Response and evoked potential latencies associated with commission errors in visual monitoring

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Eight male subjects performed a 40-min visual monitoring task in which they were required to detect the occasional dim flash from a background of brighter flashes. Response latencies associated with correct detections (CDs) and commission errors (CEs) were recorded, as were the peak latencies of evoked potential (EP) components averaged separately for each of the two response categories. Response latencies for CEs were significantly longer than those for CDs, and "late" EP component latencies (P₂, N₂, and P₃) associated with CEs were also significantly longer than component latencies associated with CDs. These results are discussed with reference to EP concomitants of decision processes and to various theories of monitoring behavior.

Commission errors, or false positives, frequently occur in the performance of monitoring tasks and have been systematically treated within the framework of signal detection theory, as a manifestation of the subject's degree of caution in reporting an event as a signal (Broadbent, 1971). However, one aspect of commission errors that has received little attention is the latency associated with such errors. When response latencies have been discussed in relation to vigilance performance, only latencies associated with correct detections have been considered (cf. Buck, 1966). A few studies have investigated latencies associated with commission errors and other responses in detection and discrimination tasks of brief duration (Nickerson, 1973; Pike, 1971; Sekuler, 1965), but no similar studies have been reported for prolonged monitoring or vigilance tasks.

In a review of the various response measures used in describing performance at vigilance tasks, Davies and Tune (1970) briefly reported the findings of two unpublished studies in which latency data for different types of response were collected. In particular, they pointed out that in both studies, latencies associated with commission errors (CEs) were considerably longer than latencies associated with correct detections (CDs) and that both latencies increased with time on task. These preliminary findings are further investigated in the experiment reported here. In a 40-min visual monitoring task, response latencies for CEs and CDs were recorded. Furthermore, in order to obtain physiological correlates of possible latency differences between CEs and CDs, averaged visual evoked potentials (EPs) were also recorded. EPs were averaged *separately* for CEs and CDs. There is some evidence that latency

measures of EP components are sensitive to between- and within-subject differences in response latency (Donchin & Lindsley, 1966; Ritter, Simson, & Vaughan, 1972).

METHOD

Monitoring Task

The monitoring task consisted of a series of circular light flashes occurring regularly every 4 sec (nonsignals) which were occasionally and randomly replaced by dimmer flashes (signals), with the restriction that the temporal location of signals in the two halves of the 40-min task was the same. The decrease in brightness that defined a signal was 0.05 log fL. Subjects responded to every event by depressing one of two microswitches, "Yes" for signals and "No" for nonsignals. Intersignal intervals were randomized within successive 5-min blocks, and 120 signals were presented during the 40-min vigil, 60 in each half of the task. The light flashes (33 msec in duration) were presented to the right eye in Maxwellian view at a visual angle of 2 deg. The subjects fixated a faint spot appearing at the center of flashes.

Recording of Evoked Potentials

The EEG was recorded from scalp Ag-AgCl electrodes at the right occiput (O₂) referred to the right earlobe (A₁) with a ground electrode at the left earlobe (A₁). Scalp signals were amplified by a high-gain preamplifier, bandpass 1-50 Hz, and then fed to the A-D input of a PDP-9 computer for sampling and averaging. EPs were averaged separately from CEs and CDs for each half of the task.¹ Response times and EP data were also collected for the other two response categories (omissions and correct rejections) but are not reported here.

Subjects

The subjects were eight young adult males aged 18 to 24, all of whom had normal EEGs and no visual abnormalities. Before performing at the monitoring task, each subject was trained and then given a 10-min practice task in which the same signal and event rates as in the main task were used.

RESULTS

Response Latencies

Table 1 gives the means and the standard deviations of the response latencies associated with CDs and CEs for both halves of the

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Table 1
Mean Response Latencies (Milliseconds) for Correct Detections
and Commission Errors for the Two Halves
of the 40-Min Monitoring Task

	Correct Detections		Commission Errors	
	First Half	Second Half	First Half	Second Half
Mean	693	751	895	973
SD	46	53	67	59
N	40	32	28	20

Note—*N* represents the mean number of observations per subject from which the mean response latency was determined.

task. Latency differences between response categories and within the same response category in both halves of the task were analyzed using a Wilcoxon matched pairs signed-ranks test (Siegel, 1956).

The results were that for both halves of the task, the mean response latency associated with CEs was significantly greater than that associated with CDs ($p < .005$ in both cases). This difference was found in all eight subjects, the lowest number of commission errors made by any subject being 16. In addition, both CE and CD latencies increased significantly from the first half of the task to the second ($p < .01$ in both cases), and this increase in CE latencies was significantly greater than the increase in CD latencies ($p < .01$). Finally, for each half of the task, Spearman rank correlation coefficients were computed between the number of correct detections and the number of commission errors and between the mean latencies associated with the two response categories. In the first case, the correlation coefficients were, for the first half of the task, 0.58 and, for the second, 0.54. In the latter case, they were 0.51 and 0.43, respectively. None of these values reaches an acceptable level of significance.

