fixed-interval schedule of 30 seconds (occasion for reinforcement of a response occurs 30 seconds after the previous reinforced response), for a 5-second presentation of a drinking tube containing various concentrations of dulcin. The different concentrations were presented in a Latin-square fashion to preclude order effects. The squirrel monkeys were subjected to two series of four concentrations each. The first series consisted of the following molar concentrations: 10^{-6}, 10^{-5}, 10^{-4}, and 10^{-3}. The second series was run to provide a finer scale with which to examine the critical portion of the reinforcement curve. The molar concentrations used were 1.8×10^{-4}, 3×10^{-4}, 5.6×10^{-4}, and 1.8×10^{-3}. Each session lasted 30 minutes; at the time of testing the monkeys had been deprived of fluids for 16 hours.

Figure 1 illustrates the squirrel monkeys aversion to sodium saccharin. Dulcin, on the other hand, was preferred by these animals. The aversion threshold (set at 25 percent, or less, of total intake) for sodium saccharin was about $5 \times 10^{-4}M$. The preference threshold (set at 75 percent, or more, of total intake) for dulcin was about $10^{-4}M$. The rats showed a clear preference for the sodium saccharin beginning about $3 \times 10^{-4}M$ and only a suggestion of a preference for dulcin (65 percent of total intake) at only one value, $3 \times 10^{-3}M$. The solubility of dulcin limited the extent of the ascending series, however, $6 \times 10^{-3}M$ was presented, and the earlier suggestion of a preference was contraindicated.

Figure 2 shows that a concentration of $1.8 \times 10^{-4}M$ provided about the same incentive as the $10^{-6}M$. The next step, 3×10^{-4}, generated a noticeably higher rate which progressed with increasing concentration. The reinforcing concentration of the dulcin appeared to increase the preference threshold value by about half a log dilution. The individual curves were very similar to the average curve.

Three human subjects provided data for thresholds of reported sweetness for sodium saccharin and dulcin. The subjects were given an ascending series with a "water break" between the two series. Two glasses, one containing the sapid solution and the other water, were presented simultaneously to the subject. The subject tasted the contents of one of the two glasses, rinsed, tasted the other, and reported the taste quality. The order of tasting the solutions in each pair was randomly determined.

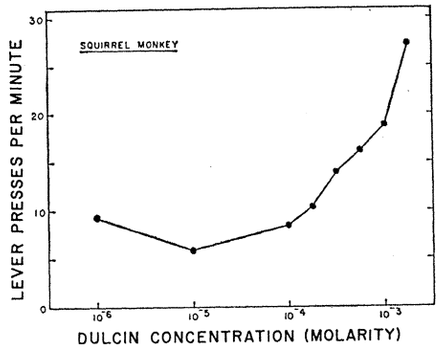

Fig. 2. Combined rates of lever-pressing for three squirrel monkeys maintained by dulcin reinforcement.

One minute was allowed for each judgment, and a 2-minute intertrial period was observed.

The reports of sweetness of the three individual subjects were in perfect agreement. The subjects reported that saccharin tasted "like water" at $10^{-5}M$ and "sweet" at $3 \times 10^{-5}M$. The report of "sweet" continued for all higher concentrations. Similarly, the subjects reported that $3 \times 10^{-4}M$ dulcin was "like water" and $10^{-3}M$ dulcin and higher concentrations, "sweet." Subject N.K. later reported both dulcin and sodium saccharin pleasant above threshold; D.A. considered the highest concentration of dulcin and sodium saccharin "sickeningly sweet"; B.N. reported only the highest concentrations to be too sweet to be pleasant.

Our data indicated that squirrel monkeys have a strong preference for dulcin and an aversion for sodium saccharin above a certain concentration. Rats, on the other hand, preferred the saccharin and were indifferent to the dulcin. Dulcin is not only preferred to water but may be used to maintain operant behavior in squirrel monkeys. Saccharin will do the same for rats (*4*).

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29 July 1965

Adrenaline and Noradrenaline: Relation to Performance in a Visual Vigilance Task

Abstract. *Concentrations of adrenaline and noradrenaline in the circulating blood were measured in blood samples taken from subjects as they performed a visual vigilance task or viewed movies, both under identical conditions. For those subjects whose vigilance performance deteriorated it was concluded that the concentration of circulating adrenaline decreases as a function of time in a vigilance task but not under "relaxed" conditions, such as watching motion pictures.*

The typical decrement in signal-detection performance which occurs in many "vigilance tasks" (*1*) is related to various physiological changes, which suggests decreasing arousal of the cortex (*2*) and of the sympathetic-autonomic nervous system (*3*).

Arousal, both cortical and autonomic, is correlated with activity within the ascending reticular activating system (ARAS) of midbrain and diencephalon (*4, 5*). It has been postulated (*6*) that when the cortex is aroused, this activating system serves a "vigilance function," making the cortex responsive to neural "cues" or signals as they arrive by way of classical sensory tracts. Perhaps the deterioration of detection performance frequently found in vigilance tasks results from decreasing ARAS activity. If so, sources of activation should show a quantitative decrease throughout the course of a vigilance task.

