THE INFLUENCE OF EXTRINSIC KNOWLEDGE OF RESULTS UPON PERFORMANCE IN A MONITORING TASK

by

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B. S., University of Wichita, 1960

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Psychology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

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CHAPTER

PROBLEMS OF VIGILANCE

The fact that people who in their work just sit and watch often get very tired may seem a trivial observation. But with modern increased technological advances and a very real trend towards automation the fact asserts itself as an ever-growing problem which needs to be both understood and dealt with in a scientific manner. Because heavy machinery easily surpasses man's strength and endurance, man is more and more delegated the role of a more-or-less passive observer. As such, information is supplied to him for his processing because of his so-far unreplaceable capability as a monitor, error detector, and decision maker. And although a monitoring task requires little physical effort and appears very simple, the detecting of a malfunction, a defective piece or product, or the blip of an approaching aircraft on a radar screen, may be of the greatest importance in terms of lives, safety, money, and time.

Recent observations and research seem to offer and substantiate the conclusion that man is actually not very effective as a monitor for any extended period of time. In cases of infrequent and rather subtle changes in a sensory display his efficiency may under normal conditions drop to a low level in a matter of only minutes (see Figure 1). He gets tired very fast. (The variables and conditions affecting the rate and amount of decrement in efficiency will be discussed later in this paper.) The term vigilance will also be discussed shortly but for the present time any task in which man is involved in as a monitor of sensory data can be considered a vigilance situation. In a common sense manner, the monitor is vigilant for certain types of signals.

Although discussions of vigilance and the vigilance decrement are frequently limited to those situations in which man's role is a rather passive one--because vigilance decrement is then easily separated from muscle fatigue, the author feels that the general phenomenon is also present in all sorts of tasks in which the man is active. Broadbent (1957) has discussed the higher frequency of accidents on the London docks as the morning progresses in terms not of muscle fatigue but rather of decrement in perception, i.e., the failure to notice the usual danger signs when something unexpected happens. And Saldanha (1956) has reported that while small handwheel movements are made just as quickly when the man has been working for an extended period of time the settings become significantly less accurate after only fifteen minutes. The worker looks at the scale and accepts readings as correct when in fact they were not.

Man acting as a monitor is a very pervasive situation and research in this area is considered by some, such as Broadbent (1957), as the most important single topic now being studied by psychologists.

The Practical Problems

It is not necessary to belabor the point that the vigilance problem is a very real one and some indications of the practical problems associated with it have already been discussed above. In industry, vigilance behavior accounts for a major proportion of the work in quality control, inspection, monitoring equipment, detecting errors in printed materials (editing), and much more. The failure to detect error, or

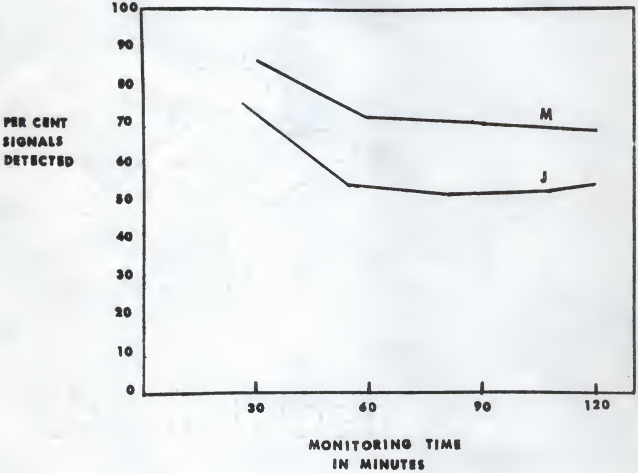

Fig. 1. Per cent signals detected as a function of time on watch. Mackworth (1950) who used 30 minute time blocks and Jerison & Wallis (1957) who used blocks of time of approximately 27 minutes. Both experimenters used the Mackworth Clock Test. In this task a clock hand makes small and equal jumps as it traverses around a uniformly plain clock face. Infrequently, double jumps are programmed into the movement of the hand. The task of the subject is to detect these infrequent double jumps.

change, may result in accidents, lost material, ruined equipment and poor workmanship. In the military, vigilance behavior is seen in the monitoring of dials in aircraft, air-traffic control, radar and sonar monitoring, watch or guard duty, and much more. Failure in detection includes those results mentioned for the industrial situation plus the possibility of national disaster.

The Psychological Problem

Psychologically, what is going on in vigilance behavior may possibly be described in terms of somewhat more basic processes and discussed in terms of concepts and research already existing in the general fund of scientific psychological knowledge. Mackworth (1948, 1950) has drawn an analogy between vigilance behavior and the extinction (internal inhibition) of a classically conditioned response. Holland (1958) has shown good evidence for considering the observing response as an operant response which is instrumentally conditioned by the reinforcing effects of signal detection. Jenkins (1958) offers an explanation of generalized inhibition. Deese (1955), and, more recently, Baker (1958) have expanded Mowrer's (1940) concept of preparatory set or "expectancy" into a cognitive theory of vigilance, and in addition, Deese (1955) and McBain (1959) offer an "activation hypothesis" based on central excitation processes similar to those of Hebb (1955). Berlyne (1951), Bakan (1952), and McCormack (1958) explain the vigilance decrement in terms of Hullian learning theory as a function of the accumulation of reactive inhibition. Broadbent's (1953) explanation has to do with the intrinsic attention-demanding properties of intense and novel stimuli and the loss of attention with familiarization of repeated stimulation. Decrement is a function of stimuli competing for the attention of the monitor. Also some research work is now in process which demonstrates certain advantages of considering vigilance performance in terms of Adaptation-Level Theory (Helson, 1959).[1]

Frequently authors give the term vigilance primary concept status as an intervening variable. It is considered to describe a central process or state of the organism which is measurable in terms of the individual's readiness to respond to rare and unpredictable changes in his environment. An obvious but not critical argument against this view is the circularity of the reasoning. The "state of vigilance" is inferred from the performance of the monitor and then used to "explain" the performance of the monitor.

It might be mentioned here that some of the above mentioned "explanations" suffer somewhat from certain inadequacies. Mackworth is hard pressed to show that classical conditioning has first taken place in order for the concept of extinction to be applicable. Also, generally from this type of learning paradigm (e.g., Hull), it is predicted that with a higher signal rate (signal = CS) and lack of knowledge of results (KR = UCS) the detection response (pressing response key = CR) would extinguish faster than with a slower signal rate (massing of extinction trials). This is contrary to his own empirical findings. Furthermore, complete extinction never takes place. Holland's operant conditioning

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[1]Research currently in progress at Kansas State University under project G1038 with William Bevan as principle investigator.

paradigm puts the whole load of explanation upon the stimulus conditions, but with stimulus conditions held constant, experiments still get a wide variation in performance from different individuals. In fact, for many individuals there is no vigilance decrement. An experiment by Blair (1958), using a different response measure, showed results contradictory to those of Holland.

The approach which seems most promising to the present author is a two-factor approach, similar to that of Deese, in which cognitive aspects or expectancies are viewed as a function of the immediate expectancy level (based on time since the occurrence of previous stimulation and the range of variation of the intersignal intervals of all previous input) and considered against a background of specific task motivation.

Some facts pointing towards an explanation in terms of the central origin of the vigilance decrement are the similarity of decrement curves across modalities and the generalized lessening of efficiency which goes beyond the specific task. Thus, Bartlett et. al. (1955) found no evidence of ocular fatigue after two hours of visual monitoring. And, Solandt & Partridge (1946) reported no decrement when observers alternated between monitoring both an auditory sonar display and hydrophone sound, even though this task made the same demands on the sensory mechanisms that monitoring either one singly did. Singly performed, there is the usual vigilance decrement for both.

The term vigilance was first used by Henry Head in 1936 to denote physiological or psychological readiness to respond and was taken up by Mackworth in his World War II research. Mackworth's definition of vigilance (1957) is "a state of readiness to detect and respond to certain specified small changes occurring at random time-intervals in the environment." The feelings of the present author are that a definition of the vigilance process can be replaced by defining the vigilance situation and using the term vigilance in such a way as to loosely denote the task relevant behavior of the participating individual. Any situation in which information is displayed over an extended period of time and which contains certain specifiable and unpredictably occurring aspects to which the observer must respond is a vigilance situation. A person working in a vigilance task is often referred to as a "monitor."

RESEARCH ON VIGILANCE

This chapter is a review of some of the research performed upon the variables which characterize vigilance situations. These variables have been grouped as a matter of convenience into the following four general categories: (a) Task Variables, (b) Environmental Variables, (c) Motivational Variables, and (d) Personal Variables. The review here is limited by the requirements of space, since the literature of the last fifteen years in this area, and related to this area, is voluminous. The above mentioned classifications of variables are by no means considered independent.

