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Effects of olfactory stimulation on performance and stress in a visual sustained attention task

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Synopsis

Subjects performed a visual sustained attention (vigilance) task for 40 minutes during which they received periodic 30-second whiffs of pure air or a hedonically positive fragrance, Muguet or Peppermint, through a modified oxygen mask. The former fragrance had been independently judged as relaxing, the latter as alerting. Subjects receiving either fragrance detected significantly more signals during the vigil than unscented air controls. Subjective reports of mood and workload indicated that the subjects experienced the vigilance task as stressful and demanding. However, the fragrances had no impact on the latter measures. These results provide the initial experimental evidence to indicate that fragrances can enhance signal detectability in a task demanding sustained attention, though the exact characteristics of effective fragrances have yet to be determined.

INTRODUCTION

Vigilance, or sustained attention, tasks require observers to remain alert and to detect infrequent and unpredictable stimulus events over prolonged periods of time (1–2). Although subjects engaged in such tasks are required only to dedicate themselves to looking or listening for the specified events that constitute signals for detection, their performance on these tasks is remarkably fragile, and the tasks tend to induce considerable stress.

The brittle character of vigilant behavior is revealed through the decrement function, a decline in the frequency and/or speed of signal detections over time. This decline is often complete from 20 to 35 minutes after the initiation of the vigil (1–2); in some cases, it can even be observed as early as the first five minutes of watch (3). Along with the decrement function, vigilance performance is accompanied by increased catecholamine and cortisol output, indicating physiological stress (4–5), and by subjective reports indicating that monitors feel less energetic, more strained, bored, irritated, drowsy, and headachy at the end of a vigil than at the beginning (6–7). Moreover, measures of subjective workload show that what may appear to be a simple assignment is in fact quite demanding (8–9).

For obvious practical reasons, it would prove very useful to develop techniques for improving the overall level of vigilance performance, for moderating the vigilance decrement, and for alleviating the feelings of stress attendant on engaging in vigilance tasks. Such tasks can be found in many work settings, including those confronting radar and sonar operators, quality control inspectors, system monitors in power plants, medical personnel in intensive care units, long distance drivers, and so on. Failure to detect and respond to critical signals in these settings can sometimes have disastrous consequences (2). Efforts to moderate the vigilance decrement and combat the feelings of stress induced by vigilance tasks have utilized exercise (10), added stimulation such as music in a visual vigilance task or visual stimulation in an auditory task (11–12), and stimulant drugs (13–14) to keep monitors aroused. While somewhat successful, these techniques have limitations. Exercise at the workstation is not always possible, added stimulation can be distracting and impair working memory (15), and drugs can produce unwanted side effects and addiction (16).

To our knowledge, no one, prior to the present study, has appealed to the olfactory sense as a source of stimulation for the maintenance of sustained attention. Olfactory stimuli can be quite salient and can play important roles in emotion and in recall and recognition (17–18). There is also evidence that some fragrances can enhance alertness and that some can reduce stress, at least on a short-term basis. While this evidence is in part anecdotal (19), much of it comes from empirical research using both psychophysiological and self-report techniques (20–21). If the purported alerting and stress-reducing properties of fragrances can operate over extended periods of time, fragrance administration might serve as a benign vehicle for enhancing the quality of sustained attention and/or reducing the stressful feelings that accompany vigilance performance.

Our hypothesis was that fragrances assessed as alerting might beneficially affect vigilance performance and that fragrances assessed as relaxing might reduce the tension and feelings of stress consequent on performing a vigilance task. Moreover, we were prepared to speculate that alerting fragrances might also reduce the stress of vigilance by creating a closer match between task demands and subjects' ability to perform those tasks; that is, part of the stress may arise from subjects' need, but inability, to remain sufficiently alert to do well on the vigilance task. Fragrances that help them stay alert might therefore also help them feel better. Similarly, relaxing fragrances might affect performance efficiency as well as feelings, since subjects who are tense and uncomfortable may find it hard to concentrate on the task.

In short, it seemed reasonable to expect that both alerting and relaxing fragrances might have both performance- and mood-enhancing effects, albeit for somewhat different reasons. But our main concern, at the outset, was whether we could find any effects of fragrance at all in comparison with an appropriate control condition.

