THE EFFECT OF SELF-CHECKING ON VIGILANCE TASK PERFORMANCE¹

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Four groups of 10 Ss were engaged in one-hour vigilance work. The critical signal to be detected was pointer deflection of a greater amplitude and was presented 24 times at irregular intervals during the monitoring period. Ss in one group were informed about their correct detection and false response (P-KR group). Ss in 12 Check and 24 Check groups were asked for to do self-checking in order to get the same sorts of information. The checking was admitted up to 12 in 12 Check group and 24 in 24 Check group. Control group was not provided with any information about their performance. P-KR and 24 Check groups were superior to Control group ($p < .01$) and 12 Check group to Control group ($p = .05$) in terms of correct signal detection. Detection response speed, in order, was: P-KR group, 24 Check, 12 Check and Control. And, all the differences were significant. Self-checking thus proved to improve vigilance task performance.

The present study was designed to see whether or not self-checking would improve vigilance task performance in a visual monitoring task. Self-checking is an information-seeking response made by S: By self-checking S can get information about signal and/or the result of his detection response.

As recent researches on vigilance (cf. Frankman & Adams, 1962) pointed out, the *Knowledge of Results* (KR) improves vigilance and postpones the vigilance decrement—the deterioration of signal detection performance which occurs under the ordinary vigilance task conditions (cf. Mackworth, 1948). The KR is essentially a procedure in which S can be given three kinds of information about his detection performance. As is seen in Chinn &

Alluisi's experiment (1964), for example, S can be informed when he missed the signal (omissive error information), when he correctly detected the signal (correct detection information), and also when he made a false response (commissive error information). The KR is one of the most effective ways to prevent the vigilance decrement. However, the KR does not seem to be the most efficient way to inform S about his detection performance. It is because those sorts of information in the KR are delivered thoroughly mechanically and irrespective of whether they are actually sought by monitoring S. Information in general seems to be more influential when it is needed. And, thus it seems highly reasonable to expect that the effect of information may be more magnified when delivered at S's request. The self-checking procedure is an alternative in which S can get information about his detection behavior according to his need to attain it. The KR proved to improve vigilance performance. And, the self-checking procedure, it was expected, would have the same effect of improvement on vigilance task performance.

¹ The present study was conducted when the writer was at Department of Industrial Engineering of Nagoya Institute of Technology. He is greatly indebted to Professor Chuichi Murai for his generosity in solving financial problems and to Mr. Satoshi Narukawa, now a graduate student of the institute, who willingly took the trouble of making the apparatus as well as executing almost all of the experiment.

There is another reason to believe that self-checking facilitates vigilance performance. The evidence for the belief comes from the result of the recent studies on vigilance (Komaki & Murai, 1965) in which it was found that an interpolated drawing work, when some sort of spontaneity in the way of drawing was admitted, exclusively produced vigilance recovery. In the experiment *Ss* were initially engaged in a 45 min vigilance work and immediately afterwards a drawing task for 15 min. The task was to fill up small open circles one by one with a color pencil at a predetermined speed. Some *Ss* (Spontaneity group) were admitted during the task to choose the position of the circles to fill up and also select and exchange the color pencil for the drawing. Statistically significant recovery appeared in the spontaneity group, but did not in others who were prescribed in more details in the manner of their drawing. If it can be assumed that vigilance recovery is a reflection of motivational arousal, spontaneity of performance brought into vigilance task itself would similarly contribute to maintain *S's* motivation to the task. Self-checking is a response which monitoring *S* can make spontaneously. And, it was expected that spontaneity of performance achieved in the form of self-checking would maintain *S's* motivation to the task and hence cause the effect to improve vigilance performance.

Both of the above considerations lead to the expectation that self-checking aids in vigilance task performance. The aim of the present study is to test the expectation and at the same time to obtain evidence for understanding the effect of the checking in vigilance if it would produce any effect in the task situation.