Task Variables

Types of Tasks

In a recent paper on theories of vigilance, Frankmann & Adams (1960) classify the vigilance tasks used in research into four types: (a) The first and most frequently used type is the classical vigilance task. An example of this type is the Mackworth Clock Test (Mackworth, 1950). Here, signals differing slightly from the standard signal are interpolated randomly in the order of presentation. (b) Multiple display situations where a critical signal can occur at any one of several locations. An example of this type is Broadbent's Twenty Dials Test (Broadbent, 1950). Constant scanning is required in this task. (c) Threshold measurements, [e.g., Bakan (1955)]. Here series of signals are presented starting at random intervals in time and intensity is incrementally increased with each successive presentation until the observer detects the signal. (d) Observing response experiments [e.g., Holland (1958)]. In this task attention is measured through a response which illuminates the display and thus controls observing. More detections lead to increased illuminating (observing) responses from the observer.

Besides the above-mentioned Clock Test and Twenty Dials Test, other displays which have been used include simple lights or patches of light (McCormack, 1958), simulated sonar (Mackworth, 1950), voltmeter deflections (Jenkins, 1958), a Twenty-Lights Test (Broadbent, 1953), simulated radar scopes (Adams, 1956), changes in pitch (Wherry & Webb, 1959), and many others. The critical signal can be either transient (momentary) or persistent (re-set after detection) and can arise out of a background "noise" of similar signals, or out of the quiet or null position.

Performance Measures

The most frequently used performance measure is the per cent of signals detected, or the probability of detection, given generally for blocks of time, i.e., thirty, forty, or sixty minutes. However, it is possible to show performance "signal by signal" by plotting the percentage of subjects who detected each particular signal.

Occasionally latency of detection has been used and this measure reflects performance decrement as a curve similar to the probability of detection curve.

Changes in absolute or differential thresholds have been used by some investigators to show performance decrement (Bakan, 1955).

And, as mentioned earlier, Holland (1958) has used the observing response as a performance measurement.

Other measures which have been used but whose reliability is somewhat suspect are: motor activity (Baker, 1959), skin-conductance level (Dardano & Mower, 1959), and c.f.f. (Wittenberg, Ross, & Andrews, 1956).

When the signal is very subtle, subjects will report detections when no signal has actually occurred. These errors are termed Type I errors or commissive errors. In contrast, failure to detect a true signal is called a Type II error or an error of omission. Type II errors have generally been more of interest than Type I errors.

Length of Vigil and the Decrement Curve

In general, the efficiency of the monitor decreases with the amount of time on watch. In terms of probability of detection, the curve is a negatively decelerating function which levels off after about thirty minutes (see Figure 1). This type of a function was originally published by Mackworth (1948) and has been substantiated consistently by researchers using different types of displays and different sense modalities. However, when Jerison (1957) replotted data "signal by signal" he found the decrement to be much more rapid than it was earlier assumed to be. He accounted for the earlier conclusion as the result of plotting the percentage of detections in blocks of longer time intervals (30 to 40 minutes). In re-analyzing his own data, he found the decrement to be maximal at the end of the first 15 minutes. In addition, Deese & Ormond (1953) have found a slight improvement in performance during the first few minutes of a session. This they attribute to warming-up.

Research by Bartlett et al. (1955), indicates the possible existence of a subject by vigil-duration interaction in vigilance tasks.

Jerison (1958) has also found that a subject's expectations concerning the length of the vigilance session have an affect upon the slope of the decrement function although the eventual plateau remains at the same level. Habituated subjects expecting a long session show the steepest drop while naive subjects expecting long sessions have an intermediate slope, with naive subjects expecting short sessions having the least rapid decrements.

Display Variables

Jerison & Wallis (1957) compared the performance of groups with a single Mackworth Clock and three Mackworth Clocks. The group with three clocks received three times as many signals as the one-clock group. The one-clock group showed the usual decrement while the three-clock group showed no decrement. Meanwhile, overall level of performance for the latter group was about 50 per cent of the single clock group. A subsequent signal by signal analysis showed that there was a decrement for the three-clock group, however, it was very rapid and took place within the first three minutes of watch.

Fraser (1950) showed that performance on a vertical display was superior to performance on either a horizontal display or one set at a 45° angle.

Nicely & Miller (1957) found that contrast of signal with display background was an important variable in detecting signals, and Jenkins (1958) similarly found increased probability of detection with higher signal-to-noise ratios.

Bartlett et al. (1955) studied the speed of a scope sweep line and found that performance is somewhat higher on a scope with a faster sweep line.

Finally Baker (1955) found that signals in the periphery of a display are less likely to be detected than those more centrally located.

Signal Variables

Keeping in mind that the definition of a vigilance situation requires that signals be more or less subtle; one notes that the intensity of a signal is related to the overall level of detection while the shape of the decrement curve remains the same. More intense signals have a higher probability of being detected if other conditions are held constant (Mackworth, 1950; Adams, 1956). Obviously, there probably would be no vigilance decrement to signal equivalent to a one hundred and ten decible truck horn. And Adams (1956) has also shown that the probability of detection is greater for a two second signal than for a one second signal.

Rate of Signal Presentation

Probability of detection is positively correlated with signal rate. Jenkins (1958) used signal rates of 7.5, 30, 60, and 480 signals per hour and found that the slower the signal rate, the larger the decrement in performance. Deese & Ormond (1953) found percentages of detections of 46, 64, 83, and 88 per cent for signal rates of 10, 20, 30, and 40 signals per hour.

Variability and Duration of the Intersignal Interval

Although not independent of the signal rate, variability of intersignal interval appears to be related to performance. Less variable intervals between signals allow for better prediction and consequently higher probabilities of signal detection (Baker, 1958).

Conclusions concerning the relationship of the duration of the intersignal interval and the probability of detection of a signal have varied because of certain differences in method of analysis. Investigators who measure the intersignal interval from the presentation of one signal to the presentation of the next, regardless of whether or not the first signal was detected, report an increase or no change in the probability of detection with increased intersignal interval duration (Deese & Ormond, 1953; Jerison & Wallis, 1957; Mackworth, 1950; McCormack, 1958). Investigators who measure the interval from the detection of one signal to the presentation of the next, report that the probability of detection decreases with longer durations of the intersignal interval. Recent work by Baker (1962) shows that the individual quickly establishes a mean interval point of reference (expectancy) and the probability of detection of a specific signal can be shown to be a function of the distance of the intersignal interval from the mean interval point of reference. Expectancy is low for signals occurring immediately after a detected signal but increases as the interval approaches the mean reference point and then decreases again beyond this maximum expectancy point (see Figure 2).

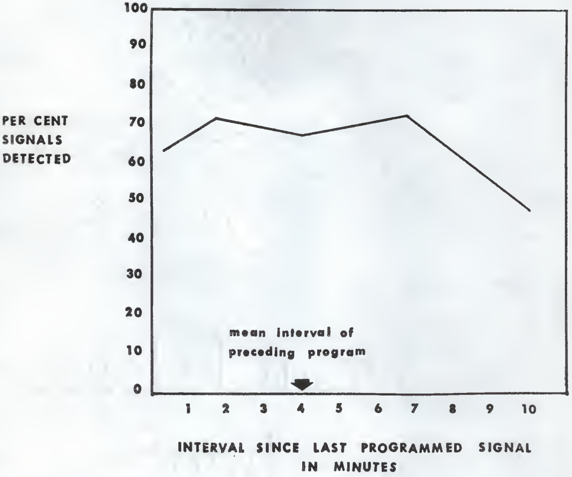

Fig. 2. Per cent of signals detected as a function of the length of the interval between the last programmed signal and the test signal (Baker, 1962).

Interpolated Rest Periods and Activity

Research generally supports the conclusion that interpolated rest periods reduce the decline in performance of a monitor. Jenkins (1958) gave each subject a 30 second rest every 270 seconds and found that the frequent rest periods result in a higher level of percentage of detections and latency of responses. Mackworth (1948) raised the overall performance level of one hour of monitoring by interpolating 30 minutes of rest between the first half hour and the second half hour, but the familiar decrement was evident in both sessions.

McFarland et al. (1942), found that a severe decrement in brightness discrimination performance occurred as a function of time at the task and that when the subjects were merely allowed to shift positions every thirty seconds, their performance recovered briefly.

In the above-mentioned experiment by Jenkins (1958), no differences were found between the performance of a group which was allowed to leave the room and walk around in their 30 second break and one which was required to remain at the work station.

Howland (1956) found that to effectively raise performance, activity must be interpolated between monitoring sessions and not concomitant to the task. Concomitant activity interferes with and reduces the level of performance.

Environmental Variables

One obvious conclusion concerning vigilance is that anything that would interfere with the sensing of an information display would decrease the overall level of performance in a vigilance situation. An example of this is a problem that was encountered in the first two manned Mercury shots, where the astronauts were unable to visually monitor the controls under conditions of high frequency vibrations in the initial boost phase. However, this problem and many similar ones have yet to be thoroughly investigated and little experimental data is available to this author. Some of the variables which are currently of great practical interest are acceleration, weightlessness, and the effects of different artificial atmospheres.

Three variables which have been the subject of research in respect to vigilance performance and are available in the general literature are temperature, noise, and illumination.

Temperature and Vigilance Performance

Mackworth, using "effective temperature" (a single value which combines the effects of temperature, humidity, and air movement on the sensation of warmth and cold) as a variable, found maximum vigilance performance at an effective temperature of 79°. Performance level decreased with any significant increase or decrease from that temperature, and higher temperatures increased the rate of decrement.

