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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE / Public Health Service
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ABSTRACT

Nitrous oxide and halothane, in respective concentrations as low as 50 parts per million (ppm) and 1.0 ppm, caused measurable decrements in performance on some psychological tests taken by healthy male graduate students. Nitrous oxide alone caused similar effects. The functions apparently most sensitive to these low concentrations of anesthetics were visual perception, immediate memory, and a combination of perception, cognition, and motor responses required in a task of divided attention to simultaneous visual and auditory stimuli. These effects were absent in subjects exposed to 25 ppm N_2O and 0.5 ppm halothane. Findings from this study suggest that N_2O and halothane levels in the ambient air of hospital operating rooms should not exceed 25 ppm N_2O and 0.5 ppm halothane.

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INTRODUCTION

Devices for the delivery of anesthetic agents to patients possess pressure-relief valves in their construction, a design which allows trace amounts of anesthetic gases to escape continuously into the atmosphere of the operating room. The anesthetist is the individual maximally exposed to these gases, both because of close proximity to this "pop-off" valve, and because he or she is present during all anesthesias, whereas the surgeons and surgical nurses are not. Linde and Bruce (1) documented both the exposure to, and the resultant expired-air concentrations of, halothane (2-chloro-2-bromo-1, 1, 1-trifluoroethane) and nitrous oxide (N_2O) in these workers. Peak levels of 27 ppm halothane and 428 ppm N_2O were found in the breathing zone of the anesthetist, and the mean concentration of halothane was 10 ppm. The corresponding mean concentration of N_2O was subsequently shown to be erroneously low and actually approximated 500 ppm (2). These figures of 10 ppm halothane and 500 ppm N_2O are about 1/1,000 of the customary clinical concentrations of 1 and 50 percent that are inspired by the anesthetized patient. Studies from other centers have shown similar, or even greater, concentrations. Danish workers (3) reported 85 ppm halothane and 7,000 ppm N_2O in the inhalation zone of the anesthesiologist using a nonrebreathing technique of anesthetic administration. These findings focused attention on the need to know if such exposures were harmful to the anesthetist.

Several surveys of general health experience of anesthetists have been conducted. An adverse effect on pregnancy and gestation was suggested by findings from female anesthetists reported by Vaisman (4), Akrog and Harvald (5), Cohen et al. (6), Knill-Jones et al. (7), and in a nationwide survey in the United States (8). The latter survey also suggested an increased risk among female personnel of liver and kidney disease as well as certain kinds of cancer. The question of malignancy as an occupational hazard had previously been raised by the reports of Bruce et al. (9) and Corbett et al. (10). A problem in these studies is that of the potential post hoc ergo propter hoc fallacy, i.e., assuming that anesthetic exposure causes these health probelms. Although a causal relationship has not been proved in the relationship of organic disease to anesthetic exposure, a functional impairment has definitely been identified with trace anesthetic inhalation. Performance on psychological tests of perceptual, cognitive, and motor skills was worse in the presence than in the absence of anesthetics (11, 12, 13).

In the performance studies, Bruce, Bach and Arbit (11-13) exposed healthy male subjects either to air or air containing anesthetics in concentrations similar to those found in the breathing zone of the working anesthetist. Following four hours of such exposure in an ordinary "oxygen tent" surrounding the subject, he was given a battery of psychological tests. Significant decrements in performance were shown following exposure at: 1) 500 ppm N_2O in air; 2) 500 ppm N_2O plus 15 ppm halothane in air; and, 3) 500 ppm N_2O plus 15 ppm enflurane (2-chloro-1, 1, 2-trifluorethyl difluoromethyl ether) in air. These subjects were tested immediately after removal from the exposure tent. Since the anesthetics were thus being exhaled continuously during the tests, the concentrations of agents present in the subjects were not those with which they had been equilibrated. Despite this fact, the findings were positive. However, concurrent exposure and testing would have been preferable in order to know exactly what concentrations of anesthetics were present in each subject's inhaled air and also to assess the dose-response relationship of exposure to performance deficit.

The present studies were undertaken to answer the dose-response question and to establish a lower limit of exposure at which performance decrements were undetectable. Halothane and N_2O were the anesthetic agents selected for study. In the United States, halothane is usually administered in a carrier gas mixture of oxygen and N_2O. Thus, occupational exposure to halothane is almost always coincident with exposure to N_2O. On the other hand, many anesthesia techniques consist of administering N_2O as the only inhalation agent, supplemented with intravenous injections of sedatives, narcotics and muscle relaxants. In these cases, the anesthetist breathes only N_2O that overflows from the administration equipment. Accordingly, the present study was designed to detect decrements in performance produced either by a mixture of halothane and N_2O or by N_2O alone. The concentrations selected were those commonly found in the operating room where anesthesia is being dispensed from devices not equipped with a scavenger system to rid the operating room of these gases. Gas concentrations were then lowered to 10 percent of these initial values and a second set of studies were done. Finally a group of subjects were exposed to 5 percent of those first concentrations, a reduction easily attainable by available methods of scavenging (2) which can, in fact, lower the levels considerably below the nominal figures of 0.5 ppm halothane and 25 ppm N_2O (14).

LITERATURE REVIEW

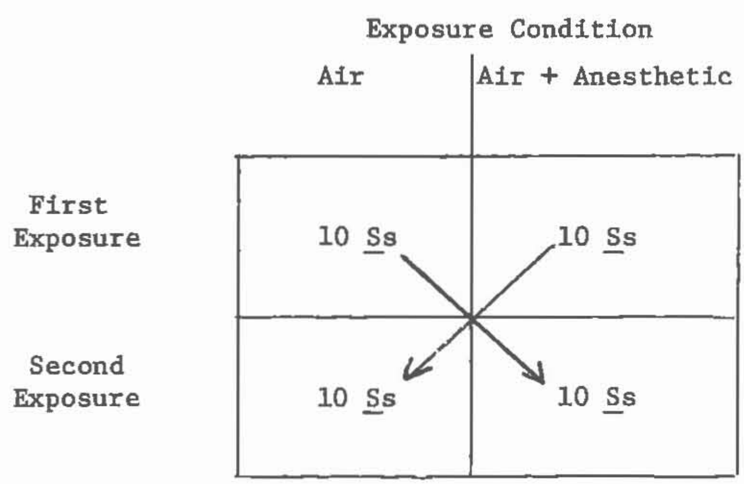
The review of literature concerning effect of trace anesthetics on psychological performance must be brief, since few studies have been conducted. Reports of psychological effects of alcohol (15), marihuana (16), tranquilizers, and sedatives (17) are numerous but irrelevant to the present studies. It is unlikely that effects of higher doses of anesthetics, approaching those concentrations used clinically, are any more relevant. Obviously, an anesthetized, unconscious patient will be unable to perform tests of perception, cognition, or motor skills. Studies of effects of N_2O in inhaled concentrations between 25 and 40 percent (18, 19, 20, 21) are of considerable interest, but involve inhaled concentrations from 500 to 800 times greater than the maximum amount used in the present studies (500 ppm). Similarly, the concentrations of cyclopropane, ether, enflurane, methoxyflurane, and fluoroxene used by Adam and associates (22, 23) were subanesthetic but still several hundred times greater in terms of potency than the levels employed in these studies.

