SOME ASPECTS OF MONITORING IN A COMPLEX PERCEPTUAL-MOTOR TASK

DISSERTATION

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GUSTAVE JOSEPH RATH, B.S., M.S.

The Ohio State University
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Approved by:

Paul M. Fitts
Adviser
Department of Psychology
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CHAPTER I

INTRODUCTION

Throughout history some men have been concerned with overseeing, supervising, or directing the activities of other men. Recently, men have also become increasingly concerned with performing the same activities with respect to machines. Thus, one might consider that similar supervisory functions are carried out with respect to a crew of laborers, an army division, or an automatic factory. In some instances such behavior might be called "monitoring." A monitor keeps track of the operations of some group, machine, activity, or organization, and judges its performance with respect to a "criterion." As long as the performance is judged to be satisfactory he does not interfere with the operation. However, if he judges that performance is not satisfactory, he may take direct action to change, reorganize or issue new instructions to the critical parts of the monitored system. In order to carry out a monitoring assignment, a human operator needs a set of criteria for judging the effectiveness of the operation, information regarding the relative or absolute values of different parts of the system, and information regarding the frequency or probability of failure or unsatisfactory functioning of each of the parts.¹

In many common tasks monitoring and tracking are carried out simultaneously. As an illustration consider the task of driving a car. The driver is concerned with a continuous tracking task, which may consist

¹ A more detailed discussion and definition of monitoring is found in the Appendix.
of keeping the car steady over a rough and winding road, and trying to stay three feet to the right side of the white line. At the same time he must watch for other cars, traffic lights and signs, police and pedestrians. He must periodically look inside the car at the instrument panel to see if he has enough gasoline and water, and to observe his thermometer and electric ammeter. These latter activities are examples of monitoring behavior.

Monitoring involves the use of prior information concerning expected frequencies and values. A driver has learned, for example, that looking out the windshield is more important than looking inside the car. He will respond to red lights which are round and near the street, but will disregard red neon advertisements. He will look at his speedometer frequently if he is on a radar patrolled street, where heavy traffic fines may be given for speed violations. He will watch his radiator heat carefully if driving across the desert. He will not be expecting airplanes to be towed across the street, since they are very low probability events, but will look for children, who might dart out from sidewalks.

The preceding example illustrates each of the aspects which have been previously mentioned with regard to monitoring. The driver has several criteria of satisfactory performance, which may include driving safely, averaging x miles per hour, etc. He divides his time among different parts of the environment in accordance with the values which he attaches to his different instruments as well as to events he might see. He also considers the frequency with which different conditions may change.
In the present experiment monitoring behavior was studied in a task which embodied several of the elements described above. Continuous tracking plus periodic monitoring was required, and the effect of frequencies and values in monitoring were investigated systematically. The operator was instructed to try to maximize his score on a one-dimensional compensatory tracking task. He had to watch a meter in order to perform the tracking task, and at predetermined intervals he also had to select one of three auxiliary controls, which gave him an opportunity to increase his score. Each of the auxiliary controls payed off in accordance with fixed probabilities and values. The net score resulting from his tracking and monitoring activities could be observed on a cumulating counter and heard in a headset.
CHAPTER II
REVIEW OF PREVIOUS WORK AND FORMULATION OF HYPOTHESES

Monitoring has been studied in molar studies in which the experimenter (E) was interested in inhibition or fatigue effects. These studies have dealt mostly with vigilance, which is a phase of monitoring that emphasizes the state of alertness of the monitor during the course of a watch. In a typical vigilance task the observer watches for low-probability events and simply reports these events when they occur. He has little to do and the situation often leads to boredom. Mackworth (15), who pioneered in this type of research with his investigations of "clock-watching" directed toward problems of vigilance in radar observation, found that severe decrements could be expected in the first 30 min. of a watch. Bakan (3) concluded that the intensity necessary for the threshold detection of targets increased as a function of time during the course of a watch. One important contribution to the study of vigilance has been made by Holland (13) who is finding performance in vigilance tasks to be similar to that observed in intermittent reinforcement schedules. Holland (12) considers that each detection is a reinforcement to the "vigilance response" and has limited his independent variable to the schedule of reinforcements.

