, even though the period of stimulation by high levels of noise and vibration was $4\frac{1}{2}$ hours in length, neither noise nor vibration, nor the two in combination had any measurably significant effects on reactions.

While the results of the experiment were generally negative, in terms of statistical significance of differences between reactions under the various conditions, the study furnished a number of incidental observations. For example, the experimenters gained the impression that those subjects who appeared to be most highly motivated and who seemed to perform best in their trials on the Mashburn apparatus were those who tended to be most irregular in their breathing. This impression is supported by the negative correlation between breathing regularity and Mashburn scores. However, the correlation is too low to give any confidence in the relationship.

The experimental design did not permit a detailed examination of changes in attitudes and feelings under conditions of noise and vibration and of the possible increases in effort required to maintain "efficiency" under such conditions. Because of this and also by reason of the limitations of the experimental conditions, the results cannot be accepted as conclusive in terms of planning a schedule of work and rest periods for pilots.

PROBLEM[1]

The original purpose of the project was to determine the effects of noise and vibration upon performance on a modified form of the Mashburn Automatic Serial Action Apparatus. The work was undertaken because of the common belief that continued noise and vibration reduce the efficiency of fliers. Performance on the Mashburn apparatus involves a series of adjustments resembling in some ways performance in flying, while the noise and vibration in the experiments resembled those encountered in military aircraft. To supplement the work of other investigators,[2] studies were also undertaken on the effects of noise and vibration on heart rate, breathing, tilt perception, brain waves, and hearing acuity.

The project included two series of experiments: a first series in which the exposure to noise and vibration was an hour or less; and a second series in which the exposure was four and one-half hours. In the present report the apparatus will be described first, since it is common to both series of experiments.

EQUIPMENT

The small building which housed the project was sufficiently isolated from other University buildings to avoid disturbance by the high levels of noise produced. The walls and floors of the building were of cut limestone. There was no ordinary ceiling: the roof was peaked-gable construction of heavy rafters and slab shingles. The floor plan of the interior is shown in Fig. 1. There were a large room 24 by 30 feet, and two smaller rooms each

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[1]This project was financed by grants from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration. The fullest cooperation was obtained from the head of the Department of Psychology and from the Dean of the Graduate College of the University of Iowa, and also from other University officials, including especially Mr. Elmer Lundquist, who supervised the Civilian Pilot Training Program. Professor E. F. Lindquist helped in designing the experiments. Half-time research assistants who worked on the project for varying lengths of time were: Douglas E. Wheeler, Earl D. Shubert, Morris W. Loving, and William M. McPhee. Part-time service of great value was rendered by Mr. Paul E. Griffith and Mr. J. G. Sentinella, electrical technician and instrument maker, respectively, in the Department of Psychology of the University.

[2]This work is reported in:

Stevens, S. S. The Effects of Noise and Vibration on Psychomotor Efficiency. (Progress Report of Project II, March 31, 1941.) Washington, D. C.: National Research Council Committee on Sound Control in Vehicles, 1941.

Stevens, S. S. Report on: I. The Effects of Noise on Psychomotor Efficiency; II. Noise Reduction in Aircraft as Related to Communication, Annoyance and Aural Injury. (OSRD Report No. 274, Progress Report of Project II, December 1, 1941.) Washington, D. C.: National Research Council Committee on Sound Control, 1941.

about 9 by 10 feet. The large room was quite reverberant and served as the main testing room, while the smaller rooms contained the control and recording apparatus.

A photograph taken from one corner of the testing room is shown in Fig. 2. The loud speakers are in the foreground. The modified Mashburn apparatus is in the center, the light panel being clearly shown. Beyond the Mashburn, in the corner, is the tilt apparatus, with a blindfolded subject seated in the typical position and with an experimenter ready to make adjustments. At the right, a subject is shown seated in the shielded cage which was used in connection with the recording of brain waves. The pneumograph and electrodes used to secure breathing and heart records are being worn by the subject on the Mashburn apparatus, but they are difficult to detect. The doors leading to the control rooms may be seen in the end.

Noise Generator

The equipment used to produce simulated airplane noise was composed of a variable-frequency multivibrator (a relaxation oscillator) and a random noise generator feeding through a single-tube mixing amplifier into a 50-watt power amplifier and a Jensen two-way speaker system, Type B. A schematic diagram is shown in Fig. 3.

The multivibrator circuit was the familiar thyratronpentode arrangement so connected that the plate resistance of the pentode controlled the discharge time of a condenser connected across it. The rate of discharge could be varied by changing the grid bias on the pentode. A single stage buffer amplifier was used to isolate the multivibrator from the rest of the noise-generating circuit.

Random ("white") noise voltage was obtained from a thyratron tube connected in series with a battery and output transformer. The characteristics of the circuit were such that there was no appreciable voltage below about 50 cycles.

The two signal-generating units were connected in parallel across the grid of the mixing amplifier through suitable isolating networks. The mixing amplifier connected directly into the first stage of a Thordarson 50-watt power amplifier.

The random noise spectrum was rolled off on the high-frequency end to give needed characteristics to the sound. The multivibrator was typically adjusted to a frequency of about 55 cycles, at which point its output seemed slightly unstable and gave the familiar beating effect of multi-motor plane noise, or something very similar to it. (The beating was due to interference between the fundamental component of the multivibrator and a 60-cycle component from the AC supply.)

Control of the voltage from each generating unit was attained by means of potentiometers placed across the output of the random-noise generator and across the input to the buffer amplifier in the multivibrator circuit. Adjustment of the output power into the loud speaker system was controlled with the master dial on the 50-watt amplifier.

The intensity level of the noise produced with the generating system was measured with a General Radio Sound Level Meter, Type 759-A. The values obtained with this meter were checked against those secured with a more exactly calibrated

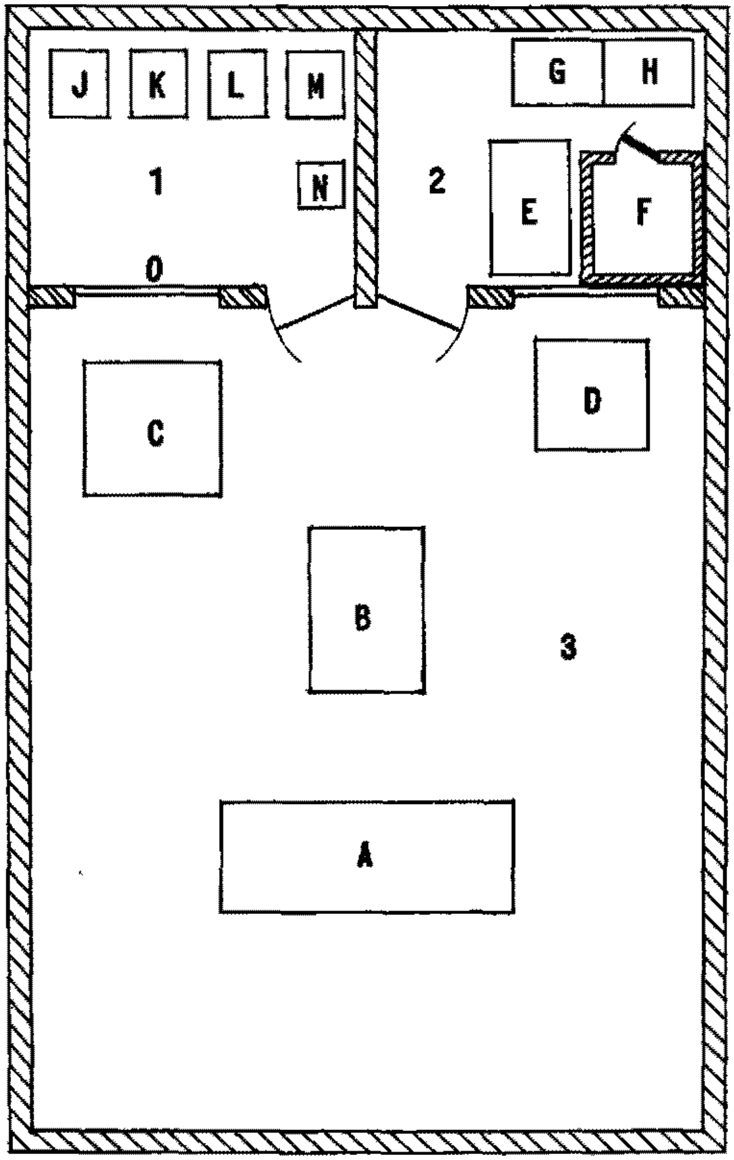

Fig. 1

Floor plan of the main testing room (3) and control rooms 1 and 2. A. loud speakers, B. Mashburn apparatus, C. tilt perception apparatus, D. electrically shielded cage, E. audiometer, F. telephone booth, G. amplifiers for recording EEG, H. Grass ink-writing oscillograph, J. polygraph, K. wave analyzer, L. sound generator, M. noise meter, N. chronoscope, O. viewing window.

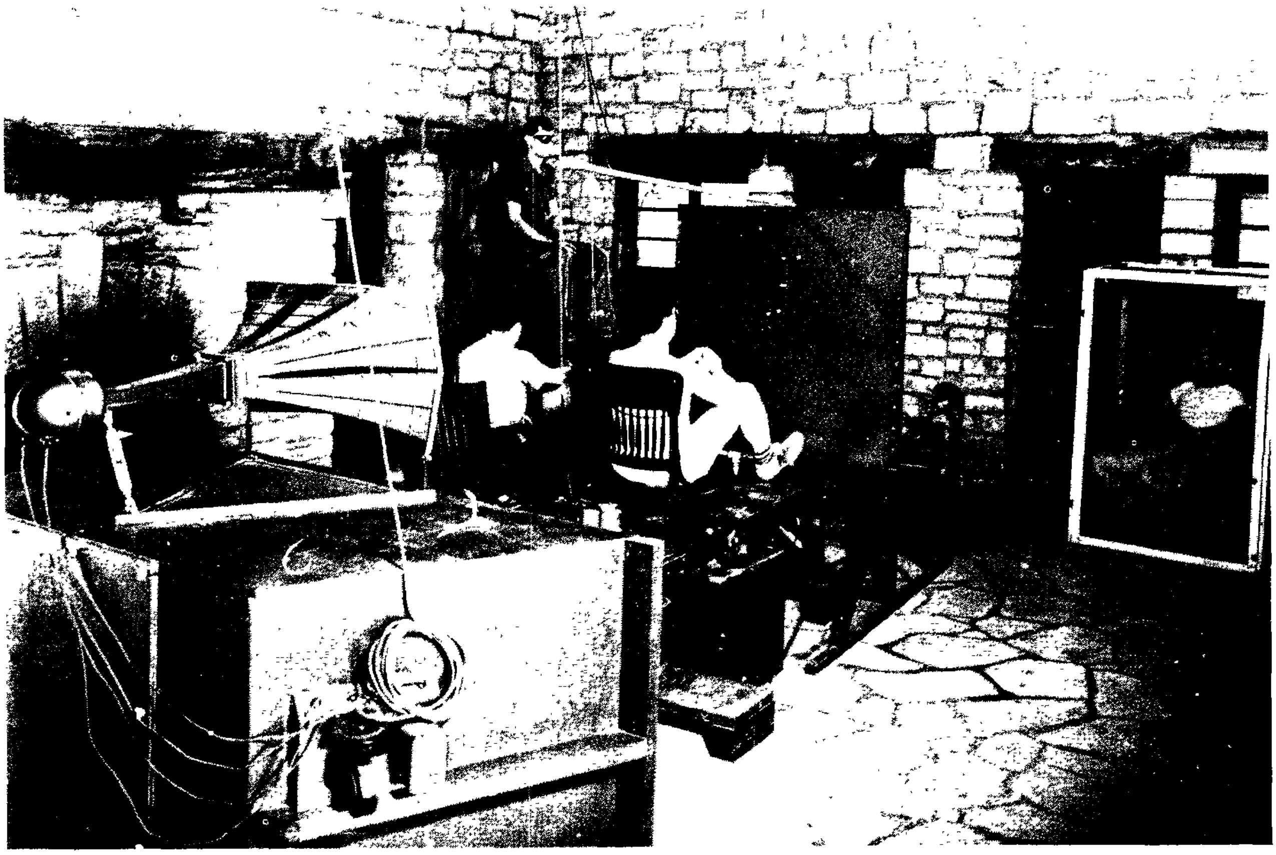

Fig. 2

Photograph of one end of the main testing room. The speaker unit is in the foreground, the Mashburn apparatus in the center, the tilt apparatus in the far corner, and the shielded cage on the right. The vibration pickup is fastened to the boom directly above the head of the person sitting on the Mashburn apparatus. When the pickup was used, the boom was lowered until the point of the pickup made firm contact with the subject's head. It will be seen that the light panel was not connected to the main platform of the Mashburn apparatus. This arrangement was to prevent vibration in the light panel.

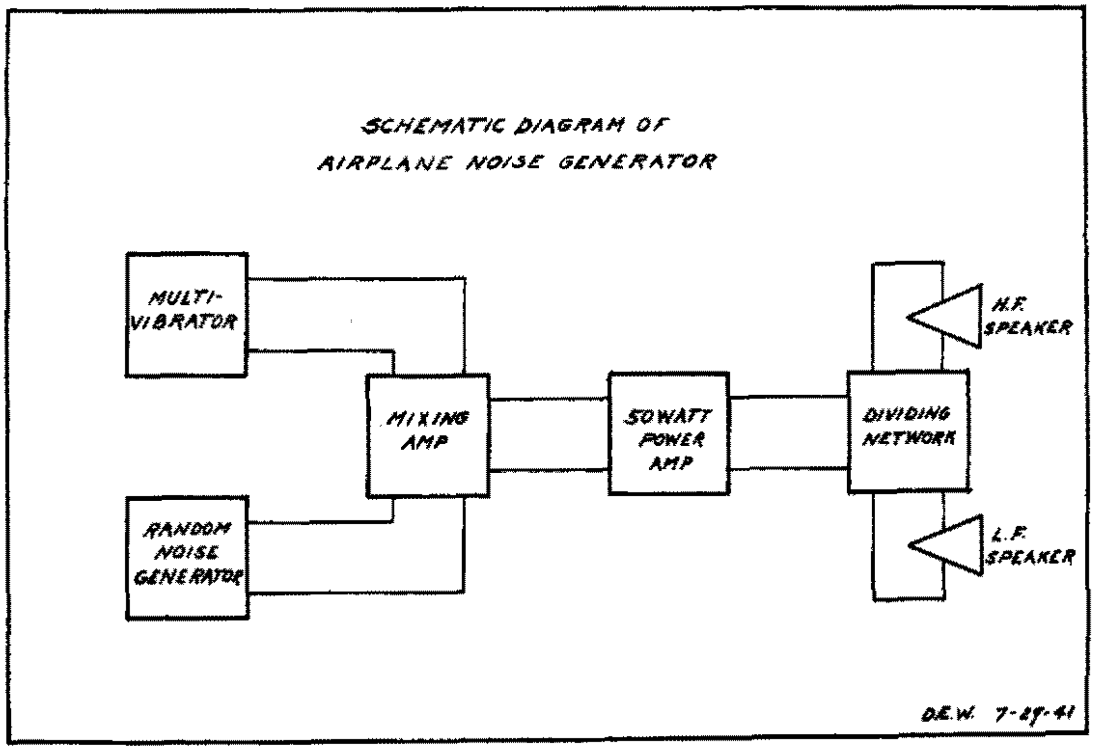

Fig. 3

Schematic diagram of
airplane noise generator.

circuit. The spectrum of the noise was determined with a General Radio Wave Analyzer, Type 636-A, and was made to conform in a general way to the frequency characteristics of airplane noise.[3]

The Mashburn Apparatus

Two views of the modified Mashburn apparatus are shown in Figs. 4 and 5. The apparatus was basically the same as that described in 1934 by Lt. Col. Mashburn,[4] the essential difference being in the way the platform was supported. In the present instrument, the platform was mounted at the four corners on heavy coil springs. This non-rigid construction made it possible to induce required amounts of vibration in the platform.

Basically, the apparatus consisted of three double banks of small pilot lights, and of a control stick and rudder bar. Each bank had a row of 13 red stimulus lights and a corresponding row of 13 green response lights. Three-way combinations of stimulus lights were flashed on automatically in random order, while the three rows of response lights were controlled separately by commutators and brushes fastened on the stick and rudder bar and were lighted serially when the controls were moved.

The three double banks of lights may be seen on the upright panel in Fig. 4, although the photograph does not show them as clearly as could be desired. The response lights in the horizontal bank (at the bottom) were connected to the commutator on the rudder bar and lighted one after another, from left to right, as the rudder bar was pushed with the right foot. Elevator and aileron controls were related to the response lights in the vertical and curved banks, respectively.

When a subject performed on the Mashburn apparatus, he was presented with three randomly-chosen red lights, one in each of the three double banks. It was his task to manipulate the stick and rudder bar until he got a green light opposite each of the three red lights. When this condition was attained, a stepping relay operated automatically to bring up a new combination of stimulus lights. The procedure continued until a total of 39 matches had been made.[5]

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[3]See pages 50 to 87, inclusive, of:

Beranek, L. L. Materials and Techniques for Sound Control in Aircraft. (Progress Report of Project I, March 31, 1941.) Washington, D. C.: National Research Council Committee on Sound Control in Vehicles, 1941.

[4]Mashburn, N. C. Mashburn automatic serial action apparatus for detecting flying aptitude, J. Aviat. Med., 1934, 5, 155-160.

[5]The original Mashburn apparatus provided for 40 matches in a series. It was more convenient to use only 39 in the present set-up. A subject made 39 matches. He could be asked to go through the same series of matches a second time, or third time, or many times in a row. On the other hand, he never had to go through exactly the same series twice; the apparatus was such that a different series of stimulus light combinations could be used for successive runs. The amount of learning of specific combinations was negligible, a fact which made it unnecessary to change the order of stimulus combinations.

The record that was usually wanted of performance on the Mashburn apparatus was a time score: the total time taken by the subject to complete a specified series of 39 consecutive matches. However, a more elaborate record was sometimes secured with an ink-writing polygraph having seven writers. Six of the writers were simple signal magnets that had been modified for the purpose; the seventh was an ink-writing tambour. The wiring circuit on the modified Mashburn was such that whenever a red stimulus light was correctly matched with a green response light, a relay was closed. When the relay was closed, a corresponding ink writer was activated. There were three such relays, individually related to elevator, aileron, and rudder manipulations. The three relays were connected in series and were inserted in one side of the battery supply to the solenoid on the stepping relay. When the three red stimulus lights for a given match were simultaneously matched with green response lights, the three relays were closed and their respective ink writers were activated. At this same time, furthermore, current flowed through the solenoid, and the solenoid drove the stepping relay one step ahead to bring up the next stimulus setting. An ink writer was also connected in parallel with the solenoid so that an exact indication was given of the time of completion of each match. Thus, the polygraph record revealed to some extent how a subject coordinated his manipulations of the controls.

A sample polygraph record is shown in Fig. 6. The three lines related to rudder, elevator, and aileron are designated, along with the line for the stepping relay. In addition, there is a time line at the bottom of the record, the breathing curve in the middle, and a record of heart beat (EKG) at the top. The paper ran through the polygraph at a speed of one inch per six seconds. Inasmuch as the speed was quite uniform, the time line was ordinarily not required, but it sometimes facilitated the measurement of heart and breathing records.

The polygraph record of Mashburn performance was found to have a limited usefulness mainly because it did not supply enough information to reveal the number and kind of errors made by a subject. But a satisfactory measurement of errors would have required the use of 39 ink writers -- one connected in parallel with each response light.

Breathing and Heart Records

The breathing and heart records were taken during performance on the Mashburn apparatus. A pneumograph was placed on the subject at a point on chest or upper abdomen where maximum deflection was obtained. A long tube led from the pneumograph (in the main testing room) to the polygraph (in control room 1) where it connected to an ink-writing tambour.