As the reticular activating system is normally excited by the direct action of circulating biogenic stimulants, particularly adrenaline (*5*), the hypothesis of this experiment was that circulating adrenaline decreases in human subjects when their detection performance deteriorates during a vigilance task.

Illumination of a 32-mm, circular aperture was continuously cycled from dim (2 sec) to brighter (1 sec) every 3 seconds. Occasionally a "signal," defined as a still greater brightness, was generated during the 1-second part of the cycle, and the task was to report the detection of such signals by pressing a hand-held response button.

Subjects were 16 males ranging in age from 20 to 34. One week prior to serving in the experiment each subject undertook a psychophysical test aimed at determining the signal brightness which he could detect in 90 per-

cent of presentations under alerted conditions. Each subject also undertook a prior 90-minute vigilance task to determine whether or not his performance suffered a significant decrement ($p < .01$) in the percentage of signals detected during an extended watch. The 13 subjects whose performance deteriorated were designated as "decrementers" while the three subjects whose detection performance did not deteriorate in the vigilance condition were designated as "nondecrementers." Base line pulse and blood-pressure readings were taken for each subject after 30 minutes of seated rest.

In the main experiment a week later six decrementers were assigned to an experimental condition and seven to a control condition. The three nondecrementers were assigned to the experimental condition only.

Seated in a soundproof, air-conditioned booth (1.2 by 1.2 by 2.4 m) a subject undertaking the experimental condition faced the visual display, whereas a subject undertaking the control condition faced a rear-projection screen (20 by 25 cm). In addition, each subject inserted his left arm through an opaque sleeve into an enclosed shelf-like arm rest which was accessible to the experimenters through a hatch, 0.3 by 0.9 m. Novocaine (2-percent solution, without adrenaline) was administered subdermally and a catheter (*7*) was inserted into an antecubital vein. The catheter was connected to a tube-stopcock system which extended through the wall of the booth and made it possible to obtain serial blood samples without the subject's knowledge.

After catheterization, each subject rested until a series of pulse and blood-pressure readings indicated that the previously determined base line levels had been reestablished. This period varied between 30 and 75 minutes. The booth was then sealed, and the experiment began.

In the experimental condition subjects undertook signal detection tests before and after the main watch. Both tests were 4 minutes in length, and each contained 12 signals at randomly selected times. The subjects were alerted to the imminence of signals during these tests by a 1-minute cessation of display cycling before and after each test. The main watch lasted for 180 minutes. Signal frequency in the main watch was 24 per hour, 6 signals being randomly located in each 15-minute interval. Blood samples of 30 ml each were drawn midway through the tests and at half-hour intervals during the main watch, beginning 15 minutes after onset of the watch.

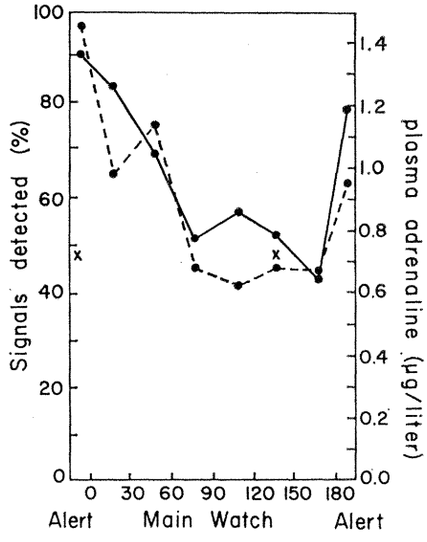

Fig. 1. Average percentage of signals detected (solid line) and plasma concentration of adrenaline (broken line) in experimental decrementers during alerted tests and as a function of time on watch. *X*, Average concentration of adrenaline in control decrementers.

Conditions were identical for the control subjects, with the exception that they viewed a connected series of 12 silent motion-picture features, each lasting 15 minutes, instead of the cycling display.

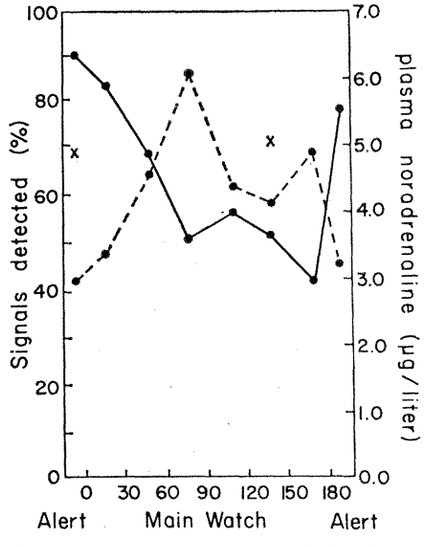

Fig. 2. Average percentage of signals detected (solid line) and plasma concentration of noradrenaline (broken line) in experimental decrementers during alerted tests and as a function of time on watch. *X*, Average concentration of noradrenaline in control decrementers.