Noise and Vigilance Performance

The effect of noise on an auditory vigilance task would appear to decrease the signal to noise ratio. Therefore to the degree that it interferred with detecting the signal, it would be expected to decrease performance.

The effect of intense noise on a visual monitoring task was first studied by Broadbent (1953). His findings in one study were that noise

(100 db) increased the number of response errors in multiple response monitoring tasks, and in another (1954), that noise interferred with signal detection on a 20-dials test but not on an easier 20-lights test.

Jerison & Wing (1957) found that the performance curve on a single source was no different under conditions of quiet (79 db) and noise (112.5 db). But with a complex task (three clocks) the subject performed at a lower overall level and suffered a decrement in performance during the last 30 of a 120 minute watch under the noise condition.

Loeb & Jeantheau (1958) confounded a number of variables in testing vigilance performance in the back-end of an army truck. Their findings showed longer response latencies when the truck was moving (at least noise and vibration present) as compared to standing still.

Illumination and Vigilance

Simonson et al. (1948) found that monitoring performance of a visual display under "Verd-A-Ray" lamp illumination was significantly better than under normal illumination sources or frosted lamp sources. Illumination intensity is directly related to visual acuity and visual contrast. To the degree that illumination improves contrast of signal-to-field, it will tend to increase probability of visual detection. Such variables as position of illumination source (to eliminate glare) and spectral energy distribution of the illuminating source (to insure maximum contrast and acuity) are most important and have to be considered for any type of display and any position taken by the observer in relation to display and illumination.

Motivational Variables

Variables discussed under this heading are placed here largely by virtue of their role in energizing or de-energizing the task-related behavior of the monitor.

One very important variable is the availability to a monitor of information on performance. This is termed knowledge of results and will be dealt with in another part of this paper in greater detail.

Motivational variables which have received some experimental attention and which will be discussed here are: the presence of other persons, the use of drugs, the use of alcohol, and the use of incentive conditions.

The Presence of Other Persons

Persons other than the monitor, in the monitoring situation, can be grouped into (a) persons with no authority and no evaluative function and (b) persons of authority who have evaluative functions. Pollack & Knaff (1958) found no difference in individuals working in isolation and those working in the same room with other operators. However, Fraser (1953) found that when a person seen as an authority figure stayed in the room with the monitor, the monitor performed significantly better than when he was alone.

Drugs and Vigilance

Solandt & Partridge (1946) found that 10 mg. of benzedrine sulfate reduced the vigilance decrement significantly for a maximum of eight hours. Mackworth (1950), using the same dosage found that the decrement was, for all practical purposes, eliminated for the two hours of testing time he used. The authors reported no drug hangovers. But because of the possible side effects of this drug and also because it is habit forming, its use is certainly no long range remedy for the performance decrement in any vigilance situation.

Breakfast is by no means a "drug" but it is a variable that influences performance. For example, Tuttle et al. (1949) found that heavy and light breakfast groups performed better than no breakfast and coffee-only groups.

Alcohol and Vigilance

Solandt & Partridge (1946) found that moderate dosages of alcohol did not affect vigilance performance. It is probably safe to assume that larger amounts of alcohol would at least not improve sustained and difficult monitoring.

Incentives and Vigilance

Pollack & Anaff (1958) used neutral ("Do the best you can."), reward (extra pay for good performance), and punishment (0.5 second blast of a truck horn near the ear) conditions to test the effect of incentive condition upon vigilance performance. Under the punishment condition the percentage of signals detected increased, latency of response was shorter, and there were more false detections made. Performance was better under the reward conditions than under neutral conditions, but the improvement was not as great as that produced by punishment. There was, however, a consistent decrement in performance as a function of time on watch for all conditions. These investigators suggest that the truck horn served three functions: (a) as a "general arousal" stimulus, dispelling drowsiness; (b) it served as "punishment", jolting the observer for failure to detect the signal; (c) and as an "information" source notifying the observer that he missed a target.

Personal Variables

Individual differences among monitors in vigilance performance efficiency are very evident and tend to increase as the amount of time at the task progresses. The consistently reoccurring and reliable decrement curve is strictly the result of combining data from individual monitors. In almost any large group of monitors there will be a portion, usually 20 to 50 per cent of the total, which will show no decrement in performance at all (Solandt & Partridge, 1946; Mackworth, 1950; Holland, 1958).

Meanwhile, there is little information available concerning the reasons for the range and variability of individual performance.

Bakan (1955) and Jenkins (1950) found that vigilance performance is correlated with an individual's initial sensitivity for the detection required. That is, the individual's ability to perform under momentary, alerted conditions may be the best predictor of his performance under prolonged, watch-standing conditions.

Mackworth (1958) found no correlation between scores on a general intelligence test and vigilance performance. Kappauf & Powe (1959) did find a small correlation between AFQT (general intellectual aptitude) and vigilance performance, but significant only for high signal rates.

Visual acuity (Snellen eye chart) does not correlate with visual vigilance performance (Jenkins, 1958), women may be better performers than men (Whittenberg et al., 1956), less active subjects may perform better than active subjects (Baker, 1959), and extroverts benefit more from the introduction of a second task than do introverts (Bakan, 1957).

Finally, Dardano & Mower (1959) found that skin conductance is related somewhat to vigilance decrement and suggest that this could be used to activate a device which would arouse a failing observer.

KNOWLEDGE OF RESULTS

In a recent volume of the Annual Review of Psychology (1961) Bilodeau & Bilodeau make this statement:

> Studies of feedback and knowledge of results (KR) show it to be the strongest, most important variable controlling performance and learning. It has been shown repeatedly, as well as recently, that there is no improvement without knowledge of results, progressive improvement with it, and deterioration after its withdrawal.

This statement was made in a discussion of motor-skill tasks. Most of the research dealing with knowledge of results has been with performance in tasks which call for fine motor adjustments and response differentiation. The following discussion attempts to point up the fact that knowledge of results is also an extremely important variable in the performance of observers in sensory tasks. As pointed out by Wiener (1961), in motor-skills tasks such as tracking, the operator is continuously active and knowledge of results is in the form of error information which leads him to the target. With practice, performance increases to an asymptotic level. In a monitoring task the observer is inactive, the response is typically binary (detect or not detect) and the information provides little guidance in the usual sense. Performance decreases to an asymptotic level with time on task and there is no practice effect from session to session.

Since the topic of knowledge of results is both extensive and complex, and its relevance for the present paper limited to those feedback operations specifically applied in the experiment later discussed, only a few studies will be reviewed. These either discuss or demonstrate distinctions in the types, use and/or inferred functions of knowledge of results. No distinction will be made between the terms knowledge of results and feedback and they will be used interchangeably.

Miller (1953) has distinguished between two types of knowledge of results: action feedback and learning feedback. Learning feedback informs the subject what to do next as contrasted with action feedback which tells him what he should have done.

Brown (1961) sees knowledge of results as a process providing the subject with information as to how good or accurate his reactions are.

To the present author it seems that in these as well as other definitions a rough dichotomy is at least implied wherein straight information, as opposed to evaluation, is more important to learning while the evaluative aspect of knowledge of results is more motivational and an important variable in performance.

A second distinction is made by Annett (1961): intrinsic and extrinsic knowledge of results. Intrinsic knowledge of results is the proprioceptive data associated with making the response (c.f. Bahrick, 1957; Noble & Bahrick, 1956), or the exteroceptive data normally related to the response. Extrinsic knowledge of results refers to any additional data which is supplied to the subject by the experimenter.

For the purposes of this paper the term knowledge of results will be used only to refer to the extrinsic feedback to the subject from the experimenter, based on knowledge of performance, not available to the subject otherwise. The importance of the distinction between informational and evaluative feedback will be discussed below.

Knowledge of Results and Learning

There has generally been little interest in the learning that occurs during a vigilance session. Usually before a subject is run in a vigilance task, he is presented a few signals which are pointed out to him as such and he is then given a short trial run in order to insure that he is able to discriminate the signals and also understands the response he is to make when he detects the signal. Vigilance behavior is typically assumed to reflect strictly "performance."

The fact that observers can come to make finer discriminations of stimulation with practice is a well-documented fact (Gibson, 1953; Bevan, 1961). Research has shown that improvement occurs if the observer is informed of the correct response after each judgment but the results are somewhat unclear as to whether there is improvement in the absence of this or a similar feedback procedure. Gibson (1953) points out that the observer has an opportunity to learn, without explicit information from the experimenter, the range of the stimuli which provide him with a series of reference points for judging other stimuli. The array of the task series provide him with anchors which he can use to check his performance. Wedell (1934) has experimentally confirmed the capacity of observers to recognize end stimuli. This may simply mean that intrinsic rather than extrinsic knowledge of results is important here.

Knowledge of Results and Motivation

To say that providing knowledge of results is intrinsically and always reinforcing would be presumptuous. Hearing or seeing the results of one's performance may be reinforcing (negatively or positively) to an individual who has strong needs to achieve and sets his standards at high performance, but the implications might not be the same for a subject who reluctantly volunteers for, or has to participate in, an experiment which he neither understands nor finds interesting.