For EKG, flat zinc electrodes about 2 by 3 inches were first covered with EKG paste and were then firmly fastened by means of sponge-rubber pads and a belt to points on the subject's chest which yielded maximum voltage. A standard high-gain low-frequency amplifier served to raise the voltage from the heart to a value which permitted the operation of a vacuum-tube-controlled relay. This relay served to control the response of one of the ink writers on the polygraph.

The Vibrator Used with the Mashburn Apparatus

A schematic diagram of the vibrator used with the Mashburn apparatus is presented in Fig. 7. The vibrator consisted essentially of a motor-driven flywheel which was made eccentric through the attachment of a weight to it.

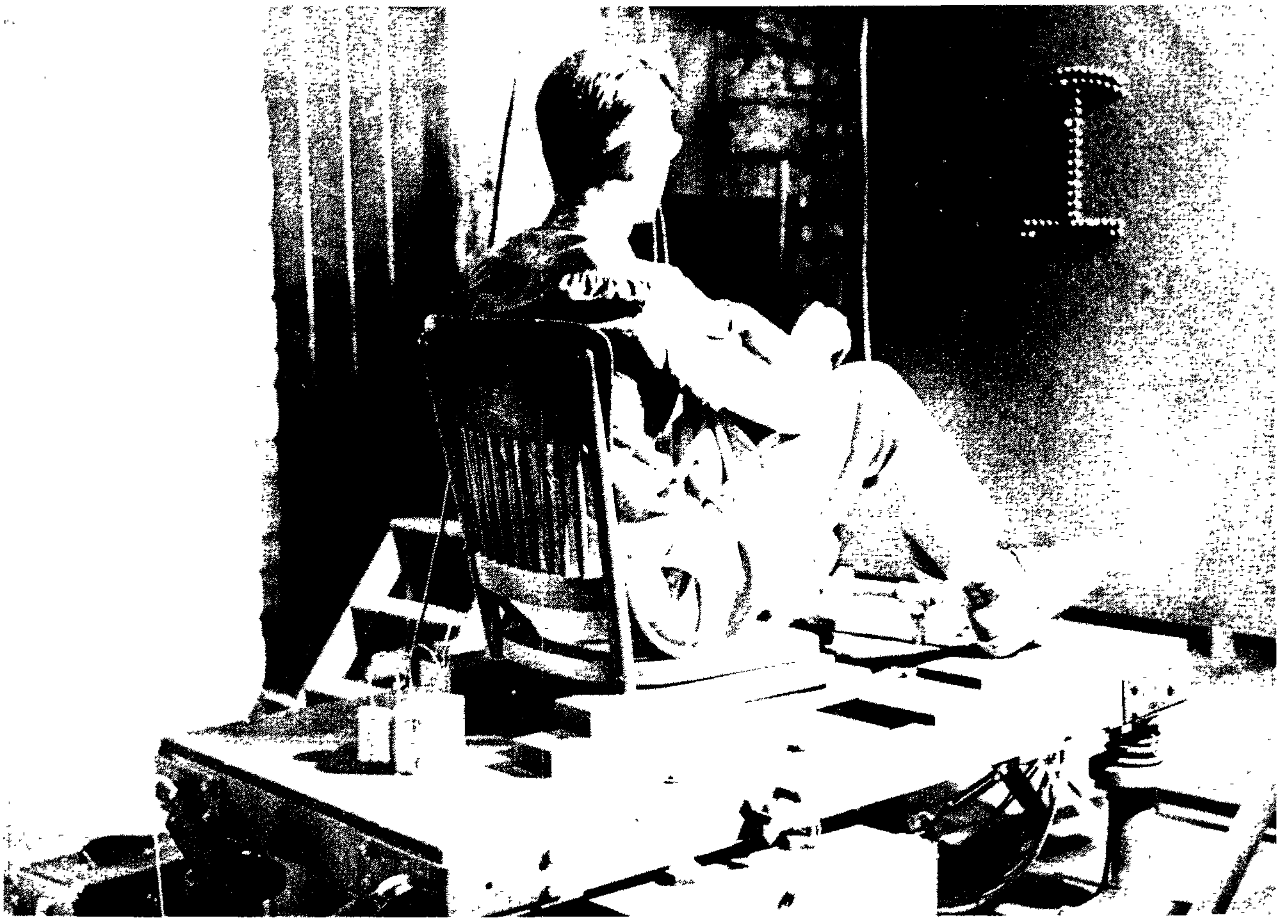

Fig. 4

View of the Mashburn apparatus taken from the rear. The light panel with its three double banks of lights may be seen, although shadow effects tend to obscure some of the details. The seat on the apparatus was adjustable for subjects of different leg-length.

Fig. 5

View of the Mashburn apparatus taken from the side. Both the rudder bar and stick may be seen, with some of the brushes and commutators visible under the platform at a point directly beneath the subject's feet. The corners of the main platform are seen to rest on coil springs. The box which housed the vibrator is beneath the platform toward the rear.

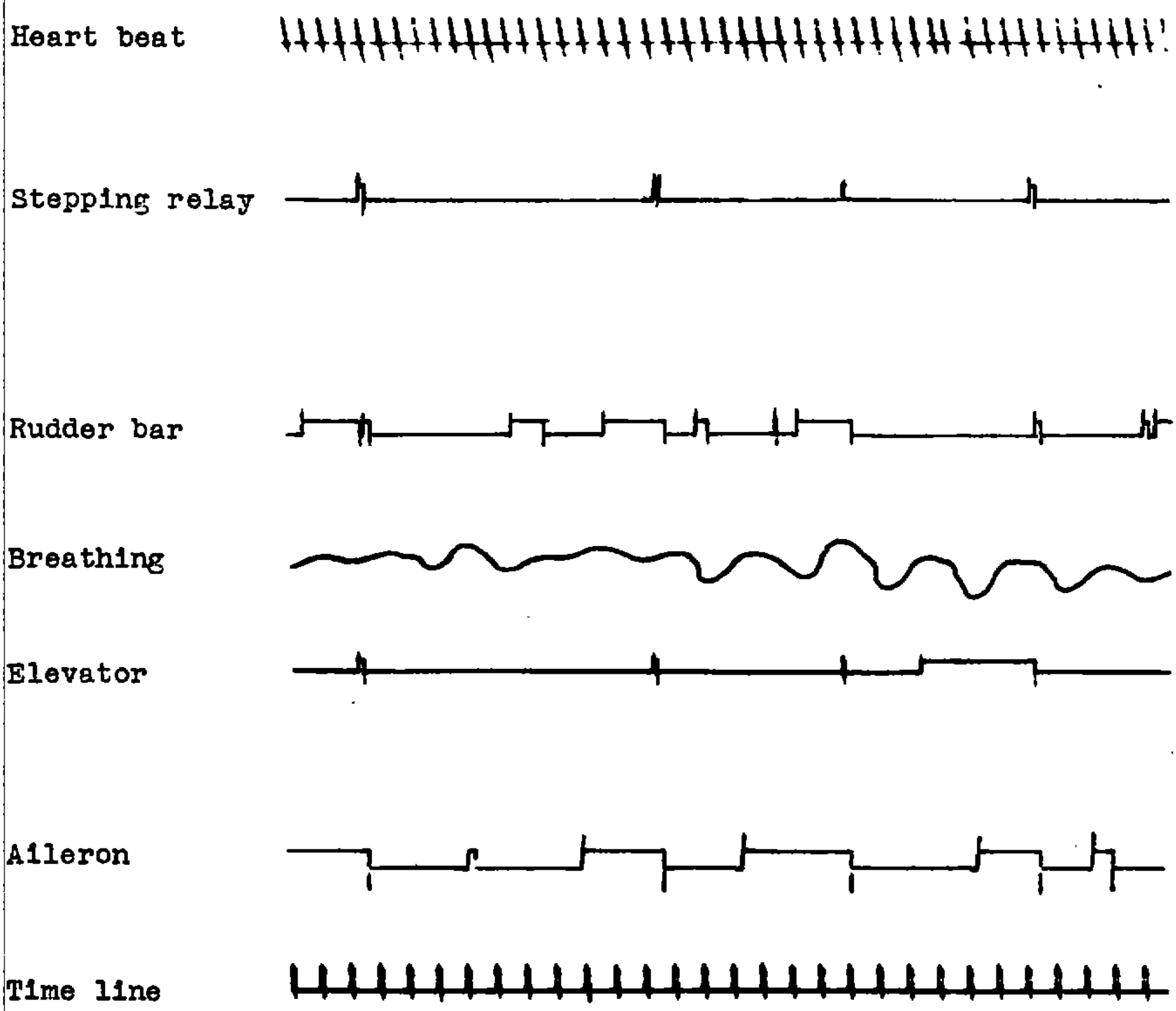

Fig. 6

A sample polygraph record.

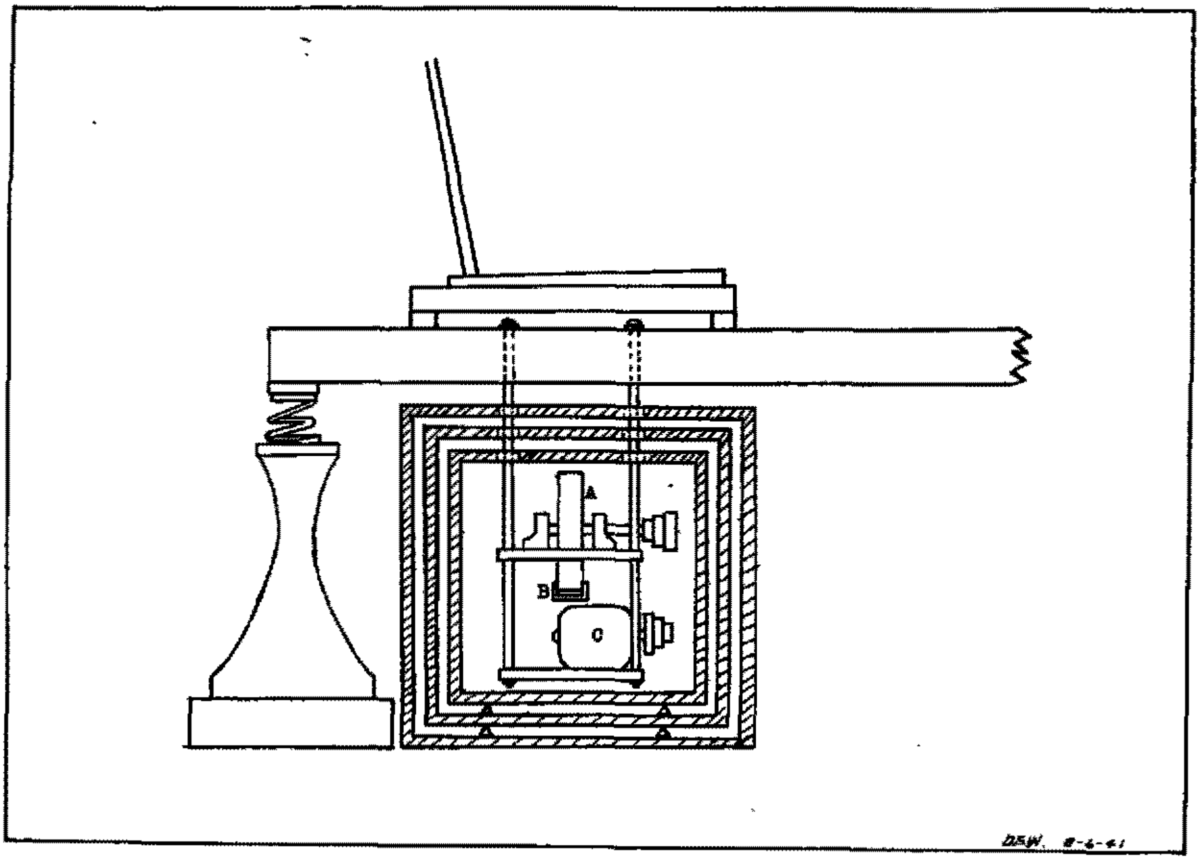

Fig. 7

Schematic drawing of the vibrator used with the Mashburn apparatus. The counterbalanced flywheel (A) was mounted in ball bearings which were fastened to a heavy, iron base. The flywheel was made eccentric by a small weight (B) which was fastened firmly on a specified point on its periphery. The system was driven by a synchronous motor (C). Pulleys of different ratios provided for different speeds of rotation of the flywheel, and thus for different frequencies of vibration. The vibrator proper was suspended at four corners to the platform, and was housed within-a-box-within-a-box-within-a-box. At every revolution of the flywheel, the platform was given a sharp downward thrust.

A flywheel, labeled A in the diagram, was carefully counterbalanced as a means of avoiding spurious vibratory frequencies. The amount of vibration in the platform for a given mass (weight of platform and subject) depended upon the weight of B, a small metal collar which could be firmly attached ... a specified point on the periphery of the flywheel. The flywheel weighed 30 pounds. The weight of B could be varied. Weights around 25 grams were typically used. A weight of two or three grams was sufficient to produce a faintly perceived vibration. In contrast, a weight of 80 grams (about 2.5 ounces) gave rise to a magnitude of vibration which the average subject, seated in the usual position on the platform, did not care to tolerate for more than a few seconds.

The shaft of the flywheel was mounted in ball bearings, the bearings being attached to a heavy iron frame. The synchronous motor (1/8 h.p.; 1800 r.p.m.) was also attached to the iron frame. The vibrator was completely enclosed within a-box-within-a-box-within-a-box. It was not fastened rigidly to the platform of the Mashburn; rather, it hung from the platform by four strands of braided cotton rope 5/8 inch in diameter (two strands on each side of the platform about 12 inches apart; one strand at each of four corners of the vibrator frame). Once every revolution of the flywheel (when B was attached), the platform was given a sharp thrust downward. Because the platform was mounted on coil springs, vibration was set up in it, the frequency of vibration depending upon the rotational rate of the flywheel. The rate of rotation could be altered by means of pulleys attached to motor and flywheel. The most commonly used rate was 1200 r.p.m. (20 cycles per second).

The boxes enclosing the vibrator were made of 5/8 inch plywood and were separated by 1-inch air-gaps. The outside box rested on the floor. (This box may be seen resting on the floor beneath the seat in the photographs in Figs. 4 and 5.) The inside boxes rested at the bottom on small blocks of ozite. The ropes which supported the frame of the vibrator passed through small holes drilled in the tops of the boxes. It is of some interest to note that, with rigid coupling between platform and vibrator frame, the platform apparently acted as a sound radiator and emitted noise at an intensity level of about 90 db. With non-rigid coupling and with the vibrator enclosed as indicated, there was a noise level from the vibrator of about 40 db -- a level which was heard by a subject seated on the Mashburn as a "low hum." When the synthetic airplane noise was sounding, the noise from the vibrator was completely masked -- and it was usually completely masked before the special soundproofing devices were installed. It should be remembered, however, that an attempt to isolate the effects of vibration from those of noise required that vibration be produced without an appreciable amount of accompanying noise.

Measurement of Vibration

In the measurement of magnitude of vibration, use was made of a comparison technique. The circuit was one in which a Brush Piezoelectric Vibration Pickup, Type DP-1, was operated in series with a General Radio Beat-Frequency Oscillator, Type 613-B, and was fed into a vacuum tube voltmeter. The vibration pickup was calibrated in terms of voltage output per mil (0.001") of displacement of the contact point. It was an easy matter to make a reading on the vacuum tube voltmeter for a specified magnitude of vibration. This reading was then matched by adjusting the gain dial on the oscillator. The voltage of the oscillator output under these circumstances was read on a microvolter. This voltage was taken to be equivalent to the output voltage of the vibration pickup, and was converted into mils of displacement. The technique was highly reliable.

The frequency characteristics of the vibration were checked with a General Radio Wave Analyzer, Type 636-A, the output of the vibration pickup being fed directly into the analyzer. An analysis was quickly made because all of the components except the fundamental (the one whose frequency corresponded to the rotational rate of the flywheel on the vibrator) were inconsequential.

One of the major problems was that of determining the amount (amplitude) of vibration actually affecting a subject. A specified weight could be attached to the flywheel of the vibrator. The result would be a measurable and repeatable magnitude of vibration in the chair or on the platform of the Mashburn apparatus. This amount of vibration was easily determined, and it was reasonably stable. Difficulties arose the moment a subject gotinto the chair, and the subject became the object undergoing vibration. With a subject seated in the typical position, it was still an easy task to determine the magnitude of vibration at some spot on the chair or platform. The problem was one of determining the magnitude of the vibration actually affecting a particular subject.

When trained pilots were asked to pass judgment on the vibration (asked, for example, to compare the vibration they experienced on the Mashburn apparatus with that which they had encountered in flight conditions), they would agree fairly well on the frequency of vibration but not on magnitude. It became clear that the <u>perceived magnitude</u> of vibration (in the sitting position) depended not only upon physical magnitude of vibration but also, for one important thing, upon the amount of flesh between the coccyx and the seat of the pants. In other words, subjects differed markedly in the amount of upholstery they carried around with them and thus in their perceptions of vibration in the sitting position on the Mashburn. Furthermore, the interrelated factors of erectness (or stiffness) of posture and muscle tension (especially in the back and neck) were of some importance.

Recourse was finally made to the measurement of the amplitude of vibration on top of the subject's skull. For this type of measurement, the vibration pickup was mounted on a boom, one end of which was hinged to a non-vibrating structure (to the light-panel of the Mashburn apparatus, for example). The boom with pickup attached (as used with the Mashburn apparatus) may be seen in Fig. 2. With a subject in position on the seat, the boom was lowered until the contact point of the pickup rested firmly on his skull over the parieto-occipital area. The amplitude of vibration was then determined. The procedure yielded reliable results for any specified subject so long as the subject's posture was essentially constant and the subject retained about the same amount (degree) of contact with the back of the seat. The chief difficulty was that during performance on the Mashburn apparatus, a subject did not retain exactly the same position and posture. Nevertheless, measurements taken from the top of a subject's skull were found to be the most meaningful. A vibration of from four to six mils on top of the head was typically used.

The Tilt Apparatus

Two views of the tilt apparatus are shown in Figs. 8 and 9. The apparatus consisted basically of a main platform, 5 feet square, which was pivoted for tilting about a horizontal axis and whose angle of tilt was controlled with a hydraulic system; and of a small platform, 2 by 3 feet, which could be rotated and on which were mounted the seat, the box which housed the vibrator, and the control stick. The main platform could be tilted in only one plane (that is, about a single axis). However, because the small platform, along with the seat and control stick, could be rotated to any desired position, provision was made for tilting a subject longitudinally (in the forward-backward direction) or laterally (sidewise) or sagittally. (In the actual experimental tests, the sagittal direction was not used.)

The photographs in Figs. 8 and 9 show the small platform adjusted for longitudinal tilt. In both cases, the apparatus is shown tilted (backward) 5.5 degrees. It was possible to tilt the main platform (and whatever was on it) through a total arc of 20 degrees — 10 degrees each way from level. Angles of greater magnitude could have been obtained but were not deemed necessary. Fig. 8 shows, in the foreground and to the right, the dial and pointer which were used in reading the angle of tilt. The dial was constructed with a dividing engine, and its divisions (5 minutes of arc apart) were probably accurate to about one-fifth minute of arc. Readings were usually taken to the nearest division.

The hydraulic system was composed of two water-tight brass cylinders, each 3 inches in diameter and 15 inches long (high), and each with a piston and plunger rod. The cylinders were each mounted on a cast iron base; and as shown in the figures, they were placed in an upright position beneath the main platform, one on either side of the axis of rotation, with the upper ends of the plunger rods pressing against the platform from below. Each cylinder, at its base, had an intake pipe as well as a drain pipe. The water supply had a pressure of about 90 pounds per square inch. Each intake pipe and each drain pipe was opened and closed with an electrically-operated (solenoid) valve. The circuit was such that one cylinder drained while the other one filled. This meant, of course, that the intake valve of one cylinder and the drain valve of the other were connected in parallel. The rates of filling and draining were adjusted to be essentially the same, the result being that the platform was always under the influence of the forces provided by the hydraulic system.

The system was silent except for indistinct clicking sounds which accompanied the opening and closing of the valves. These sounds apparently had no bearing on the performance of a subject on the apparatus.

