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PERFORMANCE OF 40- TO 50-YEAR-OLD SUBJECTS ON A RADAR MONITORING TASK: THE EFFECTS OF WEARING BIFOCAL GLASSES AND INTERPOLATED REST PERIODS ON TARGET DETECTION TIME

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16. Abstract

The present study examined the effects of wearing bifocal glasses and interpolated rest periods on the performance of 40- to 50-year-old subjects on a radar monitoring task. The visual display was designed to resemble an air traffic control radar display containing computer-generated alphanumeric symbols. Forty men and women were divided into four equal-sized groups, with each group consisting of one of the four possible combinations of bifocal/no-bifocal and rest/no-rest conditions. All subjects were tested over a 2-hour session. Rest periods (a 5-minute break every 30 minutes) significantly reduced the performance decrement of 40- to 50-year-old subjects, bringing performance to a level approximating that of 18- to 29-year-old subjects without rest periods. The wearing of bifocal glasses did not contribute to visual strain or somatic discomfort.

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Introduction.

Previous studies of simulated air traffic control (ATC) monitoring performance conducted in our laboratory have generally found that target detection times remain relatively constant, or even decline, over the first hour of a 2-hour session, but increase significantly during the second hour (7,9,11,12,13,15). We have found that this general pattern is not influenced by such variables as sex of the subject (11), presence or absence of a sweepline (13), relatively high ambient noise level (7), or previous ATC experience (15).

Results from one of our more recent studies, however, suggest that this pattern is significantly altered by age (14). The earlier onset and greater magnitude of performance impairment found for 40- to 50- and 60- to 70-year-old subjects revealed a pattern that was quite different from the pattern obtained in the studies mentioned above, virtually all of which used younger (18- to 29-year-old) subjects. Of the many possible explanations for the greater performance impairment of older subjects, it was concluded that some form of fatigue process related to age was one of the more plausible hypotheses. A fatigue concept seemed reasonable, since there were no performance differences between the age groups initially. Further, it appeared likely that this fatigue was related to the visual search requirement of the task.

One of the obvious differences between young and old subjects that might contribute to the development of visual search fatigue involves the increased need for bifocal or trifocal visual correction with age. Most of the 40- to 50-year-old and all of the 60- to 70-year-old subjects used in our age study required such visual correction. At least one manufacturer of video display terminals (VDT's) has cautioned that the wearing of bifocal glasses during prolonged viewing of such displays may contribute significantly to fatigue because of the tilted head posture often required for clear vision (5). Moreover, because bifocal glasses are typically fitted to bring objects into focus at a reading distance of approximately 13 inches, an individual wearing such glasses and viewing a visual display may be required not only to tilt the head back, but also to lean forward in order to bring the image on the screen into focus. This body posture could result in painful discomfort in the back as well as the neck (1). It is certainly conceivable that various visual and bodily strains associated with the wearing of bifocal glasses could adversely affect visual search patterns, and this may have contributed to the greater performance impairment of older subjects found in our earlier study. A primary purpose of the present study, then, was to investigate this possibility.

A second purpose of the study was to examine the relative benefit of rest periods on the performance of older subjects with and without bifocal correction and to investigate possible reasons for any differences and benefits that occurred. Vigilance studies and studies of industrial inspection have generally found that brief rest periods materially improve performance and frequently assume that this benefit occurs because rest periods serve to relieve task monotony (2,3). Articles and studies dealing more specifically with video display usage, however, have tended to place greater emphasis on the benefits of rest periods in reducing visual fatigue and visual discomfort (1,4,5,6). While it was expected that rest periods would generally improve performance, if older individuals monitoring a simulated radar display experience considerable visual fatigue, then subjects wearing bifocals might be expected to benefit less from rest periods than those without bifocals, if the wearing of such glasses contributes to additional forms of fatigue.