The approach taken in the present paper follows more the troubleshooting research of Detambel (8) and the decision theory approach of Edwards (9, 10) than it does the approach used in vigilance studies.

The decision theory approach, in its simplest form, is found in the area of probability learning where predictions are made regarding the
asymptotic behavior of subjects (Ss) on the basis of the probabilities of the occurrences of two choices. The theories of Estes (11) and Bush and Mosteller (6) exemplify the probability learning area. Edwards (10) summarizes the probability learning and partial reinforcement studies and points out discrepancies between empirical findings and the behavior predicted from a probability matching hypothesis. The probability matching hypothesis, as applied to the commonly used two-choice situation, states that the asymptotic behavior will be directly proportional to the stimulus probabilities. Edwards (10) finds that the predictions based on a probability matching hypothesis does not hold, for Ss usually prefer higher probabilities disproportionately. Edwards' research interests have been in the field of gambling behavior, where the magnitudes of pay-offs are an important consideration as well as their probabilities in two-choice situations. Other things being equal, Edwards predicts that the higher probability will be preferred and that the rank order of the preferences will follow a decision criterion.

Employing the same ingredients, probabilities and pay-offs, Detambel (8) used negative pay-offs (work) and required search until the correct solution was found in his studies of trouble shooting. He used a three-choice "maintenance" situation where S had to find where the trouble was located. He concluded that (a) probability and pay-off are the main determiners of behavior in this class of situations, (b) probability is the stronger determiner of behavior, and (c) people use non-optimal solutions (a mixed strategy) when a pure strategy is called for. For example, if a car engine stops, a driver does not always check the gas first (a pure strategy), but at times opens the hood first.
Another important phase of monitoring involves the amount of information given Ss regarding the probabilities of pay-offs. Bruner suggests that "willingness to sustain indecision . . . gives the appearance of being a relativity constraint. It may be a function of how much information a person requires before making a decision, or, indeed, a function of how much risk he is willing to take" (5, p. 230). This statement may be paraphrased to say that preferences should be influenced by the information given Ss about the task.

Lastly, an important topic for study is the effect of the monitoring tasks on performance in continuous tasks. Bahrick (2) found that the characteristics of one task influence learning on other tasks carried out simultaneously.

Summarizing the reviewed research and conclusions, it is generally agreed that frequency is a major variable, but its relationship to payoff is still loosely defined; the effects of information regarding the probabilities and pay-offs has not been studied; and lastly, interaction effects that appear to exist between simultaneous tasks have not been studied in monitoring tasks.

The important areas calling for further study in monitoring seem to be (a) the effect on continuous tasks of intermittent probabilistic monitoring, (b) the study of the effects of information regarding the probability, pay-off and/or expected value (E(v)) on monitoring performance, (c) the control of both frequencies and pay-offs, and (d) the use of situations permitting more than two choices.

Three hypotheses follow from the previous discussion: (a) that the tracking will be influenced by the monitoring; (b) that S's choices will
be uninfluenced by the information they receive relative to the probabilities and the pay-offs of the several alternatives; and (c) that Ss will be guided by the E(v)'s of their choices, except when these are equal, in which case frequency will be a stronger determiner of behavior than pay-off.
CHAPTER III

METHOD

Apparatus

A simplified one-dimensional tracking version of the Ohio State Electronic Tracking Apparatus was used. A zero-centered voltmeter display and a round knob control were provided. The tracking problem input was a 1 cpm sinusoidal signal. The tracking performance measure was all-or-none or time on target score, which cumulated whenever S was in a 20 per cent scoring zone. This score was cumulated on a counter which normally counted at one count per second, except when a pay-off was made on the monitoring task. In the event of a pay-off it increased to 2, 4, or 8 counts per second, depending on the value assigned the pay-off. In addition to seeing the score on a counter, S could also hear the clicking in a set of earphones. Figure 1 illustrates the apparatus.