For our initial investigation, we decided to use two hedonically positive fragrances, one assessed as alerting and the other as relaxing. Toward that end, the initial phase of the research involved an evaluation of the hedonic and mood-inducing qualities of seven fragrances supplied by International Flavors and Fragrances, Inc.: Benzoin, Cashmeran, Forest-Plus, Muguet, Peppermint, Sandlewood, and Spiced-Apple. We report below details of that evaluation study, and we then describe the main experiment.

PILOT STUDY

Forty subjects, 20 male and 20 female students from the University of Cincinnati, judged each of the seven candidate fragrances on two scales, a hedonic, or pleasantness scale, and a scale of alertness/relaxation. The hedonic scale was a 16-cm line, with the zero point labeled "very unpleasant" and the 16-cm point "very pleasant." Subjects placed a mark on the line corresponding to their judgment of how pleasant or unpleasant each fragrance was. The other scale, a 15-cm line, was labeled "more alerting/ stimulating" at the zero point and "more relaxing" at the 15-cm point. To aid in making the latter judgment, subjects were asked to imagine that they were engaged in a tedious task and to note whether each fragrance, if present during the conduct of that task, would be more relaxing or more alerting/stimulating. For the hedonic scale, marks above the midpoint of 8 cm were considered to designate a pleasant fragrance; for the other scale, marks above the midpoint of 7.5 cm were considered to designate a relaxing fragrance.

Each subject judged each fragrance once on each of the scales. The order in which subjects experienced the fragrances as they progressed through the experiment was varied at random for each individual, while the sequence in which they responded to the two scales was balanced within the gender groups. Subjects sampled each fragrance once via a squeeze bottle containing fragrance-impregnated polyethylene pellets. Preliminary inspection of the data for both types of scales revealed that ratings were similar for the male and female subjects. Accordingly, the data were collapsed across gender prior to further analysis.

Overall mean hedonic and alerting/relaxing ratings are displayed in Table I.

Separate analyses of variance revealed statistically significant differences among the fragrances on both dimensions. For hedonic ratings, $F(6,234) = 21.31, p < 0.001$; for alerting/relaxing ratings, $F(6,234) = 5.08, p < 0.001$. On the basis of these ratings,

Table I
Means and Standard Errors for Hedonic and Alertness/Relaxation Ratings

	Hedonic rating		Alertness/relaxation rating	
Fragrance	M	SE	M	SE
Benzoin	8.02	0.57	7.88	0.43
Cashmeran	5.26	0.59	5.27	0.52
Forest-Plus	6.09	0.56	6.07	0.47
Muguet	11.40	0.59	8.34	0.56
Peppermint	11.02	0.56	5.63	0.56
Sandlewood	5.22	0.55	6.04	0.45
Spiced-Apple	7.61	0.65	6.65	0.45

H Scale: <8, unpleasant; 8, neutral; >8, pleasant.
A/R Scale: <7.5, stimulating; 7.5, neutral; >7.5, relaxing.

we selected two fragrances, both with high mean hedonic values. One, Peppermint, had a high alertingness rating; the other, Muguet, was rated as relaxing. In both instances, the mean ratings were at least one standard error beyond the neutral point, as illustrated in Table I.

MAIN EXPERIMENT

SUBJECTS

Thirty-six subjects, 18 men and an equal number of women, from the Cincinnati metropolitan area participated in the experiment. The subjects were solicited through a newspaper advertisement and were paid $15 for serving in the study. They ranged in age from 18 to 30 years, with a mean of 26.6 years. The sample reflected a variety of educational and occupational backgrounds. All subjects had normal or corrected-to-normal vision and passed a test for anosmia, designed by International Flavors and Fragrances, Inc., as a condition for gaining entry into the study. Six male and six female subjects were assigned at random to one of three fragrance groups, a control group which received unscented air and groups receiving air scented with either Muguet or Peppermint.

VIGILANCE TASK

All subjects participated in a continuous 40-minute vigil divided into four consecutive 10-minute periods during which they monitored the repetitive presentation of a pair of 1 × 13-mm lines with a 1-mm dot centered vertically and horizontally between them. The distance between each line and the centering dot was normally 10 mm. Critical signals for detection were configurations in which both lines were 2 mm farther from the centering dot than usual. Stimuli were presented at the rate of 24 events/minute, with an exposure time of 150 msec. In all conditions, five critical signals were presented during each 10-minute period of watch (signal probability = 0.02). Intersignal intervals ranged from 20 to 240 seconds, with a mean of 120 seconds.