Trichloroethylene (TCE) is used widely as an industrial solvent, but also has limited use as an inhalational anesthetic agent. Salvini et al. (24) reported that inhalation of 110 ppm TCE caused decrements in psychophysiological function. This concentration is about 1/100 of that commonly used clinically, but the Salvini study could not be confirmed in careful studies by Stewart and colleagues (25). Other than the previous reports from our laboratory (11, 12, 13) the only published work on occupational exposure to anesthetic agents is that from Gamberale and Svensson (26). They reported that anesthetic nurses had a significantly greater intra-individual variation in performance of simple reaction time tests than did a control group. This difference disappeared after 16 hours away from the job and the authors interpreted this as evidence for an effect of anesthetic exposure. Unfortunately, no measurements were made to quantitate such exposure.

METHODS

A. Experimental Design

The basic experimental design for subject testing is shown below. Twenty subjects were used, each one twice, and half were exposed first to air while the other half received anesthetic first.



There were five such sets of exposure, the anesthetic conditions being the following:

1. N_2O, 500 ppm, + halothane, 10 ppm
2. N_2O, 500 ppm
3. N_2O, 50 ppm, + halothane, 1.0 ppm
4. N_2O, 50 ppm
5. N_2O, 25 ppm, + halothane, 0.5 ppm

Thus, a total of 100 subjects were exposed to anesthetic gases and each participant was tested twice. Each subject was exposed and tested during the same hours of the same day, one week separating the two exposures.

Only male subjects were used, since there are data suggesting an increased risk to the pregnant female occupationally exposed to anesthetic gases. The use of females would have necessitated testing each subject for pregnancy before each exposure, greatly complicating the experiment. The subjects chosen were all between ages 20 and 30, and most were dental, medical, or law students at Northwestern University. The others were graduate students or laboratory technicians. All were questioned very carefully about exposure to anesthetics, either as a patient or in their work. Patient exposure within the past three months or occupational exposure within the past six weeks were grounds for disqualification from the study. Subjects were given a medical questionnaire (Appendix A) to complete in which information was sought concerning their general health, any recent acute or existing chronic illnesses, and their habits with respect to alcohol and drug use. These forms were reviewed by Dr. Bruce, who questioned each subject about items of interest in the survey and the subjects were allowed to keep their forms so as to preserve the confidentiality of this process. Each was cautioned not to use any alcohol or mood-altering chemical within 48 hours of their study days. Each signed a consent form (Appendix B) to participate in the study, the form having been approved for use by the Human Subjects Review Committees of Northwestern University and the National Institute for Occupational Safety and Health (NIOSH), the contract sponsor.

B. Anesthetic Administration

Compressed air was passed through a filter and then delivered at a flow rate of 8 liters per minute into a standard anesthetic circle system, composed of a soda lime cannister for CO_2 removal, a reservoir bag, the mask worn by the subject, lightweight plastic breathing tubes that delivered and removed gas from the mask, and a "pop-off" valve to vent overflow gases from the circle. The mask was not a standard one used for giving anesthesia, but was fashioned from an inhalation therapy mask used to give humidified, oxygen-enriched air to patients. The aim of all choices of hoses and masks was to minimize the weight, and consequently, to maximize the comfort with which the subject wore the mask. No subject complained, and those who needed to wear eyeglasses could do so. Figure 1 shows a subject with this system in operation.

In separate tanks, mixtures of 10% N_2O in air and 1% halothane in N_2 were prepared. These tanks were then fitted with valves and flowmeters and, as indicated by the experiment, very low flows from one or both of these tanks were introduced into the main, carrier flow of air. This system, although homemade and inelegant to the eye, was very stable and delivered predictable and reproducible final concentrations of gases during daily use. The subject was never able to tell when the anesthetic was being administered, either by looking at the apparatus or by smell. It was therefore unnecessary to disguise any odor by introducing another for the purpose of masking gas exposure conditions.

Samples of gas were taken during the first two hours of every exposure by drawing 10 ml of gas from the inspiratory limb of the breathing circle into a gas tight glass syringe, which was then capped. If the subject was breathing only air, the sample was later discarded, but at the outset of these experiments the samples were analyzed to be sure there was no residual anesthetic in the circuit that could contaminate subsequent air exposures. This was not the case, but as a safeguard the air flow was always left on in order to keep the tubing flushed with air to remove any residual halothane. For N_2O and halothane analyses, the samples were injected into a gas chromatograph. In the first phase of the study, where N_2O (500 ppm) and halothane (10 ppm) were used, these analyses were done with an F and M *(Model 500) chromatograph. Following delivery of a Packard Becker (Model 419) gas chromatograph equipped with ^{63}Ni and ^{3}H electron capture detectors, all analyses were done with this instrument, which was much more sensitive. Its lower limits of detection are 5 ppm N_2O and 0.001 ppm halothane. At about 1 hour and 45 minutes from the initiation of exposure, samples of each subject's end-expired air were also taken for analysis. The subject removed his mask, exhaled to a point of normal emptying of his lungs, then forcefully exhaled as much as possible. At the end of this second phase of exhalation, which consists of alveolar air equilibrated with anesthetic content of his blood, a sample was drawn into a gas-tight glass syringe inserted into his pharynx. Analysis of this air showed that the mask fitted properly and that he did, in fact, have anesthetic in his system. This sampling was done for every exposure, even in the air condition, so the subject would not know in which condition he was currently being exposed. Ratios were calculated for inspired and end-expired contents of the anesthetics.

After the subject had begun breathing the gas mixture appropriate to his place in the study, he was cautioned not to sleep during the course of the study and was allowed to read, write, or simply sit and equilibrate with the anesthetic. Two hours later, testing began.

C. Psychological Tests

The sequence of performance testing was as follows:

Hours of Exposure	Test
0	
1	
2	Tachistoscope
	Raven Matrices
	O'Connor Dexterity
	3 Minute Audiovisual
3	60 Minute Vigilance
4	7 Minute Audiovisual
	Digit Span

*Mention by name of company or product does not constitute NIOSH endorsement.

These tests were chosen to assess anesthetic effect on several performance parameters and each will be described.