The monitoring task consisted of a three choice apparatus which Ss interrogated with three keys. A monitoring choice was required each 6 sec., and was signaled by the offset of a blue trial light. A correct choice was signified immediately by a flash of a green light and by an increase of the clicking rate of the counter which was heard in S's earphones whenever S was on-target in the tracking task. The increased counter rate lasted until the onset of the next blue trial light. An incorrect choice was signaled by a red light and the rate of counter clicking did not change. The probabilities of the three choices were either 1/7, 2/7, and 1/7, or else equal at 1/3. Specific pay-offs were
Fig. 1. Schematic drawing of the apparatus: continuous tracking and three-choice monitoring.
determined randomly with replacement in accordance with these probabilities.

Subjects

One hundred and forty-four male and female undergraduate students at The Ohio State University were used. They were assigned sequentially, in threes, to one of ten experimental conditions, until all ten conditions were exhausted.

Experimental Groups

There were four different E(v) groups. Group I had equal E(v)'s. Group II had different E(v)'s. Group III had different probabilities and equal pay-offs of 8. Group IV had different pay-offs, but equal probabilities of 1/3. All four groups had one treatment (A) where no information was given regarding the probabilities or the pay-offs of the monitoring choices. Groups I and II had three other instructional treatments in addition to treatment A. These were: treatment B, where the probabilities of the choices were told to Ss; treatment C, where the pay-offs of the three choices were told to Ss; and treatment C, where Ss were told both the probabilities and the pay-offs of the choices. The experimental groups are summarized in Table 1.

Procedure

Each S served under only one group and one treatment. The S was instructed and then given four 1-min. trials which alternated with the three 10-min. monitoring and tracking sessions. One hundred monitoring trials and continuous tracking occurred during each session.

The instructions were written using the analogy of controlling and monitoring a rocket flight in order to (a) make the experiment more
Table 1
Summary of Experimental Conditions and Number of Subjects per Condition for the Three-Alternative Monitoring Choices

<table>
<thead>
<tr>
<th>Groups</th>
<th>I P(L) P(M) P(H)</th>
<th>II P(L) P(M) P(H)</th>
<th>III E(v)_L E(v)_M E(v)_H</th>
<th>IV E(v)_L E(v)_M E(v)_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>1/7 2/7 4/7</td>
<td>1/7 2/7 4/7</td>
<td>1/7 2/7 4/7</td>
<td>1/3 1/3 1/3</td>
</tr>
<tr>
<td>V</td>
<td>8 4 2</td>
<td>2 4 8</td>
<td>8 8 8</td>
<td>2 4 8</td>
</tr>
<tr>
<td>E(v)</td>
<td>8/7 8/7 8/7</td>
<td>2/7 8/7 32/7</td>
<td>8/7 16/7 32/7</td>
<td>2/3 4/3 8/3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatments (Instructions)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Total N = 144</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:—P = probability of pay-off, V = amount of pay-off, E(v) = expected value of pay-off, H = high, M = medium, L = low.
interesting, (b) make the instructions easier to understand, and (c) increase motivation.

Common instructions were used for all groups: "Imagine that you are controlling a new type of automatic rocket with which you are trying to break an altitude record. Flying this rocket is very easy and you have three tries to break the altitude record. You have only enough fuel to last 10 min. on each try, so you must get as high as possible in that time. You can see your altitude on this display (point). You must accomplish two jobs in order to carry out your mission. The first consists of keeping the rocket pointing up. This meter indicates how it is pointing (point). You must keep it from tilting one way or the other using this knob (point). Turning the knob to the right moves the rocket to the right and turning it to the left moves the rocket to the left. Try it. Now we will give you a 1-min. practice trial with the knob only. ..... There are three motors in the rocket which must be cooled. This panel tells you which motor you are cooling and if the cooling is needed. By pressing the button marked A you may cool A, likewise for B and C. You may cool one engine once during the period between successive flashes of these blue lights (point). That is, when the blue lights are off, you may cool one engine once. You may think of the blue lights as indicating that the cooling system is recharging and that you may cool only once with each charge. If the light turns green you are cooling the engine that needs it; if it turns red you are cooling the wrong engine. If no light appears, you have cooled the engine, and you must wait for the blue lights to go on and off before trying again. By cooling the correct engine you will get an extra burst of altitude. At
times the same engine might need cooling twice in a row. Remember to
watch your meter, because if it tilts too much to the right or left you
will gain no altitude whatsoever. Make sure the blue lights are off be-
fore you cool any engine."