The actual procedure, in the experimental situation, was for the blindfolded subject to be tilted a given number of degrees in a given direction, to be left in the tilted position for a given number of seconds, and then to be tilted [illegible] the level position. The subject responded [illegible] — until he judged his [illegible] level. [illegible] in the valve circuit [illegible] of the platform. For example, when lateral tilt was being used, the platform began tilting to the subject's left if he moved the stick to the left; to the right if he moved the stick to the right. The platform remained stationary so long as the stick was in the normal (neutral) position. For longitudinal tilt, a forward motion of the stick initiated forward tilting of the platform, while a backward motion initiated backward tilting. The circuit was automatically broken, and the platform stopped moving, when the angle of tilt reached 10 degrees in either direction.

Because of some interaction between the two drain pipes as well as between the two intake pipes and also because of random fluctuations in the water pressure from the University main, the rate of tilt was not constant. However, it was sufficiently uniform to meet experimental requirements. The usual rate was a little slower than 1 degree per second. Variations over a fairly wide range could be introduced for exploratory purposes. The lack of uniformity in rate had the advantage of ruling out the use of temporal cues by the subjects.

As may be seen in either Fig. 8 or Fig. 9, the subject sat on a sort of box. An ordinary heavy chair bottom formed the top of the box which housed the vibrator used with this set-up. The vibrator was similar to the one used with the Mashburn apparatus, and yet there was this difference: instead of having flywheel and motor mounted separately and connected by belt, it had a counterbalanced flywheel fastened directly on the shaft of a synchronous motor (1500 r.p.m.). The motor was rigidly attached to a frame weighing about 15 pounds. The frame was suspended, inside the box, by four lengths of braided rope (sash cord) which were fastened to the underside of the seat. The counterbalanced flywheel could be made eccentric through the attachment of a weight at a point on its periphery. The magnitude of the weight determined the amplitude of the vibration in the seat. The noise from the vibrator was virtually inaudible to the subject; and the vibration in the seat (and box) was isolated from the small platform and control stick by means of four stacks of rubber washers, the non-rigid coupling of box to small platform being with four snugly tightened strands of rope which passed through the washers. The frequency of vibration (25 cycles per second) was fixed by the motor speed.

Those being tested on the tilt apparatus could be subjected to desired levels of the synthetic airplane noise. The intensity of the noise was determined in the usual manner, the microphone of the noise meter being placed near the position occupied by the subject's head.

The amount of vibration a subject underwent on the tilt apparatus was measured in terms of mils of displacement at the top of his skull. The vibration pickup was mounted on a wooden boom which was hinged at one end of a non-vibrating structure. The boom was lowered until the contact point of the pickup rested firmly against the top of the skull; whereupon the measurement was made. The limitations of the technique have already been stated.

An attempt was made to construct equipment with which the subjects, instead of being blindfolded while they were tested, could be presented with a special visual field which sometimes would and sometimes would not rotate with the platform -- a kind of "crazy house" arrangement. It was thought

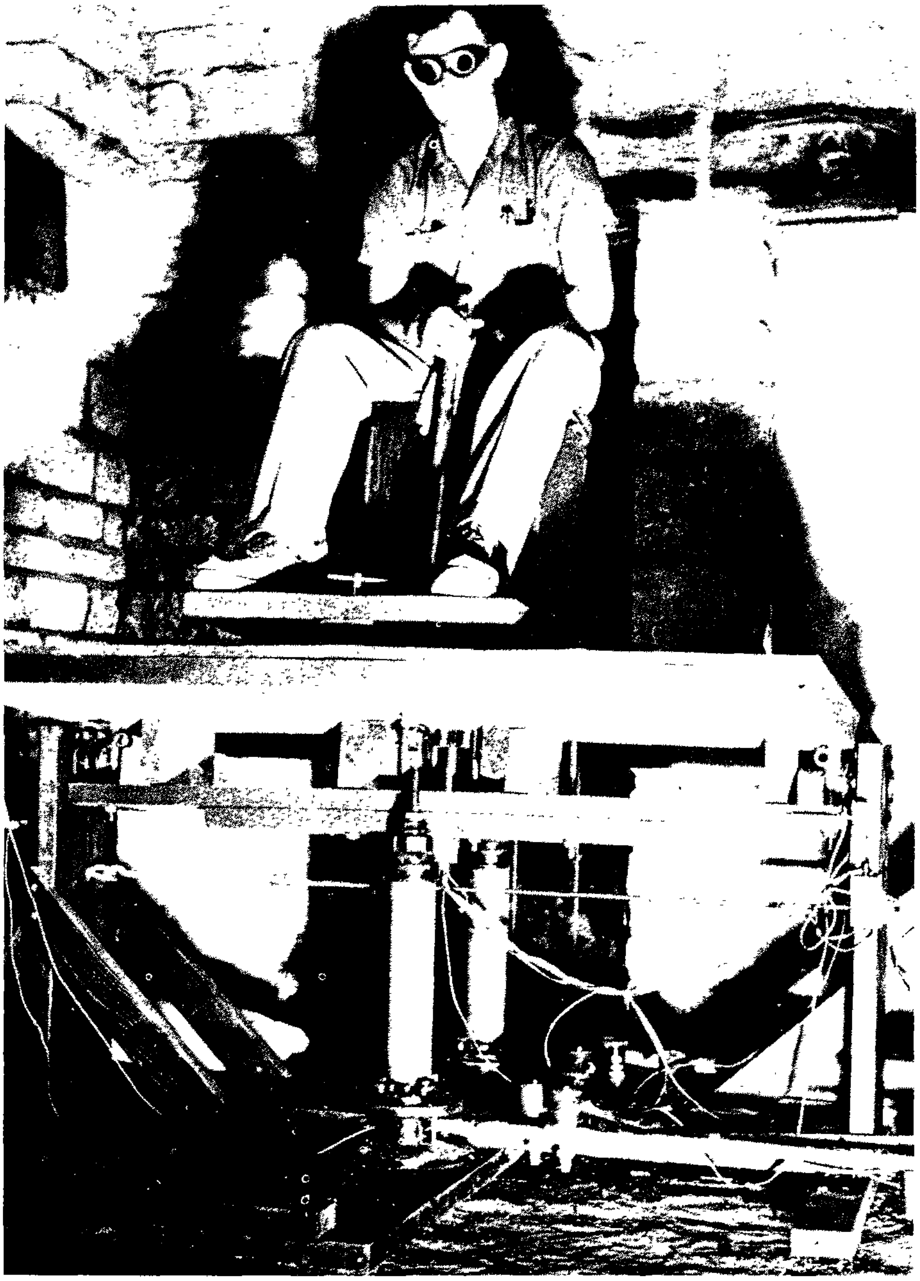

Fig. 9

A second view of the tilt apparatus. The small platform is adjusted for longitudinal tilt. This view shows the two upright cylinders of the hydraulic system quite clearly, together with the water pipes and solenoid valves.

Fig. 10

A view of the subject seated comfortably in the shielded cage used in connection with the recording of brain waves.

that the introduction of anomalous cues might impair perception of uprightness. Unfortunately, a satisfactory method of controlling the visual field could not be developed.

Brain Waves

The equipment for securing brain waves (EEG) consisted of a high-gain low-frequency amplifier which fed into a Grass ink-writing oscillograph. The electrodes were small lead discs and were attached in the usual manner. The subject sat comfortably in an electrically-shielded cage which was placed in one corner of the main testing room. (See Fig. 10.) The amplifying equipment and the oscillograph were located in control room 2 where, as checks revealed, they were not disturbed by noise levels in the main testing room up to 115 db.

A satisfactory method of recording brain waves while the subject was being vibrated could not be worked out. The difficulty arose because of the strong electrical field induced by the motor needed for producing vibration. It seemed unnecessarily complicated to devise a means of conducting vibration to the subject from a vibrator placed at a distance.

The experimental procedure was to secure brain wave records from subjects before and after stimulation by given levels and durations of noise and of vibration. Readings were made of the frequency of the alpha rhythm. Also, a careful watch was made for gross qualitative changes in the waves before and after stimulation.

Audiometric Tests

Fig. 11 gives a schematic diagram of the circuit used to secure information on hearing losses resulting from prolonged stimulation by high levels of airplane noise. The output of an oscillator (G. R., Type 613-B) fed through two attenuators (G. R., Type 249-H and G. R., Type 329-J) into Brush crystal phones. A photograph of the oscillator, the attenuators, and the voltmeter is shown in Fig. 12. It might be said that a Western Electric 2-A Audiometer was available for the measurements. This standard instrument was not used, however, because of its fixed frequencies and relatively gross calibration. The special circuit, aside from providing for any desired frequency, had the advantage of being calibrated in steps of one-half decibel.

The subject sat in a telephone booth which was located in control room 2. Threshold data, for either monaural or binaural conditions of listening, could be secured before and at specified intervals after the subjects had been bombarded by noise at given intensity levels, for given lengths of time.

THE FIRST EXPERIMENTS

Performance on the Mashburn Apparatus

The main purpose of the experiments with the Mashburn apparatus was, of course, to determine whether or not performance was affected to any measurable extent by either noise or vibration or by the two in combination. Six experimental conditions were used, as follows:

- A Silence
- B Noise - 85 db
- C Noise - 110 db
- D Vibration - 4 to 6 mils
- E Noise - 85 db; vibration - 4 to 6 mils
- F Noise - 110 db; vibration - 4 to 6 mils

The design was such as to permit an evaluation of the interaction effects (if any) of noise and vibration.

In the first experiments, conducted mainly during June and July, 1941, three different groups of subjects were run on the Mashburn apparatus. In all, there were 80 subjects in the three groups. The subjects within each group were assigned randomly to the six experimental conditions. The first group was composed of 24 male students from a class in beginning psychology. They volunteered to serve. The second group consisted of 39 student pilots who were enrolled in C.P.T. courses at the University. All of them had completed, or were close to completing, the primary course, and all were in training at the time. The third group (N = 17) was made up of applicants for the summer (1941) C.P.T. primary course. The plan had been to have at least 60 applicants in this third group, but the number was reduced to 17 by a sharp and unexpected reduction in the number of men applying. All available applicants were tested.

Each of the 80 subjects was given five trials on the Mashburn. A trial consisted of making 39 consecutive three-way matchings of green and red lights. The pre-trial procedures were about as follows. A subject, after being seated in the chair, was instructed on the general nature of the task he was to perform. He was told that a red stimulus light would appear some place in each of the three banks of lights; that it was his job to match these three red lights with green response lights by moving the stick and rudder bar in appropriate directions; and that a new combination of stimulus lights would appear as soon as the three-way matching had been attained. He was to continue, striving always for greater speed and accuracy, until all of the lights went off--for a total of 39 matches. The instruction period usually lasted from three to four minutes. An effort was made to get the subject relaxed and at ease. When the experimenter was certain that the subject understood the task, he turned on the green response lights (but not the red lights), and for a period of <u>one minute</u> allowed the subject to move the controls freely and observe how the green lights came on one after another in each row as the

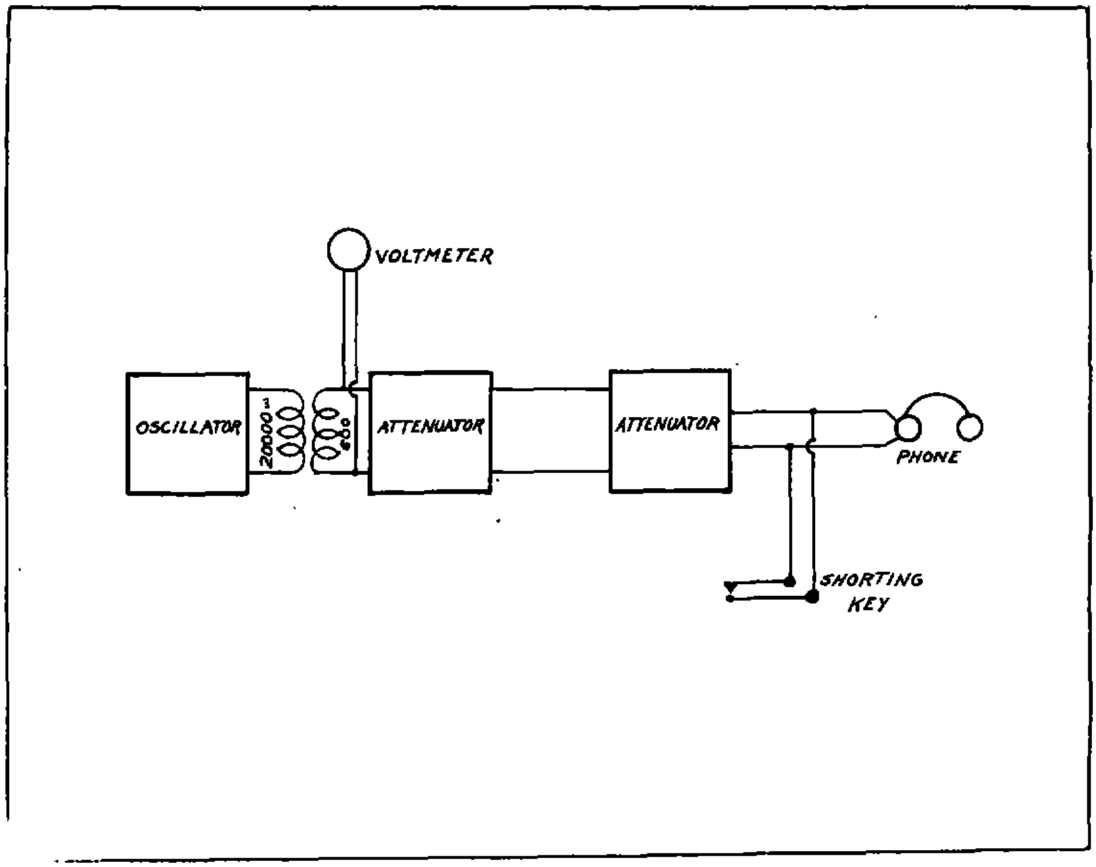

Fig. 11

A schematic drawing of the circuit used to measure threshold of audibility.

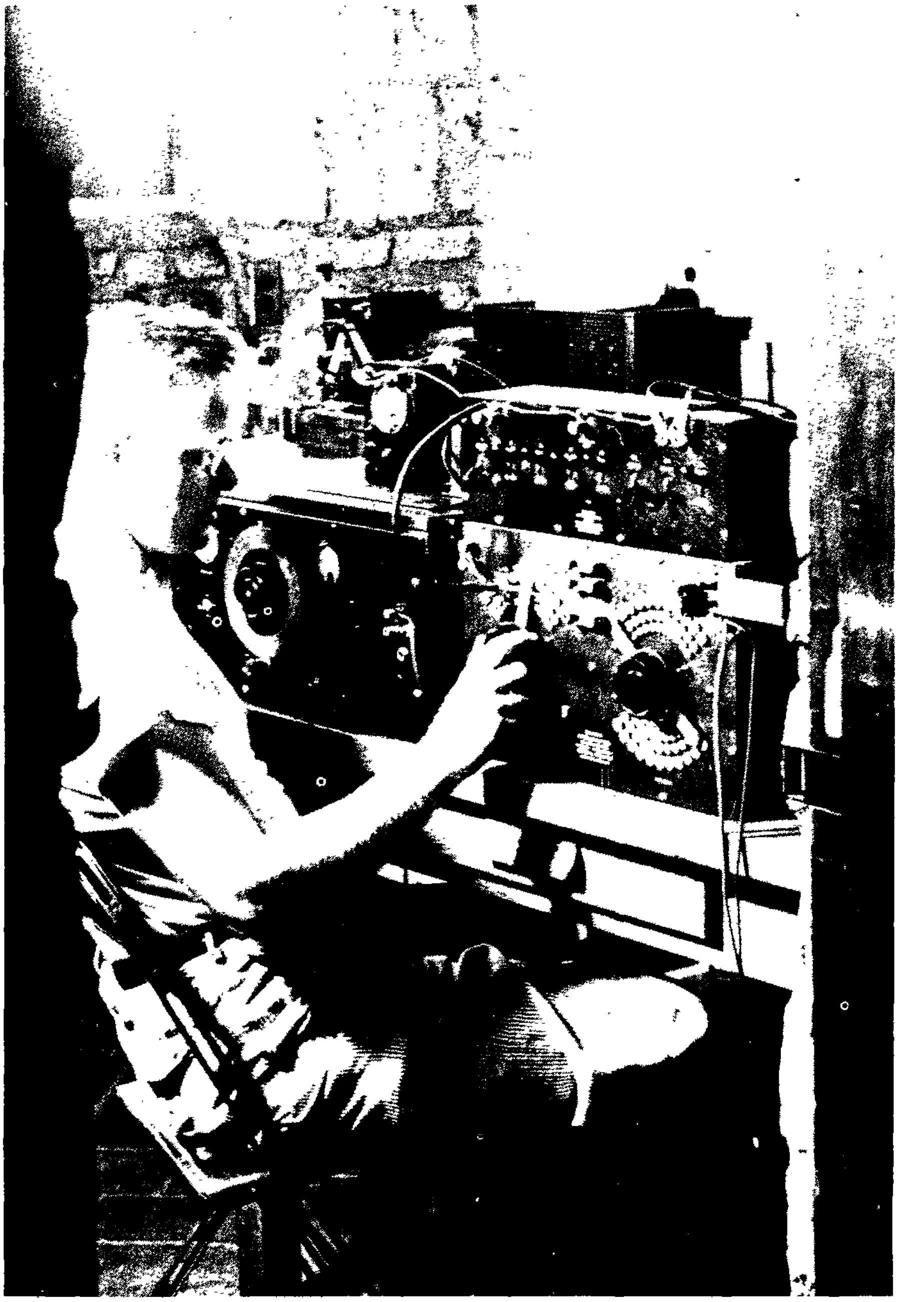

Fig. 12

Photograph of the audiometer.

controls were moved. At the end of this one-minute interval, the subject was told to get ready for the first trial, which would begin immediately. It should be noted that the subject began from 'scratch' — that is, he was given no actual practice in matching the red with the green lights. The only thing that approached practice was his manipulation of the controls while the green lights were turned on.

As already indicated, each subject was given five trials. As a usual thing, there was a short rest interval of one minute between consecutive trials. The subject remained in the seat but was told to relax. Occasionally, there had to be some amount of deviation from the one-minute interval between trials, to allow for adjustments of the apparatus (including the pneumograph and the electrodes for EKG). However, any marked deviation in scheduled time led to the discarding of the records of the involved subject.

Time scores for the five trials of each of the 30 subjects in the three groups are presented in Tables I, II, and III. The scores are given in minutes. The results for the first group (labeled Non-Pilots) are in Table I. In this table, as well as in the other two, the first column gives subject-number; the second column, the experimental condition; and the remaining five columns, the scores. As an example: subject 1, a Non-Pilot, performed under condition F (Noise - 110 db; vibration - 4 to 6 mils). His score for trial 1 was 6.38 minutes; for trial 2, 5.07 minutes; and so on. Tables II and III are easily interpreted, Table II being for student pilots in training (labeled Trainees) and Table III for applicants for training (labeled Applicants). Mean time scores for each trial are given at the bottom of the columns.

A graph based on the five mean scores for each of the three groups is shown in Figure 13. In the figure, time in minutes is represented along the ordinate and trials along the abscissa. It is obvious, from the three curves, that the trainees and applicants were about equally proficient in performance on the Mashburn apparatus and that both of these groups were superior to the non-pilot group. Application of Fisher's t-test showed that all the differences between trainee and applicant means lacked statistical significance, but that all of the differences between trainee and non-pilot means, and also between applicant and non-pilot means, were significant at better than the 1% level of confidence.