Blood samples were drawn from subjects in the control condition at the same intervals as, and in equal volume to, the samples from subjects in the experimental condition, but, because of the high cost of the analytic method, not all of these samples were analyzed. The assumption was made that a valid comparison of the progressive effects of both conditions could be made by comparing the differences between terminal samples for the two groups of subjects. Therefore, only the samples drawn from the controls after 2 minutes and 140 minutes of watching the movies were analyzed, since these samples corresponded in time to the first and last samples obtained from subjects in the experimental condition (*8*).

Concentrations of adrenaline and noradrenaline in the blood plasma were estimated by a chemical method (*9*). These estimations were averaged and are shown separately for the control and experimental decrementers (Figs. 1 and 2). The percentages of signals detected by the experimental decrementers in the tests and in the main watch are also shown.

There was a decline in mean concentration of adrenaline in the decrementers from the initial (alerted) measurement through the main watch. This trend was significant with $p < .025$ (*10*). In addition, there was a suggestion from the data of a rise in the concentration of adrenaline in the decrementers during the final (alerted) measurement. The average percentage of signals detected by the experimental decrementers was roughly parallel to the average concentration of adrenaline, the product-moment correlation between these variables being $+.84$ ($p < .01$).

The average concentration of adrenaline in the control decrementers was approximately the same after both 2 and 140 minutes of watching the movies. The difference between initial adrenaline concentrations in control and experimental groups was significant ($p < .025$), but after 140 minutes (135 minutes through the main watch) this difference had virtually disappeared. In comparison with the control decrementers, the decrease in adrenaline in the plasma of the experimental decrementers was highly significant ($p < .001$).

Apparently, the average concentration of noradrenaline in the experimental decrementers increased from the first test to the main watch, but this trend was not significant. Nor were there significant differences between

noradrenaline concentrations in the control and experimental decrementers.

Each nondecrementer detected at least 83 percent of the signals presented in tests before and after the main watch, and in every 15-minute period of the main watch. However, because of the paucity of data, little can be said of this group's adrenaline and noradrenaline responses in the experimental condition. In general, the average concentration of noradrenaline for the nondecrementers was similar to that of the decrementers. With respect to adrenaline, two of the three nondecrementers (the third never yielded samples with measurable quantities of adrenaline) demonstrated an increase from the first test to the average of six samples taken during the main watch. The average concentration rose from 0.4 to 0.8 μg/liter. This reaction was unique to the nondecrementers in the experimental condition.

For those subjects whose performance deteriorated over time on watch, the results reported here indicate that vigilance as inferred from signal detections in a watch-standing task is paralleled by a concomitant change in the concentration of circulating adrenaline.

An unexpected finding was that in the experimental decrementers, the initial concentration of adrenaline was high in comparison to that in the controls. Perhaps anticipation of the difficult watch-standing task was stressful and resulted in an increased production of adrenaline. (Comments by the subjects indicated that they considered the watch-standing task to be noxious and the movie-watch relatively enjoyable.) Similar responses have been noted in persons subjected to such psychological stresses as performing difficult, lengthy mental tests (*11*) and awaiting rides in a centrifuge to determine tolerance limits (*12*).

Whatever the cause, this increased initial production of adrenaline could serve an adaptive purpose to a monitor, since it has been shown with an infusion technique that an increased amount of circulating adrenaline facilitates human ability to concentrate in tedious tasks (*13*). Still, it appears from my results that few monitors can maintain this increased production. The concentrations of circulating adrenaline decline, as hypothesized, to approximate the concentrations found in control decrementers under "relaxed" conditions.

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14. Supported under Nonr contract 4120(00) by the Engineering Psychology Branch, Psychological Sciences Division, Office of Naval Research. I thank Dr. Marcel Nimni for chemical analyses, M. Lieberman and A. Schmidt for technical assistance, and Dr. C. H. Baker for valued criticism.

16 July 1965

Convection-Plume-like Phenomenon

Hackman's comment [*Science* **149**, 764 (1965)] on Peterson and Damman's report on convection plumes from trees [*ibid.* **148**, 392 (1965)] brings to mind a phenomenon observed on several occasions by myself and others. At times close to sundown, vertical columns of tiny insects (smaller than mosquitoes) would be seen directly above guests at a lawn party. These columns would doggedly remain with the person afflicted with them, try as he might to lose them. The ability of the columns to follow very rapid movements of the "host" and still remain vertical seems to cast doubt on a convection-current explanation, but tipsy bystanders often proposed a more ribald explanation having to do with aroma.

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Contaminants: Addendum

Two additional references are pertinent to my report on "Fluorescent contaminants from plastic and rubber laboratory equipment" [*Science* **149**, 1382 (1965)]: P. R. White, *The Cultivation of Animal and Plant Cells* (Ronald Press, New York, 1963), p. 52; and C. D. Swift, *Steam Power Plants* (McGraw-Hill, New York, 1959), pp. 263–64. White points out that Bakelite caps sometimes release volatile and toxic phenolic residues, and Swift provides information concerning the use of morpholine in steam plants to prevent corrosion of steampipes.

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