The instructions for Group A, which were told no information, were
as follows: "Are there any questions?"

The instructions for Group B, which were told the probabilities of
the choices, were as follows: "Reports on the experiments conducted in
checking out the engines indicate that ___ (A, B, or C) will overheat
1/7 of the time, ___ will overheat 2/7 of the time and ___ will overheat
k/7 of the time. These numbers placed under the lights are to remind you
in case you forget. Are there any questions?"

The instructions for Group C, which were told the pay-offs of the
three choices were as follows: "The rocket is so constructed that
engine ___ (A, B, or C) is twice as powerful as engine ___ and ___ is
twice as powerful as ___. Thus ___ contributes twice as much to the
climbing ability of the rocket than ___ and therefore has a greater ef-
fact on the score. These numbers over the lights will remind you of the
power of the engines in case you forget. Are there any questions?"

Instructions for Group D, which were told both the probabilities and
the pay-offs of the choices, were as follows: "Reports and experiments
dealing with the construction and test of the rocket show that engine ___
(A, B, or C) is liable to overheat 1/7 of the time, ___ 2/7 of the time,
and ___ k/7 of the time. This is marked in the cards under each instru-
ment. But, engine ___ (A, B, or C) is four times as powerful as engine
___ and twice as powerful as ___, so ___ contributes twice as much as ___
and four times as much as ___ to the climbing ability. This information is written over the lights in case you forget. Are there any questions?"

The final instructions for all groups were as follows: "Please put on your headset. Ready?"
CHAPTER IV

RESULTS

The per cent responses made by the group on each of the three choices for each treatment was computed for each of the three sessions and for each group. Percentages are used, rather than the actual frequencies, because some Ss made more than one response per trial and others omitted responses on a few trials. Results are shown in Fig. 2. The first four graphs represent the data for the four informational conditions with equal (I) and unequal (II) expected values ($E(v)$) shown for each. The last graph summarizes the data for conditions III and IV which were both run under the "no information" (A) condition. The distributions of Ss' preferences, in per cent, within the three sessions for the three choices under treatments I and II are shown in Fig. 3. Results for the four informational conditions are pooled in this figure.

A Chi-square was computed on the last session of Group IV against the generated probabilities of the choices ($1/7, 2/7, \text{ and } h/7$) and no significant difference was found. The .05 level of significance was required in all tests.

The instructional variable was found to have no significant effect on the frequency of choices, when treatments I and II were analyzed by the Friedman Chi-squared $\chi$ with three degrees of freedom. Comparing similarly the "no information" group across treatments I, II, III, and IV, the frequency of response on the high frequency and/or expected value ($P(H)$ and/or $E(v)_{H}$) key was significantly different at the .025
Fig. 2. Preferences for three choices in monitoring. A comparison of equal and unequal $E(v)$ is made in the first four sections. The last panel shows the $-P$, $\neq V$ and the $-V$, $\neq P$ group.
Fig. 3. Distributions of Ss' preferences for the three keys. Group I and II are compared pooling the instructional variable.
level and of the low P(L) and/or E(v)\textsubscript{L} key at the .005 level with three
degrees of freedom.

Comparing the distributions of Ss' preferences by the Kolmogorov-
Smirnov Test across trials and choices, the difference was only signifi-
cant for the P(H) and P(L) choices in the third trial, which may be seen
by observing the difference in the shapes of the two distributions in
Fig. 3. A further analysis of the distributions of Ss' preferences may
be carried out by noting the change of preference from trial to trial in
10-per cent steps of the distribution. A Sign Test applied to the change
of preferences revealed that all groups changed significantly between
Trials 1 and 2. Between Trials 2 and 3 there was no significant change
in Group I (equal E(v)), but there was a significant change in Groups II,
III, and IV.

