understanding of the mechanisms controlling the microecology and metabolic activity of the human gut flora, as well as more consistently effective drug therapy.

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20 October 1982; revised 27 December 1982

Visual Sustained Attention: Image Degradation Produces Rapid Sensitivity Decrement Over Time

Abstract. *Perceptual sensitivity to a visual target presented in a random continuous sequence of targets and nontargets decreased rapidly over time when stimuli were highly degraded visually but not when moderately degraded or undegraded. Large declines in sensitivity, independent of changes in response criterion, were found after only 5 minutes of observation. These rapid decrements of sensitivity to degraded targets seem to result from demands on the limited capacity of visual attention.*

The capacity to sustain attention to visual targets typically deteriorates over a period of continuous observation. The decrement in target detection rate can result from a loss in perceptual sensitivity, from changes in response or decision criteria, or from both (*1, 2*). Sensitivity declines have been linked to the combination of a high stimulus processing rate and a target that requires memory for successive stimuli (*1, 3*). Such sensitivity decrements are generally small and occur only after about 30 to 45 minutes (*1–3*). However, Nuechterlein has recently developed a task requiring detection of degraded visual targets without memory for successive stimuli that appears to elicit sensitivity decrements within time periods as short as 5 to 10 minutes (*4, 5*) when single-response data (yes responses) are evaluated. The task is an adaptation of the continuous performance test (CPT) commonly used to assess clinical populations (*6*); image degradation is used to burden early stimulus encoding and analysis during information processing.

We now show through derivation of receiver operating characteristic (ROC) curves that rapid decrements in perceptual sensitivity over time occur as a function of degree of image degradation. Repeated sessions of observation did not abolish the sensitivity decrement. Sensitivity decrements under such conditions occurred more rapidly than those reported for other sustained attention tasks (*1, 7*).

Volunteers, 21 males and 21 females, aged 17 to 23 years and with normal (20/20) or fully corrected vision, participated. Each subject sat 1 m from a rear projection screen on which single digits (0 to 9) were presented for 40 msec every 1 second. Subjects indicated their confidence each time that the digit 0 was detected by depressing one of three response keys on a terminal, the three keys being labeled "sure," "not so sure," and "unsure." No response was required for nontarget digits. Targets were presented irregularly with a probability of .25. Target and nontarget digits were presented in a pseudorandom sequence with the restrictions that identical digits never follow one another and that targets be preceded by each nontarget digit an equal number of times. A total of 486 stimulus trials (120 targets and 366 nontargets) were presented over an observation period lasting just over 8 minutes. Although the stimuli were presented continuously, trials were divided into three 2.7-minute blocks of 162 trials for analysis.

Stimuli were presented with a Kodak Carousel model E-2 slide projector (focal length 6 inches) fitted with an Ilex No. 4 Synchro Electronic shutter and Ilex Speedcomputer. The digit stimuli subtended approximately 3° of visual angle vertically and 2° horizontally. Illumination from the screen was 159 lux with the projector lamp off and 191 lux with it on. A visual mask, consisting of a transparency containing typed plus (+) characters, was mounted on the back of the rear projection screen to decrease figure-ground contrast and visual persistence. Stimuli were degraded at three levels—low, moderate, and high—by decreasing the object (slide-to-lens) distance for a fixed slide-to-screen distance (by blurring or defocusing the image). The power of a correcting lens, P_c, required to restore the image to the undegraded (focused) level at the same screen distance indexed the degree of image degradation (*8*). Phenomenally, the digits appeared almost focused at the low level, blurred at the moderate level, and highly blurred at the high level of image degradation.

Subjects were assigned randomly to one of the three image degradation conditions (with the restriction that each group contain an equal number of males and females). Subjects were given a minimum of 200 trials of practice before performing the task. During the practice period, targets and nontargets were presented at the same rate as in the subsequent main task. A digital computer controlled the presentation of stimuli and recorded responses in all phases of the experiment.

Hit and false alarm probabilities were computed cumulatively over the confidence rating categories to derive ROC's (*9, 10*). The ROC analysis was restricted to the high and moderate image-degradation conditions, because few errors were made in the low condition (*11*). The vigilance decrement, a decline in the hit and false alarm rate over blocks, was observed in both conditions (*11*). The ROC analyses made with confidence ratings, rather than the hit and false alarm rates across all confidence levels, were used to determine sensitivity levels for each block most reliably.

Performance evaluation was based on the individual ROC's, which were highly reliable (*12*). Each ROC was fitted through the use of a maximum-likelihood solution to yield a robust measure of sensitivity. The area under the normalized, maximum-likelihood fitted ROC, A_z, is equivalent to the percentage correct in a two-alternative forced-choice task, a distribution- and bias-free measure of sensitivity (Fig. 1) (*13*).