1. Tachistoscope: This was chosen as a test of visual acuity, the primary perceptive modality used by the anesthetist in assessing the medical status of the patient. Monitors used in surgery and attended by the anesthetist are numerous and almost all of them have visual data displays. Vision is essential, particularly the ability to perceive sudden and often subtle changes.

   In this test the subject saw, for 50 milliseconds, a nine square grid containing 4, 5, or 6 filled black circles. After each presentation, he checked the squares, on a blank grid, in which he saw these circles. He viewed each of ten grids twice, for a maximum correct response of 20. Each subject had a session consisting of two practice patterns on the tachistoscope before his first exposure in the study. The test is illustrated in Figure 2.

2. Raven Matrices: The ability to think clearly and logically is essential to the anesthetist, particularly when trying to solve a complex problem in patient care that arises intraoperatively. The Raven test was selected to test the ability of the subject to recognize a pattern of changes in a sequence and to decide logically which pattern could be expected to appear next.

   Twenty patterns were selected from the Raven Progressive Matrices Test, ten for each of the two sessions. The basis of selection was the comparability of difficulty, that is, each pattern of one set was matched with one in the second set for which the scores accompanying the set indicated a pattern of equal difficulty. Even though care was taken to match the two tests for difficulty, our subjects found one of the forms, the one administered second, more difficult. This was corrected in all phases of study after the first one (halothane, 10 ppm; N_2O, 500 ppm) by counterbalancing forms so that half of the subjects received one form first and the other half received the remaining form first. Subjects were instructed by use of a printed booklet which contained two examples of practice patterns, which were not used in subsequent testing. A test pattern is shown in Figure 3.

3. O'Connor Dexterity Test: Manual skills are involved in the manipulations performed from time to time by the anesthetist, and it seemed appropriate to include a test of eye-hand coordination. The subject's task in this test was to place three pegs in each of 100 holes as rapidly as possible using only his preferred hand. The test is illustrated in Figure 4.

3. O'Connor Dexterity Test (continued):
As a large practice effect from one session to the next is usually shown in a motor task, each subject was required to fill the entire board in the practice session. His time was recorded at this session, but these data have not been used in any of the analyses. The actual task during the testing session consisted of alloting three minutes in which to fill as many holes as possible with three pegs each. The number of holes correctly filled during this time period was recorded. The data analysis assumed that the better the eye-hand coordination of a subject, the more holes he could fill.

4. Audiovisual Task: Many, if not most, psychological tasks test performance in one main area at a time, or the integrity of one sensory modality. In the operating room, the anesthetist is always using more than one of his senses simultaneously. For example, he may be feeling the pulse while watching a cardiac monitor while also listening to the sound of the mechanical ventilator providing the patient's breathing. An appropriate divided attention task was needed to simulate this situation. Since sight and sound are the two most important stimuli monitored by the anesthetist, an audiovisual task was devised and used. This task has been described previously (11, 12, 13), but was modified slightly during these studies by decreasing the difference in beat frequency of the sound stimulus and by putting the visual pattern on one beam of the oscilloscope, rather than two.

   Subjects wore earphones while viewing an oscilloscope as shown in Figure 5. A 4-channel FM instrumentation tape recorder (Hewlett-Packard, Model 3960) played a pre-recorded test pattern to the earphones and oscilloscope. The subject responded by pushing one of four buttons on a battery-powered response box. These were recorded on an empty channel of the tape as 1/2 or 1 volt, positive or negative square waves. The auditory signal was the clicking of a metronome either at 100 or 160 beats per minute. The visual signal was a flat line of a pattern of ventricular fibrillation recorded from an electrocardiographic simulator. This pattern is a rapidly oscillating continuum of positive and negative spikes shown in Figure 6. Thus, a 2 x 2 design existed as follows: visual flat line, auditory slow; visual flat line, auditory fast; visual spikes, auditory slow; visual spikes, auditory fast. In three minutes, there were 10 changes in each of the four conditions making a total of 40 changes to a new condition. The seven minute task required the detection and appropriate response to 100 changes, 25 to each of the four conditions. The subject responded as quickly as possible to each change by depressing a button corresponding to the new condition,

4. Audiovisual Task (continued):
that is, to the one to which the change had been made. A set of instructions for this task was dictated on the sound channel of the tape before the test was begun, and the subject then had the next 15 minutes to practice before the actual test began, a time previously determined to assure reaching the asymptote of performance and allowing retention of this asymptote for one week. The test was given in two segments - three minutes at this point in the test sequence and then seven minutes after the vigilance task. After the subject's departure, the tape was replayed through a Grass polygraph, giving a visual record both of the test and of the subject's performance. Scoring was manual and the mean reaction time was computed and used as the measure of performance. Percent correct responses was always 97% or better. The rare error was not scored. With manual scoring, it was possible to see where the subject made an incorrect response, recognized this, and immediately pushed the correct button. Machine scoring would have counted this as an error, whereas in the present studies it was counted as correct and the time to the correct response was measured. The lag time for response from the subject to be encoded on the tape was estimated by the following procedure: a response pulse was generated and sent either directly to the input of the polygraph or through the tape recorder to the polygraph. The difference in arrival time, representing the lag time in the recorder, was constant at 0.3 seconds and this was subtracted from all data to derive real reaction time. The accuracy of scoring itself was estimated to be $\pm$ 0.02 seconds.

5. Vigilance Test: In the anesthetic care of a patient having a prolonged operation, there often are periods lasting an hour or more, during which there is little action required of the anesthetist. During these times, boredom and inattention to the monitors may result. This would favor missing an occasional irregularity in data display from such a monitor. The vigilance task was modeled after this clinical situation, although it was over-simplified to the extent that the subject needed only to watch an oscilloscope and nothing else.

The subject watched an oscilloscope for 60 minutes, on which was displayed continuously a normal electrocardiogram, recorded from an ECG simulator. Twelve times during this hour, at intervals from three to eight minutes, a brief (one to two second) change to a pattern of atrial fibrillation was interposed in the otherwise normal series of ECG complexes. Figure 7 illustrates this change. For this test also, recorded instructions were heard by the subject while he practiced this task for three minutes (during the practice session, changes occurred more often than during actual testing). His response was simply

5. Vigilance Test (continued):
to depress a button when he saw the change occur. The mean reaction time was used as the dependent measure for this test, since it was soon evident in the study that the subjects were able to detect every change and the only measurable variable was reaction time.

6. Audiovisual Task, 7 Minutes: This test was identical to that described in item 4, except that the duration was increased from 3 to 7 minutes. It was given after the vigilance task to assess the effect of an one hour test of a rather boring nature, plus another hour's inhalation of anesthetic. Many times, the clinical course of anesthesia is characterized by rapidly changing conditions at the beginning, a stable and uneventful maintenance state, and another period of rapid changes at the end where the patient is emerging from anesthesia. The two audiovisual tasks of rapid change, separated by a monotonous one hour vigilance task, mimicked this.