METHOD

Subjects. Fifty-four undergraduates of Nagoya Institute of Technology from 19 to 25 yr old served as *Ss*. They were male volunteers and

naive with respect to vigilance task. Visual acuity of them, corrected or uncorrected, ranged widely (from 0.2 to 1.5). They were assigned to one of the 4 groups described below in a counter-balanced way according to the order they appeared to the laboratory. Because of the considerably great individual differences and of the restriction for applying *repeated-measures-design* (Edwards, 1950), 14 *Ss* were discarded by applying a statistical test (Iwahara, 1955, p. 125) to false response. Number of *Ss* rejected was 4 in Control group, 3 in P-KR group, 4 in 12 Check group, and 3 in 24 Check group. Each of the groups (fully described below) was thus comprised of 10 *Ss*.

Apparatus. In front of *S* on a desk were placed a display panel and a response-key box and a check-key box. The panel was 45 cm high and 25 cm wide and painted grey. At the height of 25.5 cm on its surface was mounted an AC voltmeter the dial face of which was a plain white board and 5.5 cm in diameter. It had a 2 cm long pointer and the resting position of the pointer was 40 degrees of arc left from vertical axis. At the height of 4 cm above the dial two small light bulbs were mounted horizontally with a space of 9 cm between them. The right side bulb was red and the left side one was green. The panel was illuminated from above with a light bulb and the brightness measured at the place of the dial was about 300 lux.

The response-key box was 20 cm wide, 10 cm high and 10 cm deep and placed in front of *S* on the right-hand side. On the top of it was attached a Siemens-key switch which, when *S* pushed it forward, activated a recorder and under P-KR condition an equipment devised for information-delivery. The check-key box placed on the left-hand side had the same dimensions and Siemens-key switch as the response-key box. On the left of the switch a three-digit, electro-magnetic counter was mounted. Each time *S* (of 12 Check and 24 Check groups) pushed it forward, the recorder and the information equipment were activated and the digit displayed on the counter was stepped-up as well. It was for the purpose to inform *S* the cumulative number of his self-checking.

S wore a pair of headphones which was connected to a tape recorder. During the entire monitoring period *S* heard through the headphones tape-recorded white noise for masking any extraneous sound. The noise level was adjusted so as to have a mean value of about 72 db. Every event during the experiment (presentation of the critical signal, *S*'s response-key pushing as well as his check-key pushing) was recorded on a hot-pen recorder. Since its paper speed was 0.5 cm per second, occurrence of these events could be measured up to 0.2 second.

Procedures. The pointer of the dial deflected once for every second with an amplitude of 24 degrees. Occasionally it deflected with a greater amplitude (30 degrees). It was the critical signal to which *S* was asked for to respond. The signal was presented 24 times during the 60 min monitoring period. The familiar Mackworth sequence of signals (1950) involving intersignal intervals of 3/4, 3/4, 1½, 2, 2, 1, 5, 1, 1, 2, 3, and 10 min was applied to the first and the second half of the period.

Each of Control group *Ss* monitored for 60 min without any information about his performance. He was instructed beforehand to neglect the check-key box on the desk and the light bulbs on the panel. Every *S* of P-KR group was given partial knowledge of results. When he pushed the response switch within the 5 sec interval after the critical signal had been presented (designated as *signal interval*), the green light was lit on the panel. The light informed that his detection was correct. The light remained to be lit as long as he was pushing the switch. If he made the response in the period other than the signal interval (false response), the red light informing a commissive error was lit which was turned out as soon as he released the switch. P-KR group *Ss* were instructed to neglect the check-key box placed on the desk.