However, one finds much evidence that, in general, knowledge of results has a reinforcing effect on performance.

What is reinforced can be any discrete response, a series of responses, a response class, the direction of responding, the rate of responding, the omission of responses, or a general level of responding. The stimuli which can be used are such things as "right - wrong, good - bad, uh hum - huh uh, have a cookie," lights, buzzers, shock and the giving and taking away of points, money, or rating. These stimuli, in terms of the distinction which was earlier attempted, are all more in line with what we termed "evaluative" feedback as opposed to more strictly informational feedback such as "off 3.2 inches, etc." which often may have more of a directional component and less evaluation.

Ross (1927) trained three groups to overlearning in a cancellation task. During the next few days the first group was given full information including the previous day's score, the second group was told whether performance was above or below average and a third group was given no knowledge of results at all. After the third practice session the full knowledge of results group drew ahead of the other two groups and later, after seven more days of practice, the partial knowledge of results group drew ahead of the no knowledge of results group.

McClelland & Apicella (1947) experimentally induced success and failure in a timed card sorting task by means of real and false knowledge of results and found a failure group inferior to a neutral group. Then after the groups were allowed to rest by practicing another task successfully, the failure group proved to be superior when retested on the original task. The authors concluded that perceived failure produced conflicts in responding which lowered the level of performance.

McClelland (1955) discusses the use of knowledge of results to foster self or social competition and labels the motivation as a desire to achieve success in the task.

Arps (1917) reported that performance on an ergograph was improved by giving knowledge of results even when there was no directional component. The work without knowledge of results was reported to be dull and subjects were said to be poorly motivated.

Crawley (1926) found similar results in a task where his subjects lifted weights to the beat of a metronome almost to the point of exhaustion. Then, on being allowed to watch a kymographic record of their efforts, they recovered completely and even exceeded the limits of performance reached on "non-incentive" trials. After the removal of knowledge of results, however, performance dropped below the original level.

Knowledge of Results and Vigilance

Research findings show that providing the monitor with knowledge of results greatly decreases or even prevents the vigilance decrement.

Mackworth (1948), using his regular two-hour vigilance session, informed one of two groups that sometime during their monitoring they would receive an important telephone call. After one hour had passed, each subject was called and told to "get busy" and to try to detect more double jumps during the next hour. Performance improved during the next half-hour to a level above the highest level before the occurrence of the decrement. The second group acted as a control (see Figure 3). The interpretation here is that the subject perceived Mackworth's message as an evaluation of his previous performance as not satisfactory.

In another study, Mackworth (1950) compared the performance of an experimental group given total knowledge of results (knowledge of correct and incorrect detections and failure to respond) and a control group given no knowledge of results. The experimental group showed no significant decrement. The nature of the knowledge of results was "Yes, that was right" if a signal was correctly detected, "No, that was wrong" for a commissive error and "You missed one there" for an error of omission.

Baker (1959c) compared the performance of groups under two different types of knowledge of results and no knowledge of results. The first type was total knowledge of results given through an auxillary display (a box in which the words "correct," "miss," or "false," were illuminated for one second when a signal was correctly detected, missed, or when a non-existent signal was reported). The second type consisted of repeating a missed signal at five-second intervals until it was reported, and the observer was credited with a missed detection. His results showed no significant decrement for the two types of knowledge of results. In contrast the no knowledge of results group did show decrement.

McCormack (1959) compared the performance of a group with knowledge of results and a group with no knowledge of results, using response-time

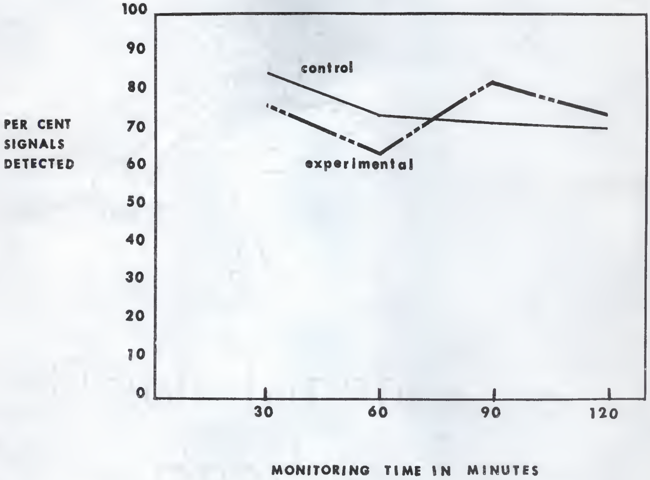

Fig. 3. The effects of a telephone message delivered to subjects at the end of 60 minutes of time on watch. (Mackworth, 1948).

to reflect decrement. Under the knowledge of results condition, a red light was presented each time S made a response which was slower than the preceding one. If a faster response was made, a green light appeared. Under the control condition, the red and green lights were not used. Response-time of both groups increased significantly throughout the duration of the task, this increase being more pronounced under the no knowledge of results condition than under the knowledge of results condition.

Wiener (1961) found result similar to those above using a series of three lights to give both full knowledge of results and partial knowledge of results.

While the experimental results are in full agreement, the explanations offered to account for the maintenance or recovery of performance under knowledge of results conditions are not.

Although most writers consider the function of knowledge of results in a vigilance task as motivational, Baker (1959) does not. He sees knowledge of results as providing information to the observer concerning the "true temporal nature" of a series of signals. This knowledge in turn increases the probability of confirmation of expectancies. Thus, knowledge of results merely tells the observer when a signal has occurred and whether it has been detected.

Mackworth sees knowledge of results as providing repeated reinforcement to a conditioned responses and thus preventing its extinction. In the case of the telephone message he interprets this call as functioning as a disinhibiting stimulus.

Deese & McBain, in line with their "activation approach," would probably attribute the increased performance with knowledge of results as a function of the added total stimulation and/or of the less monotonous and varied input. But findings of Weidenfeller et al. (1962) show that the subject must perceive the feedback as "relevant to the task" in order for it to be effective. Knowledge of results and false knowledge of results both enhanced performance but additional task-irrelevant information did not.

An interpretation which arises out of the earlier general discussion concerning knowledge of results and motivation suggests that the observer perceives the situation as one challenging certain needs (achievement, competence, etc.) and consequently enters into a type of competition with himself or the experimenter.

Meanwhile certain previously discussed discrepancies in the theory of the vigilance decrement as extinction of a classically conditioned response tend to discredit Mackworth's interpretation of the working of knowledge of results.

Baker, suggesting an explanation with no motivational or energizing component, takes a very tenuous position. He states (1959) that his expectancy approach should hold for any level of motivation on the part of the observer. A highly motivated observer may lose efficiency with brief, weak, irregularly-spaced infrequent signals. At the same time a poorly motivated observer may perform acceptably if signals are strong, prolonged, frequent, and regularly spaced. In light of our previously acquired knowledge about the relationship of performance and motivation and the vigilance studies having to do with extrinsically induced motivation it is hard for the author to accept this explanation as sufficient.

In addition, in McCormack's (1959) knowledge of results condition, the feedback in no way gave any indications of omissive errors, therefore, no additional knowledge was available to the knowledge of results group about the "true" temporal intervals.

Knowledge of Results in the Training of a Monitor

The first published speculation concerning the possibility of training a monitor by the use of knowledge of results was by Baker (1958). In considering the function of knowledge of results as an aid to the learning of "expectancies" (mean intersignal interval) for maximum prediction of the next signal; he reasoned that once learning had taken place, the knowledge of results could be discontinued with no decremental after-effect.

Wiener (1961) using three lights for knowledge of results found that the enhancing effect of knowledge of results upon monitoring performance transferred to subsequent performance a day later under no knowledge of results conditions. In addition, there was no practice effect in the control group. In the same experiment he also tested for a transfer-of-training effect using signal rates of 48, 32, and 16 signals per hour with a test rate on day 2 of 32 signals per hour. His results showed a significant transfer effect for a group trained on a faster signal-rate (trained on 48 signals per hour and tested on 32 signals per hour).

THE INFLUENCE OF EXTRINSIC KNOWLEDGE OF RESULTS UPON PERFORMANCE IN A MONITORING TASK

The previous discussion of vigilance, knowledge of results, and the effects of knowledge of results upon vigilance performance was intended to set the background for the presentation of the following experiment. The purpose of this experiment was to test certain previous findings and to further determine the extent of the transfer effects of training under two forms of knowledge of results. More specifically, subjects were introduced into a vigilance task on Day 1 under conditions of total feedback given (a) verbally, (b) by means of lights, or (c) under conditions of no knowledge of results. They were all then tested on Days 2 and 8 under equivalent conditions of no knowledge of results.

Method

Apparatus

The vigilance task used was a modified version of the Mackworth Clock Test (Mackworth, 1944). The display was a Standard Laboratory Timer with the clock face reversed such that a uniform white surface with a single black hand was seen by the observer. The timer was enclosed in a slightly larger black wooden box, padded with foam rubber and having a clear plexiglass side which allowed the subject to view the clock face.