7. Digit Span: The anesthetist must remember what drugs he has given, what the patient's last blood pressure was, and other data registered and recalled by the function of immediate memory. This test was used to assess this capability. Since the subject had to speak to the experimenter, it was done last and the subject was allowed to remove his mask. He was given a standard series of numbers, from the Wechsler Adult Intelligence Scale, which he had to repeat correctly to the experimenter. The series increased in length (maximum: 9 digits forward, 8 digits backward). The subject had to recall them both in the order given and in the opposite order. The mean number of digits recalled correctly was scored for each test session.

Test results were tabulated in the same format as shown for the exposure, which was:

	Exposure Condition	
Order of Exposure	Air	Air + Anesthetic
1st	A	B
2nd	C	D

The criteria for assessing participants' responses were as follows:

If practice improves performance:

C will be better than A
D will be better than B

If anesthetic causes poorer performance:

A will be better than B
C will be better than D

If both occur, but anesthetic effect is dominant:

C will be the best score
A will be next
D will be next
B will be the worst score

Statistical treatment of these data was by analysis of variance, whereby the significance of anesthetic effect and practice effect could each be evaluated, as well as the interaction of the two (27). The null hypothesis was that neither anesthetic nor practice (order of exposure) would cause changes greater than that expected by chance alone. An additional analysis was made of the correlation between correctly guessing which condition they were in, and audiovisual test performance, in the subjects exposed to 500 ppm N_2O and 10 ppm halothane (28).

RESULTS

A. Gas Analyses:

1. Nominal values: 500 ppm N_2O, 10 ppm halothane

Agent	Mean Measured Concentrations		E/I
	Inspired (I), ppm	End-expired (E), ppm	
N_2O	528	286	0.54
Halothane	10.1	2.6	0.25

2. Nominal values: 50 ppm N_2O, 1.0 ppm halothane

Agent	Mean Measured Concentrations		E/I
	Inspired (I), ppm	End-expired (E), ppm	
N_2O	49.7	36.1	0.72
Halothane	0.93	0.54	0.58

3. Nominal values: 25 ppm N_2O, 0.5 ppm halothane

	Mean Measures Concentrations		
Agent	Inspired (I), ppm	End-expired (E), ppm	E/I
N_2O	23.6	14.6	0.61
Halothane	0.56	0.30	0.53

4. Nominal value: 500 ppm N_2O

	Mean Measured Concentrations		
Agent	Inspired (I), ppm	End-expired (E), ppm	E/I
N_2O	525	365	0.69

5. Nominal value: 50 ppm N_2O

	Mean Measured Concentrations		
Agent	Inspired (I), ppm	End-expired (E), ppm	E/I
N_2O	49.4	33.8	0.68

B. Test Results:

The test results are given in Appendices C, D, E, F and G and summarized in Appendix H. For convenience of presentation, the mean values are combined for both orders of exposure and air or anesthetic conditions, although in the analyses of variance these contributions to variance were treated separately. The significance figures used in the tabulated data are derived from those statistical analyses.

C. Discussion of Results:

The test data indicate that measurable and statistically significant decrements in performance may result from exposure to anesthetics in concentrations down to 50 ppm N_2O, a figure well below those measured in studies of anesthetic content of operating room air. The tests themselves were not equally sensitive to anesthetic effect, varying from the extreme sensitivity of the audiovisual task to none in the O'Connor Dexterity test.

Surveying the results test by test, it appears that visual perception was impaired by anesthetics, as shown by the effects on both the tachistoscopic and audiovisual tasks. This was not borne out by the vigilance task, however, which was also a test primarily of visual perception. Perhaps the infrequent changes in that task, compared to the rapid reactions required in the tachistoscopic and audiovisual tasks, allowed the subject to focus his attention more forcefully during the periods between changes requiring a response. The improvement in vigilance response in the group exposed to 50 ppm N_2O and 1 ppm halothane cannot be explained. Perhaps the monotony of the test was masked by the slight anesthetic effect, so that interfering neocortical phenomena such as daydreaming were suppressed. This is only speculation, of course.

Innate intellectual ability to reason logically was evidently relatively resistant to anesthetic effect, as judged by the marginal effects on the Raven Matrices test. This function may be so deeply ingrained in the person that it might be relatively insensitive to pharmacologic agents. Alternatively, there might exist a different test which would have been sensitive. The results are nevertheless consistent with the clinical impression that an anesthetist who is not at his best, either from fatigue or other causes, knows what to do but may be slow in seeing the situation in which he should do it.

Manual dexterity is not a very important part of giving anesthesia, and the negative results from the O'Connor Dexterity tests indicate this skill to be resistant to anesthetics anyway. Of real concern is the evident high sensitivity of immediate memory to anesthetic effects shown in the Digit Span test. This is a very important function of the anesthetist, who is usually the only person in the surgical team who keeps track of the patient's general condition on a minute by minute basis.

The development of an anesthetist has been characterized as occurring in three stages: 1) he gets into trouble and can't get out; 2) he gets into trouble but now he can get out; 3) he recognizes the early warning signs and stays out of trouble. Of all the tests, the one most closely allied to the anesthetist's work was the audiovisual task, where two modes of perception were challenged continuously and rapidly, requiring recognition of changes, decisions about their nature, and appropriate responses. This test was the most sensitive of all to anesthetic effect.

The actual job performance of an anesthetist cannot presently be objectively measured, since no methods exist with which to do this. The 100 subjects in the present study were not anesthetists, 87 percent of them coming from postgraduate programs in medicine, dentistry, law or biomedical sciences. They were highly motivated "achievers" who were accustomed to performing at a high level of excellence and who, accordingly, gave remarkably uniform scores on the tests. The error terms in the statistical analyses were thus very small, allowing significance to be assigned to differences as small as 5 percent in mean scores. Similar studies with negative results were reported by Dr. Graham Smith, from the University of Glasgow, at a meeting of the Anaesthesia Research Society in London, England, in October, 1975. At that meeting, attended by one of the authors (DLB) it was pointed out that his subjects were undergraduate psychology students and their test scores were characterized by very large variances so that statistical analyses showed no effect. The choice of subjects is clearly important, and may even be more critical if anesthetists develop any sort of "tolerance" to the effects of chronic exposure to traces of anesthetics. The present study does not show that the actual work performance of an anesthetist is affected adversely by occupational exposure to anesthetics. It only suggests strongly that this could be the case.

CONCLUSIONS

These studies suggest strongly that the performance of an anesthetist could be adversely affected by anesthetics in amounts found in the air of an operating room not provided with a means of evacuation of overflow anesthetic gases. Although it may not be concluded that this does, in fact, occur in such situations, the data warrant the recommendation that scavenging systems be employed to lower levels of agents to 25 ppm N_2O and 0.5 ppm halothane.