Ss of 12 Check and 24 Check groups could obtain information about the two kinds of signals and/or the result of their detection response by pushing the check-key switch. When *S* of these groups pushed the check-key switch within the signal interval, the green

light was lit on the panel regardless of whether he made detection response or not. The green light following the detection response informed him that his detection had been correct. On the other hand, the green light without prior detection response indicated him that he had missed the signal (omissive error). The pushing of the response-key switch after he had been informed of his omissive error was forbidden. The light was turned out at the instant he released the check switch. When he pushed the check-key switch within the period other than the signal interval, the red light was turned on irrespective of whether he had made the detection response. If he had made the response before it, he was informed that his detection was false (commissive error). If he made only the checking response, he was informed that the pointer deflection at the time was the non-critical background deflection. The red light continued to be on as long as the check-key switch was closed. These sorts of self-checking were admitted until 12 times for 12 Check group and until 24 times for 24 Check group. *S* could know the cumulative number of his self-checking by reading the digit displayed on the counter. These chances for the checking were unfortunately not always fully utilized.

S was individually introduced to the laboratory and his wristwatch, if wearing, was removed. Instructions corresponding to the group to which he belonged were given. Each of the critical and the background signals was presented alternatively 10 times on the dial. Preliminary training was then conducted for 2 min during which the critical signal was presented 6 times at irregular intervals. Questions, if any, were then replied. *S* wore the headphones and the 60 min monitoring session was started. *E* sat during the session behind *S* by a table on which the information equipment, the recorder and the tape recorder were placed.

RESULTS

Detection Percentages. Every detection response that occurred within the signal interval was defined as correct detection.

TABLE 1
Summary of an F test applied to transformed scores of percentage correct detection within each of the 4 signal blocks

Source of Variance	SS	df	MS	F
Between Individuals				
Groups (A)	20,140.90	3	6,713.6	17.95**
Individuals	13,462.67	36	374.0	
Within Individual				
Signal Blocks (B)	3,032.96	3	1,011.0	4.66**
A $\times$ B	2,216.88	9	246.3	1.14
Residual	23,411.20	108	216.8	
Total	62,264.61	159		

** $p < .01$

FIG. 1. Group means of the percentage correct detection within each of the 4 signal blocks.

Percentage of the correct detection was obtained for each S within each of the 4 signal blocks into which, according to their sequential order, every 6 signals were assigned. Group means of these scores are shown in Fig. 1 for the 4 groups. Detection performance was best in P-KR group and worst in Control group.

Individual detection percentages were

transformed to their inverse sine roots, and an F test of a *repeated-measures-design* was applied to them. As seen in Table 1, groups was highly significant. By the use of Tukey's method of pairwise comparison, P-KR as well as 24 Check group proved significantly superior to Control group ($p < .01$). The difference between 12 Check and Control groups was significant at exactly the 5% level of confidence, but the other group differences were not. Either P-KR or self-checking apparently improved the signal detection.

However, the effect of improvement was not so great as to prevent any deterioration in vigilance. As shown in Table 1, signal block was highly significant and the interaction between signal blocks and groups was not. Pairwise comparisons revealed significant difference between signal blocks 1 and 2 as well as 1 and 4 ($p < .01$), and between the blocks 3 and 4 ($p < .05$). The difference between the 1st and 3rd signal blocks was not significant. Although statistically unreliable, detection level was raised in the block 3.

Response Speed. Time from the critical signal presentation to the occurrence of detection response was defined as response time. To every omissive error a response time of 5 sec was arbitrarily assigned and 24 scores were obtained from each S .

They were transformed to their reciprocals and every 6 of them were pooled to produce the mean signal block response speed. Group means of these scores are plotted in Fig. 2 for the 4 groups.

An F test of the same design as applied to detection percentages was conducted on these response speed measures. Groups was significant ($F=8.83$; $df=3,36$; $p<.01$), and all the differences between the groups proved to be significant by the use of pairwise comparisons. Group differences which had not revealed in the analysis of the detection percentages were made apparent. The P-K produced the highest performance. Self-checking procedure, though did not reach the level achieved by P-KR group, similarly improved detection performance, and the effect of improvement was greater in 24 Check than in 12 Check group.