In addition to studying performance, a number of selected subjective and physiological measures were included. These consisted of questionnaire items relating to visual discomfort, general fatigue, attentiveness, tension, boredom, and monotony, along with physiological measures of heart rate, heart rate variability, and gross body movement. Heart rate variability has shown a relationship to reported attentiveness and performance impairment in a number of our previous studies (8,10); heart rate was included to provide a general measure of arousal, and body movement was included to assess restlessness resulting from general physical discomfort.

Method.

Subjects. Forty paid volunteer subjects (17 males and 23 females), ranging in age from 40 to 50 years and selected from the general population, participated in the study. The 40- to 50-year-old range was chosen because it corresponded to the age range of one of the older groups in our previous age study, thus enabling comparisons, and because it was felt that we could reasonably expect to find subjects within this age range that either required or did not require bifocal correction. Educational backgrounds varied from several years of high school to some graduate study, with 90 percent of the subjects having at least a high school education. The 40 subjects were randomly assigned, in approximately equal male-female proportions, to four groups of equal size: (i) With Rest Periods - With Bifocal Correction (WR-WB), (ii) With Rest Periods - Without Bifocal Correction (WR-WOB), (iii) Without Rest Periods - With Bifocal Correction (WOR-WB), and (iv) Without Rest Periods - Without Bifocal Correction (WOR-WOB). Subjects were administered a vision test prior to the experiment, and it was determined that all had normal near-point visual acuity (corrected to 20/20 in the case of subjects wearing bifocals).

Apparatus and Design. All task programing and recording of responses were accomplished using a Digital Equipment Corporation PDP-11/40 computer, interfaced with a 17-inch cathode-ray tube that served as the subject's display. The stimuli (targets) consisted of small rectangular "blips" representing the locations of given aircraft. Adjacent to each target was an alphanumeric data block that identified the aircraft and gave its altitude and speed. A simulated radar sweepline made one complete clockwise revolution every 6 seconds. A target was updated as to location and any change in its data block moments after the sweepline passed the target's prior location. Targets normally moved in a linear fashion unless a course change was necessary to avoid target overlaps. Sixteen targets were present at all times; as one left, another appeared on the screen. The critical stimulus or signal to which the subject was instructed to respond consisted of a change in a target's displayed altitude to a value greater than 550 or less than 150. The values of the increases or decreases in altitude were randomly determined, except that the changed altitude value could not be greater than 599 or less than 100. Ten such critical stimuli appeared in each 30-minute period; five occurred in the first 15 minutes and five in the second. The subject's response to a critical stimulus consisted of pressing a button held in the right hand and then holding a light pen over the critical target. The light pen caused the altitude portion of the data block to revert to its previous value. If the subject failed to detect a critical stimulus within 1 minute, the data block automatically reverted to its previous value. All performance data were recorded by the computer for subsequent processing.

A Beckman Dynograph was used in recording heart rate, heart rate variability, and gross body movement. Heart rate was obtained from chest electrodes with leads connected to a cardiotachometer coupler. Gross body movement was obtained from a crystal finger-pulse transducer attached to the chair directly below the seat. This location gave an output from the transducer that was approximately proportional to the magnitude of body movement. The transducer's output was amplified and integrated (using a pulse integrator) and both the analog and integrated outputs recorded on the Dynograph. Outputs from the cardiotachometer and pulse integrator also lead to the computer for subsequent analysis of heart rate, heart rate variability, and body movement.

The computer and other recording apparatus were located in an adjacent room from which the subject was monitored via closed-circuit TV. Indirect lighting was used in the subject's room, and the level of illumination at the display was 21.5 meter-candles. This level approximates that used in operational air traffic control environments.

Procedure. After chest electrodes were attached, the subject was seated in a straight-backed chair directly facing the visual display. A 9-point subjective rating scale was then administered, dealing with present feelings of attentiveness, tension boredom, and fatigue. Following task instructions, all subjects were administered a 4-minute practice period containing six critical stimuli. Those subjects assigned to one of the rest conditions were told that 5-minute rest periods would be given at various times during the task session. During these periods, they were to shift their eyes away from the screen, look around the room, roll the head around to relieve any neck tension, and generally relax. The 2-hour task session was interrupted after every 30 minutes of performance for those subjects assigned to one of the rest conditions. During the rest periods, the display program was turned off and a tape recording of quiet background music was played.