The single clock hand was driven by a control unit built by the Yellow Springs Instrument Company to specifications of Dr. Harry Jerison. The hand moved clockwise around the clock face in equidistant discrete jumps every one second and covering an angle of 15 degrees each. There were 24 jumps per complete revolution. The critical signal was a "double jump" (actually 27 degrees) and was presented to the subject in a predetermined schedule which was based on a rate of 36 signals per hour. The schedule was punched into standard 5-channel Western Union tape and stepped through a Western Union Model 24-B tape reader. The time intervals between double jumps ranged from 30 to 180 seconds. (For an exact specification of the schedule see Appendix I.)

The clock was placed slightly below average eye-level on a black wooden typewriter stand. On either side of the box was a small (7 volt) incandescent light bulb, one green and one red. The former was used to signal correct, the latter incorrect responses. A small black spring loaded switch was also mounted on the display stand. Black muslin cloth was then draped over all the display except the feedback lights, the response switch and the clock itself so as to increase the uniformity of the total display. A small amplifier which delivered the verbal knowledge of results was concealed from the observer.

The observer's compartment was approximately 3 feet by 7 feet, painted or otherwise colored by only uniform gray or black, and dimly illuminated.

In one form the knowledge of results was given to the subject by way of the green (correct) or the red (Type I and Type II errors) lights and was presented by the experimenter 1 second after the subject's response for a correct response or a commissive error, 3 to 4 seconds after the signal in the case of an ommissive error. The experimenter did not have to monitor but rather received his information about the occurrence of the signal and the subject's response by way of a network of very apparent lights, buzzers, and a vibrator located in his trousers pocket. Therefore the statement that the experimenter missed no signals can be made with a high degree of confidence. The second form was knowledge of results presented verbally to the subject through an amplifier located near the subject. The word "right" was given for correct detections and "wrong" was given for Type I and Type II errors using the same intervals as those preceding the knowledge of results presented with the lights.

Each signal presented to the subject and each response made by the subject was automatically recorded on separate channels of an Esterline-Angus 20 Pen Event Recorder. (The time line of the record proved to be extremely accurate.)

The subject wore earphones during the entire monitoring session and received white noise at an intensity level of 79 db. This masked all equipment noise and isolated the subject auditorily. However, the subjects receiving verbal knowledge of results during the training session were able to clearly hear the reinforcement.

Subjects

The subjects used were drawn from several introductory psychology classes at Kansas State University, where serving as experimental subjects constitutes a course requirement. A total of 60 subjects were used of which 30 were males and 30 females. Subjects were assigned randomly to the control and two experimental groups. However, an equal number of males and females was maintained in all groups.

Design

The design of the experiment may be described in terms of six conditions for Day 1. The conditions were factorial aspects of two variables: (a) types of knowledge of results and (b) experimenter present in the room with the subject or not in the room with the subject (see Figure 4). On days 2 and 8 the subjects were all tested without knowledge of results and with the experimenter absent. The group which was trained without knowledge of results and with experimenter not present for all three sessions provided the traditional control conditions as well as a check on any practice effects which might occur.

Uncorrelated or "between subject," components in the design were type of knowledge of results, subject's sex, experimenter present or not present, and their exclusive interactions. Correlated or "within subject" components were trials (successive blocks of performance time) and days as well as all possible interactions containing a "within" term.

Procedure

As mentioned before, prior to the first session the subjects were randomly assigned to conditions and upon arriving they were seated and read the instructions appropriate to their particular condition (see Appendix II). All subjects wearing watches were asked to remove them and they were placed on a table which was out of sight and reach of the subject. Subjects were then shown the regular jumps of the clock hand, a sample double-jump, and the appropriate response for a detection. They were next given a short series with occasional double-jumps interpolated within the series of regular jumps and were instructed to activate the

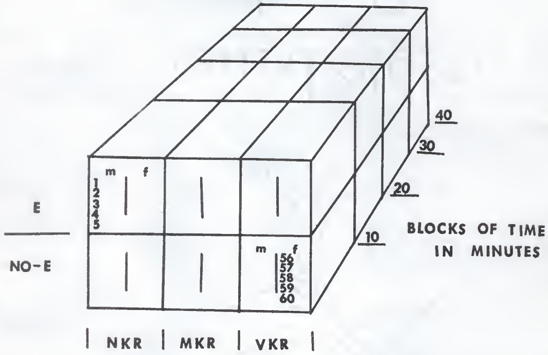

Fig. 4. Experimental design for Day 1. NKR refers to the control group which was given no knowledge of results, MKR refers to the condition of knowledge of results presented through signal lights (mechanically), and VKR refers to the condition of knowledge of results given verbally by the experimenter. E refers to experimenter present in the monitoring situation and NO-E refers to the conditions in which the experimenter was not in the monitoring situation.

response switch as quickly as possible upon seeing a double jump. All subjects received complete verbal knowledge of results concerning their performance with these introductory signals. The actual monitoring session began after the subject detected three of the sample double jumps, had responded appropriately, and had had answered for him questions concerning procedure.

On Days 2 and 8 the subject was not given the introductory signals. He was simply told that the task was the same. If he had received knowledge of results, he was told that there would be none and asked if there were any questions.

Under those conditions calling for his presence, the experimenter simply sat in a chair placed directly behind the subject. When the experimenter was not present in the room with the subject, he was located in a room adjacent to the subject's room (where the control equipment was also housed) and a one-way vision window allowed him to closely observe the subject.

Results

Analyses of the data in this experiment were performed upon the number of correct detections per ten minute block of time. However, for ease of comparison the data are graphically presented in terms of per cent correctly detected.

Figure 5 compares the per cent detected by each group as a function of lapsed time, on day number 1. The types of knowledge of result are summed over the sex and experimenter present or absent conditions.

Figure 6 compares the per cent detected over time for the control

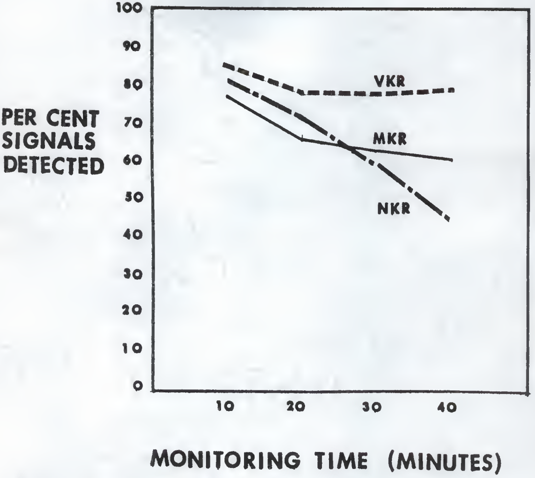

Fig. 5. Per cent of signals detected for 3 conditions of knowledge of results for Day 1 only. NKR refers to the control group which was given no knowledge of results, MKR refers to the condition of knowledge of results presented through signal lights (mechanically), and VKR refers to the condition of knowledge of results presented verbally by the experimenter.

and the types of knowledge of result conditions summed over the days, sex, and experimenter present or absent variables.

Figure 7 compares the per cent detected for the two condition of knowledge of results and the control group for each individual day.

Table 1 is the grouping of the raw data into the smallest groups of subjects within simple conditions and presented in terms of per cent of the signals detected.

Table 1

Per Cent Detection for Type of Knowledge of Results, Day, Sex, and Experimenter Present or Not Present

		NKR		MKR		VKR	
		E	No-E	E	No-E	E	No-E
Day 1:	Male	67	59	67	66	77	83
	Female	53	77	71	66	70	90
Day 2:	Male	67	72	64	63	75	70
	Female	46	66	76	63	71	84
Day 3:	Male	67	67	72	68	79	67
	Female	51	72	64	53	69	81

NKR refers to the no knowledge of results condition, MKR refers to the knowledge of results presented mechanically (lights) and VKR refers to verbally presented knowledge of results. E is the experimenter present condition and no-E refers to the condition of the experiment not present. It should be kept clear that these values are per cent detections while the values in the analyses tables are total number of detections.

The analysis of variance of the complete design is presented in Tables 2 and 3. The types of presentation of knowledge of results are represented by the letters KR and symbolized in the interaction terms by K. The variable of experimenter present or not present is represented

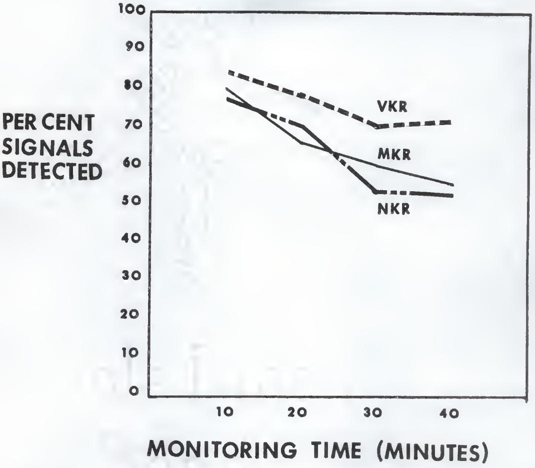

Fig. 6. Per cent of signals detected for 3 conditions of knowledge of results over all three days. NKR refers to the control group which was given no knowledge of results, MKR refers to the condition of knowledge of results presented through signal lights (mechanically), and VKR refers to the conditional knowledge of results presented verbally by the experimenter.