The groups $\times$ signal blocks interaction was not reliable and overall decline of response speed due to signal blocks was

FIG. 2. Group means of the detection response speed in each of the 4 signal blocks.

TABLE 2

Means and SD 's of omissive and commissive errors during the 60 min monitoring period

Groups	Omissive Error		Commisive Error	
	Mean	SD	Mean	SD
P-KR	2.8	2.04	3.8	2.99
24 Check	3.9	1.58	1.4	1.50
12 Check	5.2	2.14	2.0	1.79
Control	11.4	3.88	.2	.40

TABLE 3

Summary of an F test applied to omissive and commissive errors during the 60 min monitoring period

Source of Variance	SS	df	MS	F
Between Individuals				
Groups (A)	112	3	37.3	6.3**
Individuals	221	36	5.9	
Within Individuals				
Errors (B)	316	1	316.0	57.5**
A $\times$ B	399	3	133.0	24.2**
Residual	197	36	5.5	
Total	1,235	79		

** $p < .01$

significant ($F=10.71$; $df=3, 108$; $p<.01$). Tukey's method of pairwise comparison was utilized and all the differences except the one between the blocks 2 and 4 were significant. In these signal blocks in which the longest inter-signal interval (10 min) was involved the decline in response speed was more apparent.

Error Scores. When considered in the light of error scores, however, detection performance of the 4 groups was somewhat different. Omissive and commissive errors were counted for each S , and group means and their SD 's of these errors are presented in Table 2. When these two sorts of errors were pooled, 24 Check group was best: P-KR group made more commissive errors than 24 Check group. A statistical analysis supported this conclusion. As

TABLE 4
Number of times of receiving information in individual Ss of 12 Check, 24 Check
and P-KR groups during the 60 min period

12 Check group										
Notation of Ss	1	2	3	4	5	6	7	8	9	10
Self-checking after correct detection	6	9	11	1	8	5	5	4	6	8
Self-checking after false response	1	3	1	0	2	2	0	0	0	1
Independent self-checking	3	0	0	1	0	5	0	8	0	1
Total self-checking	10	12	12	2	10	12	5	12	6	10
24 Check group										
Notation of Ss	11	12	13	14	15	16	17	18	19	20
Self-checking after correct detection	9	4	14	7	8	15	15	12	2	23
Self-checking after false response	1	0	2	2	0	5	1	2	0	0
Independent self-checking	9	1	2	0	8	1	8	8	0	0
Total self-checking	19	5	18	9	16	21	24	22	2	23
P-KR group										
Notation of Ss	21	22	23	24	25	26	27	28	29	30
Correct detection information	24	23	19	21	20	22	20	21	17	24
Commissive error information	1	3	5	4	6	8	9	1	1	0
Total number of times of being informed	25	26	24	25	26	30	29	22	18	24

shown in Table 3, all of groups, errors and groups $\times$ errors interaction was significant. With respect to omissive errors, significant difference was obtained between P-KR and 12 Check groups, P-KR and Control groups, 24 Check and Control groups, and 12 Check and Control groups. However, as for commissive errors the trend was opposite. Commissive errors of P-KR group were significantly greater than those of 24 Check and of Control group.

Number of times of receiving information. Ss of P-KR group could be informed automatically at their detection response: Correct detection information was presented to them when their response was correct and commissive error information when their response was false. On the other hand, Ss of 12 and 24 Check groups had to make the response of self-checking, which could be classified into two cate-

gories: the self-checking conducted independently of the detection response and the one performed immediately after the detection response. And, the latter could be further subdivided into two in terms of the information obtained through it: the self-checking when the prior detection happened to have been correct and the one when the detection to have been false. Mean number of times of being informed in these ways, when pooled, was 24.9 in P-KR group, 15.9 in 24 Check group, and 9.1 in 12 Check group. And, individual scores in each of these cases of receiving information are tabulated in Table 4. Number of the checking responses conducted within each of the signal blocks was divided by the total number of the responses for individual S, and group means of these weighted scores are shown in Fig. 3. Also plotted in the figure are the

weighted mean scores of P-KR group *Ss*' being informed. It is quite interesting that both of 12 and 24 Check groups made considerably frequent self-checking (40.7 and 36.6%, respectively) in the 2nd block—the signal block where substantial deterioration in detection began to occur in Control group (cf. Fig. 1 & 2).