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APPENDIX A

MEDICAL CHECKLIST FOR VOLUNTEERS

PSYCHOLOGIC STUDY

	Yes	No
Have you been hospitalized within the past five years?	___	___
Have you had general anesthesia during the past year?	___	___
Have you been treated for any illness (surgical, medical or psychiatric) during the past year?	___	___
Are you taking any medications of any sort?	___	___
Is your general health good?	___	___
Do you have diabetes?	___	___
Do you have epilepsy?	___	___

NAME ______________________________

DLB:smn

7/74

APPENDIX B

VOLUNTEER CONSENT FORM

Trace Effects of Anesthetic Gases on Behavioral Performance of

Operating Room Personnel

I agree to breathe a mixture of nitrous oxide with or without halothane in air or air alone for two four hour periods. At the end of two hours, I agree to the withdrawal of 10 ml of exhaled air from my mouth for testing of its vapor content. I agree to be the subject, then, to a series of tests of alertness and mental function, none of which involves painful stimulation. I agree to participate in two such sessions and understand I will be paid $40.00 after the completion of the second session. I understand that I may withdraw from participation at any time. I agree that the data from my psychological tests may be published but it will not be revealed in a form which would identify me as the subject. I understand that the concentrations of anesthetics to which I will be exposed are those found in operating room air in which people work daily.

PROJECT SUPERVISOR:

David L. Bruce, M.D.
Professor
Department of Anesthesia
N.U.M.S.

Witness:

____
Name

____
Signature

____
City & State Zip

____
Date

SUBJECT:

____
Name

____
Signature

____
Street Address

____
City & State Zip

____
Telephone Number

____
Social Security Number

8/75 mjb

APPENDIX C

Mean Test Scores: N_2O, 500 ppm; Halothane, 10 ppm

(Scores collapsed across order of exposure)

Test	Measure	Air	Anesthetic	% Change	p
Tachistoscope	Number of Patterns Recognized	16.9	16.0	5	< 0.005
Raven Matrices	Number Solved Correctly	8.4	8.4	0	N.S.
O'Connor Dexterity	Number of Pegs Placed	40.6	39.7	2	N.S.
3' Audiovisual	Reaction Time	1.11	1.34	20	< 0.001
Vigilance	Reaction Time	1.20	1.34	11	N.S.
7' Audiovisual	Reaction Time	1.06	1.24	16	< 0.001
Digit Span	Number Repeated Correctly	14.2	12.8	11	< 0.005

APPENDIX D

Mean Test Scores: N_2O, 50 ppm; Halothane, 1 ppm

(Scores collapsed across order of exposure)

Test	Measure	Air	Anesthetic	% Change	p
Tachistoscope	Number of Patterns Recognized	17.5	16.0	9	< 0.05
Raven Matrices	Number Solved Correctly	9.0	9.1	1	N.S.
O'Connor Dexterity	Number of Pegs Placed	41.7	42.0	1	N.S.
3' Audiovisual	Reaction Time	1.39	1.54	10	< 0.025
Vigilance	Reaction Time	1.63	1.54	6	< 0.05
7' Audiovisual	Reaction Time	1.31	1.44	10	< 0.001
Digit Span	Number Repeated Correctly	15.1	14.4	5	< 0.025

APPENDIX E

Mean Test Scores: N_2O, 25 ppm; Halothane 0.5 ppm

(Scores collapsed across order of exposure)

Test	Measure	Air	Anesthetic	% Change	p
Tachistoscope	Number of Patterns Recognized	14.5	15.0	3	N.S.
Raven Matrices	Number Solved Correctly	8.4	8.5	1	N.S.
O'Connor Dexterity	Number of Pegs Placed	38.1	38.7	1	N.S.
3' Audiovisual	Reaction Time	1.31	1.33	1	N.S.
Vigilance	Reaction Time	1.36	1.28	5	N.S.
7' Audiovisual	Reaction Time	1.32	1.38	1	N.S.
Digit Span	Number Repeated Correctly	14.8	14.7	1	N.S.

APPENDIX F

Mean Test Scores: N_2O, 500 ppm; No Halothane
(Scores collapsed across order of exposure)

Test	Measure	Air	Anesthetic	% Change	p
Tachistoscope	Number of Patterns Recognized	18.0	16.7	7	<0.025
Raven Matrices	Number Solved Correctly	9.0	8.2	9	<0.050
O'Connor Dexterity	Number of Pegs Placed	39.8	40.0	1	N.S.
3' Audiovisual	Reaction Time	1.21	1.42	17	<0.005
Vigilance	Reaction Time	1.32	1.50	14	<0.050
7' Audiovisual	Reaction Time	1.15	1.35	17	<0.005
Digit Span	Number Repeated Correctly	15.2	13.4	12	<0.001

APPENDIX G

Mean Test Scores: N_2O, 50 ppm; No Halothane
(Scores collapsed across order of exposure)

Test	Measure	Air	Anesthetic	% Change	p
Tachistoscope	Number of Patterns Recognized	15.5	14.8	4	N.S.
Raven Matrices	Number Solved Correctly	8.7	8.3	4	N.S.
O'Connor Dexterity	Number of Pegs Placed	41.1	39.6	3	N.S.
3' Audiovisual	Reaction Time	1.42	1.50	5	<0.050
Vigilance	Reaction Time	1.52	1.52	0	N.S.
7' Audiovisual	Reaction Time	1.29	1.36	5	<0.050
Digit Span	Number Repeated Correctly	14.7	14.4	2	N.S.

APPENDIX H

Summary of Test Results

% = Mean per cent decrease in performance in anesthetic condition

p = Significance of anesthetic effect on performance

Test	N_2O, 500 ppm Halo, 10 ppm		N_2O, 50 ppm Halo, 1 ppm		N_2O, 25 ppm Halo, 0.25 ppm		N_2O, 500 ppm No Halothane		N_2O, 50 ppm No Halothane	
	%	p	%	p	%	p	%	p	%	p
Tachistoscope	- 5%	<.005	- 9%	<.050	--	N.S.	- 7%	<.025	--	N.S.
Raven Matrices	--	N.S.	--	N.S.	--	N.S.	- 9%	<.050	--	N.S.
O'Connor Dexterity	--	N.S.	--	N.S.	--	N.S.	--	N.S.	--	N.S.
3' Audiovisual	- 20%	<.001	-10%	<.025	--	N.S.	- 20%	<.005	-5%	<.050
60' Vigilance	--	N.S.	+ 6%	<.050*	--	N.S.	-14%	<.050	--	N.S.
7' Audiovisual	-16%	<.001	-10%	<.001	--	N.S.	-20%	<.005	-5%	<.050
Digit Span	-11%	<.005	- 5%	<.025	--	N.S.	-12%	<.001	--	N.S.