When the non-pilot group was seen to be so clearly inferior in Mashburn performance to the trainee and applicant groups, the thought was that the difference should be attributed principally to differences in motivation. Trainees as well as applicants were required to take the tests by the local C.P.T. coordinator, and they were given to understand that their performance would be taken into account in determining their future status in the training program. As a consequence, with one or two exceptions they seemed to be trying hard to do their best. The members of the non-pilot group were not indifferent, but it seemed possible that they were less well motivated than either the applicants or the trainees.[6]

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[6]This explanation in terms of motivation has since been discarded as being unlikely. In experiments not to be summarized in this report, motivational conditions for unselected university men students who volunteered to take the tests were such that they gave indication of trying as hard as the trainees and applicants. And yet, the non-pilots as a group were still found to be markedly inferior in Mashburn performance to applicants and trainees. The C.P.T. program apparently serves as a selective factor, attracting those young men, for the most part, who have better than average ability to perform on the Mashburn apparatus.

Analysis of Variance. To evaluate the effects of noise and vibration on performance on the Mashburn apparatus, analysis of variance techniques were employed.[7] The original plan had been to combine the three groups (trainees, applicants and non-pilots) so as to have from 12 to 15 subjects in each of the six experimental conditions. However, combining the groups seemed inexpedient not only because the mean scores for non-pilots on the five trials were significantly larger than those for trainees and applicants, but also because there was only one of the 17 applicants who, by chance assignment, had served in Condition F.[8] It was decided, therefore, to make the analysis on the results for the trainees only. There were 39 subjects in the trainee group. Three of them (Nos. 26, 30, and 50) were eliminated by random selection, leaving a total of 36 subjects - six in each of the six experimental conditions. The scores for the five trials were treated separately. The total variance of the scores for each trial was analyzed into conditions variance and within groups variance. The hypothesis to be tested was that there were no differences among conditions means which could not be attributed to sampling. The hypothesis was evaluated by applying the F-test, F being taken as the ratio of the conditions to the within groups variance.

For purposes of illustration, the scores involved in the analysis for trial 1 are presented in Table IV, along with a summary of the results. The subject-numbers and scores for the six conditions are arranged in the columns. Totals and means for conditions are given at the bottom of the columns. The grand mean was 6.406. As will be seen at the bottom of the table, the conditions variance was 0.1766, while the within groups variance was 1.4252. The F-value was 0.124, and provided no basis for rejecting the hypothesis that there were no differences among conditions means which could not be attributed to random sampling. It is clear that the performance of these subjects on trial 1 was not affected to any measurable extent by either noise or vibration or by the two in combination. A difference of about 1.90 between any pair of means would have been required to give a t-value that was significant at the 1% level of confidence. Actually, there were no differences between means greater than 0.4. Because the F-test failed to reveal a significant difference between the variances, the use of the t-test was, of course, made unnecessary. Also because the F-value lacked significance, an analysis of the total variance into three components would have been superfluous.

The results of the application of analysis of variance techniques to the scores for the other four trials are presented in Tables V, VI, VII, and VIII. Only conditions means, grand mean, and the principal results of the analysis are given in each table. As will be seen, all of the F-values were far from being significant. The obvious conclusion is that noise and vibration had no measurable effect on the time scores made by the trainees on the five trials on the Mashburn apparatus.

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[7] The statistical procedures employed in this report are described more fully in:

Lindquist, E. F. Statistical Analysis in Educational Research. Boston: Houghton Mifflin, 1940.

[8] As indicated above, the plans for this group had called for an N of 60. Only one of the first 17 subjects was assigned to Condition F.

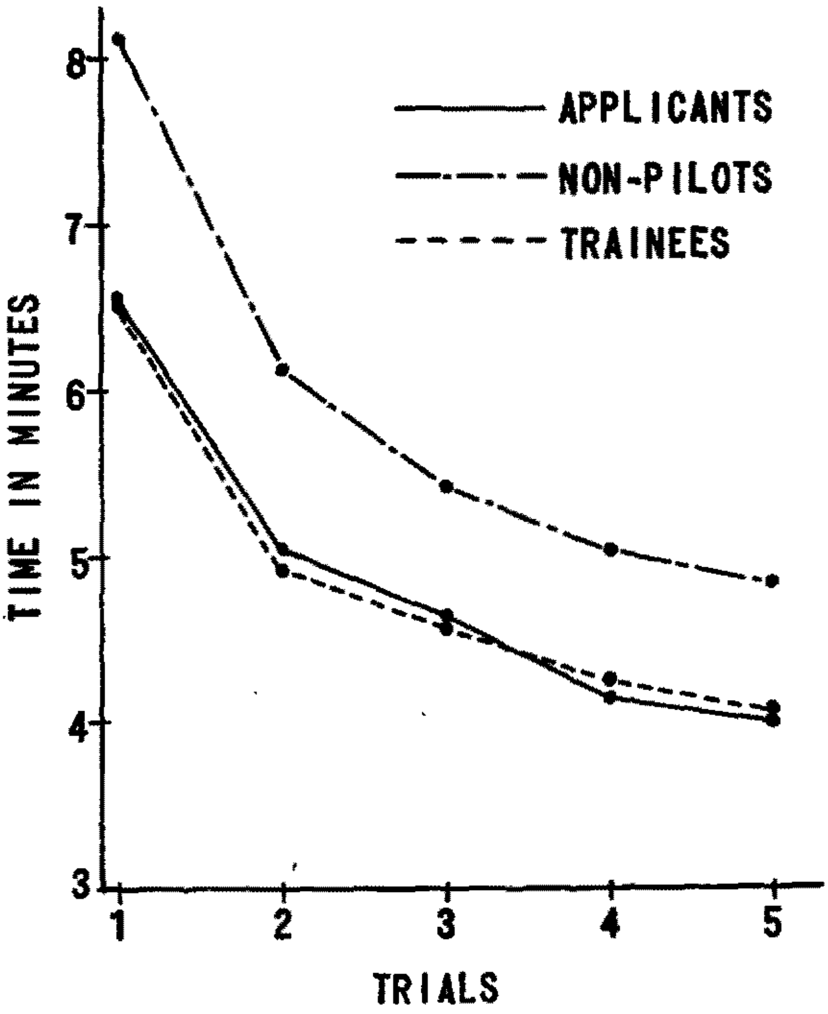

Fig. 13

Average time in minutes for each of three groups in five trials on the Mashburn apparatus.

[illegible] Records of Mashburn Performance. The ink-writing polygraph, in addition to recording EKG and breathing patterns, provided a record of the time taken for each of the 39 individual matches in any trial, and it also gave general information on the temporal sequence of the movements of the three controls (aileron, elevator, and rudder) that each subject used. However, measurements obtained from the records served no useful purpose in interpreting Mashburn performance. It was not possible to get from them a statement of errors which was at all adequate. For this reason, the polygraph records were used only as a check on gross time scores, except, of course, where they were related to EKG and breathing.

Correlation Coefficients. Of incidental interest were some Pearson product-moment correlation coefficients obtained by correlating Mashburn scores on trials 1 and 2 and also those on trials 1 and 5 for the whole group of 80 subjects. The correlation for scores on trials 1 and 2 was .824, and for scores on trials 1 and 5 it was .807. For an N of 80, these r's were highly significant. A correlation of the scores for applicants and trainees alone yielded an r of .733 for trials 1 and 2, and an r of .720 for trials 1 and 5. The lower coefficients can be thought of as resulting largely from the increase in the homogeneity of the population which came with the exclusion of the scores for the non-pilots.

The r for scores on trials 1 and 2 was the nearest thing available to a reliability coefficient for Mashburn scores; and, of course, it was in no true sense a measure of the reliability of scores on either of the trials considered separately.

Heart Rate

During all of the time they were performing on the Mashburn apparatus, the subjects in the pilot and applicant groups wore electrodes for recording EKG. The electrodes were made of flat pieces of zinc about 2 x 3 inches. After being covered with EKG paste, they were held firmly in place by sponge rubber pads and a flexible belt. They were located on the subject's chest at points which yielded maximal voltage. A typical record of heart beat is shown in the top line of Figure 6.

Great difficulty was encountered at first in getting the EKG equipment to work properly. The chief trouble seemed to be in finding a method to shield the subject and the electrodes from the electrical field set up around the Mashburn apparatus whenever the vibrator was operating. Difficulty was at a minimum during the experimental conditions which did not call for vibration (Conditions A, B, and C); but even here, the first records were often unsatisfactory. For this reason, of the 56 EKG records for trainees and applicants, only 35 were suitable for measurement, and of these 35, several were incomplete in part.

Table IX gives heart-rate values for each of 35 subjects during Mashburn trials 1 and 5. The first column shows subject-numbers (numbers which correspond exactly to those for subjects in Tables II and III) while the heart rates are given in the third and fourth columns. The values are in terms of beats per quarter minute. Each value is an average of at least ten, and in some cases of as many as twenty, individual measurements. The values may, therefore, be regarded as fairly stable.

Analysis of Variance. Analysis of variance techniques were applied to the results of 30 of the 35 subjects. There were only five measurable records for Condition D, so the analysis was carried out in terms of five subjects in each of the six conditions. Where there were more than five subjects for a condition, five were chosen from the number available by means of random selection. The data for subjects 31, 43, 49, 54, and 63 were eliminated.

The results of the analysis for trial 1 are given in Table X, and those for trial 5 in Table XI. In neither case could the F-value be regarded as significant. Therefore, differences between conditions means lacked significance; and it may be concluded that, at least during trials 1 and 5, noise and vibration had no measurable effects on heart beat.

The grand mean for trial 1 was 23.658, while that for trial 5 was 21 998. The difference was 1.660 (or 6.640 beats per minute). The application of Fisher's t-test showed that this difference was significant at the 1% level of confidence. Apparently, the subjects became less excited and more relaxed as time went on, with the result that heart beat was slower during the last Mashburn trial than during the first one. But the deceleration was seemingly independent of the experimental conditions.

Correlations between Heart Rate and Mashburn Performance. Correlations were run between heart rate and Mashburn performance for each of the two trials. The correlation for trial 1 was .369; and for trial 5, .112. With an N of 35, the r for trial 5 lacks significance, while that for trial 1 is significant at about the 5% level.

Breathing

During performance on the Mashburn apparatus, the trainees and applicants wore a special pneumograph that was adjusted on the chest or upper abdomen so as to give a suitable deflection of the ink-writing tambour which traced the breathing curve on the polygraph record. A representative curve is shown in Figure 6. Measurements were made of the breathing rate of the trainees during trials 4 and 5 of Mashburn performance. Average values, in terms of number of respiratory movements per minute, are given in Table XII. The averages are each based upon six separate measurements.

Analysis of Variance. Analysis of variance techniques were applied in order to determine whether the breathing rates of trainees were affected by noise and vibration. The average rates of 36 subjects were analyzed, those for subjects 29, 31, and 59 being eliminated by chance selection. The results are presented in Table XIII. As indicated, the F-value was 2.793. This value, for 5 and 30 degrees of freedom, was significant at almost the 2% level of confidence. The standard error of the means was computed from the within groups variance to be 1.3979—a value which yielded an estimated standard error of differences between means of 1.9710. Application of the t-test showed that the differences between means B and A, B and C, F and A, and F and C were all significant at the 2% level or better, while the difference between means B and D was significant at about the 3% level. All other differences gave t-values which fell below the 5% point.

Noise and vibration appear to have had an accelerative effect on rate of breathing, although the results are somewhat paradoxical. For some reason that is not clear, the mean for condition C (noise - 110 db) was the same as the mean for A (quiet), even though the mean for B (noise - 85 db) was significently greater (1% level) than the mean for A. It is hardly likely that

Subject	Rank
44	1.2
36	15.4
60	29.4

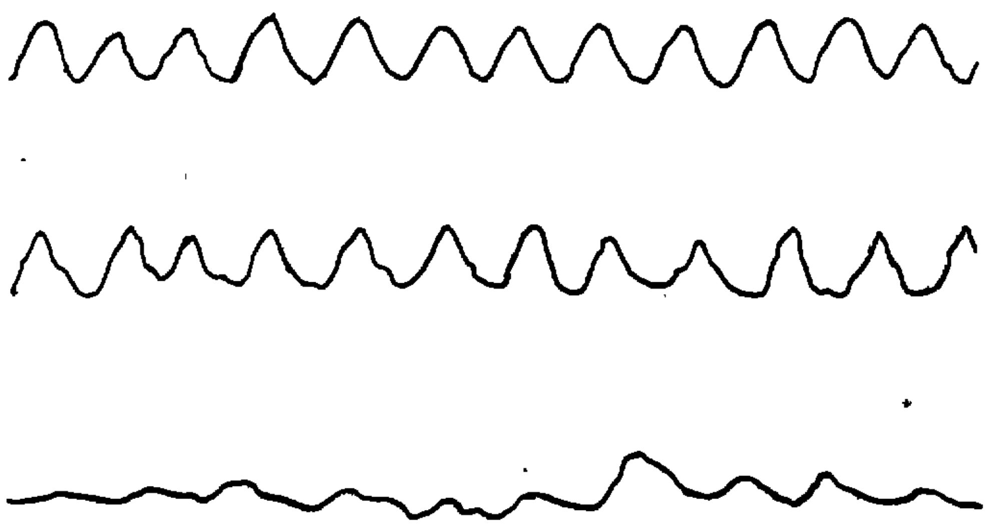

Fig. 14

Three samples of breathing patterns

with subject number and rank on regularity

noise would accelerate breathing up to a certain intensity level and then cease to have an accelerative effect. The differences must all be interpreted with great caution. The results of a t-test are never conclusive, especially for means based on small samples; and the F-value (4% level) was not large enough in this case to lead to satisfactory confidence in the existence of true differences among conditions means.

Regularity of breathing. It was obvious from the polygraph records of breathing that some of the subjects breathed smoothly and regularly throughout their performance on the Mashburn apparatus while other subjects were very irregular and erratic in breathing. As would be expected, many of them showed about an average amount of regularity.

No satisfactory way of quantifying regularity in terms of exact measurement could be worked out. It was decided, therefore, to have the breathing patterns of the trainees ranked by each of several observers, and to take the average rank as an index of amount of regularity. To facilitate the rankings, six representative samples of the breathing pattern of each of 32 trainees were cut from the polygraph records and pasted on white cards of uniform size. Each sample covered a time interval of 30 seconds. Because of low amplitude, the patterns of subjects 29, 30, 31, 39, 41, 46, and 48 couldn't be ranked along with the others.

The cards for the various subjects could be shuffled easily by the five observers, and arranged in appropriate order. The observers were instructed to study carefully all of the samples on each card and to make the rankings in terms of all of them. The cards were to be placed in rank-order from the one having the most regular breathing pattern to the one having the most irregular and erratic pattern. In their evaluation of regularity, the observers were told to consider both the frequency and the magnitude of the respiratory changes.

There was fairly good agreement among the five sets of rankings. Rank-difference correlation techniques were employed to get an indication of the reliability of the rankings. The inter-observer correlations ranged from .79 to .93. One of the observers was asked to make two sets of judgments. The correlation in this case was .89. The average ranks for two of the observers were correlated with the average ranks of two other observers, the resulting correlation being .96. All of these values of rho were satisfactorily high.

The average ranks for 32 trainees are given in Table XIV.

Three samples of breathing pattern, each representing a duration of 30 sec., are shown in Fig. 14. The pattern at the top (subject 44) was judged to have the greatest regularity and, as shown, received an average rank of 1.2 (Actually, of course, the rankings were made on the basis of several samples for each subject.) The middle pattern (subject 36) was judged to have about an average amount of regularity while the bottom pattern (subject 60) was judged to be highly irregular.

Regularity of breathing was found to be unrelated to experimental conditions, to heart rate, and to breathing rate, and only slightly related (if at all) to performance on the Mashburn apparatus. Average ranks on regularity for the 32 trainees were correlated with time scores for the fifth trial on the Mashburn apparatus. The correlation was -.254, which for an N of 32, was significant at less than the 8% level of confidence. The experimenters gained the impression, during the experimental runs, that those trainees who appeared to be most highly motivated and who seemed to perform best in their trials on the Mashburn apparatus were those who tended to be most irregular in their breathing. This impression is supported by the negative correlation between regularity and Mashburn scores. However, the correlation is too low to give any confidence in the relationship.

Tilt Perception

In the experiments on tilt perception, the purpose was to determine whether or not noise or vibration or the two in combination impaired ability to return to level position from specified angles of tilt. The premise underlying the investigation was that high levels of either noise or vibration might disrupt the normal functioning of the receptor mechanisms in the vestibule and semicircular canals, and that vibration might interfere with the functioning of cutaneous and kinesthetic receptor mechanisms--the mechanisms presumably operating when a pilot "flies by the seat of his pants". The exact role played by the different sense modalities in determining perception of uprightness is not known. In the airplane situation, the pilot might make use primarily of cues from the vestibule and semicircular canals, or he might depend importantly upon cutaneous and kinesthetic cues. In any event, it is not inconceivable that high levels of noise and vibration could have a deleterious effect upon the perception of tilt.

The design of the first experiment on tilt perception called for a group of 60 subjects, all males and all students at the University, each of whom would make 48 judgments--eight judgments under each of six different experimental conditions. The experimental conditions were the same as those used in the first experiments on Mashburn performance. They were:

A Silence
B Noise - 85 db
C Noise - 110 db
D Vibration - 4 to 6 mils
E Noise - 85 db; vibration - 4 to 6 mils
F Noise - 110 db; vibration - 4 to 6 mils

Of the eight judgments (returns to level position) made by a subject under each of these six conditions, four were for tilt in the longitudinal (forward-backward) direction and four for tilt in the lateral (sidewise) direction. Two of the longitudinal trials called for forward tilt and two for backward, while two of the lateral trials were for rightward and two for leftward tilt. Six different angles of tilt might be used for any specified judgment. These angles were 0, 2, 4, 6, 8, and 10 degrees.

The subjects were assigned to orders of experimental conditions and to angles of tilt with the use of a table of random numbers. The requirement was that the same distribution of angles of tilt would be used in each experimental condition and that in 48 trials, each subject would be assigned each angle of tilt eight times. Half of the subjects made judgments on longitudinal tilt first; the other half, on lateral tilt first.

The total time spent by each subject on the apparatus was approximately 60 minutes. There was some variation depending upon the speed with which the subjects responded.

Typically, after a subject had mounted the platform and was comfortably seated, he was carefully blind-folded with a dark cloth held securely over the eyes with a pair of blackened goggles. If he was to make judgments on lateral tilt first, he was shown that movement of the control stick to the left would produce a leftward tilt while movement of the stick to the right would produce a rightward tilt. Appropriate instructions of a similar type were given if longitudinal judgments were to come first. The subject was now told that he would be tilted to a specified angle, the direction undesignated; that after a few seconds' time he would be told, by a light touch on the arm, to bring himself to the level position; and that he could take whatever time was needed and could start and stop the tilt platform as often as he pleased. As soon as he felt that he was in a level position, he was to signal the experimenter by raising his hand. The trials would then be given, the order of experimental conditions to be used for each subject having been predetermined along with the order of angles and directions of tilt. As soon as a subject finished the longitudinal or the lateral trials (whichever came first), the apparatus would be adjusted for the other variety. The subjects were often encouraged to try harder, and to make their adjustments with care and precision.

Perhaps it should be stated that the experimenter, in setting the platform to a prescribed angle of tilt, did not go directly to that angle but first moved the platform in the opposite direction for a few degrees before making the correct adjustment. This procedure was followed primarily to preclude the possibility of the subjects' using temporal cues in judging the return to the level position.

After each judgment, when the subject signaled that he was in a level position, the experimenter read and recorded the angle at which the platform was standing. The recorded values were in terms of deviation from the level position.

Table XV presents average deviations for <u>longitudinal</u> tilt, expressed in minutes of arc, for each of the 60 subjects in each of the experimental conditions. Table XVI presents similar data for <u>lateral</u> tilt. In either table, the first column gives subject-number, while the next six columns give values (average deviations) for the six experimental conditions. Subject means are shown in the last column, and conditions means are given at the bottom of the six center columns.

<u>Analysis of variance.</u> Analysis of variance techniques were employed to evaluate the differences between conditions means for longitudinal as well as for lateral tilt. The total variance of the deviation scores of the 60 subjects in each of the six experimental conditions was analyzed into three [illegible]: [illegible] variance, subjects variance, and remainder (conditions [illegible] variance. The results for longitudinal tilt are given in

Table XVII, while those for lateral tilt are given in Table XVIII. The F-test was applied, F being defined in this case as the ratio of conditions to remainder variance. For both longitudinal and lateral tilt, the F-values were far from being significant, even for 235 and 5 degrees of freedom. A few of the differences between conditions means for longitudinal tilt were fairly large (for example, the difference between means for conditions C and F was 15.133) but the largest of the differences were little more than twice the estimated standard error of differences.