Analyses of variance of the A_z scores showed that the main effect of blocks $[F(2, 52) = 4.81, P < .025]$ and the interaction between blocks and image degradation $[F(2, 52) = 9.63, P < .005]$ were significant. An analysis of the simple effects of blocks revealed a significant decrement in sensitivity over blocks only for high-degradation $[F(2, 52) = 9.60, P < .005]$. Overall, sensitivity was lower for high than for moderate degradation $[F(1, 26) = 7.27, P < .025]$; however, the simple effects of degradation were not significant for the first 2.7-minute block of trials $[F(1, 26) < 1]$. Thus, perceptual sensitivity did not differ initially for the two image degradation conditions. For hits, degradation level $[F(2, 39) = 35.82, P < .001]$, blocks $[F(2, 78) = 16.53, P < .001]$ and their interaction $[F(4, 78) = 6.97, P < .001]$ had significant effects. Image degradation increased the decrement in hit rate and lowered the overall hit rate (*11*). Simple effects of degradation were significant for hit rate during the first block of trials $[F(2, 39) = 10.80, P < .01]$, but the high and moderate conditions did not differ significantly $[t(39) = 1.27, P > .20]$. For false alarms, the only significant effect was that of degradation level $[F(2, 39) = 7.90, P < .005]$; degradation increased false alarms. The primary influence of image degradation was on perceptual sensitivity rather than response criterion; no effect of blocks $[F(2, 52) = 0.53]$ or degradation level $[F(1, 26) = 1.12]$ was obtained for the criterion measure log β.

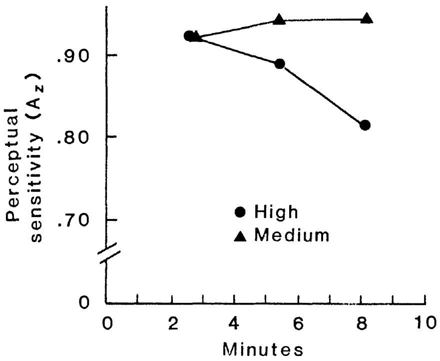

Fig. 1. Mean values of ROC-derived index of perceptual sensitivity, A_z, as a function of time on task for the two image degradation conditions (*High* and *Medium*). Image degradation produces a sensitivity decrement over time after 5 minutes of observation.

Although subjects were trained at target discrimination and given a practice session before performing the main task, it seemed possible that the sensitivity decrement was caused by insufficient learning of the target and nontarget characteristics, and that the decrement over time would disappear as target representation became consolidated in long-term memory. To study the effects of further practice, a second experiment was carried out with six of the subjects who had participated in the first. Each subject performed the task at the high-degradation level four times in separate sessions held on consecutive days. All aspects of the procedure and data analysis were the same as in experiment 1.

The main effect of blocks reflected significant declines over blocks for both hits $[F(2, 10) = 4.23, P < .05]$ and sensitivity $[F(2, 10) = 5.80, P < .025]$, but there were no significant effects of sessions on either measure (*14*). Thus, repeated sessions did not improve the overall level of performance and did not abolish the sensitivity decrement over time.

The results of both experiments indicate that very rapid decrements in sensitivity are obtained when visual targets are highly degraded. The demonstration of large decrements in sensitivity within 5 minutes contrasts with studies showing smaller decrements over much longer periods, on the order of 30 to 45 minutes (*1, 3*). While previous target-by-target analyses of sustained attention suggest an apparent decrement in detection rate after the very first presentation of a target and considerable fluctuation thereafter, these analyses have not shown similar rapid decrements in perceptual sensitivity (*1, 7*). Furthermore, the sensitivity decrement was not related to task difficulty per se. Targets were equally detectable under high and moderate degradation during the first 2.7-minute block of trials, and the intersubject correlation between the sensitivity decrement (difference between blocks 1 and 3) and perceptual sensitivity in block 1 was weak and not significant ($r = .22$, $N = 14$).

The cognitive processes involved in target discrimination in these experiments can be described as limited by signal-data limits rather than by memory-data limits (*15*). Thus, overall performance may depend on the fidelity with which the individual can discriminate ambiguous visual patterns presented against a noisy background (*15–17*), but it does not depend on the quality of the stored representation of the immediately preceding stimulus. The marked sensitivity decrement over time is atypical of vigilance tasks requiring simultaneous discrimination of target stimuli (*1, 3*).

The conventional CPT using the target X requires the discrimination of this undegraded target letter from other clearly presented nontarget letters (*6*). This and other typical simultaneous-discrimination tasks (*3*) entail an encoding of stimulus patterns to the recognition level that may either occur "automatically" or with only limited demands on processing capacity (*18, 19*). Recognition of highly degraded images, on the other hand, has been suggested to be distinctive, requiring "effortful," capacity-loading sequential processing of multiple individual target features (*19*). Because automatic encoding leads to incomplete representations of a degraded target, automatic detection develops slowly, if at all. Thus, the processing capacity demands of this degraded stimulus CPT are relatively high and do not decrease notably over time. The combined demands of signal-data limits, serial processing of stimulus features, and high event rates may contribute to a sensitivity decrement over time in a manner paralleling the combined influence of memory load and high event rate on the decrement (*3*).

