THE EYE BLINK AND WORKLOAD CONSIDERATIONS

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ABSTRACT

Two parameters of the eye blink, blink rate and blink duration, were used to assess workload in two independent operational studies. Both studies involved high fidelity strategic bomber mission simulations. The first study was an extended wartime mission where workload was evaluated during mission segments. The second study involved shorter, discrete training missions where task difficulty was systematically manipulated. Both studies produced complementary results. Results show that: (1) blink rate is significantly affected by task demands; (2) blink rate is sensitive to task modality; (3) blink duration is significantly affected by task modality and complexity; and (4) blink duration is a sensitive index of time on task effects.

These data support the use of eye blink measurement in "noisy" complex environments as both a feasible and valuable assessment technique.

INTRODUCTION

We will review data and results conducted in two strategic bomber simulation experiments using the eye blink as a measure of workload variability. The first study dealt with aspects of blinking on the part of the pilot and copilot while conducting a 4 1/2 to 5 hour wartime mission (Purvis et al., 1984). The second one dealt with the same aspects of blinking in tailgunners while actively involved in a series of training exercises differing in task difficulty. Each exercise lasted approximately 5 minutes within a 30-minute session. The two parameters of interest are blink rate and a measure we have defined as 50 percent closure duration. The first measure is self-explanatory, the second necessitates a few words of description. This measure identifies blink amplitude, selects the point in time during the blink when the lid has reached half this amplitude during the closing portion of the blink, and the point in time where the reopening portion of the blink achieves this same level. The time difference between these points is referred to as the "50 percent closure duration window," or simply, "50 percent closure duration."

These measurements were selected for operational applications based on substantial laboratory research indicating the eye blink is a sensitive index of a broad spectrum of information processing variables (Stern et al., 1984). For example, the effects of subject variables, both general and momentary task demands, are reflected in eye blink changes during performance of a cognitive task. These effects are robust and can be reliably reproduced; thus making the eye blink an ideal candidate for workload evaluation in operational situations.

METHOD

In other studies, blinks and other physiological data were recorded on analog tape. Blinks were processed on a minicomputer which was programmed to identify the two parameters of interest. In the study on pilots, blink data were sampled at 10 msec intervals; for the tailgunner study, at 5 msec intervals. The pilot study involved nine pilot-copilot teams; the tailgunner study, 13 subjects. Data collection and analyses for the two studies were conducted independently. They are presented jointly because of the complementary nature of results.

RESULTS

Blink Rate

In the pilot study, blink rate significantly discriminated between the person in control of the aircraft and the person acting as copilot. In this experiment, the pilot and copilot reversed roles for one "leg" of the experiment (approximately 20 percent of the mission). The entire mission was comprised of 23 separate segments (seven in-flight baseline segments; seven segments involving terrain avoidance; five segments dealing with weapons delivery; and four segments dealing with threats, some of which damaged the aircraft). The copilot was in control during one baseline segment, two terrain avoidance, and one weapon delivery run. Average blink rate is consistently lower for the pilot in control of the aircraft regardless of nature of task performance. Highest average blink rate during any leg was about 21 blinks per minute, the lowest approximately 7 per minute.

Statistically reliable effects for crew position within similar mission segments were obtained for (1) terrain avoidance flying--the pilot in control had significantly fewer blinks than the copilot ($p < .0001$); (2) the weapons delivery phase ($p < .0005$); and (3) dealing with threats ($p < .02$). For this latter task, a significant effect attributable to the nature of threat (and action required to deal with threat or damage to aircraft) was also obtained ($p < .01$). The nature of the task also produced significant effects ($p < .007$) coping with threat and weapons delivery segments leading to fewer blinks than baseline segments or terrain avoidance flying. These results are based on approximately 2 minutes of data per segment. No significant effects for baseline segments were obtained nor were there any significant temporal trends in blink rate.

Blink rate in the gunner study also produced significant effects. In this study, blink rate was evaluated under six conditions. In the first (A) and last (F) conditions, subjects performed only an auditory discrimination task. In the second (B), he tracked friendly aircraft on his radar scope, and conditions C, D, and E were tasks judged to be increasingly difficult by the gunnery instructors. The entire "mission" (tasks B through E) was embedded in a realistic scenario, one that might well be encountered in a standard mission. Analysis of variance involving the four "mission" segments was significant ($p < .0006$); that involving all six measures was also significant ($p < .02$). Higher "workloads" are associated with lower blink rates. Average blink rate for the highest workload condition was 12 blinks per minute while that for the first run-auditory discrimination task was 20 blinks per minute.

Thus, both studies demonstrate that blink rate is significantly affected by task demands. Visual task performance leads to lower blink rate than performing an auditory task, while increasing visual workload levels leads to further reductions in blink rate.

Blink Duration

The second measure (50 percent closure duration) has, in a number of experiments conducted at the Washington University Research Laboratories, demonstrated robust time on task effects as well as discriminating between auditory and visual task performance. The time on task effect involves an increase in average closure duration over time (30 to 45 minutes), while visual tasks are associated with shorter average closure durations than (relatively) comparable auditory vigilance tasks.

The results for the study involving pilots demonstrate that closure durations are significantly shorter for the pilot in command of the aircraft as compared to the copilot; this is true for all segments of the flight, including baseline segments. In addition to these effects, there is a time-on-task effect with average closure durations longer during late as compared to early mission segments ($p < .004$). Last but not least, nature of task performed is significant with terrain avoidance and baseline segments having longer closure durations than the weapons delivery and threat avoidance segments ($p < .006$). The average difference is 10 msec (130 versus 120 msec), a small but reliable effect.

Similar effects were obtained in the gunner study where closure duration during performance of the auditory discrimination task averaged 148 msec, during the simple visual tracking task it was 129 msec, and during the three more complex tracking tasks, 115 msec. These results again are robust ($p < .002$).

CONCLUSION

We would briefly like to introduce a third aspect of blinking that can provide useful information to researchers concerned with aspects of workload assessment. Not only is blink frequency and closure duration informative, but the time of occurrence of blinks provides additional information. In our laboratory investigations, it appears that blink latency is reasonably tightly time-locked to the decision-making process. Blinking is inhibited during the "taking-in" of information, whether such information is presented visually or auditorily. Also, in many subjects, it is inhibited during the decision-making process. Once a decision is made whether it requires action or requires the inhibition of action, a blink is likely to occur. We have found in our laboratory investigations that the noninhibition of blinking during the above-mentioned time periods is associated with a higher likelihood of occurrence of missed signals and erroneous responses (false alarms). We propose to extend these latter phenomena to the more complex environment encountered in the simulator and then to the assessment of in-flight performance.

CONCLUSION

In both operational studies reviewed, the significant results are concordant with results obtained under laboratory conditions where more extraneous variables can be controlled and where measures of performance effectiveness can be obtained. The reliability of the measures reviewed and the promising laboratory results of other parameters support use of the eye blink as a valuable workload assessment metric.

REFERENCES

Purvis, B., Skelly, J., Simons, J., and Detro, S. Aircrew workload assessment in a sustained environment: B-52 operations. AFAMRL-TR-84- (in press). Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Stern, J. A., Walrath, L. C., and Goldstein, R. The endogenous eyeblink. Psychophysiology (in press).