An Apple IIe microcomputer was used to generate the stimuli and to control the presentation of critical signals and neutral events in all experimental conditions. The computer also recorded the subjects' responses. The subjects indicated their detection of critical signals by depressing the spacebar on the computer's keyboard. In all conditions, responses occurring within 1.25 seconds after the onset of a critical signal were recorded automatically as correct detections. All other responses were recorded either as errors of commission (failing to detect a signal) or false alarms (calling a neutral event a signal).

Subjects were tested individually in a 1.9 × 1.8 × 2.0-meter Industrial Acoustics sound chamber. Each subject was seated in front of a table containing a video display terminal (VDT). Viewing distance was approximately 43.5 cm. A glare reduction screen was mounted on the VDT to enhance the clarity of the display and to minimize visible phosphor decay following offset of the pixels that made up the stimulus configuration. Ambient illumination was provided by a 40-watt bulb mounted in an aluminum cone-shaped fixture that was positioned to diffuse light evenly within the chamber.

FRAGRANCE DELIVERY

The fragrance delivery system consisted of a pair of aquarium pumps (Hagen Optima and Whisper 1000) that forced air through Teflon tubing into a charcoal filter and then into a 35-ml glass reservoir housed in a refrigerator that was maintained at 70° F. The reservoir contained 9 × 9-mm polyethylene pellets that incorporated the fragrance to be used. Air from the reservoir was transmitted through additional tubing under pressure from the pumps to a modified home oxygen mask worn by the subject while seated in the experimental chamber.

The fragrance delivery equipment was located outside the chamber. Total travel distance from the reservoir to the mask was 2.15 meters. Odor concentration at the mask was controlled by the air flow (0.80 liters/minute) and by the number of pellets in the reservoir. Five pellets were used for delivering the Peppermint fragrance and 10 for Muguet. The concentration of Peppermint was 0.05 parts/million, while that for Muguet was 0.13 parts/million. Fragrance concentration was determined by pilot work that equated the fragrances for salience when delivered against an unscented background. In the control condition, unscented air was delivered to the mask by forcing the air through an empty reservoir in the refrigerator. The duration of air flow through the mask was controlled by a decade interval timer in conjunction with a Gerbrands tape timer. The timing system activated the air pumps for limited intervals at specified times during the experimental session. In the course of the experiment, subjects experienced 30-second whiffs of either scented or unscented air through the mask 4.5 minutes after the start of the vigil and every five minutes thereafter. At other times the fragrance delivery system was dormant.

The masks used in the study were modified by cutting triangular openings (with a base of 6 cm and an altitude of 4 cm) in both sides, which permitted subjects to breathe room air comfortably when the fragrance delivery system was not engaged. Fresh air was provided to the experimental chamber through a ceiling fan. An electronic air cleaner (Sears Model 635.830000) cleansed the air within the chamber and insured against contamination by lingering odors. Containers of charcoal and baking soda placed within the refrigerator offered similar protection for air entering and leaving the fragrance reservoir. To further insure against contamination, three separate reservoirs were used for the Muguet and Peppermint pellets and in the unscented control condition. These reservoirs had separate tubing leading to masks reserved for them. To protect against the possibility of infection, masks were bathed in alcohol after being used. Subjects reported little discomfort in wearing the masks. The tubing leading to each mask was of sufficient length to permit the subjects considerable freedom of movement as they sat at their workstation. Schematic drawings of the fragrance delivery system and of the experimental chamber are presented in Figures 1 and 2, respectively.

STRESS AND WORKLOAD MEASUREMENT

Stress measures were obtained from three scales. They included (a) the Thackray Mood Scales—a nine-point rating scale measuring attentiveness, sleepiness, strain, boredom, and irritation, in which values below five reflect negative feelings (22); (b) the Yoshitake Symptoms of Fatigue Scale—a 30-item checklist of fatigue indicants such as headache, dizziness, eye strain, etc. (23); and (c) the Stanford Sleepiness Scale—a seven-item rating