The demonstration of a sensitivity decrement within 5 minutes of testing suggests useful clinical applications. Previous demonstrations of sensitivity decrements over 30- to 45-minute periods are of limited clinical value because of difficulties in testing clinical groups for long periods of time. The degraded stimulus test thus offers more rapid assessment of a sensitivity decrement than commonly used tests of sustained attention do (*6, 20*) and allows effective separation of overall performance, sensitivity decrement over time, and shifts in response criterion. Signal detection measures can be derived either with the use of a confidence rating scale, as in this study, or from single response data (*5*). The test has detected deficits in overall sensitivity during sustained attention among children born to schizophrenic mothers and lower response criteria among hyperactive children (*4, 5*). Further application may help clarify which clinical groups have actual deficits in sustained attention, as evidenced by unusually sharp sensitivity decrements over time, rather than deficits in overall performance (*6*). Furthermore, certain clinical disorders may be characterized by altered response criteria rather than by sensitivity differences. These distinctions may provide theoretically more useful separations for clinical and psychopharmacological purposes than the more global findings of "attention deficits" characteristic of much work on sustained attention among clinical populations.

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where V and U refer to the image (screen-to-lens) and object (slide-to-lens) distances (in meters), respectively, and subscripts u and d refer to the undegraded (focused) and degraded (defocused) conditions, respectively. The values of P_c for the low, moderate, and high image degradation were 1.8, 2.0, and 2.1 diopters, respectively. The diopter correction values refer to the required change in the projector lens to focus the image. The required accommodation of the eye is determined by eye-to-screen distance, which was constant across conditions.
9. A stimulus observation interval of 1 second, corresponding to the interstimulus interval, was used. The choice of observation interval was validated through the use of reaction time data to plot functions of the response rate to targets versus time since target (latency), a method originally developed by J. P. Egan, G. Z. Greenberg, and A. I. Schulman [*J. Acoust. Soc. Am.* **33**, 993 (1961)] for tasks with undefined observation intervals. The response-rate–latency function peaked within 1 second and was subsequently flat and low for latencies greater than 1 second. This analysis indicated that a 1-second interval provided a clear cutoff between correct and incorrect responses (hits and false alarms) to targets.
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12. Chi square tests of goodness of fit of the individual ROC's showed that 75 of the 84 ROC's fitted (2 image degradation conditions by 3 blocks by 14 subjects) were well modeled by a straight line on normalized axes, the probabilities associated with the χ^2 values being sufficiently high to reject the hypothesis of nonlinearity ($\chi^2 < 3.823$, $P > .05$ for the 75 cases).
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19 October 1982

Altered Activity in the Hippocampus Is More Detrimental to Classical Conditioning Than Removing the Structure

Abstract. *Hippocampal ablation has no effect on the acquisition of the rabbit's classically conditioned nictitating membrane response. Systemic administration of scopolamine, which alters hippocampal neuronal activity, severely retards acquisition of the conditioned response in normal animals and those with cortical ablations. In animals with hippocampal ablations, however, scopolamine has no effect on conditioning. These findings suggest that altered neuronal activity in the hippocampus is more detrimental to conditioning than removing the structure.*

A number of laboratories have adopted the rabbit's classically conditioned nictitating membrane response (NMR) as a model system for studying neuronal substrates of associative learning in mammals (*1–3*). Research with this preparation has implicated the hippocampus in the acquisition of the conditioned NMR.

Berger and Thompson (*4*) reported increased neuronal activity in the hippocampus during NMR conditioning. Specifically, both single and multiple unit activity in the pyramidal cell layer of the hippocampus increased during the first few pairings of the conditioned stimulus (CS) and the unconditioned stimulus (US). This increased neuronal activity preceded the behavioral response by as much as 35 to 40 msec and formed a temporal model of the NMR. Other studies have demonstrated that this hippocampal neuronal response is a more general phenomenon that occurs to a variety of CS's (*5*) and US's (*2*) and in more than one species (*6*).

Although these findings suggest that the hippocampus is part of a neural system involved in acquisition of the classically conditioned response (CR), its precise role remains unclear since hippocampal ablations do not affect the acquisition of the conditioned NMR (*7–9*).

Although removal of the hippocampus does not disrupt NMR conditioning, manipulations that alter neuronal activity in the hippocampus do disrupt it. Manipulations that block hippocampal theta, such as systemic scopolamine administration (*10*), microinjections of scopolamine into the medial septum (*11*), and medial septal lesions (*12*) all retard acquisition of the NMR. These results are consistent with data showing a strong relationship between the occurrence of hippocampal theta and the acquisition of the conditioned NMR (*12*). Manipulations that produce hippocampal seizures, such as hippocampal stimulation after conditioning trials (*3*) and local penicillin injections (*2*), also retard NMR acquisition. In each instance, the appearance of the first CR's are greatly retarded, but once they occur, conditioning proceeds at a normal rate and becomes asymptotic. That removal of the hippocampus does not affect NMR conditioning while alteration of hippocampal activity se-