After 2 hours of task performance, the subjects completed a second form of the subjective rating scale. This form was identical to the first except that they were asked to rate the items plus one additional item dealing with task monotony, the basis of how they felt near the end of the task session. Subjects also completed a questionnaire that asked them to indicate which, if any, of the following they had experienced during task performance: smarting or burning eyes, itching eyes, eye strain, headache, neck fatigue, squinting, watering eyes, blurred images, and quivering images.

Measurement of the Performance and Physiological Data. Times from each critical stimulus onset to the button press were computer processed and mean values obtained for successive 30-minute scoring periods. In addition, the program tabulated all critical stimuli not detected in each of these periods.

The computer program described in a previous report (10) was used to obtain the mean and standard deviation of heart rate for each successive 5-minute period. These were then averaged to give values for the four 30-minute periods. A separate computer program summed the number of pulses from the body movement integrator for each 30-minute period.

Results.

Performance Data. Figure 1 shows mean detection times across 30-minute periods for the four groups. Analysis of variance applied to these data revealed a signficant difference ($\underline{p} < .05$ used throughout) between 30-minute periods ($\underline{F}(3/108) = 7.71$) and a significant main effect for rest periods ($\underline{F}(1/36) = 4.38$). The main effect for the bifocal comparison was not significant nor were any of the interactions. Although Figure 1 suggests that the bifocal group without rest was the group largely responsible for the significant main effect for rest periods, none of the comparisons (using the studentized range statistic) between this group and the other three groups at each of the four 30-minute measurement periods was significant.

Because there were no significant differences in performance attributable to the wearing or not wearing of bifocal glasses, bifocal and no bifocal groups within each condition of rest were combined. Mean performance of rest and no-rest groups is shown in Figure 2. These data reveal a relative superiority in performance of the rest period group that occurred following the first rest break and that was maintained throughout the remainder of the 2-hour session. Newman-Keuls comparisons of the first with subsequent 30-minute periods in each group revealed no differences between the first period and any of the subsequent periods for the group

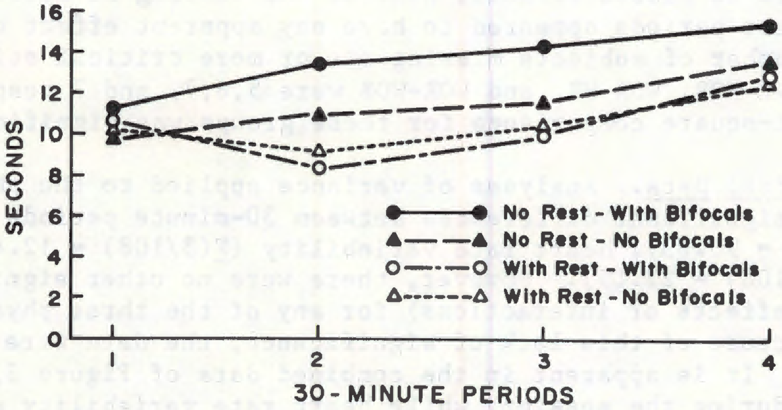

Figure 1. Mean target detection times for the four experimental groups.

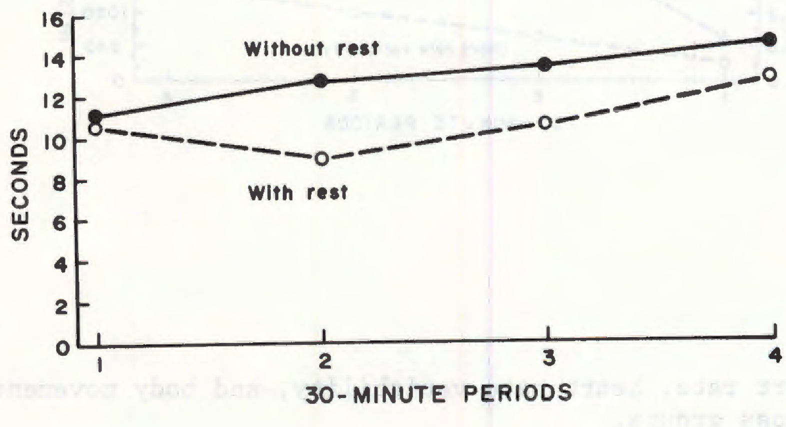

Figure 2. Mean target detection times for rest and no-rest groups.