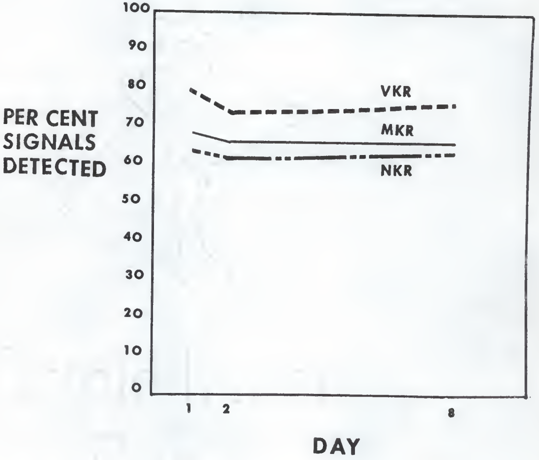

Fig. 7. Per cent of signals detected under 3 conditions of knowledge of results for each day. NKR refers to the control group which was given no knowledge of results, MKR refers to the condition of knowledge of results presented through signal lights (mechanically), and VKR refers to the condition of knowledge of results presented verbally by the experimenter.

by the word "experimenter" and symbolized in the interaction terms by E. The sex variable is represented by "sex" and by S in the interaction terms. The word "blocks" refers to successive ten-minute blocks of monitoring time and is represented in the interaction terms by B. "Days" stands for the three days on which data was collected, i.e., Day 1, Day 2, and Day 8. Days are represented in the interaction terms by D. Only those F-ratios which have a probability level of less than .01 are considered significant.

The results of the analysis are simple and clear cut. The only significant components of variance are (a) between types of knowledge of results, and (b) between blocks of time.

Table 2

Summary of the Analysis of Variance of Uncorrelated Measures

Source	df	MS	F	p
BETWEEN SUBJECTS	59			
Knowledge of Results	2	490.72	5.31	$<.01$
Experimenter	1	166.66	1.80	n.s.
Sex	1	4.26	.05	n.s.
K x E	2	208.54	2.26	n.s.
K x S	2	51.12	.55	n.s.
E x S	1	355.28	3.85	n.s.
K x S x E	2	204.30	2.21	n.s.
Between subject's error	48	92.36		

Table 3

Summary of the Analysis of Variance of Correlated Measures

Source	df	MS	F	p
WITHIN SUBJECTS	719			
Blocks	3	66.94	48.51	< .01
Days	2	2.52	1.94	n.s.
B x D	6	1.00	.39	n.s.
K x B	6	3.55	2.57	n.s.
K x D	4	1.00	.75	n.s.
B x S	3	.85	.62	n.s.
B x E	3	1.71	1.24	n.s.
D x S	2	1.29	.99	n.s.
D x E	2	.71	.55	n.s.
K x B x D	2	1.46	.56	n.s.
K x B x S	6	1.58	1.14	n.s.
K x B x E	6	3.00	2.17	n.s.
K x D x S	4	4.28	3.29	n.s.
K x D x E	4	.42	.32	n.s.
B x D x S	6	.58	.45	n.s.
B x D x E	6	.22	.08	n.s.
B x S x E	3	.53	.38	n.s.
D x S x E	2	.27	.21	n.s.
K x B x D x S	12	.90	.35	n.s.
K x B x D x E	12	.77	.30	n.s.
K x B x S x E	6	1.22	.88	n.s.
K x D x S x E	4	1.74	1.34	n.s.
B x D x S x E	6	1.55	.61	n.s.
K x B x D x S x E	12	1.20	.47	n.s.
Error Terms				
Sj x B	177	1.38		
Sj x D	118	1.30		
Sj x B x D	354	2.59		

Since the knowledge of results variable is a fixed effect, a subsequent msd (most significant difference)[1] was computed. Mean comparison data for the three different conditions of knowledge of results are shown in Table 4. This comparison showed that there is no significant difference between no knowledge of results and knowledge of results provided by signal lights while verbally presented knowledge of results is significantly better than the control group (also see Figure 7).

Table 4

Comparison of Means of the 3 Types of Knowledge of Results for All 3 Days (Values Are Mean Number of Detections)

$$\text{msd}^1 = t_{.01}, \text{ df } \sqrt{\frac{2 \text{ MS within}}{n}}$$

$$\text{msd} = 2.68 \sqrt{\frac{2\ (92.36)}{20}}$$

$$\text{msd} = 2.68 \times 3.03$$

$$\text{msd} = 8.12$$

Mean Value for Type of Knowledge of Results

NKR	MKR	VKR
45.70	47.85[2]	55.15

(45.70 and 47.85 are underlined together.)

[1]msd = most significant difference. When used following an F-test it approximates the .01 alpha level with good power and reasonable insurance against frequent Type II errors.

[2]Means which are underlined are not significantly different at .01 level.

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[1]This is the 1 per cent corollary of the more popular lsd discussed in Federer (1955).

Table 5 is an analysis of variance performed on the three conditions of knowledge of results on Day 1 only. The overall results are significant. Table 6 is a comparison of mean performance for Day 1. This reveals that the verbally administered knowledge of results yields significantly better performance than mechanically presented knowledge of results or no knowledge of results, and mechanically presented knowledge of results and no knowledge of results are not significantly different from each other.

Table 5

Summary of an Analysis of Variance Performed on the 3 Conditions of Knowledge of Results for Day 1 Only

Source	df	SS	MS	p
Between knowledge of results	2	172.90	86.45	$<.01$
Within knowledge of results	57	601.95	10.56	
Total	59	774.85		

As shown in Tables 2 and 3, there is no significant difference between the performance of males and females or performance in the presence of the experimenter as contrasted to performance in his absence.

A negative, but important finding is that there are no significant differences in performance among the monitoring days. This finding taken along with the significant differences in performance under the condition of verbally presented knowledge of results and no significant interactions indicates that the higher level of performance is maintained over all days.

Table 6

A Comparison of Means of the 3 Types of Knowledge of Results for Day 1 Only (Values Are Mean Number of Detections)

$$msd^{1} = t_{.01},\ df \sqrt{\frac{2\ MS\ (within)}{n}}$$

$$msd = 2.66 \sqrt{\frac{2\ (10.56)}{20}}$$

$$msd = 2.66 \times 1.03$$

$$msd = 2.74$$

Mean Value for Type of Knowledge of Results

NKR	MKR	VKR
15.35	16.20[2]	19.30

[1]msd = most significant difference. When used following an F-test it approximates the .01 alpha level with good power and reasonable insurance against frequent Type II errors.

[2]Means which are underlined are not significantly different at .01 level.

Discussion

The major finding of this experiment is that the enhanced level of performance associated with verbally presented knowledge of results carries over to monitoring on the same task a day later and also a full week later.

The enhancement of performance during the presence of verbally supplied knowledge of results (Day 1) is generally in agreement with the findings of Mackworth (1948, 1950).

The findings that knowledge of results provided by signal lights have no effect upon performance is in disagreement with the findings of Baker (1959c) and Wiener (1961). One difference between the feedback display of this experiment and the displays of the two experiments previous cited is the lack of written words displayed with the illuminated signal. The experimental subjects in the present experiment were simply informed that the red light meant that he had either missed a double jump or that he had mistaken a single jump for a double jump. Similarly he was told that the green light meant that he had correctly detected a signal. "Red is for wrong and green is for correct." The above-mentioned difference may or may not account for this discrepant finding, but in the present study the findings are clear cut, consistent over days, and highly reliable.

Figure 7 shows that the decrement is common to all conditions of knowledge of results but that the overall level of efficiency is clearly higher for verbally presented knowledge of results than for the other two conditions.

No significant differences were found in vigilance performance as a function of the physical presence or the absence of the experimenter at the subject's work site. Similarities of age and dress of the experimenter and the subjects may account for the lack of any motivating effect due to the experimenter's presence. Discussed earlier were the findings of Fraser (1953) who found that when a person viewed as an authority figure remained in the subject's room, the subject's monitoring behavior improved and the findings of Pollack & Knaff (1958) who found no difference in individuals working in isolation and those working in the same room with other operators.

Whittenberg et al. (1956) have suggested that women may be better monitors than men but the results of the present experiment point to no sex differences in vigilance performance.

The consistent differences between verbally presented knowledge of results and knowledge of results presented with lights needs to be examined. Why should knowledge of results supplied verbally by the experimenter lead to enhanced performance but knowledge of results supplied by mechanical signals not enhance performance? A simple but plausible explanation concerns the attitudes that individuals adopt when they are part of a man-machine system. Common sense suggests that not many persons are distressed when a machine reveals to the operator himself the limits of his own performance, because one does not compete in the usual sense with a machine nor does the machine evaluate in the usual sense. The signal lights as knowledge of results were a part of the display and were activated in a mechanically regular fashion. Although for half of the signal light conditions the experimenter was sitting directly behind the subject, he was unable to view the display and his relation to the presentation of knowledge of results was not perceived by the subject. Here it would appear that the subjects viewed the feedback mechanism as a strictly mechanical and automatic affair and viewed the experimenter as unrelated to systems operation. They therefore did not feel the pressures ordinary associated with personal evaluation.