The results of the analysis indicate that there were no measurable effects of either noise or vibration or of the two in combination upon the perception of tilt under the conditions of the experiment.

Difference Between Lateral and Longitudinal Tilt

The grand mean of the deviations for longitudinal tilt was 77.775 while that for lateral tilt was 68.400. In the evaluation of the difference between these two means, the remainder variance was used to estimate the standard errors of the two means. These error terms were used to compute the standard error of the difference, correction being made for the correlation between subject means for longitudinal tilt and subject means for lateral tilt. This correlation was .24. The standard error of the mean for longitudinal tilt was computed to be 4.768, while that for lateral tilt was 2.866. The standard error of the difference between means was estimated to be 4.893. The difference was 9.375; and the critical ratio was 1.902. The size of the CR showed that the difference between means was significant at only the 6% level of confidence. Inasmuch as the results of another experiment on tilt perception (which will be summarized later in the report) revealed a superiority of lateral over longitudinal tilt perception, and inasmuch as Burtt had previously reported a similar superiority, the superiority of lateral over longitudinal tilt in the present study may be accepted with greater confidence.

<u>Reliability of subject means.</u> In view of the fact that conditions means for lateral as well as for longitudinal tilt were found not to be significantly different, it was possible to compute a coefficient of reliability for subject means on lateral tilt by correlating subject means on conditions A, B, and C with subject means on conditions D, E, and F. Similarly, a coefficient could be secured for longitudinal tilt. The two r-values were found to be approximately the same, the r for lateral tilt being .677 and for longitudinal tilt, .683. These coefficients, when stepped up by means of the Spearman-Brown Prophecy Formula, were .807 and .812, respectively. Obviously, they indicate the reliability of measures for direction of tilt and not the reliability of measures for conditions.

<u>Direction of errors in tilt perception.</u> The values presented thus far have been average deviations of the platform from the level position. In the computation of the averages, no account was taken of the direction of the deviation. It might be supposed that the errors of adjustment would be as often in one direction from level as in the other, provided an equal number of trials was given in each direction. In other words, it might be expected that the algebraic sum of a large number of deviations would be zero. Actually, when account was taken of the direction of errors, the <u>point of subjective</u>

level was found to be 45.7 minutes to the right of level for lateral tilt, and 33.3 minutes backward from level for longitudinal tilt. The tendency to adjust the platform to a point backward from level and to the right of level was quite general. Only two of the subjects failed to show a preponderance of errors to the right in lateral tilt and only thirteen failed to show a preponderance of errors in the backward direction. Of these thirteen, four revealed no preference but adjusted on the average to physical level. A total of 1440 single adjustments was made by the sixty subjects in the lateral plane and an equal number of judgments in the longitudinal plane. Of this total number, 79.4% of the lateral adjustments ended to the right of center, while 63.7% of the longitudinal adjustments ended backward from center. The explanation for these results will probably be found, for lateral tilt, in the right-handedness of most people; and for longitudinal tilt, in the backward tilt of one or more degrees of most of the chairs in which people customarily sit.

Brain Waves

In the study of the effects of noise on brain waves, the help of Dr. John R. Knott was secured. Either he or his chief assistant attached the electrodes and made the recordings, and a graduate student trained by him made the measurements of the records.

Thirteen male students at the University served as subjects. They were chosen because it was known that they typically gave alpha rhythms, the frequency of which could be satisfactorily determined. This restriction in choice of subjects grew from the fact that the chief aim of the investigation was to determine whether or not noise affected the frequency of the alpha rhythm.

The electrodes were small lead discs and were attached in the customary way. One of them was fastened with collodion on the occiput and the other on the lobe of the ear. The subject was seated comfortably in an electrically-shielded cage and was told to close his eyes and relax but not to go to sleep. Recordings were first made during a ten-minute period of silence. This was the pre-noise period—control period I. Next, the noise was turned on at an intensity level of 110 db. The period of noise stimulation was 40 minutes in length. The recording was not continuous during this time, but a large number of representative samplings was secured. At the end of the noise period, a ten-minute period of silence ensued during which recordings were again made. This post-noise period provided for additional control—control period II.

The measurements were made in relation to stretches of 100 cm., this distance representing a time interval of 33.3 sec. The frequency of the alpha rhythm over successive 10-cm. segments of the total length of 100 cm. was first determined. The frequency values obtained in this way were then averaged to give the average frequency for each 100-cm. length. With a few exceptions, five average values for each subject were secured for each of the two control periods, and from 15 to 20 average values were obtained for the noise period. Because there was no systematic tendency for these average frequencies either to increase or decrease during the three periods, all of the values for each subject were averaged for each period. These final averages are shown in Table XIX where the first column gives subject-number and the remaining columns give the average frequency of alpha rhythm during each of the three parts of the experimental period. Means for the three periods are given at the bottom of the columns. It should be remembered that each value in the table is the mean of from about 50 to about 200 individual estimates of the frequency of the rhythm.

As found by the application of Fisher's t-test, there were no differences among the means which could not be attributed to sampling. It follows, therefore, that noise, at the level and for the duration used, had no measurable effect upon the frequency of the alpha rhythm. Dr. Knott made a careful survey of the various records and reported that, in his opinion, noise did not significantly modify any feature of the EEG's.

Hearing Loss

In the investigation of the amount of hearing loss resulting from stimulation by noise and vibration, three conditions were used, as follows:

- A Silence
- B Noise - 110 db
- C Noise - 110 db; vibration - 4 to 6 mils

Twelve university men students served as subjects and were assigned at random to the three conditions, four to each condition. All of the subjects had essentially normal hearing.

Prior to the actual experimental runs, all of the subjects were given practice in the audiometric tests, at which time their pre-stimulation thresholds were determined. Measurements were made for each of the following frequencies: 120, 250, 500, 1,000, 2,000, 4,000, 6,000, and 9,000. The two ears were tested separately to give monaural thresholds. The typical procedure in determining the threshold for a specified frequency was to use the method of limits and to take four measurements--two in descending and two in ascending order. The average of these four readings was taken as the threshold. It should be emphasized that the subjects were given enough practice to make them reasonably proficient in the actual test situation.

The experimental (stimulation) period lasted for one hour. During this time, the subjects performed on the Mashburn apparatus, taking one trial after another with only short pauses between trials. They were given the impression that the major purpose of the work was to test their skill on the Mashburn apparatus, and that the hearing tests, while rather important, were more or less incidental to the main purpose. This slight subterfuge was employed to keep them from thinking that their ears might be damaged by the loud noise.

At the close of the period of stimulation, the subjects left the Mashburn apparatus and went immediately to the listening booth for the hearing measurements. The order of presenting the eight different frequencies was varied from subject to subject, to provide for a counter-balancing for time differences. All of the measurements were made on one ear before the other ear was tested. It was possible to get suitable measurements on both ears for each of the eight frequencies in a little less than 30 minutes. Since there were four subjects in each of the experimental groups and since the tests were made on the two ears separately, the average threshold values were each based on an N of 8.

The results are presented in Table XX. The first column lists the various frequencies, while the other columns give the hearing losses or gains (in db) for the three experimental conditions. Losses are indicated by minus signs and gains by plus signs.

The values for condition A (silence) are all quite small. Most of them are positive. This apparent shift toward greater acuity was probably due to practice. The hearing losses for conditions B and C (noise, and noise and vibration, respectively) were principally for frequencies between 1,000 and 6,000 cycles. Some of the losses were close to 20 db. For example, at 4,000 cycles, the average loss for condition B was 19.1 db and for condition C was 18.5 db. The differences between the values for conditions B and C probably lack significance, indicating that vibration added little to noise in producing a decrement in hearing acuity.

It should be emphasized that the values in Table XX represent hearing losses or gains at a time about 15 minutes after the end of stimulation.[9] The losses immediately after stimulation were, without doubt, considerably greater.

The results make it clear that stimulation for one hour by synthetic airplane noise or by noise and vibration in combination at a rather high level produced significant losses in hearing acuity for frequencies between 1,000 and 6,000 cycles. Presumably such losses would become permanent in ears which were stimulated at high levels for fairly long periods at frequent intervals.

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9 About 30 minutes were required for making the measurements on each subject. Because the order of presenting the frequencies varied from subject to subject and from ear to ear, the average time at which the measurements were made was about 15 minutes after stimulation ceased.

THE SECOND EXPERIMENTS

Introduction

The results of the first experiments indicated that, under the prescribed conditions, there were no important effects of noise and vibration on performance on the Mashburn apparatus, on the perception of body tilt, on heart rate, or on the frequency of the alpha rhythm. Prolonged exposure (one hour) to loud noise served to elevate thresholds of audibility for frequencies between 1,000 and 6,000 cycles; and there was some indication that breathing rate was accelerated during some of the experimental conditions. On the whole, however, the results were negative--that is, they revealed no important measurable effects of either noise or vibration alone, or of the two in combination. It should be emphasized, however, that all of the durations of noise and vibration that were used were one hour or less. As an example, subjects performed on the Mashburn apparatus for a total of five trials each. The typical length of time for these five trials was between 40 and 50 minutes. In the tilt perception experiment, a subject seldom spent longer than about ten minutes in any one of the six experimental conditions. There was the strong possibility that the negative character of the results depended upon the shortness of the exposure time. It was thought that if subjects were exposed for considerably longer periods, noise and vibration might be found to have deleterious effects. The decision was therefore made to set up a series of experiments in order to evaluate the effects of longer exposure.

Thirty-six applicants for the C.P.T. Primary Course were available for the experiments. Arrangements were made with the local coordinator whereby each applicant, before beginning flight training, would be required to spend a total of five hours in the testing situation. Although the results of the tests did not affect standing in the training course, each applicant was told that the results would have a bearing on whether or not he was finally accepted. This subterfuge seemed desirable as a means of motivating the subjects.

Other motivating devices included payment to the students for the time spent at the rate of 30 cents an hour and six cash awards of $5 each which were given for "most skilful performance" and "greatest improvements in performance" on the Mashburn apparatus. The subjects were to spend the greater portion of the time performing on the Mashburn apparatus, so the cash awards seemed most meaningful in terms of that experiment.

The plan called for four experimental conditions, as follows:

- A Silence
- B Noise - 110 db
- C Vibration - 4 to 6 mils
- D Noise - 110 db; vibration - 4 to 6 mils

Measurements were to be made of Mashburn performance, heart and breathing rates, tilt perception, and brain waves. The five-hour period was divided as follows:

Time in Minutes	Activity
10	Attaching EKG and EEG electrodes and adjusting pneumograph
10	Recording brain waves (EEG)
210	Continuous performence on Mashburn apparatus
60	Tilt perception tests
10	Recording brain waves

This time schedule was adhered to as strictly as possible.

The general arrangement made it possible to record brain waves under uniform conditions for all subjects prior to any exposure to either noise or vibration, and then to make recordings again near the end of the five-hour period. Because suitable methods of recording brain waves while the subjects were undergoing vibration could not be worked out, the final records, like those at the beginning, were taken during silence and without vibration for all subjects.

As soon as the preliminary brain waves had been recorded, the subjects began performing on the Mashburn apparatus, and for the next 210 minutes (3 1/2 hrs.) they performed continuously on the apparatus except for brief periods between consecutive trials and for occasional pauses during which necessary repairs were made on the apparatus or adjustments made on the electrodes and pneumograph. As a usual thing, performance was virtually continuous. The results on two of the 36 applicants had to be discarded because of breakdowns in the apparatus and the consequent disruption in the temporal sequence of experimental events. However, for the 34 subjects for whom detailed data will be presented, the five-hour period was adequately controlled.

Immediately following the period spent on the Mashburn apparatus, the subjects were carefully blind-folded and then seated on the tilt apparatus where they spent 60 minutes. As soon as the tilt judgments had been completed, the subjects were ready for the final brain wave records.

Except for the first 20 and last ten minutes, all of the five-hour period was spent under one of the four experimental conditions. For example, those subjects who were assigned to condition B (noise – 110 db) were exposed to noise at the specified level for four hours and 30 minutes. During this time, they performed on the Mashburn apparatus 210 minutes and made judgments on the tilt perception apparatus 60 minutes. As a further example, subjects who served in condition D (noise – 110 db; vibration – 4-8 mils) were subjected to noise and vibration for four hours and 30 minutes—for three and one-half hours while they performed on the Mashburn apparatus and for 60 minutes while they made judgments on the tilt apparatus. The heart and breathing records were taken during performance on the Mashburn apparatus.

The aim of the experiments was to get measurements while the subjects were "under pressure". The notion was that if subjects could be highly motivated and if they were kept performing continuously in some way for almost five hours, differential effects of the experimental conditions might be present and detectable. Records of heart rate and breathing were made only during what were called <u>crucial trials</u> on the Mashburn apparatus. The reason for this and also the reason for using the crucial trials will become evident.

Performance on the Mashburn Apparatus

As indicated above, there were 36 applicants for the Primary C.P.T. Course who were available for testing. The experimental design was such as to provide for nine subjects in each of the four experimental conditions. The subjects were assigned to experimental conditions through the use of a table of random numbers. The results on two of the subjects had to be discarded because of a serious disruption in the tests resulting from a breakdown in theapparatus. Further difficulty arose when it was discovered that two of the subjects had had previous practice on the Mashburn apparatus as volunteers in the first experiments. This necessitated an arbitrary deviation in one case from random assignment of subjects to conditions.

Just as in the first experiments with the Mashburn apparatus, each subject was given preliminary instructions on the general nature of the task he was to perform. He was told that he would work continuously on the apparatus, making one trial after another for a period of three and a half hours. (A single trial consisted, as usual, of completing 39 three-way matchings of the green and red lights.) The subject was told, further, that at specified times there would be <u>crucial trials</u>. The cash awards were to be made, he was told, in relation to scores made on these crucial trials. He was told he would always be informed which trials were the crucial ones.

The distribution of crucial trials was as follows: After the first trial was completed, two crucial trials were given. These were designated as crucials 1 and 2. Polygraph records of heart rate and breathing were taken during these and all subsequent crucial trials. Following crucials 1 and 2, a subject took one trial after another until 30 minutes had elapsed or until he had finished the trial which was nearest the end of a 30-minute period. He was then told that the next two trials would be crucial ones—crucials 3 and 4. Again, at the end of another 30-minute interval of continuous practice, two crucial trials were introduced, crucials 5 and 6. This general procedure continued until the end of the total period of three and a half hours when the last two crucials (crucials 13 and 14) were given.

Each subject was urged to strive on every trial for maximal speed and precision, and to do this regardless of whether or not the trial was a crucial one. It was suggested that while the non-crucial trials were not related to determining the cash awards, attainment of skill on non-crucial trials would contribute to greater skill when the crucial trials came up. The experimenters tried in every way to keep the subjects highly motivated at all times toward attaining the best possible scores.

The subjects sat in the seat of the Mashburn apparatus continuously for three and a half hours, and with the exception of brief pauses which were required for taking readings or making slight repairs, they performed on the apparatus continuously. No attempt was made to avoid fatigue in the subjects. The desire was for performance under conditions of "stress" and fatigue.

Time scores, in seconds, for each of 34 subjects are given to Tables XXI to XXV, inclusive. As indicated in Table XXI, subjects 1 to 7 served in condition A (silence). The first column gives trial number, while the next seven columns give the scores for designated subjects. The last column gives the group or conditions means.

Some of the subjects had many more trials than others. For example, as shown in Table XXI, subject 1 had 39 trials while subject 4 had 57. The differences in number of trials resulted from differences in the time taken to complete each trial. A subject who was very proficient in the task would complete a trial in a shorter time than a subject who was inefficient. The length of the total performance period was controlled and not the number of trials.

Scores for the other subjects are given in the other tables. As will be seen, subjects 8 to 14 were assigned to condition B (noise), subjects 15 to 21 to condition C (vibration), and subjects 22 to 28 to condition D (noise and vibration). These 28 subjects were the ones whose scores were used in the detailed analysis of the results. Analysis of variance techniques were to be applied and a symmetrical design made the treatment of results easier. The scores for subjects 29 to 34 are presented in Table XXV. In this table, the letters in parentheses indicate the experimental conditions in which the subjects served.

Analysis of variance. It was decided to apply analysis of variance techniques to the scores on the crucial trials. The scores on these trials for subjects 1 to 28, inclusive, are given in Tables XXVI to XXIX. It should be borne in mind that crucial trials 1 and 2 came immediately after a subject had completed the first trial on the apparatus, that crucials 3 and 4 came a half-hour after crucial 2, that 5 and 6 came a half-hour after 4, and so on. For purposes of the analysis, the scores on each pair of crucial trials were averaged. This resulted in seven different analyses, one for crucials 1 and 2, another for crucials 3 and 4, another for 5 and 6, etc.

The total variance of the scores was analyzed into two components: conditions variance and within groups variance. The results are given in Tables XXX to XXXVI, inclusive. As will be seen, all of the F-values are far from being significant. The conclusion must be, therefore, that neither noise nor vibration nor the two in combination affected performance on the Mashburn apparatus to any measurable extent during the crucial trials. There seemed to be no reason for analyzing the scores on any of the other trials.

Correlations between certain Mashburn scores. Pearson product-moment correlation coefficients were run between scores on the preliminary (or first) trial on the Mashburn apparatus and scores on certain other trials. The correlation between scores on the first trial and the first crucial trial (actually, the first two trials) was .821. This r was about the same as those secured in the first experiments (see p. 29). Other r's were as follows: between the first trial and the third crucial trial, .536; between the first trial and the fifth crucial trial, .459; between the first trial and the best trial (the trial on which the time score was minimal), .468. It will be remembered that the third crucial trial came after more than 30 minutes and that the fifth crucial trial came after more than an hour of practice. The best score was typically attained on a trial which came fairly late in the whole series of trials.

There was a general tendency for the size of the correlation coefficient to decrease as the correlated trial became more remote from the first trial. This fact indicates that initial performance on the Mashburn apparatus was not an entirely satisfactory index to later skill in performance.

Performance curves. The six graphs in Figure 15 are presented not only to show the general course of learning to perform on the Mashburn apparatus but also to show that subjects who were initially superior in performance did not necessarily maintain superiority and that some who were initially inferior became quite adept at the task as practice continued. In all of the graphs, time in seconds is plotted against trials. Data for the first 25 trials are represented.

Performance curves for three selected groups of subjects are shown in graph A, in the upper left-hand corner of the figure. The superior group was composed of subjects 3, 4, 13, 14, 22, and 27--the subjects who completed an unusually large number of trials. The average number of trials for this group was about 56. The inferior group was composed of subjects who completed a small number of trials--about 39 trials on the average. In this group were subjects 5, 6, 10, 18, 25, and 26. The average group (subjects 2, 8, 12, 17, 24, and 28) were those who completed an in-between number of trials. The average number for this group was about 45. It is clear from these curves (graph A) that the superior group had a superior initial performance and maintained its superiority for the 25 trials represented. On the other hand, the average and inferior groups began with about the same proficiency and remained about equally proficient for the first seven or eight trials; but the average group then became more proficient than the inferior group.

The fact that initial performance was not a certain index to later proficiency is shown, in particular, by graphs B to F. The individual curves in these graphs were first selected more or less at random from the whole group and were then paired off to emphasize differences in rate of learning. The two curves in graph B, for example, show that subjects 6 and 27 had initial scores which were quite similar but that subject 27 improved much more than 6 did and was somewhat less variable. The initial score of subject 14 (graph C) was far inferior to that of subject 4 and yet 14 showed very great improvement, the result being that after trial 4 his performance was about equal to that of subject 4. The initial score of subject 8 (graph D) was inferior to that of subject 10 and yet 8 was consistently better than 10 after trial 11. Subjects 18 and 13 (graph E) were about equal in skill at the outset but 13 had a higher rate of learning and was the superior performer after trial 1. Subject 11 (graph F) was generally superior to subject 25 even though they had the same initial score. The various combinations of curves emphasize the fact that initial skill in performance was not an adequate index of the skill to be attained later, and reveal the basis for the relatively low correlation coefficients which resulted from correlating scores on the first trial with scores obtained on trials after (say) an hour's practice.