The tracking scores (true time on target) of each S were converted
to per cent gain scores by the following transformation:

\[
\left( \frac{x_i - x_1}{x_1} \right) \times 100
\]

where \( x \) is the true time on target and \( i = 1, 2, \ldots, 7 \) (trial num-
ber).\(^2\) The tracking scores plotted in per cent gains of TOT are shown
in Fig. 4 for the four instructional conditions comparing Groups I and
II for each treatment. The instructions, again, have no significant ef-
facts on the tracking task when evaluated with the Friedman Chi-squared

\(^2\) Figure 4 reads Trials I, II, III, and IV which correspond to the
tracking trials or \( i = 1, 3, 5, 7 \), respectively, while the tracking
and monitoring trials are labeled 1, 2, and 3 corresponding to \( i =

2, 4, \) and 6.
Fig. 4. Per cent gains in time on target for four instructional conditions and equal (I) and unequal (II) E(ν) conditions.
while the different E(v) treatments give significant Chi-squared \( r^2 \) when used with three degrees of freedom.

An analysis of Ss' reaction time under the instructional treatments and the E(v) groups was made separately for the three trials. The analysis revealed significant effects only in the Chi-squared \( r^2 \) across the instructional variable on the first trial of Group I.
CHAPTER V
DISCUSSION

Learning

Groups that experienced unequal E(v)'s showed increasing preference for high E(v) key, but did not stabilize by the last session. However, Group I which had equal E(v)'s stabilized on all keys during the second trial. This may be interpreted to mean that it is easier to learn that there is no solution (Group I), than to learn a specific solution to the problem (Groups II, III, and IV). The monitoring task interference with the tracking task performance—this effect, found in the comparison of Groups I and II, is consistent with the predictions of Bahrick (1, 2). The tracking task was very easy, so asymptotes were reached too early to permit a sensitive analysis of the effects of the late trials. The transformation to per cent gain scores was made in order to use each S as his own control and to contrast in the study the effect of monitoring on tracking. Lastly, if there is no best solution to monitoring the simultaneous acquisition of a tracking skill is easier.

Oral and Written Information

The finding that oral and written instructional information does not affect the frequencies of choice contradicts Bruner's (5, p. 290) prediction that information should induce changes. In the present instance this lack of an effect may have resulted from (a) S's failure to listen to instructions, although it appears more plausible to assume that (b) the task conveyed all the necessary information. The effects of information about the task on reaction time in Trial 1 of Group I
which had equal E\(v\)'s is difficult to explain and might be a chance ef-
fect since no significant effect was found for other groups or sessions.
One may hypothesize, however, that Ss in this group experienced greater
difficulty in making monitoring decisions, and that this was reflected
in longer reaction time.

Expected values

Variations in the two independent variables probability and amount
of the pay-off both produced significant changes in behavior. It has
been pointed out earlier that when values are not specified, the fre-
quencies of S's responses seem to approach approximately the probabili-
ties generated by the problem (10). This effect was found in treatment
III (equal values, no information only) where the asymptotes shown in
Fig. 4 are not significantly different from the pay-off probabilities of
the three choices. The important finding in the present experiment is
that the effect of pay-offs, when unequal, significantly shifted the be-
havior toward the E\(v\) choices. Edwards (10) holds that probability
matching is a weak predictor, and feels that E\(v\) is better, but prefers
the "Relative Loss Minimization Criteria." Even though more trials were
given in the present study (by a factor of 4 to 1) than were used by
Edwards, the curves have not asymptoted at 0 or 1, so there is a ques-
tion whether the prediction will hold for the present type of task.
This question may only be resolved experimentally. Some Ss volunteered
the comment that they changed their working hypotheses between sessions,
apparently for the sake of variety. They reported that they started
trying to guess the next light instead of trying to maximize their
scores. This type of behavior would make asymptotic behavior unlikely.
in any case. The present data support Edward's (10) suggestion that with equal or small $E(v)$ differences probability is the main determinant of choice, but that with higher $E(v)$ differences the latter may become the more important determinant of choice behavior. An alternative explanation of this phenomena would be that the objective pay-offs, probabilities or $E(v)$ are not metric and should be scaled subjectively to eliminate this apparent preference.