administered rest breaks. Although detection times of the group without rest breaks increased throughout the session, only the last 30-minute period differed significantly from the first.

With regard to missed stimuli, neither the wearing of bifocals nor the inclusion of rest periods appeared to have any apparent effect on omission errors. The number of subjects missing one or more critical stimuli in groups WR-WB, WR-WOB, WOR-WB, and WOR-WOB were 5,6,7, and 7 respectively. None of the chi-square comparisons for these groups was significant.

Physiological Data. Analyses of variance applied to the physiological data revealed significant differences between 30-minute periods for heart rate ($\underline{F}(3/108) = 90.63$), heart rate variability ($\underline{F}(3/108) = 12.47$) and body movement ($\underline{F}(3/108) = 22.09$). However, there were no other significant effects (main effects or interactions) for any of the three physiological variables. Because of this lack of significance, the data were combined across groups. It is apparent in the combined data of Figure 3, that heart rate declined during the session, while heart rate variability and body movement increased. This general pattern was expected and has been found in several of our previous studies (8,9).

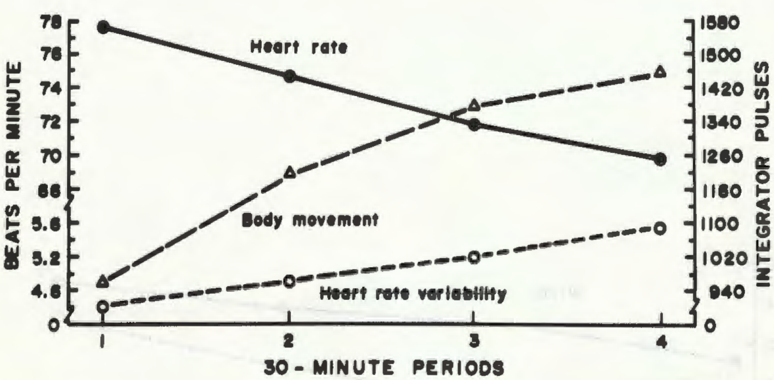

Figure 3. Heart rate, heart rate variability, and body movement combined across groups.

Subjective Data. Analyses of variance were also applied to the subjective ratings of attentiveness, tension, boredom, and fatigue. Significant differences between measurement periods were obtained for attentiveness ($F(1/36) = 24.22$), boredom ($F(1/36) = 32.92$), and fatigue ($F(1/36) = 23.11$). The increase in tension was nonsignificant. No significant main effects for bifocal glasses or rest periods and no significant interactions were obtained for any of the above variables. Separate t tests conducted on the monotony data collected only at the end of the experiment likewise revealed no evidence of significant differences between groups. Statements on the scales corresponding to the mean ratings at the completion of the task period suggested that the subjects were moderately interested and attentive during the experiment, but felt the task to be rather monotonous and tiring. Actual mean values obtained on the scales are not presented, since they would add nothing to the verbal descriptions just given.

Symptoms relating to visual complaints and to general discomfort were treated as follows: for visual symptoms (i.e., smarting or burning eyes, itching eyes, eye strain, squinting, watering eyes, blurred images, and quivering images), all items checked were summed for each subject and means computed for each of the four groups. Means for groups WR-WB, WR-WOB, WOR-WB, and WOR-WOB were 2.5, 1.8, 1.6, and 1.8. Separate t tests revealed no significant differences between groups. Reports of headache were extremely uncommon, with one subject reporting a task-induced headache in each of groups WOR-WOB and WR-WOB and no reports of headache in the other two groups. Fifty percent of the subjects in three of the groups reported a slight degree of neck fatigue, while in one group (WR-WOB), 30 percent reported this symptom. It is evident that there were no differences between the groups in the reported frequency of either headache or neck fatigue.