One subject in the verbal knowledge of results condition carried on a running commentary with the verbal knowledge of results source (the experimenter), and two other subjects, at the end of the session, challenged the experimenter's ability to be absolutely correct in saying for sure when there was and was not an elusive double-jump. These data are taken by the experimenter as evidence of personal involvement with the task, arising from the personal nature of the knowledge of results. In the verbal knowledge of results condition with the experimenter present the identification of the experimenter as the source of evaluative knowledge of results was manifestly clear. It would thus appear that an observer must have a defined role relative to the subject's task in order to have any significant effect on his monitoring performance.

It has just been suggested that there may well be a difference in implication between knowledge of results supplied by a human observer and knowledge of results supplied by parts of the equipment programmed to indicate right and wrong. It is conceivable that the subject may not perceive an "evaluator" in a mechanical feedback loop at all. If the mechanical means is to be an effective reinforcer, then the subject must perceive a human component somewhere in the feedback loop, i.e., the experimenter must be seen to assess and evaluate the behavior and directly initiate the reinforcement.

Since there was just as much information concerning the "true temporal course" of the signals in the mechanically presented knowledge of results as in the verbally presented knowledge of results, Baker's theory would have predicted that the two groups would have performed at the same level. But, they did not. Occasionally, one observes that subjects in the Clock Test will count all the single jumps between critical signals. This attempt to gain knowledge of the regularity or spacing of the signals would appear to be consistent with Baker's expectancy hypothesis. But the subjects who count also appear to be the highly motivated subjects and are high performance subjects. Gaining accurate knowledge of the temporal point of maximum probability of signal occurrence is definitely an important variable, but this type of performance in itself demands an active interest and involvement in the task, and thus a high level of motivation. It is this "task motivation" which is missing from Baker's (1959) theory. Also, in the practical monitoring situation the mean intersignal interval may be meaningless as the signal rate is often highly variable and changing and frequently contingent on the operators performance itself.

Perhaps the possible role of task motivation and level of activation in vigilance situations needs to be examined. The dock workers discussed by Broadbent (1957) and the hand-wheel operators studied by Saldanha (1956) were active but still suffered a vigilance decrement. One could not say these people were stimulus deprived but it is quite possible that the stimulus patterning was monotonous and their work was probably only minimally challenging. Theoretically, if it were possible to raise the level of activation of the worker (by providing non-monotonous, frequent, varied, and moderately intense stimuli) or to increase his task motivation (by creating personal challenge in his work with appropriate and response-contingent reinforcement), then to the degree that these were increased we would expect an increase in the worker's performance. But the type of signal in a vigilance situation by definition is subtle and infrequent and the adding of task un-related stimulation is just adding noise. Also, if one simply raises a monitor's activation level by introducing prominant stimulation into the task, one is only providing a temporary support. With the removal of these stimuli, performance will resume its former lower level. However, in the case of reinforced behavior (knowledge of results) we have learned that situational stimulation can come to function in a reinforcing manner after removal of the originally reinforcing stimulus. Also, performance in this situation can be maintained for an indefinite length of time by the re-introduction of the original reinforcement, or even without any support from the original stimulation (functional automony). Therefore, only one of these concepts is relevant for the task of lastingly energizing the performance of a monitor. Training for a nonlearning performance task such as vigilance work, should be in the form of creating a reinforcing work situation.

During the present research it became clear to the author that experimental conditions which may be capable of psychologically arousing a monitor to a well-motivated and persistently high-performance level in a typical vigilance situation, must be task relevant. The task itself must make sense to the subject and be perceived by the subject as challenging. Reinforcement should be contingent upon the subject's performance. The determination of what is significantly reinforcing in a vigilance task is primarily an empirical matter.

One implication of this study is that it would appear to be possible to devise a training program for monitors involving verbally presented knowledge of results which would yield a higher level of monitoring performance on subsequent monitoring tasks under conditions of no knowledge of results. Such a training program would be inexpensive and of short duration. It is necessary that a person with a clear evaluative role in training furnish the knowledge of results.

Summary

An experiment was performed to determine whether monitors trained in a vigilance task with one or the other of two types of presentation of knowledge of results would maintain a higher level of performance in subsequent monitoring tasks than subjects trained without knowledge of results. The two types of presentation of knowledge of results were (a) knowledge of performance provided by a human observer and (b) knowledge provided by a signal light. The experimental task was a modification of the Mackworth Clock Test. Each subject was tested individually after instructions to report the critical signal, a double jump of the clock hand. The subjects were presented the same task, but without knowledge of results, one day later and then again one week later.

Results indicate that the group trained with verbally supplied knowledge of results performed at a significantly higher level than the control group during initial performance as well as on Day 2 and Day 8. The group trained with knowledge of results provided by signal light did no better than the control group given no knowledge of results during training.

Several additional findings are of interest: The data show no sex differences in monitoring ability. The mere presence of the experimenter in the room with the subject had no significant effect on performance. And there is no practice effect in vigilance performance.

Possible interpretations and implications of these research findings are discussed.

ACKNOWLEDGMENTS

The author is indebted to Dr. William Bevan for his financial support of this project through contract Nonr-3634(01) between Kansas State University and the Office of Naval Research and also to Dr. Bevan and Dr. Don A. Trumbo for their roles as major advisors.

Thanks are due to Dr. Harry Jerison and Dr. Dean Chiles for their part in arranging for the loan of apparatus from the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. Thanks are also due Dr. Jerison for suggestions concerning vigilance research methodology gained through conversations with him. Finally the author is grateful to Drs. John Overall and Roshan Chaddha for their help as statistical consultants.

REFERENCES

Adams, J. A. Vigilance in the detection of low-intensity visual stimuli. *J. exp. Psychol.*, 1956, *52*, 204-208.

Annett, J. The role of knowledge of results in learning a survey. Tech. Rep.: NAVTRADEVCEN, 1961, 342-343.

Arps, G. F. A preliminary report on work with knowledge versus work without knowledge of results. *Psychol. Rev.*, 1917, *24*, 449-455.

Bahrick, H. P. An analysis of stimulus variables influencing the proprioceptive control of movements. *Psychol. Rev.*, 1957, *64*, 324-328.

Bakan, P. Discrimination decrement as a function of time in a prolonged vigil. *J. exp. Psychol.*, 1955, *50*, 387-390.

Bakan, P. The change in threshold as a measure of decrement in a vigilance task. Univer. of Illinois Train. Res. Lab. Mimeo. Rep., 1962, (Oct.), No. B-5.

Baker, C. H. Attention to visual displays during a vigilance task. II. Maintaining the level of vigilance. Med. Res. Council Appl. Psychol. Res. Unit Rep., 1958, No. 2954-58.

Baker, C. H. Three minor studies of vigilance. Defen. Res. Med. Lab. Rep., 1959, No. 234-2.

Baker, C. H. Probability of signal detection in a vigilance task. *Science*, 1962, *136*, No. 3510, 46-47.

Bartlett, S. G., Beinert, R. L., & Graham, J. R. Studies of visual fatigue and efficiency in radar observation. Hobart & Williams Smith Coll. Rep., 1955.

Berlyne, D. E. Attention to change. *Brit. J. Psychol.*, 1951, *42*, 269-278.

Bevan, W. Perceptual learning: an overview. *J. gen. Psychol.*, 1961, *64*, 69-99.

Blair, W. C. Measurement of observing responses in human monitoring. *Science*, 1958, *128*, 255-256.

Broadbent, D. E. The twenty-dials test under quiet conditions. Med. Res. Council Appl. Psychol. Res. Unit Rep., 1950, No. 130-50.

Broadbent, D. E. The twenty-dials test and twenty-lights test under noise. Med. Res. Council Appl. Psychol. Res. Unit Rep., 1951, No. 160-51.

Broadbent, D. E. Noise, paced performance, and vigilance tasks. Brit. J. Psychol., 1953, 44, 295-303.

Broadbent, D. E. The vigilant man and the active man. Advncmt. Sci., 1957, 53, 399-402.

Broadbent, D. E. A mechanical model for human attention and immediate memory. Psychol. Rev., 1957, 64, 205-215.

Brown, J. S. A proposed program of research on psychological feedback (knowledge of results) in the performance of psychomotor tasks. In Research Planning Conference on Perceptual and Motor Skills. AF HRRC Conf. Rep. 49-2, 81-87 (U.S.A.F., San Antonio, Texas, 98 pp., 1949).

Crawley, S. L. An experimental investigation of recovery from work. Arch. Psychol., 1926, 13, No. 85, 66.

Dardano, J. F., & Mower, I. Relationships of intermittent noise, intersignal interval, and skin conductance to vigilance performance. Hum. Eng. Lab. Tech. Memo., 1959, No. 7-59. Aberdeen Proving Ground, Maryland.

Deese, J. Some problems in the theory of vigilance. Psychol. Rev., 1955, 62, 359-368.

Deese, J. Changes in visual performance after visual work. USAF WADC Tech. Rep., 1957, No. 57-285.