EP Component Latencies

Figure 1 shows, for two subjects, the EPs averaged to CDs and CEs in both halves of the task, while Table 2 gives the means and, in brackets, the standard deviations of the components, P_1 , N_1 , P_2 , N_2 , and P_3 . Individual EP peaks were identified as the most positive or most negative turning points in each EP wave form, within 10-msec windows. Differences in latency between EP components were tested for both halves of the task, using the Wilcoxon matched pairs signed-ranks test.

For both halves of the task, EPs averaged to CEs had significantly longer latencies than EPs averaged to CDs only when the three later components, P_2 , N_2 , and P_3 , were considered ($p < .005$ in each case). No such significant differences were found for components P_1 and N_1 . As with the response latency measures, these EP component latency differences were found in all subjects. EP component latencies were also tested for differences between the two halves

of the task, using Wilcoxon's signed-ranks test. Only the latencies of P_2 , N_2 , and P_3 increased significantly from the first half of the task to the second ($p < .01$ in all cases). The latencies of the P_1 and N_1 components showed no such increase.

Correlations Between Response Measures and EP Component Latencies

Spearman rank correlation coefficients were also computed between latencies associated with CDs and CEs and EP component latencies for the three later components P_2 , N_2 , and P_3 . These are shown in Table 3. As can be seen from this table, uniformly high and significant correlations are obtained between response latency and the corresponding EP component latency, but not otherwise, except in the case of N_2 in the second half of the task, where the correlation between the EP component latencies for CDs and CEs just reaches significance at the .05 level. This anomaly apart, it appears that the EP component latency data faithfully reflect differences in response latency between subjects.

DISCUSSION

The results of this experiment indicate that throughout the 40-min task, correct identifications of

Figure 1. Averaged evoked potential data associated with correct detections (CD) and commission errors (CE) for two subjects for the two halves of the test. Numbers of observations are shown in brackets.

events as signals were made significantly faster than incorrect identifications of nonsignal events as signals. This increase in processing time associated with false positive responses was accompanied by similar increases in the latencies of the late components (P_2 , N_2 , and P_3) of the EP averaged to CEs.

A number of studies have investigated the late components of the EP in relation to information processing or decision making (Hillyard, Hink, Schwent, & Picton, 1974; Karlin, 1970; Roth & Kopell, 1973). The general finding has been that the P_3 wave is generated or enhanced when task-relevant information is delivered. On the basis of these and other studies, Picton and Hillyard (1974) have recently proposed that the evoked response to a detected signal comprises two distinct parts: a sensory evoked response and a later perceptual decision complex which is manifested in the amplitude enhancement of the late EP components. Most of the above-mentioned studies have used *amplitude* measures in studying late component changes; one study, however, has reported latency differences in P_3 related to the difficulty of an auditory discrimination (Ritter et al., 1972). Posner, Klein, Summers, and Buggie (1973) have also briefly reported that differences in latency between pairs of stimuli judged as "same" or "different" are accompanied by reliable differences in late-component (160-350 msec) latencies between EPs averaged to the "same" and "different" responses.² This briefly reported result is of the same form as the results of the present experiment, in which latency differences in late components (180-450 msec) were associated with response latency differences between CEs and CDs. Both sets of results appear to support the suggestion of Ritter et al. (1972) that the latency of late EP components represent temporal correlates of the information processing and decision-making activity preceding a behavioral response.

Table 2
Mean EP Component Latencies (Milliseconds) for Correct
Detections and Commission Errors for the Two
Halves of the 40-Min Monitoring Task

EP Compo- nents	Correct Detections		Commission Errors	
	First Half (N = 40)	Second Half (N = 32)	First Half (N = 28)	Second Half (N = 20)
P_1	75 (19)	78 (24)	70 (20)	73 (18)
N_1	160 (23)	174 (34)	165 (32)	176 (29)
P_2	218 (32)	251 (35)	249 (34)	261 (37)
N_2	271 (39)	285 (34)	301 (29)	332 (30)
P_3	341 (57)	360 (60)	412 (66)	424 (74)

Note— N represents the mean number of observations per subject from which the mean EP component latency was determined. Standard deviations are shown in brackets.