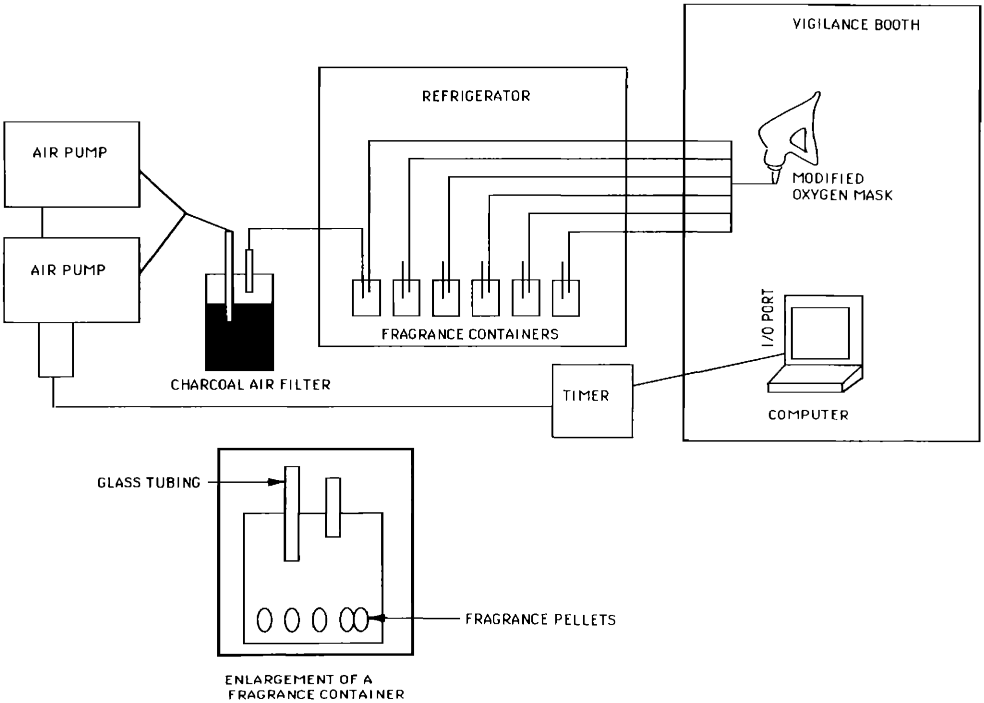

Figure 1. Schematic drawing of the fragrance delivery system.

scale ranging from "wide awake {1}" to "almost in reverie {7}" (24). Subjective workload assessments were obtained from the NASA TLX, which measures the degree of processing capacity that is expended during the performance of a task on a scale from 0 to 100 (25).

PROCEDURE

Upon reporting to the laboratory, subjects were asked to complete an informed consent form, screened for allergies, and tested for anosmia. They then completed a paper and pencil version of the Thackray, Stanford, and Yoshitake scales. The order in which they received these scales was counterbalanced within groups. Afterwards, subjects were given a 10-minute training period that duplicated the first period of the vigilance task and then assessed the workload of the training phase using a computer-generated version of the TLX.

Prior to the start of the main part of the session, subjects were given time to become acclimated to the oxygen mask and to experience the flow of fragrance or unscented air through the mask. Immediately following the main session, the subjects again assessed their workload and then responded to the Thackray, Stanford, and Yoshitake scales. Testing was accomplished between 0730 and 1100 hours and between 1230 and 1700 hours. Half of the male and female subjects in each group were tested during these morning and afternoon periods in order to control the possibility of circadian effects that have been found to influence vigilance performance (26). Prior to coming to the labo-