Deese, J., & Ormond, E. Studies of detectability during continuous visual search. USAF WADC Tech. Rep., 1953, 53-8.

Federer, W. T. Experimental design. New York: Macmillan, 1955.

Frankmann, J. P., & Adams, J. A. Theories of vigilance. Univer. of Illinois Aviat. Psychol. Lab. Tech. Note, 1960, No. AFCCDD-TN-60-25.

Fraser, D. C. The relation between angle of display and performance in a prolonged visual display. Quart. J. exp. Psychol., 1950, 2, 176-181.

Fraser, D. C. Relationship of an environmental variable to performance in a prolonged visual task. Quart. J. exp. Psychol., 1953, 5, 31-32.

Gibson, Eleanor J., & Gibson, J. J. Perceptual learning: differentiation or enrichment? Psychol. Rev., 1955, 62, 32-41.

Hebb, D. O. Drives and the conceptual nervous system. Psychol. Rev., 1955, 62, 243-253.

Helson, H. Adaptation level theory. In S. Koch (Ed.), Psychology: a study of a science, Vol. I. New York: McGraw-Hill, 1959, Pp. 565-617.

Holland, J. G. Human vigilance. Science, 1958, 128, 61-67.

Howland, D. The human as a monitor in a man-machine system. News in Engng, 1956 (July), 23-29. Ohio State Univer.

Jenkins, H. M. The effect of signal rate on performance in visual monitoring II. Amer. J. Psychol., 1958, 71, 647-661.

Jerison, H. J. Experiments on vigilance: duration of vigil and the decrement function. USAF WADC Tech. Rep., 1958, No. 58-369.

Jerison, H. J., & Wallis R. A. Experiments on vigilance: one-clock and three-clock monitoring. USAF WADC Tech. Rep., 1957, No. 57-206.

Jerison, H. J., & Wallis, R. A. Experiments on vigilance: performance on a simple vigilance task in noise and quiet. USAF WADC Tech. Rep., 1957, No. 57-318.

Jerison, H. J., & Wing, S. Effects of noise and fatigue on a complex vigilance task. USAF WADC Tech. Rep., 1957, No. 57-14.

Kappauf, W. E., & Powe, W. E. Performance decrement on an audio-visual checking task. J. exp. Psychol., 1959, 57, 49-56.

Loeb, M., & Jeantheau, G. The influence of noxious environmental stimuli on vigilance. J. appl. Psychol., 1958, 42, 47-49.

Mackworth, N. H. Notes on the clock test--a new approach to the study of prolonged visual perception to find the optimum length of watch for radar operators. Med. Res. Council Appl. Psychol. Res. Unit Rep., 1944, No. 46-348.

Mackworth, N. H. The breakdown of vigilance during prolonged visual search. Quart. J. exp. Psychol., 1948, 1, 6-21.

Mackworth, N. H. Researches on the measurement of human performance. Med. Res. Council Spec. Rep. Series, 1950, No. 268.

Mackworth, N. H. Some factors affecting vigilance. Advancmt. Sci., 1957, 53, 389-410.

Mackworth, N. H., & Winson, F. H. Effects of benzedrine sulphate on a visual vigilance test. Med. Res. Council Appl. Psychol. Res. Unit Rep., 1947, No. 72.

McBain, W. N. The arousal hypothesis and effectiveness in a monotonous work situation. Paper read at Western Psychol. Ass., San Diego, May, 1959.

McClelland, D. C. Studies in motivation. New York: Appleton Century Crofts, 1955.

McClelland, D. C., & Apicella, F. S. Reminiscence following experimentally induced failure. J. exp. Psychol., 1947, 37, 159-169.

McCormack, P. D. Performance in a vigilance task as a function of interstimulus interval and interpolated rest. Canad. J. Psychol., 1958, 12, 242-246.

McCormack, P. D. Performance in a vigilance task with and without knowledge of results. Canad. J. Psychol., 1959, 13, 68-72.

McFarland, R. A., Holway, A. N., & Hurvich, L. M. Studies of visual fatigue. Harvard Grad. Sch. Bus. Admin. Rep., 1942.

Miller, R. B. Handbook of training and training equipment design. USAF WADC Tech. Rep. 53-136, 1953.

Mowrer, O. H. Preparatory set (expectancy): some methods of measurement. Psychol. Monogr., 1940, 52, No. 2 (Whole No. 233).

Nicely, P. E., & Miller, G. A. Some effects of unequal spatial distribution on the detectability of radar targets. J. exp. Psychol., 1957, 53, 195-198.

Noble, M. E., & Bahrick, H. P. Response generalization as a function of intratask response similarity. J. exp. Psychol., 1956, 51, 405-412.

Pollack, I., & Knaff, P. R. Effect of rate on target presentation on target detection probability. Amer. Psychologist, 1958, 13, 414.

Ross, C. C. An experiment in motivation. J. Educ. Psychol., 1927, 18, 337-346.

Saldanha, E. L. An investigation into the effects of prolonged and exacting visual work. M.R.C., App. Psychol. Res. Unit Rep., No. 243. (Unpublished.)

Simonson, E., Brozek, J., & Keys, A. Effects of meal on visual performance and fatigue. J. Appl. Psychol., 1948, 1, 207-278.

Solandt, D. Y., & Partridge, D. M. Research on auditory problems presented by naval operations. J. Canad. Med. Serv., 1946, 3, 323-329.

Tuttle, W. W., Wilson, M., & Dawn, K. Effects of altered breakfast habits on physiologic response. J. Appl. Psychol., 1949, 1, 545-557.

Wedell, C. H. The nature of the absolute judgment in pitch. *J. exp. Psychol.*, 1934, *17*, 485-503.

Weidenfeller, E. W., Baker, R. A., & Ware, J. R. Effects of knowledge of results on vigilance performance. *Percept. mot. Skills*, 1962, *14*, 211-215.

Wherry, R. J., & Webb, W. B. An experiment in prolonged vigilance. U.S. Naval School of Aviation Medicine, Univer. of Florida, 1959.

Wiener, E. Knowledge of results and the monitoring problem. Unpublished doctoral dissertation, Ohio State Univer., 1961.

Wittenburg, J. A., Ross, S., & Andrews, T. G. Sustained perceptual efficiency as measured by the clock test. *Percept. mot. Skills*, 1956, *6*, 109-116.

APPENDICES

APPENDIX I

Schedule for Signals

The schedule is given in seconds between the interpolated double jumps. The first value is the time between the starting of the clock and the first double jump. The second value is the time between the first double jump and the second, etc. There are 24 double jumps with six double jumps within each 10 minute block.

115
106
116
63
32
123
103
113
111
148
98
83
92
37
175
50
135
109
129
75
163
101
106
36

APPENDIX II

Instructions to Subjects

This experiment is concerned with problems of detection. The hand on this clock will proceed around the face of the clock in regular and equal steps. Occasionally the hand will make a double-jump and it is your task to detect this double-jump and signal your detection by operating this switch. I will now show you what the single jumps and a double-jump looks like, and remember to signal the detection with this switch. (Demonstrate)

Now, I am going to give you a short series of single jumps with occasional double-jumps. You are to watch for the double-jumps and upon detecting one, pull this switch towards you. (Familiarization series in which assurrance was made that the subject could detect the signal and how the appropriate response.)[1]

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[1]Here the subjects under conditions of knowledge of results were told what to expect under what conditions.

The control group was told nothing.

For the experimental group with verbally presented knowledge of results: You will be informed as to the correctness of incorrectness of your performance by way of a small loudspeaker hidden behind the black curtain. If you correctly detect a double-jump I will say right but if you either miss a double-jump or mistakenly respond to a single jump I will say wrong.

For the experimental group with knowledge of results presented through the signal lights: You will notice the two small lights on either side of the clock. If you correctly detect a double-jump, the green light will flash on but if you miss a double-jump or mistakenly respond to a single jump the red light will flash on.

During the main part of the experiment the double-jumps will be much more infrequent. Counting the single jumps will not help you.

Are there any questions?

Do the best you can.

THE INFLUENCE OF EXTRINSIC KNOWLEDGE OF RESULTS
UPON PERFORMANCE IN A MONITORING TASK

by

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B. S., University of Wichita, 1960

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Psychology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

An experiment was performed to determine whether monitors trained in a vigilance task with one or the other of two types of presentation of knowledge of results would maintain a higher level of performance in subsequent monitoring tasks than subjects trained without knowledge of results. The two types of presentation of knowledge of results were (a) knowledge of performance provided by a human observer and (b) knowledge provided by a signal light. The experimental task was a modification of the Mackworth Clock Test. Each subject was tested individually after instructions to report the critical signal, a double jump of the clock hand. The subjects were presented the same task, but without knowledge of results, one day later and then again one week later.

Results indicate that the group trained with verbally supplied knowledge of results performed at a significantly higher level than the control group during initial performance as well as on Day 2 and Day 8. The group trained with knowledge of results provided by signal light did no better than the control group given no knowledge of results during training.

Several additional findings are of interest: The data show no sex differences in monitoring ability. The mere presence of the experimenter in the room with the subject had no significant effect on performance. And there is no practice effect in vigilance performance.

Possible interpretations and implications of these research findings are discussed.