* Significant improvement in vigilance test performance

LEGENDS FOR FIGURES

FIGURE 1:

Subject breathing through anesthetic system delivering compressed air, with or without added traces of halothane.

FIGURE 2:

Tachistoscope, showing one of the patterns seen by the subject for 50 msec.

FIGURE 3:

Sample page from Raven Matrices test booklet.

FIGURE 4:

Subject performing O'Connor Dexterity test.

FIGURE 5:

Subject taking audiovisual test.

FIGURE 6:

Oscilloscope displaying pattern change during audiovisual task. Left side of tracing is a pattern of ventricular fibrillation, changing near the middle of the screen to a flat line.

FIGURE 7:

ECG complex patterns of vigilance test, showing change from normal rhythm at left side of screen to atrial fibrillation in midportion of the display.

FIGURE 1: Subject breathing through anesthetic system delivering compressed air, with or without added traces of halothane.

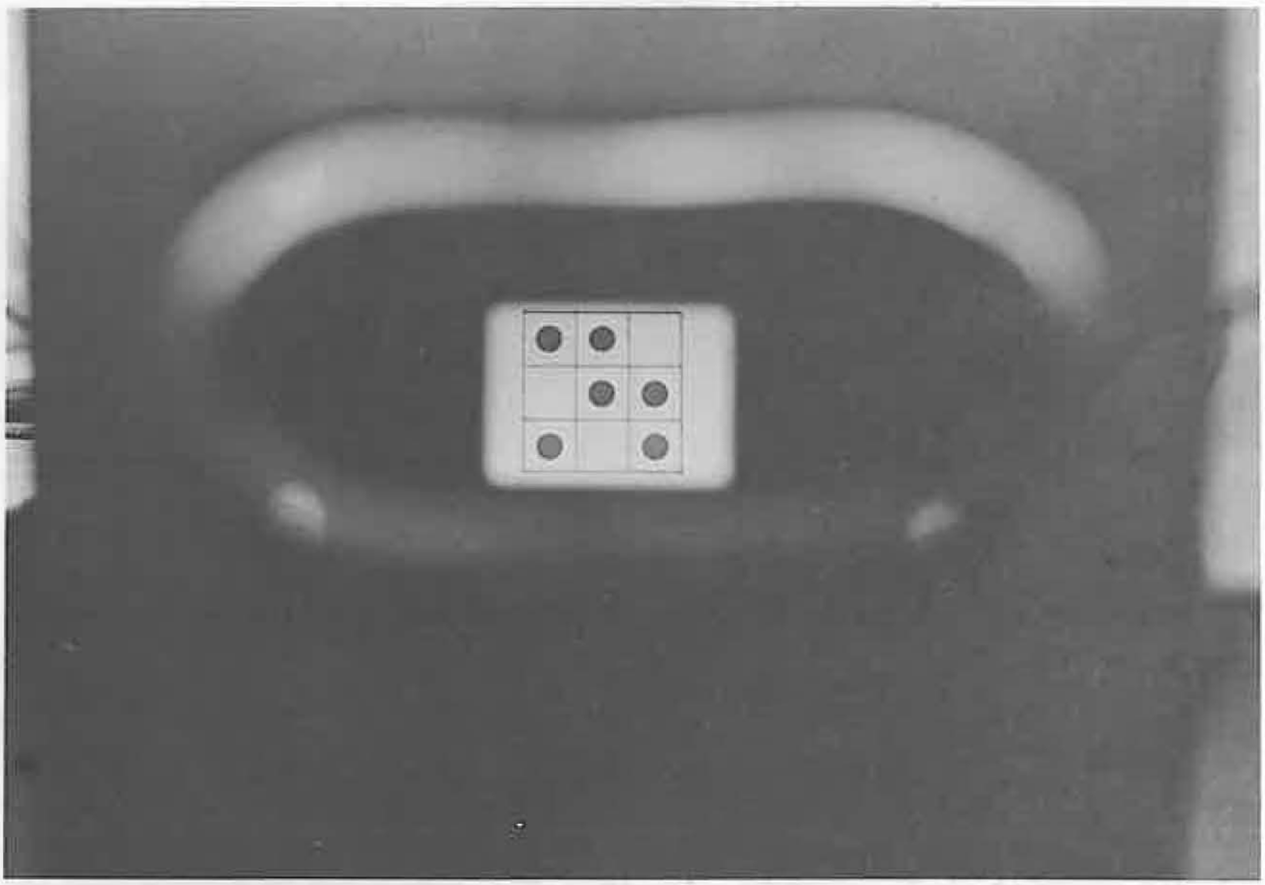

FIGURE 2: Tachistoscope, showing one of the patterns seen by the subject for 50 msec.