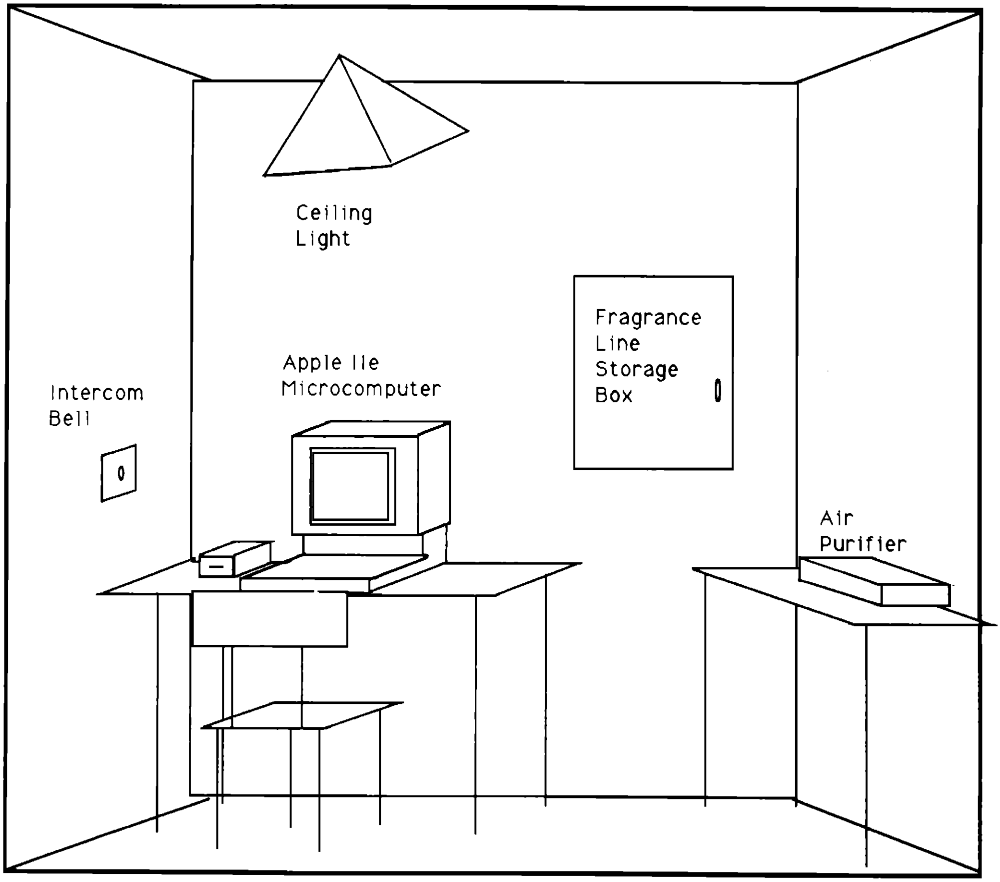

Figure 2. Schematic drawing of the experimental chamber.

ratory, subjects were requested not to wear cologne or perfume. All subjects complied with this request.

RESULTS

VIGILANCE PERFORMANCE

Percentages of correct detections and false alarms were determined for each subject during each period of watch. Preliminary inspection of the data revealed that gender and time of day had little effect upon performance. Accordingly, the data were collapsed across these factors for further analyses.

Mean percentages of the correct detections for the air, Muguet, and Peppermint groups are plotted as a function of periods in Figure 3. It is evident in the figure that the detection scores for both fragrance groups were similar and that for both groups the percentage of detections was substantially and consistently greater than that for the unscented air control. The figure also shows that the detection percentage in all groups declined over time. An analysis of variance of the detection scores revealed that the