Heart Rate

As already indicated, polygraph records of heart beat were made during Mashburn performance. Measurements were made, in terms of number of beats per quarter-minute, for the pre-trial period and also for each of the 14 crucial trials (if the record was complete). The pre-trial period lasted two or three minutes. During this time, the subjects sat on the Mashburn apparatus and were told to sit quietly for a few minutes before the trials began. While it is true that the subjects were not completely at ease, their heart rates during the pre-trial period were probably not greatly different from

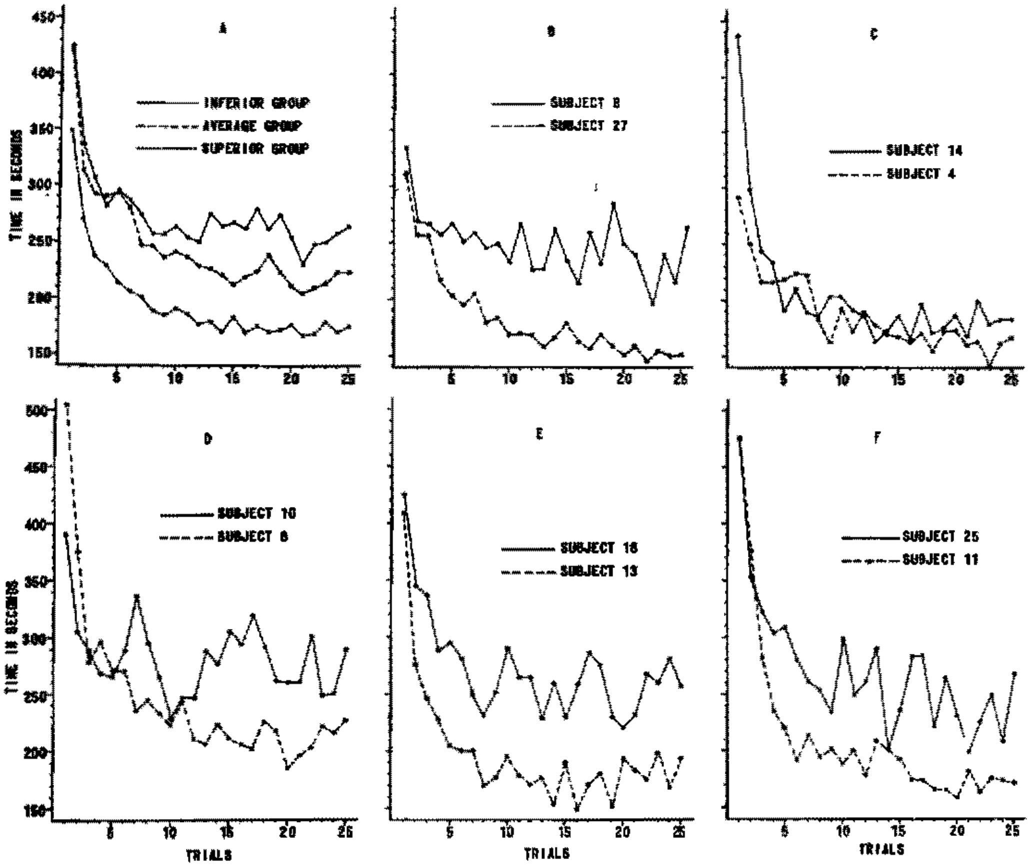

Fig. 15

Performance curves on the Mashburn apparatus for selected groups and for selected individual subjects.

normal. In any event, all of the subjects were put through the same routine. The pre-trial records were made, of course, before either noise or vibration had been introduced.

The heart rates for the crucial trials were recorded during performance on the Mashburn apparatus. Because of one sort of difficulty or another, the heart rate records were not complete on all of the subjects, for all of the crucial trial periods. The chief difficulty related to keeping the electrodes in proper contact with the subject's body. However, it was possible to make a satisfactory analysis of the results on selected subjects in each of the four experimental conditions.

Analysis of variance. Analysis of variance techniques were applied to the heart rates (per quarter minute) of five subjects in each of the four experimental conditions, during four different periods--the pre-trial period and the periods of crucial trials 1 and 2, 7 and 8, and 13 and 14. The rates used in the analyses are given in Table XXXVII. Tables XXXVIII to XLI give the results of applying the variance techniques.

The F-value for the pre-trial period (Table XXXVIII) was 0.079, and was clearly insignificant. This value of F was anticipated and showed that there was no reason for suspecting that the subjects in the four groups were not randomly selected from the same population. The F-value for rates during crucial trials 1 and 2 was 1.478, but this value, with 3 and 16 degrees of freedom, was not significant at any satisfactory level of confidence. The means for conditions B, C, and D, during crucial trials 1 and 2, were all greater than the mean for condition A (silence) but there was no basis for concluding that anything beyond chance factors was operating to produce the differences. Further, the F-values for crucial trials 7 and 8 (Table XL) and for crucial trials 13 and 14 (Table XLI) lack significance, again indicating that neither noise nor vibration nor the two in combination had any measurable effect on heart rate.

Heart rate was not related to experimental conditions. However, as compared with its value during the pre-trial period, it was accelerated during the first part of Mashburn performance. As shown in Table XXXIX, the grand mean during crucial trials 1 and 2 was 21.6 (beats per quarter-minute). In contrast, the grand mean for the same subjects during the pre-trial period was 19.5. This difference of 2.1 was significant at better than the 1 per cent level of confidence. It represented an acceleration of 8.4 beats per minute.

This acceleration of heart beat did not last beyond crucial trials 5 and 6, as shown in Tables LX and LXI. As shown, the grand means for crucial trials 7 and 8 and for crucial trials 13 and 14 were exactly the same as the grand mean for the pre-trial period.

Breathing

Records of respiratory movements were made on the polygraph during the pre-trial period and also during the first trial and all crucial trials on the Mashburn apparatus. Several of the records could not be measured for rate of breathing mainly because of irregularities in the pattern. However, satisfactory estimates of rate could be obtained for at least five subjects in each of the experimental groups.

Table XLII presents average breathing rates for five different periods. The values in the table are in terms of number of respiratory movements per minute. All but three of the values in the last four columns were used in an application of analysis of variance techniques, the values for subjects 7, 14, and 35 not being included for that purpose. The analysis was made separately for trial 1 and for crucial trials 1 and 2, 7 and 8, and 13 and 14. The principal results are presented in Tables XLIII to XLVI.

As shown in Table XLIII, the F-value for the data on trial 1 was 2.432. This value of F, for 3 and 16 degrees of freedom, is significant at about the 10 per cent level of confidence. It may be seen that the means for conditions B and D, both involving noise at high level, were greater than the means for conditions A and C, which involved silence. The differences may have been due entirely to chance factors, although it is not unlikely that breathing rate was slightly and temporarily accelerated as a result of noise.

However, the fact that rate of breathing was probably not importantly affected by either noise or vibration was indicated by the F-values for crucial trials 1 and 2, 7 and 8, and 13 and 14. All of these F-values were less than 1 and thus were far from being significant. The evidence as a whole indicated, therefore, that high levels of noise and vibration did not lead to measurable alterations in rate of breathing.

Breathing rate was apparently faster, on the average, during the whole time of Mashburn performance than it was during the pre-trial period. The four grand means given in Tables XLIII to XLVI are all 22.4 or greater. In contrast, the average rate of breathing for 18 of the subjects during the pre-trial period was 19.6. (See the third column of Table XLII for the individual values.) Application of Fisher's t-test to the differences between the mean for the pre-trial and the means for crucial trials 1 and 2, 7 and 8, and 13 and 14 showed the differences to be significant at better than the 1 per cent level of confidence, indicating a significantly faster rate during Mashburn performance than during the pre-trial period. However, rate did not vary significantly from one experimental condition to another.

Tilt Perception

As soon as the subjects had finished their long "stretch" on the Mashburn apparatus, they mounted the tilt perception platform and, after being carefully blindfolded, proceeded to make the required judgments. The procedure was basically the same as it had been in the first tilt experiment. The platform would be tilted by the experimenter to a prescribed angle. After several seconds (up to 20), the subject would be told to bring himself to a level position. One difference between the first and second experiments was that in the second one the subjects did not make judgments for all of the experimental conditions but each was assigned to a single condition—the same condition as for Mashburn performance.

A total of 24 judgments (returns to level position) was made by each subject. Of these 24, 12 were for longitudinal tilt and 12 for lateral tilt.

Half of the longitudinal judgments were made beginning from a backward tilt position and the other half from a forward position. Similarly, half of the lateral trials began with the platform tilted to the right of level and the other half to the left of level. Three different angles of tilt were used: 3, 6, and 9 degrees. There were two judgments on each angle for each of the four directions (backward-longitudinal, forward-longitudinal, rightward-lateral, and leftward-lateral).

The data are presented in Table XLVII, where two values are given for each of the 35 subjects. These two values, one for longitudinal and the other for lateral tilt, are average deviations from the level position, each average being based on 12 judgments. In the table, the data are divided into five groups. It was decided to apply analysis of variance techniques to the scores obtained by seven subjects in each of the four experimental conditions. The values that entered into the analyses are given in the four sub-tables at the top. Values for seven additional subjects are at the bottom.

Analysis of variance. The results of the analysis of variance for longitudinal tilt are given in Table XLVIII while the results for lateral tilt are given in Table XLIX. Both of the F-values are very small and are, therefore, entirely without significance. Whatever differences were found between conditions means must be attributed to chance factors. It follows that noise and vibration apparently had no measurable effect on perception of body tilt, even after they had been applied to the subjects for three and a half hours and longer.

Lateral versus longitudinal tilt. The grand mean of the deviations for longitudinal tilt was 120.1 minutes of arc while the grand mean for lateral tilt was 82.9 minutes. Through the use of the within groups variances, the standard error of this difference was computed to be 12.68. The difference itself was 37.2 and was 2.93 times its standard error. Consequently, the difference was significant at better than the 1 per cent level of confidence.

The coefficient of correlation between average deviations for longitudinal tilt and those for lateral tilt was -.171. This value of r, based on an N of 35, was too small to be regarded as significantly greater than zero. In the first experiment, it will be recalled, the correlation between deviations for lateral and longitudinal tilt was found to be .24, and this value, for the larger group of 60 subjects, was significantly different from zero at the 5% level of confidence (see p. 41). The reason for these low coefficients is not at all clear. A possible and more or less obvious explanation would be that lateral and longitudinal tilt perception depend upon a somewhat different set of receptor mechanisms.

In the first tilt experiment, the subjects had a constant error in their returns to level position (see p. 43). The platform, instead of being brought on the average to physical level, was stopped, in lateral tilt, 49.8 minutes to the right of level and, in longitudinal tilt, 73.7 minutes backward from level. As already indicated, these constant errors were probably related, in the lateral case, to the right-handedness of most of the subjects and, in the longitudinal case, to the backward tilt of small angle which characterizes most of the chairs in which people ordinarily sit.

Tilt perception and Washburn performance. There was no evidence to show that skill in performance on the Washburn apparatus and ability to perceive body tilt were in any way related. The correlations were all lacking in significance. For example, the correlation between average deviations for lateral tilt and the deviation for longitudinal tilt and scores on the first Mashburn trial was -.032. Obviously, neither of these coefficients was significantly different from zero.

Brain Waves

The brain waves of the subjects were recorded for a short time before they began performing on the Mashburn apparatus and were recorded again as soon as the tilt perception judgments were completed. The environmental condition of silence during the two periods of recording was the same.

Dr. John R. Knott and his research assistant dealt with the records and paid particular attention to the frequency of the alpha waves, to the percentage of time the alpha waves were present (alpha index), and to the percentage of time frequencies of less than 6 per second were present (the slow wave index). They searched carefully for modifications which might have been indicative of changes in the functioning of brain structures following prolonged stimulation by high levels of noise and vibration, but they were unable to find such modification. In fact, the differences which they found between pre-stimulation and post-stimulation features of the waves were so clearly lacking in significance that the use of statistical techniques was not required in order to evaluate them. As in the first experiment on brain waves, Dr. Knott concluded that noise and vibration had no detectable influence on electroencephalographic patterns.

SUMMARY OF FINDINGS

The results of the first experiments showed that noise and vibration, similar in structure and magnitude to those encountered in military aircraft, when applied to college men at high levels for relatively short periods of time (one hour or less), had no measurable effects on performance on the Mashburn apparatus, rate of heart beat, or perception of body tilt. A high level of noise, presented for about 40 minutes, had no measurable effect on the frequency of the alpha rhythm. A high level of noise, presented for one hour, impaired hearing acuity, especially for frequencies between 1,000 and 6,000 cycles. The effects of noise and vibration on breathing rate could not be satisfactorily evaluated because of inconsistencies in the data. Certain other findings which were not directly related to the main purpose of the investigation have been included in the report.

The results of the second experiments, for which the period of stimulation by high levels of noise and vibration was four and a half hours in length, showed that neither noise nor vibration nor the two in combination had any measurable effects on performance on the Mashburn apparatus, heart rate, breathing rate, perception of body tilt, or brain waves.

In general, the results of the investigation were negative. Except for their impairment of hearing acuity, noise and vibration were found to have no measurable effects on the various psychomotor responses under scrutiny.

APPENDIX

TABLES

TABLE I

Time Scores in Minutes for Performance on the Washburn Apparatus

NON-PILOTS

Subject	Condition	Trials 1	2	3	4	5
1	F	6.88	5.07	4.80	4.40	3.78
2	F	6.58	5.75	4.07	4.67	4.30
3	E	6.02	5.08	4.75	4.85	4.20
4	A	7.38	5.98	4.77	4.88	4.63
5	A	8.42	5.37	4.88	4.48	4.55
6	E	6.18	5.05	5.05	4.58	4.75
7	B	6.33	5.62	4.57	4.42	3.93
8	D	6.37	5.02	5.08	4.50	4.35
9	C	14.32	7.47	5.45	5.58	5.88
10	E	7.42	6.23	5.22	4.90	4.87
11	C	7.88	6.17	4.77	5.30	4.45
12	E	11.35	9.55	8.27	8.15	7.68
13	A	8.28	6.75	4.98	5.22	4.48
14	A	7.35	5.63	4.30	4.20	3.97
15	F	8.13	6.15	6.18	4.37	4.52
16	B	8.57	5.67	5.17	5.13	4.50
17	A	9.38	7.28	6.32	5.67	6.32
18	C	7.27	5.00	5.32	4.33	4.65
19	B	6.67	5.25	5.92	4.88	4.97
20	D	6.77	6.33	5.18	5.00	4.60
21	D	8.65	6.00	5.62	5.02	4.57
22	D	7.63	5.58	5.33	4.88	4.58
23	B	6.88	5.17	5.08	4.05	4.03
24	F	13.90	10.28	8.70	7.78	7.72
	Means	8.11	6.13	5.41	5.05	4.85

TABLE II

Time Scores in Minutes for Performance on the Washburn Apparatus

TRAINEES

Subject	Condition	Trials 1	2	3	4	5
25	E	7.50	4.37	4.28	3.82	3.89
26	B	8.13	6.35	6.00	5.38	5.68
27	F	5.07	4.15	3.53	3.48	3.62
28	A	5.36	4.47	4.23	3.55	3.53
29	B	6.44	5.03	4.40	4.18	3.95
30	B	9.03	5.37	5.00	4.73	4.46
31	B	7.63	5.23	4.93	5.08	5.07
32	E	6.30	4.63	4.32	3.45	2.90
33	D	7.27	5.33	4.77	4.88	4.72
34	A	6.90	4.27	3.85	3.95	3.76
35	C	9.45	5.88	5.88	5.68	5.62
36	A	6.34	5.82	4.45	4.57	4.06
37	B	7.39	5.78	5.08	4.92	4.51
38	A	6.58	4.97	4.65	4.33	4.58
39	B	5.37	4.82	4.63	4.18	3.58
40	C	4.62	3.97	3.42	2.98	2.93
41	D	5.63	4.45	3.85	3.63	3.85
42	E	5.43	4.45	4.20	4.10	3.41
43	A	5.67	4.17	4.07	3.53	3.21
44	E	5.47	3.88	4.03	3.65	3.45
45	F	7.00	5.03	4.30	4.33	4.00
46	F	4.94	4.53	3.27	3.35	3.28
47	F	6.50	5.63	4.65	4.78	4.87
48	F	9.00	5.82	5.88	4.77	3.93
49	E	7.88	4.88	5.17	4.38	4.00
50	D	6.03	4.55	4.13	4.07	4.20
51	D	4.92	4.02	3.78	3.63	3.80
52	F	6.46	5.08	4.93	4.37	4.21
53	D	5.83	4.75	4.50	4.03	4.15
54	C	6.91	5.42	5.25	5.00	4.67
55	C	5.77	4.92	4.30	3.75	3.75
56	B	5.24	3.85	3.85	3.88	3.78
57	D	7.66	5.95	6.53	5.40	5.03
58	A	6.45	6.45	5.58	5.20	4.73
59	D	5.81	4.47	4.45	3.23	3.53
60	C	6.00	4.83	4.55	4.12	3.93
61	E	5.74	5.30	4.90	4.70	4.10
62	C	6.67	4.37	4.47	4.00	4.40
63	B	7.40	4.77	4.62	4.50	4.08
	Means	6.51	4.92	4.58	4.25	4.07

TABLE III

Time Scores in Minutes for Performance on the Mashburn Apparatus

APPLICANTS

Subject	Condition	Trials 1	2	3	4	5
64	A	6.15	4.35	4.15	4.12	3.30
65	B	5.48	4.60	3.82	3.63	3.92
66	D	9.68	7.02	6.07	5.30	5.62
67	E	5.07	4.20	4.97	4.08	4.08
68	C	4.42	4.37	3.90	3.08	3.13
69	C	5.77	4.73	4.70	3.73	3.82
70	A	7.25	4.97	4.85	4.50	3.98
71	D	4.93	3.98	3.60	4.05	3.70
72	C	5.35	4.15	3.37	3.30	3.25
73	E	5.78	5.00	4.48	4.23	3.70
74	F	6.02	5.03	4.28	3.92	3.93
75	C	7.90	5.02	4.93	4.12	3.87
76	E	7.35	5.30	5.63	4.97	4.68
77	B	7.42	5.68	5.48	4.12	3.85
78	E	9.95	6.10	5.65	4.55	4.97
79	D	6.77	5.87	4.55	4.28	3.97
80	A	6.70	5.70	4.47	3.78	4.25
	Means	6.58	5.06	4.64	4.14	4.00

TABLE IV

Analysis of Variance of Time-Scores made by Trainees on the Washburn Apparatus – Trial 1

Conditions

A		B		C		D		E		F	
Subject	Score	Subject	Score	Subject	Score	Subject	Score	Subject	Score	Subject	Score
28	5.36	29	6.44	35	9.45	33	7.27	25	7.50	27	5.07
34	6.90	31	7.63	40	4.62	41	5.63	32	6.30	45	7.00
36	6.34	37	7.39	54	6.91	51	4.92	42	5.43	46	4.94
38	6.58	39	5.37	55	5.77	53	5.83	44	5.47	47	6.50
43	5.67	56	5.24	60	6.00	57	7.66	49	7.88	48	9.00
58	6.45	63	7.40	62	6.07	59	5.81	61	5.74	52	6.46
Totals	37.30		39.47		39.42		37.12		38.32		38.97
Means	6.217		6.578		6.570		6.187		6.387		6.495

Grand Mean = 6.406

Summary

	d.f.	Sum of Squares	Variance
Conditions	5	0.8828	0.1766
Within Groups	30	42.7574	1.4252
Total	35	43.6402	

$$F = \frac{0.1766}{1.4252} = 0.124$$

TABLE V

Analysis of Variance of Time-Scores made by Trainees on the

Mashburn Apparatus

Trial 2

Conditions Means

A	B	C	D	E	F
5.025	4.913	4.898	4.828	4.585	5.040

Grand mean = 4.882

	d.f.	Sum of Squares	Variance
Conditions	5	0.768	0.1536
Within Groups	30	14.294	0.4765
Total	35	15.062	