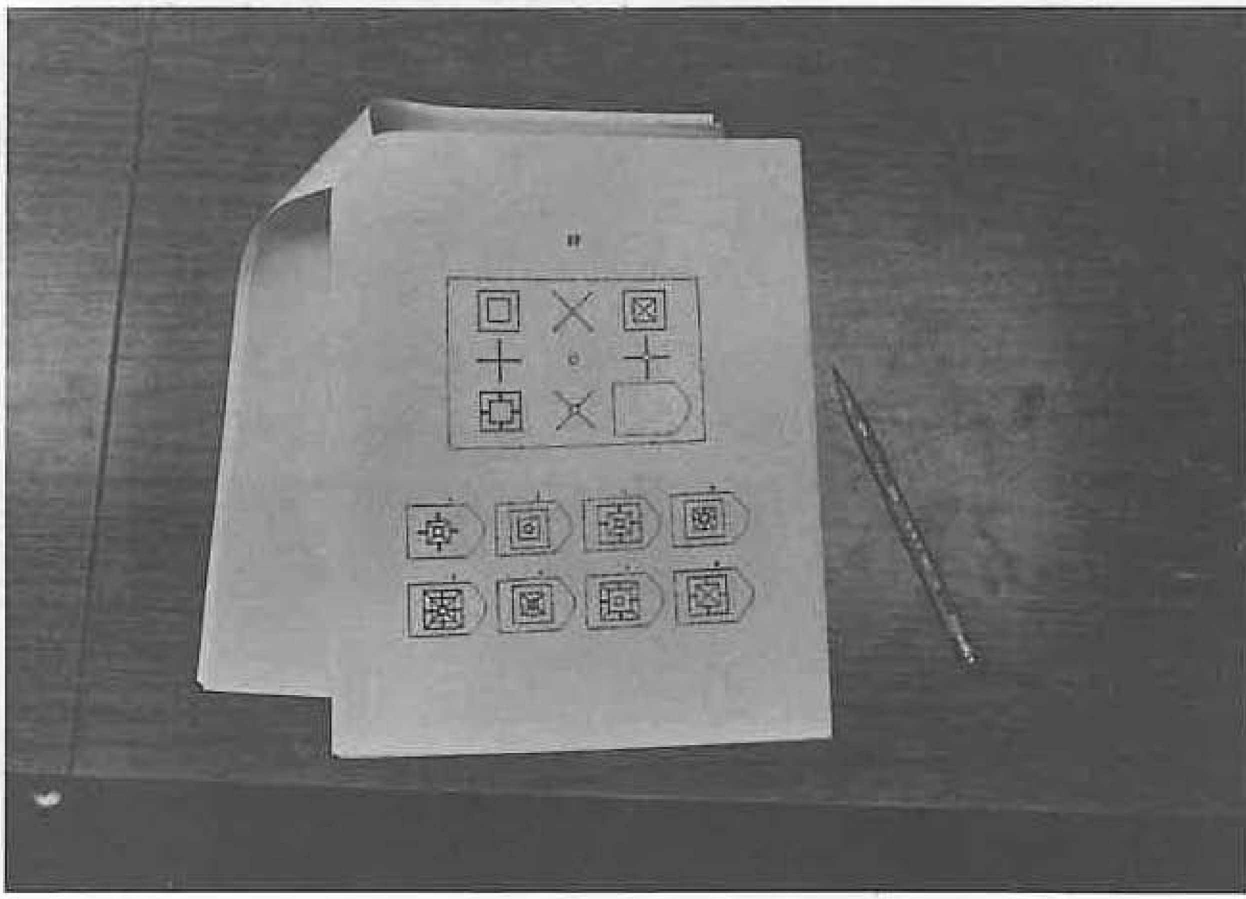

FIGURE 3: Sample page from Raven Matrices test booklet.

FIGURE 4: Subject performing O'Connor Dexterity test.

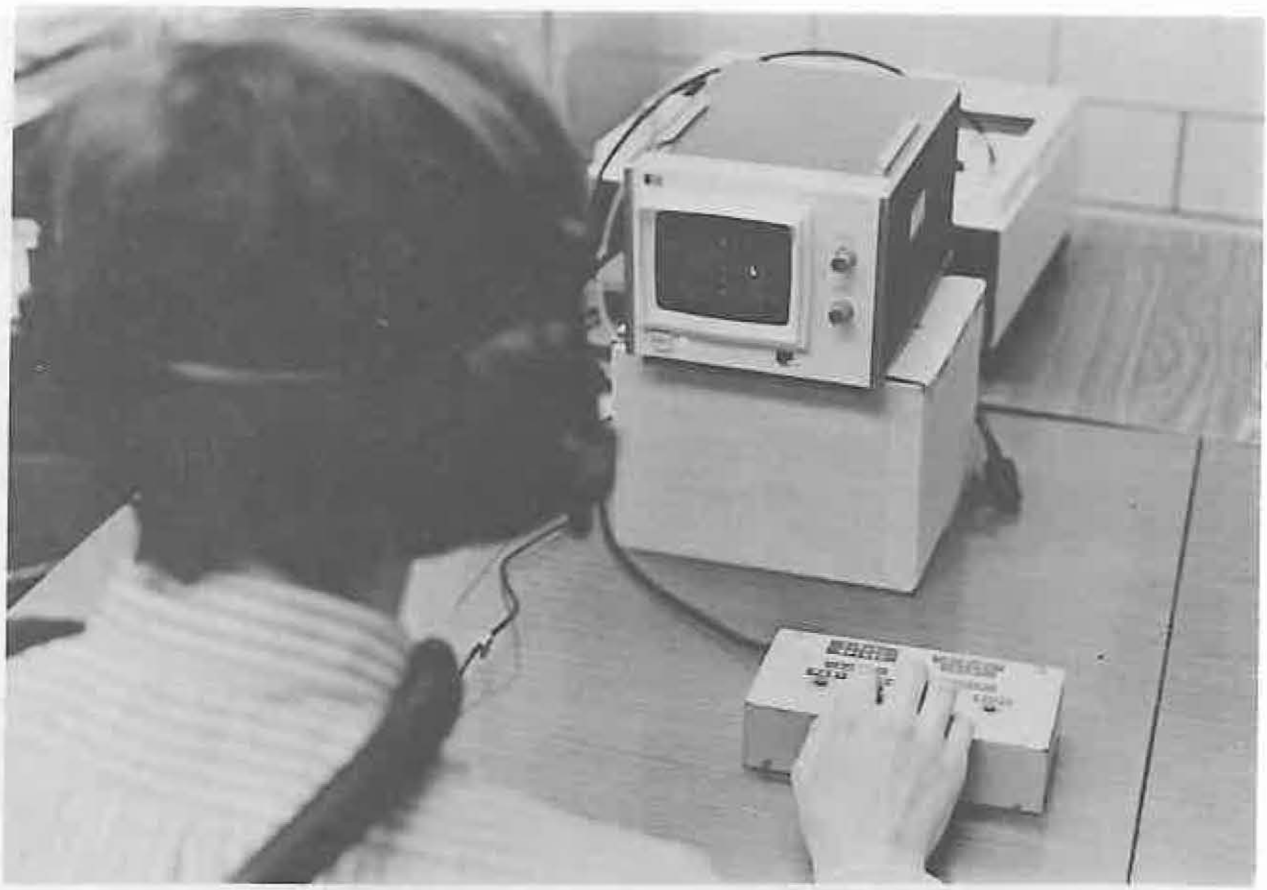

FIGURE 5: Subject taking audiovisual test.