The stability of the distributions of choices, when analyzed in terms of the changes over Trials 2-3 for Group I, seem to indicate that when there is objectively no best strategy Ss exhibit stable preferences or stereotyped behavior with a wide range of individual differences. In Group II the behavior seems to be determined chiefly by the relative $E(v)$'s of the choices and the group approaches the optimum strategy, with a smaller range of individual differences than for Group I. The failure to asymptote at frequencies of $100\%$ is in exact agreement with a prediction made by Detambel (8).

**Summary**

The preceding discussion leads the author to the following conclusions: (a) $E(v)$ value is a stronger determiner of choice behavior than is frequency or value alone, (b) as long as the information regarding probabilities and values is available within the task itself the monitor is able to use it effectively, (c) there exist interference effects between monitoring and tracking which vary as a function of the difficulty of monitoring decisions, and (d) the monitor is "rational" in the sense that he capitalizes on the system when a weakness is present, in this class of situations.
REFERENCES


APPENDIX
A FEEDBACK MODEL OF MONITORING BEHAVIOR

Mathematical and physical models have been used successfully in many fields of science including psychology. Models, even though some of them were wrong, have contributed a great deal to the development of psychology. The use of mathematical models in specifying discriminatory processes goes back to Fechner (14). Important statistical models have been developed by Crozier (16) and others as the basis for describing sensory psychological phenomena. Mechanical and electrical models have been used by Helmholtz (15), and others in the field of audition. Learning theory currently has been greatly influenced by the probability and set theoretic model of Estes (11) and the linear operator model of Bush and Mosteller (6).

A mathematical or a physical model may serve two general purposes. First, a model provides a way of combining empirical data which makes testable predictions possible. Second, a model provides a framework which assists in clarifying terms and in schematizing a field. If the model allows rearrangement and integration of the concepts involved, it aids in the establishment of programatic research in the field.

The feedback model to be described here is directed toward the second of these purposes. Before the model is presented a precise definitions of a number of words is necessary.

Definitions

Early psychologists, when discussing monitoring, used concepts like set and attention (see the reviews of Woodworth (18) and Boring (14)).
Mackworth (15) discarded these terms in favor of vigilance, but Deese (7) defines vigilance as a special case of monitoring.

**Monitoring.**—Monitoring is a purposive activity, characterized by the fact that an organism observes various aspects of some on-going process, compares system performance with his expectations, predictions, instructions, etc., with the purpose of introducing changes, from time to time, into the characteristics of the observed system. Monitoring behavior is measured by its effectiveness against a pre-established external criterion. The feedback model will be used to describe different monitoring functions and additional psychological definitions will be given to allow for systematic research.

**System.**—A monitoring system includes the monitor and that portion of the environment which affords the inputs to the monitor and receives his outputs.

**Detection.**—An O is performing a detection function when he gives a pre-arranged response to a unitary stimulus or input within an arbitrarily selected period of time with a probability significantly greater than chance.

**Time-sharing.**—If an operator is faced with a complex stimulus and must allocate his detections to different sub-sets of the stimulus using a decision rule, he is said to be time-sharing.

**Vigilance.**—Vigilance consists of an inferred state of an organism which is evidenced by a probability of detection above some arbitrarily defined level of performance.

**Controlling.**—The exercise of control in a monitoring task consists of choosing appropriate responses which may change as a function of
Predicting. — If the response precedes the stimulus, the monitor is said to be predicting.

Following. — If the response occurs after the stimulus, the monitor is said to be following.

Decision-making. — The selection of optimum modes of time-sharing, controlling, predicting, etc., in terms of a criterion is called decision making. Decision making is based on information received from external sources and attempts to optimize the monitoring behavior.

Timing and energizing. — The general level of activity of the organism is assumed to be controlled by timing and energizing functions, which are affected by external and internal processes.

Storing. — The capability of the organism to store information over long periods of time is assumed to depend on a storing process which affects subsequent decision making, timing, and energizing.

A Proposed Model

The definitions have been presented in a manner that a description of monitoring may now be made. Block diagrams will best illustrate the suggested model, while a discussion of the independent and dependent variables attached to each part of the system will clarify the accessibility of the model as a guide to systematic research.

Figure 5 illustrates the proposed model of monitoring. The problem generally consists of the interaction of a monitor, a system being monitored, and the external environment.