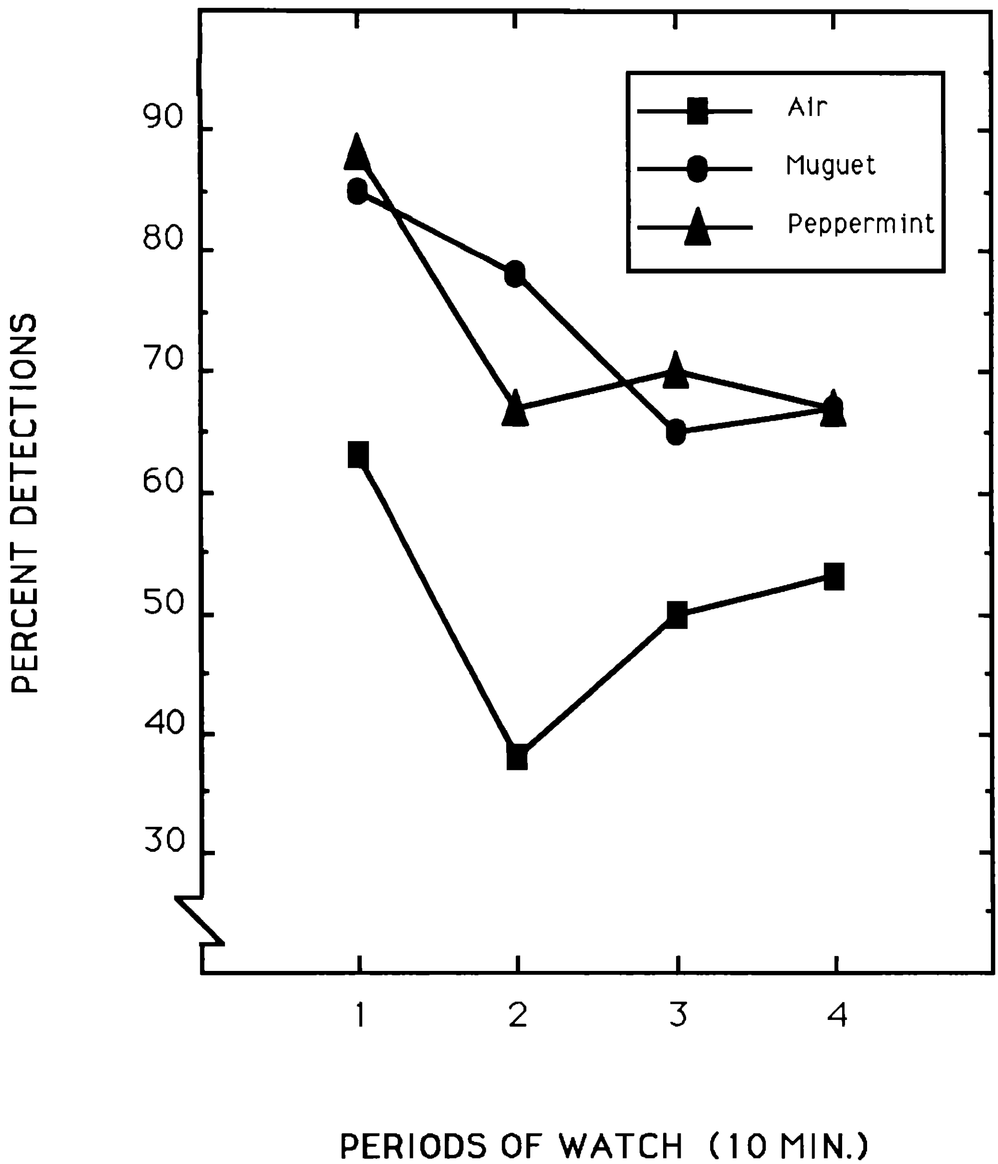

Figure 3. Percentage of correct detections as a function of periods of watch for subjects in the air, Muguet, and Peppermint conditions.

difference between groups reached statistical significance [$F(2,33) = 3.25$; $p = 0.05$] and that performance efficiency deteriorated significantly over time [$F(3,99) = 6.30$; $p < 0.001$]. The groups × periods interaction lacked significance [$F(6,99) = 1.17$; $p > 0.05$].

False alarms were generally few in all conditions. Mean percentages of false alarms for the four periods of watch were 2.7%, 1.8%, 2.0%, and 2.3%, respectively, for the air group; 8.9%, 6.7%, 6.2%, and 5.9%, respectively, for the group exposed to Muguet; and 12.4%, 7.2%, 9.3%, and 7.0%, respectively, for subjects exposed to Peppermint.

An analysis of variance of the percentage of false alarms showed that their overall frequency declined significantly over time [$F(3,99) = 7.42$; $p < 0.001$], a typical finding in vigilance experiments (1). All of the remaining sources of variance in the analysis lacked significance ($p > 0.05$).

STRESS AND WORKLOAD RATINGS

Mean pre-test and post-test scores on the Thackray, Stanford, and Yoshitake scales are presented for each fragrance group in Table II.

Preliminary inspection of the data for the Thackray ratings of attention, sleepiness, strain, boredom, and irritation indicated that the results for the five subscales were similar. Consequently, the scores in Table II for this instrument represent summated values (possible range is 5–45, with 25 as the midpoint) across the subscales. Increments in negative feelings are reflected in *lower* post-test as compared to pre-test scores. In the case of the Stanford and Yoshitake scales, however, increments in fatigue and sleepiness are revealed through *higher* post-test as compared to pre-test scores.

Perusal of Table II will show that the subjects in this study found the vigil to be quite stressful. Composite feelings of increased inattentiveness, sleepiness, strain, boredom, and irritability after the vigil are evident in the Thackray ratings, along with increased feelings of sleepiness and fatigue on the Stanford and Yoshitake scales. In the case of the Yoshitake scale, pre-test and post-test differences were dramatic. On average, symptoms of fatigue increased by 257% in the post-test measure. Analyses of variance performed on the data of all three scales revealed significant phase effects [$F(1,33) > 48$; $p < 0.001$] in each case. In no case, however, were the groups or the groups × phase components of the analyses significant ($p > 0.05$), indicating that the self reports of stress in this study were not attenuated by exposure to accessory olfactory stimulation.