F = 0.3224

TABLE VI

Analysis of Variance of Time-Scores made by Trainees on the Mashburn Apparatus

Trial 3

Conditions Means

A	B	C	D	E	F
4.472	4.585	4.645	4.647	4.483	4.427

Grand mean = 4.543

	d.f.	Sum of Squares	Variance
Conditions	5	0.2797	0.0559
Within Groups	30	16.9396	0.5647
Total	35	17.2193	

F = 0.0990

TABLE VII

Analysis of Variance of Time-Scores made by Trainees on the

Mashburn Apparatus

Trial 4

Conditions Means

A	B	C	D	E	F
4.188	4.457	4.255	4.133	4.017	4.180

Grand mean = 4.205

	d.f.	Sum of Squares	Variance
Conditions	5	0.644	0.1288
Within Groups	30	14.270	0.4757
Total	35	14.914	

F = 0.2708

TABLE VIII

Analysis of Variance of Time-Scores made by Trainees on the Mashburn Apparatus

Trial 5

Conditions Means

A	B	C	D	E	F
3.978	4.162	4.217	4.180	3.627	3.985

Grand mean = 4.025

	d.f.	Sum of Squares	Variance
Conditions	5	1.4545	0.2909
Within Groups	30	11.5647	0.3855
Total	35	13.0192	

F = 0.754

TABLE IX

Heart Rates Per Quarter-minute for Certain Trainees and Applicants During Specified Trials

Subject	Condition	Rate Trial 1	 Trial 5
26	B	28.0	24.2
27	F	24.8	21.5
29	B	25.5	23.8
31	B	23.2	22.9
36	A	19.0	19.2
37	B	27.0	27.8
43	A	23.9	23.4
44	E	23.8	23.0
45	F	21.6	22.0
47	F	20.8	19.7
49	E	26.1	27.4
50	D	21.5	22.3
52	F	17.5	18.3
54	C	20.9	20.9
57	D	21.3	20.8
61	E	21.2	20.0
62	C	23.2	22.1
63	B	26.5	23.1
64	A	23.1	22.1
65	B	22.6	21.6
66	D	28.0	22.8
67	E	19.8	18.3
68	C	24.9	21.6
69	C	25.8	22.7
70	A	19.5	17.8
71	D	23.2	22.1
72	C	19.6	17.4
73	E	27.9	22.5
74	F	23.1	22.9
75	C	30.7	26.2
76	E	23.5	20.0
77	B	21.3	20.6
78	E	26.9	25.0
79	D	25.3	25.4
81	F	23.5	22.4

TABLE [illegible]

Analysis of Variance of Heart Rates (per 1/4 minute) of Selected Trainees and Applicants during Trial 1 of the Mashburn Performance

Conditions Means

A	B	C	D	E	F
21.316	24.864	24.81[illegible]	23.348	24.36[illegible]	22.748

Grand mean = 23.65[illegible]

	d.f.	Sum of Squares	Variance
Conditions	4	[illegible].140	12.03[illegible]
Within Groups	24	200.263	8.3[illegible]
Total	28	24[illegible].403	

F = 1.[illegible]

TABLE XI

Analysis of Variance of Heart Rates (per 1/4 minute) of Selected Trainees and Applicants during Trial 5 of the Washburn Performance

Conditions Means

A	[illegible]	C	D	E	F
20.[illegible]	[illegible]	21.974	22.682	21.750	21.683

[illegible] = [illegible]

	d.f.	Sum of Squares	Variance
Conditions	4	29.823	7.456
Within Groups	24	131.365	5.474
Total	28	161.188	

F = 1.362

TABLE XII

Average Rates of Breathing of Trainees

during Trials 4 and 5

Subject	Condition	Rate
25	E	26.7
26	B	31.8
27	F	24.8
28	A	17.4
29	B	22.4
30	B	24.9
31	B	30.1
32	E	26.3
33	D	22.0
34	A	22.4
35	C	28.6
36	A	22.0
37	B	31.0
38	A	25.0
39	B	23.9
40	C	21.5
41	D	27.6
42	E	28.6
43	A	27.0
44	E	23.6
45	F	29.8
46	F	30.2
47	F	21.8
48	F	35.1
49	E	29.6
50	D	29.2
51	D	22.9
52	F	28.3
53	D	22.3
54	C	22.0
55	C	24.7
56	B	31.7
57	D	23.1
58	A	26.6
59	D	19.0
60	C	21.1
61	E	28.9
62	C	22.2
63	B	31.4

TABLE XIII

Analysis of Variance of the Breathing Rates of [illegible]

Conditions Means

A	B	C	D	[illegible]	F
23.4	29.1	23.4	24.5	[illegible]7.3	28.[illegible]

Grand mean = 26.0

	d.f.	Sum of Squares	Variances
Conditions	[illegible]	[illegible]	39.346
[illegible]	[illegible]	351.77	[illegible].726
[illegible]	[illegible]	[illegible]	

3.355

TABLE XIV

Average Rank on Regularity of Breathing Patterns for Certain Trainees

Subject	Condition	Rank
25	E	23.0
26	B	17.0
27	F	15.4
28	A	[illegible]
32	E	16.2
33	D	8.4
34	A	31.4
35	C	13.6
36	A	15.4
37	B	22.6
38	A	11.6
40	C	20.0
42	E	22.6
43	A	27.2
44	E	1.2
45	F	28.4
47	F	11.6
49	E	13.6
50	D	3.0
51	D	6.6
52	F	15.0
53	D	4.4
54	C	11.2
55	C	23.6
56	B	21.8
57	D	17.0
58	A	6.4
59	D	31.6
60	C	29.4
61	E	28.8
62	C	5.2
63	B	2.0

TABLE XV

Deviations from the level position, expressed in minutes of arc,

for six different experimental conditions

LONGITUDINAL TILT

Conditions

Subject	A	B	C	D	E	F	Subject Means
1	104	186	47	32	45	35	74.8
2	37	42	46	64	50	52	48.5
3	126	79	114	46	200	71	106.0
4	66	155	66	160	94	114	109.1
5	91	131	89	107	115	80	102.1
6	44	54	35	24	39	92	48.0
7	89	34	76	50	69	57	62.5
8	35	47	49	65	92	36	54.0
9	11	51	61	106	79	36	57.3
10	192	55	166	85	72	66	106.0
11	159	87	74	70	124	25	89.8
12	21	91	129	39	81	67	71.3
13	71	42	22	29	34	27	37.5
14	145	126	172	141	152	75	135.1
15	87	61	97	122	92	76	89.1
16	100	47	35	67	31	55	55.8
17	75	41	22	21	26	37	37.0
18	21	22	161	91	104	64	77.1
19	78	39	41	47	24	29	43.0
20	85	102	94	106	102	35	87.3
21	25	84	29	70	12	72	48.6
22	61	218	206	146	37	195	143.8
23	67	81	95	139	64	90	89.3
24	14	25	59	49	34	32	35.5
25	82	80	76	65	126	91	86.6
26	21	35	107	17	12	22	35.6
27	46	34	30	31	40	42	37.1
28	75	21	56	70	36	24	47.0
29	35	37	90	7	57	54	46.6
30	25	71	75	10	44	37	43.6
31	32	61	60	147	61	81	73.6
32	45	130	40	32	100	44	65.1
33	31	96	51	149	29	24	63.3
34	56	32	57	57	37	22	43.5
35	102	191	195	76	127	50	123.5
36	65	127	125	91	195	35	106.3
37	89	64	49	116	142	56	86.0
38	82	170	100	106	187	129	129.0
39	67	81	25	111	102	51	72.8
40	4	75	65	37	50	42	45.5
41	127	196	55	47	105	85	102.5
42	70	102	37	25	21	107	60.2
43	136	32	52	52	67	70	68.1
44	76	55	89	94	136	146	99.3
45	159	80	90	125	61	89	100.6
46	64	15	56	84	76	30	54.1

TABLE XV (Continued)

Subject	A	B	C	D	E	F	Subject Means
47	65	87	104	69	65	87	79.5
48	161	72	217	79	126	64	119.8
49	37	86	22	35	24	69	45.5
50	36	36	29	30	19	60	35.0
51	104	50	141	27	21	49	65.3
52	110	65	119	266	82	124	127.6
53	74	89	94	124	141	129	108.5
54	50	42	91	76	67	41	61.1
55	97	92	25	106	109	40	78.1
56	156	185	226	250	212	262	215.1
57	81	86	109	54	79	67	79.3
58	80	92	141	141	57	132	107.1
59	42	31	41	60	69	75	53.0
60	55	107	95	152	81	57	91.1
Conditions Means	74.017	80.083	83.650	81.567	78.917	68.417	

TABLE XVI

Deviations from the level position, expressed in minutes of arc, for six different experimental conditions

LATERAL TILT

Conditions

Subject	A	B	C	D	E	F	Subject Means
1	107	130	81	167	117	80	113.6
2	38	44	51	31	36	15	35.8
3	76	115	76	47	86	121	86.8
4	77	121	54	51	72	79	75.6
5	41	25	105	59	80	29	56.5
6	42	62	31	90	37	87	58.1
7	61	80	47	27	29	12	42.6
8	45	95	52	22	79	65	59.6
9	64	35	57	71	41	42	51.6
10	80	50	86	89	56	29	65.0
11	67	117	54	112	100	70	86.6
12	57	46	22	29	70	42	44.3
13	19	42	81	11	32	22	34.5
14	91	125	86	91	70	130	98.8
15	241	290	205	167	165	139	201.1
16	126	106	100	106	79	162	113.1
17	40	15	10	36	26	19	24.3
18	10	7	35	32	24	45	25.5
19	35	25	6	30	26	55	29.5
20	15	46	66	64	62	87	56.7
21	15	37	49	66	65	55	47.7
22	59	57	35	14	44	30	39.8
23	35	64	76	81	105	66	71.2
24	30	80	26	41	39	84	50.0
25	49	36	25	32	40	25	34.5
26	41	64	50	65	14	41	45.8
27	46	34	14	51	40	31	36.0
28	83	104	102	100	44	72	84.2
29	25	15	61	14	51	41	34.5
30	74	44	72	35	81	65	61.8
31	61	86	44	85	66	65	67.8
32	40	72	96	32	67	84	65.2
33	30	30	35	97	71	144	67.8
34	44	67	49	74	50	56	56.7
35	61	101	52	84	50	121	78.2
36	9	5	11	19	63	27	22.3
37	122	21	61	46	122	112	80.7
38	104	84	65	85	112	134	97.3
39	67	66	39	30	39	44	47.5
40	86	59	122	114	89	87	92.8
41	87	95	41	97	51	66	72.8
42	61	65	65	25	39	81	56.0
43	130	89	112	89	86	109	102.5
44	124	106	61	69	81	97	89.7
45	75	36	46	50	56	64	54.5
46	41	101	87	49	39	134	75.2
47	47	95	56	55	65	36	59.0

TABLE XVI (Continued)

Subject	A	B	C	D	E	F	Subject Means
48	41	20	155	9	27	55	51.2
49	82	46	69	72	71	132	78.7
50	84	100	35	56	54	62	65.2
51	125	37	32	60	47	59	60.0
52	36	32	129	95	87	96	79.2
53	82	114	87	187	121	132	120.5
54	71	57	12	45	75	77	56.2
55	131	140	110	147	150	70	124.7
56	67	49	85	72	114	40	71.2
57	99	79	126	64	46	57	78.5
58	65	112	75	117	122	65	92.7
59	70	51	34	55	50	25	47.5
60	130	92	105	131	176	126	126.7
Conditions Means	87.683	70.300	65.183	87.350	63.266	71.617	

TABLE XVII

Analysis of Variance of Results on Tilt Perception

Longitudinal Tilt

Conditions

	A	B	C	D	E	F
Means	74.017	80.083	83.650	81.567	78.917	68.417

Grand mean = 77.775

Analysis of Variance

	d.f.	Sum of Squares	Variance
Conditions (C)	5	9,433.655	1,886.731
Subjects (S)	59	406,775.275	6,894.[illegible]
Remainder (C x S)	295	402,370.845	1,363.969
Total (T)	359	818,580.775	

$$F = \frac{1,886.731}{1,363.969} = 1.383$$

TABLE XVIII

Analysis of Variance of Results on Tilt Perception

Lateral Tilt

Conditions

	A	B	C	D	E	F
Means	67.633	70.300	65.183	67.350	68.250	71.617

Grand mean = 68.397

Analysis of Variance

	d.f.	Sum of Squares	Variance
Conditions (C)	5	1,556.26	311.25
Subjects (S)	59	401,695.70	6,706.11
Remainder (C x S)	295	145,418.44	492.94
Total (T)	359	548,670.40	

$$F = \frac{311.25}{492.92} = 0.631$$

TABLE XIX

Average Frequency of Alpha Rhythm

During Each of Three Periods

Number	Pre-noise Period (Control I)	Noise Period (Noise 110 db)	Post-noise Period (Control II)
1	10.62	10.28	9.84
2	10.32	11.04	11.20
3	11.20	11.25	10.82
4	9.59	10.00	9.95
5	10.02	10.13	10.28
6	9.83	10.34	10.10
7	12.48	10.72	10.77
8	9.11	9.54	9.59
9	10.61	10.38	10.29
10	10.45	10.88	11.06
11	11.11	11.23	10.70
12	10.64	10.08	9.92
13	10.26	10.44	10.43
Means	10.430	10.485	10.381

TABLE XX

Changes in Threshold af Audibility

Following Stimulation by Noise and Vibration

Frequency	Conditions A	B	C
120	- 0.3	- 3.1	- 0.4
250	- 3.1	- 4.4	- 5.0
500	+ 1.1	- 8.3	- 5.4
1000	+ 2.8	- 8.3	- 6.6
2000	+ 3.7	-14.1	-13.7
4000	+ 5.8	-19.1	-18.5
6000	+ 3.0	-10.6	-19.3
9000	- 0.5	- 5.3	+ 0.8

TABLE XXI

Time Scores for Performance on the Washburn Apparatu

SILENCE

Trial	Subjects 1	2	3	4	5	6	7	Group
1	362	386	330	291	422	334	466	370
2	279	294	304	250	286	268	365	292
3	246	314	251	217	262	267	299	265
4	266	293	243	216	231	257	281	255
5	292	301	257	218	262	267	274	267
6	271	311	210	224	250	251	224	249
7	261	310	214	223	235	258	241	249
8	281	302	235	184	223	245	209	240
9	256	240	219	163	243	249	229	228
10	248	273	204	193	231	233	208	227
11	255	297	234	172	223	267	197	235
12	230	257	181	190	202	226	206	213
13	251	249	207	178	219	226	200	219
14	232	232	201	170	259	262	203	223
15	279	202	196	168	320	234	237	234
16	218	238	210	163	260	214	215	217
17	212	279	197	171	230	254	209	222
18	236	257	180	155	253	231	193	215
19	222	234	200	173	205	285	215	219
20	204	230	188	174	210	249	199	208
21	242	206	184	160	216	240	216	209
22	251	202	173	164	220	195	231	205
23	253	250	220	141	186	240	200	213
24	261	272	186	162	224	215	230	221
25	267	251	192	167	222	263	245	230
26	234	221	186	158	178	271	239	222
27	204	243	183	141	176	238	231	202
28	290	182	179	152	198	195	202	200
29	259	199	184	156	205	218	207	204
30	244	173	169	147	197	225	218	196
31	270	231	170	166	199	262	208	215
32	220	183	163	150	186	282	203	198
33	248	193	192	146	179	261	256	211
34	251	198	186	176	154	249	196	201
35	237	175	200	150	157	230	276	204
36	215	197	177	150	184	225	282	204
37	249	195	196	141	220	272	273	221
38	189	220	174	136	182	277	284	209
39	192	223	175	181	197	263	229	209
40		192	203	167	175	300	276	
41		213	160	157	214	230	251	
42		200	185	155	148	246	234	
43		169	196	161	189		258	
44		184	211	150			289	
45			184	173			261	
46			154	155			254	

TABLE XXI (Continued)

Trial	1	2	3	4	5	6	7	Group
47			182	166				
48			191	155				
49			188	135				
50			208	156				
51			193	131				
52			207	159				
53			217	144				
54			165	144				
55			182	141				
56				141				
57				144				

TABLE [illegible]

Time Scores for Performance on the Mashburn Apparatus

NOISE

Trial	8	9	10	11	12	13	14	Group
				Subjects				
1	505	419	391	475	460	403	437	[illegible]
2	375	299	305	375	306	276	298	319
3	279	254	289	282	256	247	243	264
4	296	275	268	235	262	228	234	257
5	271	231	266	220	293	205	191	240
6	271	234	288	192	250	200	211	235
7	236	212	337	213	226	200	189	230
8	245	214	295	195	255	169	186	223
9	233	191	266	201	264	177	204	219
10	223	220	229	188	236	195	204	214
11	244	210	247	201	228	178	192	214
12	211	180	247	178	225	170	187	200
13	207	190	288	208	222	176	163	208
14	229	190	276	201	236	153	173	208
15	212	171	305	193	235	190	186	213
16	207	224	294	175	229	149	166	206
17	203	163	319	174	221	171	197	207
18	226	195	291	166	283	180	171	216
19	218	171	262	166	230	152	176	196
20	185	201	261	159	201	193	187	198
21	196	178	261	182	209	163	168	197
22	203	178	301	164	204	175	200	204
23	222	178	249	176	224	198	179	204
24	216	182	251	174	214	168	184	198
25	227	167	289	172	212	194	184	206
26	213	176	238	173	216	173	181	196
27	199	171	252	194	222	192	162	199
28	196	163	259	163	212	159	176	190
29	192	168	293	176	209	176	161	196
30	199	170	229	178	210	176	159	189
31	193	179	261	182	232	209	185	206
32	203	215	265	163	205	168	155	196
33	225	196	251	172	192	183	156	196
34	218	163	233	173	248	203	152	199
35	214	166	268	157	237	174	179	199
36	171	180	265	162	244	183	164	196
37	184	171	252	165	255	161	161	193
38	193	168	241	167	226	156	168	188
39	191	183	251	167	231	160	170	193
40	221	153		173	215	183	155	
41	188	204		183	224	167	189	
42	212	151		174	235	191	175	
43	211	143		151	214	171	186	
44	199	171		161	236	185	201	

TABLE XXII (Continued)

Trial	8	9	10	11	12	13	14	Group
46		173		170	201	173	159	
47		177		164		170	172	
48		204		179		166	176	
49		170		163		176	173	
50		154		176		177	200	
51		161		182		174	190	
52		125				163	194	
53						177	194	
54						181	157	
55							174	

VIBRATION

Subjects

Trial	15	16	17	18	19	20	21	Group
1	375	355	382	425	380	436	425	377
2	252	240	289	345	279	275	288	[illegible]
3	256	267	286	337	261	260	262	276
4	230	230	345	238	276	270	256	271
5	242	223	321	295	258	240	243	260
6	229	240	305	281	229	242	258	255
7	234	228	265	249	227	247	207	237
8	226	199	217	231	208	217	224	217
9	227	193	240	252	197	236	216	223
10	214	198	222	290	236	226	231	231
11	174	218	208	265	211	240	213	218
12	185	198	213	265	177	180	194	202
13	171	185	201	229	187	168	205	192
14	193	189	219	260	220	172	192	206
15	197	182	226	230	196	174	244	207
16	216	191	229	259	195	158	191	206
17	214	185	208	287	185	169	197	206
18	181	182	246	276	186	204	220	214
19	186	198	223	230	211	184	215	207
20	185	180	217	221	173	195	208	197
21	187	177	223	232	173	196	231	203
22	209	155	231	268	168	195	193	203
23	181	164	200	260	162	184	185	191
24	174	167	221	281	179	227	177	204
25	168	167	230	257	187	172	190	196
26	152	189	206	240	165	167	208	190
27	192	192	209	238	186	216	177	201
28	181	195	207	288	201	209	179	209
29	198	191	196	265	177	172	174	196
30	170	158	215	217	192	190	166	187
31	185	156	209	241	191	172	174	190
32	199	161	220	205	176	176	198	191
33	163	173	180	229	202	198	178	189
34	166	168	209	256	189	141	173	[illegible]
35	171	177	211	293	165	173	196	197
36	159	178	235	244	204	193	187	200
37	168	169	181	249	181	224	195	195
38	170	166	170	191	183	178	198	179
39	183	161	182	211	181	181	191	184
40	160	171	202		188	179	183	
41	217	175	187		135	159	192	
42	144	173	213		203	201	171	
43	152	173	215		203	142	160	
44	165	132	[illegible]		217	137	163	