The monitor is assumed to perform five main functions: storage, timing and energizing, controlling, time-sharing, and decision-making.
Fig. 5. A general feedback model of monitoring behavior. The idealized computer model illustrates the relations between the monitor and the monitored system. All proposed possible links are shown, but they may not be all present in any particular case.
For convenience in exposition these functions will be discussed as if they were performed separately by different units, such as the units of a complex data-processing machine. The flow of information from the system being observed is picked up by the time-sharer (a very simple analog of which might be a multi-pole switch driven by a time-sharing circuit). The information in the time-sharer may go to the controller, decision maker and/or storage. The time sharing may be among task stimuli and a set of non-task stimuli. The environment may affect the timer-energizer and feed the storage unit. The criterion scorer feeds into the storage unit which then may retransmit it. The storage unit transmits information to the decision-maker and the time-energizer. The decision-maker transmits to the time-sharer and the controller. The timer-energizer affects all parts of the system in terms of synchronism, level of activity, etc. The controller chooses appropriate responses which may affect the system characteristics of the system being monitored or may go into library storage.

The system being monitored may be either an on-going open or closed loop system, and it may be tapped at a point by the time-sharer and the criterion-scorer.

The criterion scorer simply applies an external criteria which can be received by the storage unit of the monitor.

Environment affects directly, as an antecedant condition or independent variable, the state of the monitor. The effects of the environment of the time-energizer consists of regulating, inhibiting, or activating, according to the conditions imposed. Humidity, temperature,
food, drugs, etc., are some of the physical factors which affect the timer-energizer. Psychological and social situations which affect the monitor include those learnable situations which are scored and have slow permanent effects on the organism, the timer-energizer, and the decision-maker.

Before giving special consideration to the two most important parts of the monitor, the controller, and the time-sharer, a few additional comments on other parts of the model are necessary. First, a brief discussion of the other three parts of the monitor is in order. Storage may be considered as remembering in many instances, while it could encompass slow physiological changes such as maturation. It mediates the results from the criterion scorer which are used by the decision-maker. The timer-energizer regulates the activity level in all parts of the monitor. It may be assumed to have physiological correlates which will not be considered here. The decision-maker may be considered as a logical computer operating on optimization problems.

The time-sharer controls the distribution of time among the various parts of the system being monitored. Its antecedent conditions include the number of inputs, the value of the inputs, the frequency of change of the inputs, and any stored information such as instructions, set, level of activity. Its output which is fed into the controller can only be measured by keeping the controller constant and then measuring the responses.

The controller has inputs from all parts of the monitor; therefore, to study it one must hold all parts of the system controlled or constant. One has in the controller the main dependent variables,
probability of response, frequency of response, distribution of responses, phase of responses, and finally effectiveness of responses measured by the criterion scorer.

The criterion scorer is extremely important as the total character and behavior in the task may be evaluated differently depending on the criteria, as well as affecting the type of monitoring behavior the organism will have.
AUTOBIOGRAPHY

I, Gustave Joseph Rath, was born in New York City, May 19, 1929. I received my secondary education in Colegio Manuel Belgrano Hermanos Maristas, Incorporado al Colegio Nacional No. 2, Domingo Faustino Sar-miento, in Buenos Aires, Argentina. I received my undergraduate train­ing at the Massachusetts Institute of Technology, Cambridge, Massachu­setts, which granted me a Bachelor of Science Degree in 1952. I served two years in the United States Air Force and one year in civil service at the Psychology Branch of the Aero Medical Laboratory, Wright Air De­velopment Center, where I attended the Ohio State University Twilight School in the graduate program for Industrial Engineering. I came to the Ohio State University campus in June, 1955, to complete my Master of Science degree in Industrial Engineering, which was granted me in August, 1955. While in residence at the Ohio State University I worked as a re­search assistant in the Laboratory of Aviation Psychology under my ad­viser, Dr. Paul M. Fitts. In January of 1956 I transferred to the De­partment of Psychology and began an interdepartmental program in Psychology and Industrial Engineering. In February, 1957, I was appointed Research Fellow at the Laboratory of Aviation Psychology, a position which I maintained until my departure.