Discussion.

The present study found no evidence that the wearing of bifocal glasses impaired visual monitoring performance in any way. Nor did the wearing of such glasses contribute to reported visual discomfort, headache, neck muscle fatigue, or general fatigue. Although these findings might suggest that previously mentioned concerns over fatigue and discomfort among bifocal users of VDT's are unwarranted, such a conclusion should be treated with caution. In most VDT applications, the operator is required to sit close to the screen because the attached keyboard requires it. Thus, individuals with bifocal visual correction must often assume a tilted head position to view the screen clearly, and this could result in various forms of fatigue or discomfort. An air traffic control specialist (ATCS), however, is not required to be in close proximity to the radar screen at all times and frequently will sit several feet away from the screen or even observe it while standing. The present study was designed with this in mind, and subjects were allowed to view the screen from whatever distance they found to be most comfortable. Thus, the study sought to determine whether the wearing of bifocal glasses might in any way contribute to performance impairment or visual discomfort of subjects performing a visual monitoring task similar to that of actual ATCS's. The results strongly suggest that the wearing of bifocal glasses during radar control work should neither degrade performance nor contribute to visual discomfort.

With regard to the effect of rest periods, subjects not administered such breaks showed a progressive increase in target detection time that was quite similar to the performance pattern found for 40- to 50-year-old subjects in our previous age study (14). Those receiving rest breaks, however, showed no significant increase in target detection time across the 2-hour session. The general performance pattern of subjects administered rest periods was almost identical in form and magnitude to the pattern obtained for younger (18- to 29-year-old) subjects in our age study, as well as in our previous studies in which no rest periods were incorporated and in which younger subjects have been used (7,9,11,12,13).

While the results suggest that brief rest periods significantly improve monitoring performance of older subjects, bringing performance to a level approximating that of younger individuals performing without rest breaks, efforts to account for why rest periods produced this benefit were unsuccessful. There was no indication that rest periods reduced visual discomfort, general restlessness, or reported fatigue, and no evidence that attentiveness or arousal level was increased as a function of rest. If, as hypothesized earlier, the greater performance impairment of older subjects is related to some fatigue process, the present study failed to provide information as to the nature of this fatigue. Perhaps the various subjective and physiological measures were inadequate in assessing fatigue related to the visual search process. Or perhaps rest periods benefited performance not because they reduced fatigue, but because they provided some form of change or relief from the monotony of an otherwise rather repetitive task situation, an explanation frequently advanced in the vigilance literature to account for rest period effects (2,3). If this were the case, however, one might have expected to see some difference between the rest and no-rest groups in their ratings of boredom and monotony. It appears evident that, while brief rest periods clearly improve monitoring performance, the reasons for this improvement are not easily determined.

Conclusions.

The present study found no evidence to suggest that the wearing of bifocal glasses contributes to performance impairment or experienced fatigue/discomfort during simulated radar monitoring over a 2-hour period. Target detection times for 40- to 50-year-old subjects not receiving rest breaks increased significantly during the task session, while detection times for those receiving 5-minute breaks every 30 minutes showed no significant change. Although the results suggest that 40- to 50-year-old individuals administered brief rest periods perform at a level approximating that of younger (18- to 29-year-old) subjects without breaks, it is not the intent of this study to suggest that rest periods of this duration or frequency would necessarily facilitate the performance of older ATCS's in operational environments. The present study sought only to examine one possible reason for the greater performance impairment of older individuals on a simulated radar monitoring task and one way in which this impairment might be reduced. Recommendations for optimal work-rest periods of ATCS's, regardless of age, would require a much larger study performed under field conditions, taking into consideration the job constraints of ATCS's in their operational environment.

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