TABLE XXXIII (Continued)

Trial	15	16	17	18	19	20	21	Group
45	157	173	181		185	209	207	
46	192	138	169		188	195	208	
47	187	155			181	169	149	
48	175				190	183	159	
49	155				184	205		
50	120				170	195		
51	15[illegible]				192	196		
52					168	159		
53					181	178		

TABLE XXIV

Time Scores for Performance on the Washburn Apparatus

NOISE AND VIBRATION

Trial	22	23	24	25	26	27	28	Group
				Subjects				
1	304	346	381	476	497	312	413	390
2	234	270	256	353	457	257	357	312
3	199	247	284	322	369	256	335	287
4	232	233	232	304	340	217	309	267
5	206	252	285	309	375	204	292	275
6	197	211	267	280	369	195	273	256
7	181	225	181	261	308	205	261	232
8	180	244	207	254	293	179	249	229
9	159	197	185	233	300	184	252	216
10	185	198	249	298	300	168	240	234
11	170	207	218	249	273	170	225	216
12	166	222	226	261	301	168	233	225
13	189	215	228	291	395	158	251	247
14	158	167	193	201	319	166	222	204
15	177	185	188	236	276	179	210	207
16	163	197	201	283	264	162	213	212
17	154	179	198	284	297	157	235	215
18	166	169	215	222	301	169	208	207
19	174	189	206	265	397	158	233	232
20	171	186	214	231	354	150	221	218
21	151	202	210	199	230	158	187	191
22	158	165	183	226	276	145	239	199
23	182	185	169	249	318	154	217	211
24	162	197	191	208	368	155	224	215
25	158	196	212	268	282	156	208	211
26	151	189	218	232	322	146	217	211
27	161	186	231	213	246	161	189	198
28	147	204	203	207	278	166	198	200
29	154	208	190	232	321	157	179	206
30	168	189	180	239	285	151	198	201
31	149	186	167	232	302	149	190	205
32	165	177	216	199	210	150	198	188
33	168	210	175	218	251	159	199	197
34	148	170	178	268		163	206	
35	159	190	195	197		157	205	
36	154	184	207	197		151	189	
37	142	192	202	231		178	221	
38	158	175	214	240		156	212	
39	156	192	170	242		146	208	
40	154	186	179	257		140	224	

TABLE XXIV (Continued)

Trial	22	23	24	25	26	27	28	Group
41	161	134	151	217		140	212	
42	153	192	222	212		159	175	
43	147	220	181			149	200	
44	133	211	223			147	176	
45	164	191	185			143		
46	162	164	169			151		
47	173	166	178			164		
48	152					139		
49	155					162		
50	149					155		
51	158					163		
52	160					170		
53	149					159		
54	146					145		
55						158		
56						139		
57						168		
58						152		
59						148		
60						140		

TABLE XXV

Time Scores for Performance on the Washburn Apparatus

Subjects

Trial	[illegible](A)	30(B)	31(B)	32(b)	33(D)	34(D)
1	413	291	291	388	433	339
2	310	177	252	271	341	238
3	305	166	235	268	284	196
4	244	157	225	358	294	200
5	[illegible]	183	233	291	279	196
6	[illegible]	154	207	273	264	206
7	[illegible]	156	223	247	267	208
8	[illegible]	162	193	216	253	208
9	177	163	191	205	206	213
10	173	170	168	245	215	197
11	[illegible]	161	189	236	191	189
12	[illegible]	138	179	238	190	185
13	[illegible]	142	179	230	226	203
14	[illegible]	134	192	255	189	199
15	[illegible]	131	174	211	193	195
16	[illegible]	134	179	211	209	180
17	[illegible]	139	178	227	184	153
18	156	151	165	221	210	154
19	142	149	161	212	179	133
20	134	136	170	216	180	141
21	142	143	165	210	190	144
22	140	139	183	202	221	148
23	145	123	168	210	207	131
24	147	118	170	210	206	139
25	135	125	177	208	181	151
26	139	121	166	198	214	149
27	140	128	162	219	197	137
28	161	116	152	204	192	137
29	149	113	157	179	226	129
30	[illegible]	129	189	186	211	134
31	[illegible]	124	178		203	129
32	[illegible]	136	170		209	136
33	[illegible]	122	165		193	141
34	[illegible]	114	171		183	134
35	[illegible]	125	162		196	145
36	[illegible]	[illegible]	156		191	134
37	[illegible]	[illegible]	147		180	139
[illegible]	[illegible]	[illegible]	[illegible]		196	141
[illegible]	[illegible]	[illegible]	176		192	132
[illegible]	[illegible]	[illegible]	167		199	152

TABLE XXV (Continued)

Trial	29(A)	30(B)	31(B)	32(B)	33(D)	34(D)
41	124	124	173		212	142
42	136	126	171		176	127
43	139	134	165		159	139
44	136	140	164			147
45	129	123	143			141
46	139	125	151			140
47	140	116	157			152
48	129	108	162			156
49	150	110	170			145
50	134	110	173			142
51	139	132	178			143
52	133	130	182			145
53	145	122	172			145
54	144	120	177			142
55	140	144	207			135
56	140	124	149			130
57	141	119	144			136
58	149	111				143
59	139	126				137
60	133	111				136
61	125	124				139
62	142	115				142
63	132	117				136
64	132	126				138
65	132	131				141
66	130	122				134
67	129	142				
68	135	134				
69	142	122				
70	132	124				
71	133					
72	135					
73	129					
74	129					
75	138					
76	134					

TABLE XXVI

Time Scores, in Seconds, for "Crucial Trials"

on the [illegible] Apparatus

Trials	1	2	3	4	5	6	7
1	[illegible]	[illegible]	[illegible]	[illegible]	286	263	365
2	[illegible]	[illegible]	[illegible]	[illegible]	202	267	299
3	[illegible]	240	[illegible]	163	235	249	208
4	[illegible]	[illegible]	207	[illegible]	[illegible]	233	197
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	214	209
6	[illegible]	238	[illegible]	171	219	259	193
7	[illegible]	[illegible]	179	158	205	196	245
8	[illegible]	[illegible]	134	[illegible]	210	240	239
9	[illegible]	182	177	[illegible]	178	218	203
10	[illegible]	199	[illegible]	141	176	225	256
11	[illegible]	175	164	155	157	230	229
12	[illegible]	197	182	166	184	225	276
13	[illegible]	169	165	141	148	230	261
14	[illegible]	184	182	144	189	246	254

TABLE XXVII

Time Scores, in Seconds, for "Crucial Trials"

on the Washburn Apparatus

NOISE

Subjects

Crucial Trial	8	9	10	11	12	13	14
1	375	299	305	375	306	276	298
2	279	254	289	282	256	247	248
3	236	191	295	195	228	170	192
4	245	220	266	201	225	176	187
5	229	163	276	175	283	152	176
6	212	195	305	174	230	193	187
7	196	167	261	172	212	159	176
8	203	176	261	173	216	176	161
9	196	163	238	172	205	183	161
10	192	166	252	173	192	161	168
11	171	151	265	174	226	185	159
12	184	143	251	151	231	159	172
13	199	161	241	176	216	177	157
14	203	185	251	182	201	181	174

TABLE XXVIII

Time Scores, in Seconds, for "Crucial Trials"

on the Washburn Apparatus

VIBRATION

Subjects

Crucial Trials	15	16	17	18	19	20	21
1	252	240	289	345	279	275	288
2	256	267	286	337	261	260	262
3	214	199	217	249	177	217	224
4	174	193	240	231	187	236	216
5	181	189	226	229	173	169	191
6	186	182	229	260	173	204	197
7	163	155	231	230	165	172	177
8	152	164	200	221	186	167	190
9	163	158	215	240	165	141	178
10	166	156	209	238	204	178	178
11	144	166	170	205	217	142	192
12	152	161	182	229	185	137	171
13	140	138	181	191	168	159	149
14	152	155	189	211	181	178	159

TABLE XXIX

Time Scores, in Seconds, for "Crucial Trials"

on the Mashburn Apparatus

NOISE AND VIBRATION

Subjects

Crucial Trials	22	23	24	25	26	27	28
1	234	270	256	353	457	257	357
2	199	247	284	322	369	256	335
3	181	197	207	254	369	168	261
4	180	198	185	233	308	170	249
5	163	197	193	201	273	158	222
6	154	179	188	236	301	150	210
7	158	185	183	231	264	157	221
8	151	197	169	199	297	151	187
9	148	186	180	213	230	146	189
10	159	177	167	207	276	140	198
11	147	192	214	197	246	139	205
12	133	186	170	197	278	162	189
13	149	164	169	217	210	148	200
14	146	166	178	212	251	140	176

TABLE XXX

Results of Analysis of Variance of Average Scores on

Crucial Trials 1 and 2 on the Washburn Apparatus

Conditions Means

A	B	C	D
274.43	291.71	276.93	285.57

Grand mean = 282.16

	d.f.	Sum of Squares	Variance
Conditions	3	1078.95	359.65
Within Groups	24	46011.72	1917.16
Total	27	47090.67	

F = 0.1876

TABLE XXXI

Results of Analysis of Variance of Average Scores on

Crucial Trials 3 and 4 on the Mashburn Apparatus

CONDITIONS MEANS

A	B	C	D
221.79	216.07	212.43	211.43

Grand mean = 215.43

	d.f.	Sum of Squares	Variance
Conditions	3	452.17	150.72
Within Groups	24	23064.57	961.02
Total	27	23516.74	

F = 0.1568

TABLE XXIII

Results of Analysis of Variance of Average Scores on

Special Trials [illegible] and 6 on the Washburn Apparatus

CONDITIONS MEANS

A	B	C	D
[illegible]	[illegible]	199.21	201.79

Grand mean = [illegible]

	d.f.	Sum of Squares	Variance
Conditions	3	542.58	180.86
Within Groups	24	32736.64	1364.03
Total	27	33279.22	

F = 0.1326

TABLE XXXIII

Results of Analysis of Variance of Average Scores on

Crucial Trials 7 and 8 on the Washburn Apparatus

CONDITIONS MEANS

A	B	C	D
202.21	204.93	184.14	192.89

Grand mean = 196.04

	d.f.	Sum of Squares	Variance
Conditions	3	1858.08	619.36
Within Groups	24	26232.36	1093.02
Total	27	28090.44	

F = 0.5667

TABLE XXXIV

Results of Analysis of Variance of Average Scores on

Crucial Trials 9 and 10 on the Mashburn Apparatus

CONDITIONS MEANS

A	B	C	D
195.64	187.29	184.93	186.86

Grand mean = 188.68

	d.f.	Sum of Squares	Variance
Conditions	3	467.20	155.73
Within Groups	24	24071.36	1002.97
Total	27	24538.56	

F = 0.1553

TABLE XXXV

Results of Analysis of Variance of Average Scores on

Crucial Trials 11 and 12 on the Mashburn Apparatus

CONDITIONS MEANS

A	B	C	D
199.86	187.29	175.21	189.93

Grand mean = 188.07

		d.f.	Sum of Squares	Variance
Conditions		3	2165.45	721.82
Within Groups		24	31947.93	1331.16
	Total	27	34113.38	

$F = 0.5422$

TABLE XXXVI

Results of Analysis of Variance of Average Scores on

Crucial Trials 13 and 14 on the Washburn Apparatus

CONDITIONS MEANS

A	B	C	D
192.36	193.14	167.93	180.79

Grand mean = 183.56

	d.f.	Sum of Squares	Variance
Conditions	3	2915.77	971.92
Within Groups	24	40632.11	1693.005
Total	27	43547.88	

F = 0.574

TABLE XXXVII

Heart Rates per Quarter Minute for Selected Subjects

during Specified Washburn Trials

Subject	Condition	Pre-Trial	Crucial Trials 1 and 2	Crucial Trials 7 and 8	Crucial Trials 13 and 14
1	A	19.9	20.9	17.9	17.4
2	A	19.1	20.6	17.8	16.0
4	A	19.3	23.8	23.2	25.6
6	A	15.6	17.3	15.1	14.9
7	A	20.4	20.5	18.6	18.6
8	B	21.0	24.5	21.9	22.3
9	B	19.0	20.1	20.0	19.8
10	B	21.6	24.0	20.4	22.0
12	B	19.0	20.6	20.1	19.4
13	B	16.5	20.7	17.2	17.8
17	C	21.5	21.9	20.5	21.7
18	C	22.6	22.3	20.9	22.2
19	C	22.6	23.4	21.0	21.1
20	C	20.0	22.0	20.8	20.2
21	C	15.7	18.6	16.9	16.4
22	D	20.9	25.9	23.9	23.4
25	D	19.1	20.9	18.7	17.1
27	D	14.1	18.8	17.7	16.6
28	D	19.3	21.6	19.1	19.5
34	D	22.5	24.3	18.6	17.8

TABLE XXXVIII

Results of Analysis of Variance of Heart Rates per Quarter Minute During the Pre-Trial Period

CONDITION MEANS

A	B	C	D
18.9	19.4	20.5	19.2

Grand mean = 19.5

	d.f.	Sum of Squares	Variance
Conditions	3	1.54	0.513
Within Groups	16	103.38	6.461
Total	19	104.92	

$F = 0.079$

TABLE XXXIX

Results of Analysis of Variance of Heart Rates per Quarter Minute During Crucial Trials 1 and 2

CONDITIONS MEANS

A	B	C	D
20.6	22.0	21.6	22.3

Grand mean = 21.6

	d.f.	Sum of Squares	Variance
Conditions	3	23.10	7.700
Within Groups	16	83.37	5.211
Total	19	106.47	

F = 1.478

TABLE XV

Results of Analysis of Variance of Heart Rates per

Quarter Minute During <u>Crucial Trials 7 and 8</u>

CONDITIONS MEANS

A	B	C	D
18.5	19.9	20.0	19.6

Grand mean = 19.5

	d.f.	Sum of Squares	Variance
Conditions	3	12.94	4.313
Within Groups	16	156.80	9.800
Total	19	169.74	

F = 0.440

TABLE XLI

Results of Analysis of Variance of Heart Rates per
Quarter Minute During Crucial Trials 13 and 14

CONDITIONS MEANS

A	B	C	D
18.5	20.3	20.3	19.0

Grand mean = 19.5

	d.f.	Sum of Squares	Variance
Conditions	3	20.30	6.767
Within Groups	16	134.96	8.435
Total	19	155.26	

F = 0.802

TABLE XLII

Breathing Rates for Selected Subjects

During Specified Periods

Subject	Condition	Pre-Trial	Trial 1	Crucial Trials 1 and 2	Crucial Trials 7 and 8	Crucial Trials 13 and 14
1	A	17.2	19.8	19.3	19.1	19.1
2	A	21.7	22.9	21.6	19.9	18.3
3	A	23.1	23.7	22.0	22.9	23.5
5	A	20.3	28.5	28.3	25.7	25.1
6	A	14.3	22.1	19.9	20.8	17.5
7	A	22.3			20.9	
8	B	17.3	21.9	19.0	21.2	23.2
10	B	23.1	28.5	28.1	26.9	27.5
11	B	20.3	21.5	22.5	21.3	20.3
12	B		22.1	22.4	19.0	18.6
13	B	22.7	28.9	30.1	27.6	25.5
14	B	14.0			19.7	
35	B	18.8			21.3	
15	C	17.4	24.2	25.4	24.3	23.4
16	C	22.3	27.3	27.8	23.8	22.9
19	C	19.0	18.8	18.7	16.6	16.6
20	C		20.8	23.8	22.7	22.2
21	C	17.3	20.0	21.9	22.5	22.2
22	D		37.9	33.7	30.1	34.6
23	D		26.7	29.4	28.3	24.9
24	D		24.2	24.0	22.2	21.2
25	D	19.2	21.9	20.1	17.1	18.3
27	D	21.9	36.8	22.7	24.0	23.2

TABLE XLIII

Results of Analysis of Variance of Breathing Rates

per Minute during Washburn Trial 1

CONDITIONS MEANS

A	B	C	D
23.4	24.6	22.2	29.5

Grand mean = 24.9

	d.f.	Sum of Squares	Variance
Conditions	3	165.92	55.31
Within Groups	16	363.76	22.74
Total	19	529.68	

F = 2.432

TABLE XLIV

Results of Analysis of Variance of Breathing Rates per Minute During Crucial Trials 1 and 2

CONDITIONS MEANS

A	B	C	D
22.2	24.4	23.5	26.0

Grand mean = 24.0

	d.f.	Sum of Squares	Variance
Conditions	3	54.28	18.09
Within Groups	16	302.59	18.91
Total	19	356.87	

F = 0.957

TABLE XLV

Results of Analysis of Variance of Breathing Rates per Minute During Crucial Trials 7 and 8

CONDITIONS MEANS

A	B	C	D
21.7	23.2	22.0	24.3

Grand mean = 22.8

	d.f.	Sum of Squares	Variance
Conditions	3	22.29	7.430
Within Groups	16	230.95	14.434
Total	19	253.24	

F = 0.515

TABLE XLVI

Results of Analysis of Variance of Breathing Rates

per Minute During Crucial Trials 13 and 14

CONDITIONS MEANS

A	B	C	D
20.7	23.0	21.5	24.4

Grand mean = 22.4

	d.f.	Sum of Squares	Variance
Conditions	3	43.84	14.613
Within Groups	16	282.67	17.667
Total	19	326.51	

F = 0.827

TABLE XLVII

Deviations from the level position, expressed in minutes of arc, for second tilt perception experiment

CONDITION A

Subject	Long.	Lat.
1	219.2	140.4
2	89.2	105.4
3	111.7	88.3
4	183.3	37.5
5	77.5	60.0
6	80.4	125.8
29	61.7	76.3

CONDITION B

Subject	Long.	Lat.
10	130.4	44.6
13	215.8	165.4
14	177.5	49.6
28	82.1	112.1
30	113.8	85.8
32	114.6	27.1
35	98.3	71.3

CONDITION C

Subject	Long.	Lat.
15	128.8	77.5
16	130.8	87.9
17	45.8	160.8
18	101.3	89.6
19	257.9	70.4
20	128.8	60.0
21	67.1	72.5

CONDITION D

Subject	Long.	Lat.
23	77.1	71.3
24	177.1	47.9
25	65.8	109.6
26	85.0	80.0
27	179.6	48.3
33	80.0	70.0
34	82.5	86.3

ADDITIONAL SUBJECTS

Subject	Condition	Long.	Lat.
7	A	85.0	62.9
8	B	170.0	127.5
9	B	88.3	57.9
11	B	146.3	63.8
12	B	41.7	159.6
22	D	47.9	63.8
31	B	34.2	170.4

TABLE XLVIII

Results of Analysis of Variance of Average Deviation Scores for Longitudinal Tilt

CONDITIONS MEANS

A	B	C	D
117.6	133.2	122.9	106.7

Grand mean = 120.1

	d.f.	Sum of Squares	Variance
Conditions	3	2592.3	864.1
Within Groups	24	77411.5	3225.6
Total	27	80003.8	

F = 0.268

TABLE XLIX

Results of Analysis of Variance of Average Deviation Scores
for Lateral Tilt

CONDITIONS MEANS

A	B	C	D
90.5	79.4	88.4	73.3

Grand mean = 82.9

	d.f.	Sum of Squares	Variance
Conditions	3	1381.3	460.42
Within Groups	24	30874.9	1286.45
Total	27	32256.2	

F = 0.358