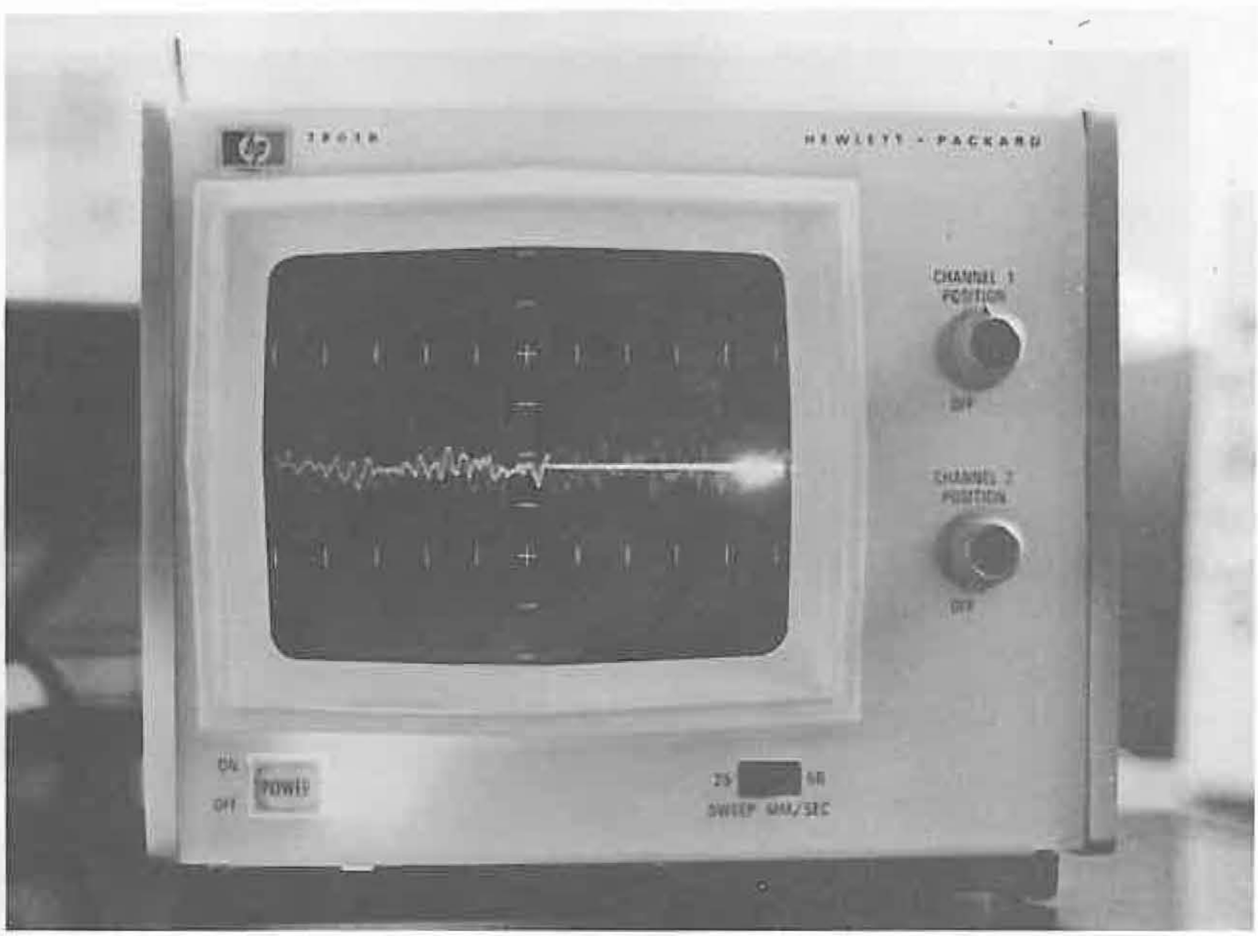

FIGURE 6: Oscilloscope displaying pattern change during audiovisual task. Left side of tracing is a pattern of ventricular fibrillation, changing near the middle of the screen to a flat line.

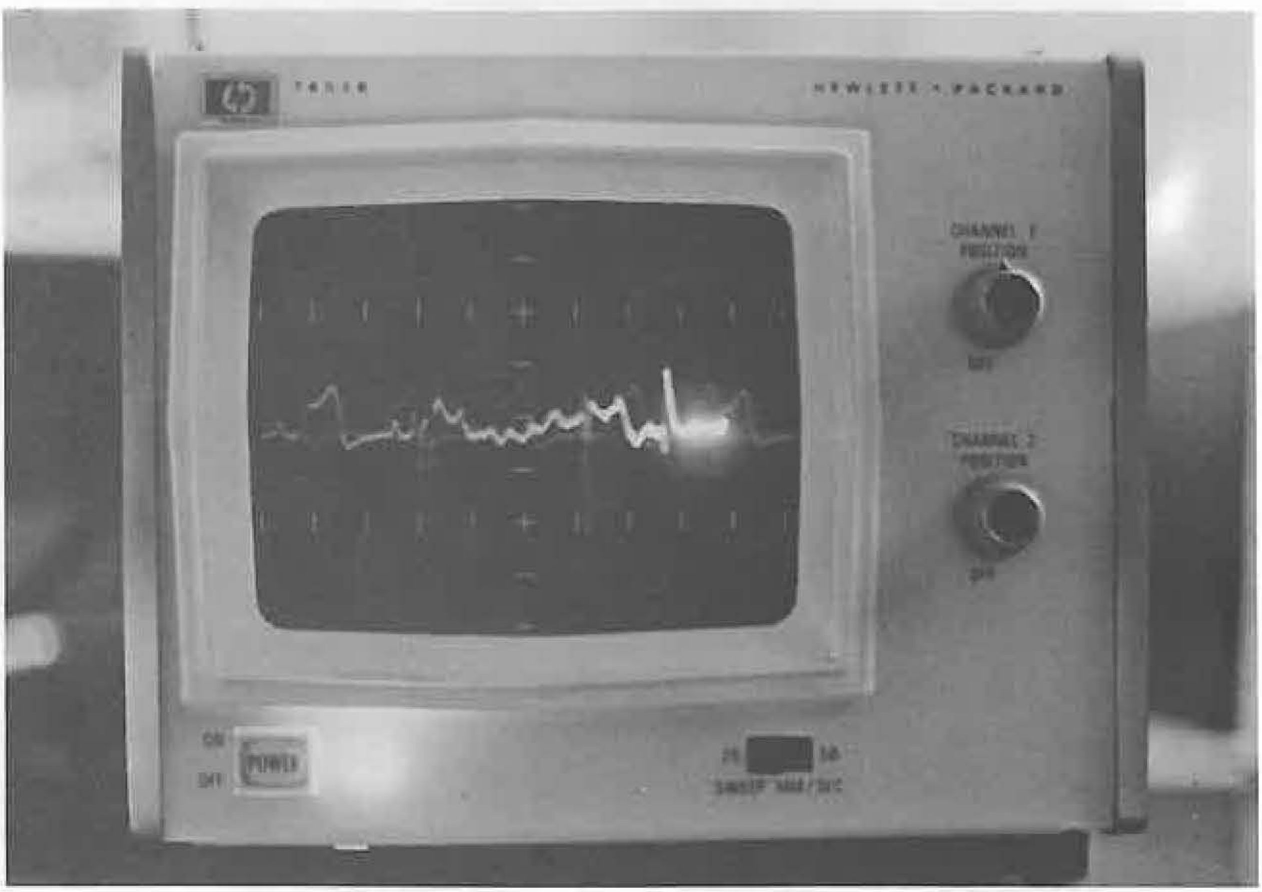

FIGURE 7: ECG complex patterns of vigilance test, showing change from normal rhythm at left side of screen to atrial fibrillation in midportion of the display.

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