Mean workload scores for the practice period and for the main task in the three fragrance conditions are displayed in Table III.

It is evident in the table that the subjects rated the workload of both the 10-minute practice period and the 40-minute vigil to be high. All scores are in the upper range of the TLX scale. Moreover, there is a trend for the air group to show a greater increment in workload from the 10-minute practice session to the 40-minute vigil than for the

Table II
Mean Pre-Test and Post-Test Scores on the Thackray, Stanford, and Yoshitake Scales for Subjects in the Air, Muguet, and Peppermint Groups

	Scales					
	Thackray		Stanford		Yoshitake	
Groups	Pre	Post	Pre	Post	Pre	Post
Air	32.5	25.6	2.3	3.6	2.5	7.4
Muguet	33.6	25.1	2.4	3.8	3.3	7.1
Peppermint	34.2	25.7	2.2	3.3	2.7	7.2
Mean	33.4	25.5	2.3	3.6	2.8	7.2

Table III
Mean Workload Scores in Practice and the Main Watch for Subjects in the Air, Muguet, and Peppermint Groups

Groups	Practice	Main watch	Mean
Air	64.7	68.2	66.4
Muguet	69.4	68.0	68.7
Peppermint	63.6	62.3	63.0
Mean	65.9	66.2	

Muguet or Peppermint groups. An analysis of variance of the data of Table III, however, failed to reveal any significant differences between groups or between phases ($p > 0.05$).

DISCUSSION

The results of this experiment indicate that two fragrances, Peppermint and Muguet, when delivered periodically during the course of a 40-minute vigil, can have beneficial effects on subjects' performance in a vigilance task. Specifically, subjects exposed to either of the two fragrances showed greater overall sensitivity to signals than those receiving periodic whiffs of unscented air; that result cannot be attributed to a change in subjects' willingness to emit detection responses, since the false alarm rates were equivalent in all groups. Moreover, the result cannot be due to differences among groups in the initial level of detectability of signals, since an analysis of variance revealed no group differences in hit rate during the practice task {$F(2,33) = 2.16; p > 0.05$}. The data did not show an effect on the vigilance decrement itself: Subjects in all three groups performed less well as the vigil progressed than at the outset. Finally, there were no differences between men and women in performance efficiency, no interactions between gender and fragrance condition, and no effects involving time of day. So, we can conclude with some confidence that the effect of the two fragrances on ability to discriminate signals from non-signals has generality over sex and time of day.

While we had reason to expect Peppermint (characterized as alerting) to be more effective than Muguet on performance measures, and Muguet (characterized as relaxing) to be the more effective on subjective reports of stress and workload, it is apparent that there was no difference between the two fragrances in their effect on performance efficiency and that neither had any dramatic impact on subjective reports. These latter results call into question the complicated scenario outlined earlier, that Peppermint facilitates vigilance performance by directly raising arousal level, whereas Muguet works through its ability to reduce the perceptually distracting effects of the symptoms of fatigue, tension, strain, headache, and so on, that typically arise in the vigilance situation. There are three simpler hypotheses that need to be tested: (a) given that both Peppermint and Muguet are assessed as very pleasant, perhaps any pleasant fragrance will suffice, and there is nothing physiologically/chemically special about these two fragrances; (b) given that Peppermint and Muguet are both fragrances, perhaps any fragrance will suffice, pleasant, neutral or unpleasant, so long as it is judged either alerting or relaxing; and finally, (c) it is possible that any perceptually salient fragrance will work by temporarily increasing subjects' alertness level via connections from olfactory centers to the midbrain reticular area (27), a brain region that plays an important role in the regulation and maintenance of vigilance (28). These possibilities warrant further investigation.

Finally, note that beyond providing the initial experimental demonstration that certain fragrances can bolster sustained attention, our results have meaning for an even broader issue, that of intersensory interaction. Studies of interactions among stimuli in different sense modalities have, for the most part, been confined to combinations drawn from the auditory, visual, and tactual modes (29). To our knowledge, the data described in this paper are the first to show that accessory olfactory stimulation can enhance the detection of visual stimuli.

CONCLUSIONS

The results of this study indicate that exposure to whiffs of air scented with the fragrance of Muguet or Peppermint can enhance the rate of signal detections in a vigilance task without a concomitant increase in errors of commission. These findings suggest that exposure to fragrance may serve as an effective form of ancillary stimulation in tasks demanding close attention for prolonged periods of time.

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