Table 3
Spearman Rank Correlation Coefficients Between Mean
Response Latencies for CDs (CD_L) and CEs (CE_L) and the
Mean EP Component Latencies for P_2 , N_2 , and P_3 Associated
With CDs [P_2 (CD), N_2 (CD), P_3 (CD)] and CEs [P_2 (CE),
 N_2 (CE), P_3 (CE)] for the Two Halves of the
40-Min Visual Monitoring Task

EP Component		First Half		Second Half	
P_2	CD_L	P_2 (CD)	P_2 (CE)	P_2 (CD)	P_2 (CE)
	CE_L	.68*	.41	.66*	.47
	P_2 (CD)	.21	.74*	.16	.79*
N_2	CD_L	N_2 (CD)	N_2 (CE)	N_2 (CD)	N_2 (CE)
	CE_L	.73*	.31	.81*	.26
	N_2 (CD)	.30	.74*	.40	.79*
P_3	CD_L	P_3 (CD)	P_3 (CE)	P_3 (CD)	P_3 (CE)
	CE_L	.85**	.25	.87**	.28
	P_3 (CD)	.39	.90**	.47	.93**

* $p < .05$

** $p < .01$

The finding that latencies associated with CDs significantly increase with time on task is well established (Buck, 1966). The present study also demonstrates a significant increase with time on task in latencies associated with CEs. In addition, the latencies of the late components of EPs averaged to *both* CEs and CDs significantly increase with time at work. It thus appears that latencies of late EP components are sensitive not only to mean latency differences between response categories but also to latency increases with time on task within each response category. The most parsimonious explanation of these findings is, perhaps, that the subjects became progressively less certain of the responses they made as a function of time at work. This may be due to a combination of several factors, among which are expectancy changes and reductions in arousal (Davies & Tune, 1970).

REFERENCES

- BROADBENT, D. E. *Decision and stress*. London: Academic Press, 1971.
- BUCK, L. Reaction time as a measure of perceptual vigilance. *Psychological Bulletin*, 1966, **65**, 291-308.
- DAVIES, D. R., & TUNE, G. S. *Human vigilance performance*. London: Staples Press, 1970.
- DONCHIN, E., & LINDSLEY, D. B. Average evoked potentials and reaction time to visual stimuli. *Electroencephalography and Clinical Neurophysiology*, 1966, **20**, 217-223.
- HILLYARD, S. A., HINK, R. F., SCHWENT, V. L., & PICTON, T. W. Electrical signs of selective attention in the human brain. *Science*, 1974, **182**, 177-179.
- KARLIN, L. Cognition, preparation and sensory evoked potentials. *Psychological Bulletin*, 1970, **73**, 122-136.

- NICKERSON, R. S. The use of binary-classification tasks in the study of human information processing: A tutorial survey. In S. Kornblum (Ed.), *Attention and performance IV*. London: Academic Press, 1973.
- PICTON, T. W., & HILLYARD, S. A. Human auditory evoked potentials. II: Effects of attention. *Electroencephalography and Clinical Neurophysiology*, 1974, **36**, 191-199.
- PIKE, A. R. The latencies of correct and incorrect responses in discrimination and detection tasks: Their interpretation in terms of a model based on simple counting. *Perception & Psychophysics*, 1971, **9**, 455-460.
- POSNER, M. J., KLEIN, R., SIMSON, J., & BUGGIE, J. On the selection of signals. *Memory and Cognition*, 1973, **1**, 2-12.
- RITTER, W., SIMSON, R., & VAUGHAN, H. G., JR. Association cortex potentials and reaction time in auditory discrimination. *Electroencephalography and Clinical Neurophysiology*, 1972, **36**, 219-225.
- ROTH, W. T., & KOPELL, B. S. P300: An orienting response in the human AER. *Perceptual and Motor Skills*, 1973, **36**, 219-225.
- SEKULER, R. W. Signal detection, choice response times, and visual backward masking. *Canadian Journal of Psychology*, 1965, **19**, 118-132.
- SIEGEL, S. *Nonparametric statistics for the behavioural sciences*. London: McGraw-Hill, 1956.

NOTES

1. The EEG was continuously monitored throughout the session on an SLE Galileo recorder. Artifact contamination of the EPs was minimized by excluding EEG epochs containing muscle or eye-blink artifacts from the averaging process. Control runs, in which subjects were instructed merely to count critical signals or to delay response by 1 sec, indicated that overt responding did not contaminate the EP.

2. It should be noted that in the present experiment response latencies for both CDs and CEs were considerably longer than the peak latency of P_3 , by, on average, 300-400 msec. This finding contrasts with those of Ritter et al. (1972) and Posner et al. (1973) and adds further support for the view that P_3 is a concomitant of decision-making activity rather than of motor activity associated with overt responding.

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