Some of the separately made checking responses shown in Table 4 happened to be conducted within the signal interval: Some *Ss* were sometimes informed that the critical signal had been actually presented at the nearby moment. When pooled for all *Ss* of the two check groups, the total number of their signal omission being informed was 7 in 24 Check group and 5 in 12 Check group. And, distribution of the scores along the successive signal blocks was 1, 2, 2, 2 in 24 Check group and 3, 2, 0, 0 in 12 Check group.

DISCUSSION

It is apparent that self-checking im-

FIG. 3. Group means of the weighted scores obtained from the number of times of receiving information in each of the signal blocks.

proves vigilance performance. Some decline in signal detection performance appeared. But 24 Check group proved to be superior to Control group in detection percentage as well as in response speed. 24 Check group was inferior to P-KR group in response speed. However, it does not seem to indicate that the self-checking procedure is inferior in all respects to the P-KR. With respect to commissive errors, 24 Check group was, contrary to response speed, superior to P-KR group.

As has been put forward by Wiener (1963), P-KR procedure without omissive error information yields increase in false response. The trend was reproduced in the present study. P-KR group made greater commissive errors than Control group. In contrast, 24 Check group was more deliberate. Several reasons may be pointed out for explaining the results. First of all, the check groups could be informed of their omissive errors. If *S* of these groups made self-checking within the signal interval, the green light was lit which informed him that the critical signal had been presented at the nearby moment. However, the presentation of omissive error information was rare. When pooled for all *Ss* of those check groups, total number of omissive error information was 7 in 24 Check group and 5 in 12 Check group.

Another possibility is the stability of the judgement. Self-checking enabled *S* to get information, whenever he needed, until the limit for the checking would be reached. *Ss* of the check groups presumably tried to maintain more stable and exact criterion for distinguishing the critical pointer deflection from the background one by knowing the nature of the signal at the time of their checking. And, 24 Check group was presumably more successful in doing so. The evidence for it, though indirect, is the temporal distribution of the checking. The use of the checking was concentrated in the 2nd

signal block where the long inter-signal intervals of 5 and 10 min were involved and thus Ss are expected to have been less confident about their distinction between the two kinds of signals. It is not certain which of the above explanation is right. However, in view of the nearly equal frequencies of signal omission being informed between 24 and 12 Check groups, the stability interpretation seems to be more plausible.

The unfortunate outcome that self-checking was not conducted to the full extent in most of the check group Ss (cf. Table 4) made it fairly difficult to understand the effect of improvement produced by the checking in more details. 24 Check group was inferior, though statistically unreliable, to P-KR group in terms of detection percentage. But between the two groups there was on the average a difference of 9.0 for the number of times of receiving information. In order to distinguish the contribution of spontaneity achieved in the form of self-checking from the effect of information provided by the checking, some modification of experimental procedure is necessary so as to ensure full usage of self-checking in at least information-seeking Ss.

Analysis of the ways in which self-checking improves vigilance seems to have some practical significance. If we decide to introduce the KR to any practical situation, it is necessary to design an equipment which is prepared to collate an operator's response with the signal at the time, make a decision about the result of his response,

and feed back the result to him. In short, a monitoring machine of a monitor must be designed. However, the requirement is practically meaningless. A human operator is needed particularly in the working situation where the monitoring machine can hardly be constructed. Self-checking seems much easier to be applied at least with information about the non-critical signals concerned: We can design easily and in various ways the equipment which informs to an operator about non-critical background signals at his request.

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(Received July 17, 1969)