On Operating Modelling and Man Machine Experiments

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On Operator Modelling and Man Machine Experiments.

To support discussions related to the planning of man - machine experiments some key points in the field of interest are reviewed in this note.

Operator Model

The functions of the operator in an industrial plant has been discussed and some properties formulated on the basis of general experience in recent reports. (Ref. 11 2). The human operator has a high degree of ability to adapt to his operational conditions, and thus the influence of deficiencies in man - machine communication, e.g. inappropriate coding of information presented to him, will mainly be demonstrated in situations with severe mental load. It therefore seems appropriate to review reported accidents with special emphasis upon this communication. In the preliminary attempt to review such reports, a need showed up for a simple schematic model of the operator's functions, to increase the mental data capacity of the reviewer, due to the great diversity of parameters influencing the reported situations.

Such a model is shown in fig. 1. According to this model the tasks of the operator may be classified into four separate categories:

I.

The first response mode is an automatic - or unconscious matching of sensed data patterns with trained response patterns. This mode is initiated automatically by the appropriate data patterns and is based upon long term training of pattern recognition and response co-ordination. The typical tasks will be regulating and tracking tasks, routine sequences (as driving a car). The transformation model of the operator (the system information stored) will be a trained, unconscious plant response model with no relation to physical understanding or knowledge of the process.

In this mode of functioning the operator may meet data patterns having no corresponding trained response pattern, and these patterns may be perceived or detected - and cause a conscious pattern identification.

II.

When an unusual situation is thus perceived, it normally will be more or less thoroughly evaluated, additional state data will be searched and to classify the condition, the pattern will be correlated to a mental model of the system and to the actual goal of operation. The situation may be classified as a condition known from the past according to the operators experience, which in this context stands for a formal behavioural model of the plant based upon system information extracted from system performance. In this case the situation will be met by a response based upon trained co-ordination.

III.

In the case where the conditions are not identified as familiar to the operator, he has to evaluate the situation according to a mental model taking into account the physical properties of the plant, based upon fundamental education in plant anatomy, dynamic properties and the physical interpretation of the data available

Whereas the goal in the trained responses to a major degree has been to optimize the average pay off, the operator in the choice between different hypothesis on the plant conditions, may aim at different goals: A scientific goal to explain the behaviour (especially relevant to repair and trouble shooting), an operational goal to secure continuity a(production (considering average cost), or a safety goal to protect the plant or members of staff (considering immediate risk).

The abnormal condition may be identified as a situation foreseen and evaluated by the system designer, who has formulated appropriate responses in instructed procedures which form a formal transformation model to the operator, influencing his identification and controlling the co-ordination of his response.

IV.

If the conditions are identified as such not foreseen and treated by the designer in the instructional system, the operator has to further evaluate the plant conditions, predict plant response to different possible countermeasures according to a highly detailed physical understanding of the system and a carefull appreciation of the relevant goal. His transformation model has to include very detailed physical and technological properties of the plant, and will be needed also to control the co-ordination of his responses.

The model is not intended as an explanation of how the operator performs and can not be used to evaluate, why a fault has taken place. it is more realistic to see the model as a classification of certain groups of tasks, the operator has to full-fill, and thus is suited to demonstrate which function has been wrong, rather than why this psychologically speaking - has been the case. When performing a task, the operator is constantly reformulating problems, the solution of one question is creating the next and psychologically speaking, the operator in all conscious tasks is circulating in the loop sensing - classification - identification - decision - (manipulation). The model has similarities to a psychological model (as suggested by Gagné, ref. 3, in which the shunting effect is similar to the branching of task in the present model), because the operator, during the education and instruction, has stored an appreciable amount of information in the form of: when *this* technical failure happens - the behaviour of the plant will be *that*, unless you are clever enough to do *these* things in correct order. This means that whatever the mental procedures are in the operator, he can only utilize this information if he has a stage in his evaluation saying this is probably the technical explanation what have I been told to do? - or what will be reasonable to do?

If the education was only "on-line" i.e. a behavioural model, this would not take place - the operator would do some statistical optimization to change the dangerous cues in the patterns, whatever the physical reason was.

Coding of Data presented to operator.

It is well known from experiments (Ref. 4) and everyday life that the human data input capacity is highly limited, but that information input capacity is very great in case of appropriate coding i.e. when data are arranged in patterns related to the mental transformation model available. The goal of the operator and the transformation model needed are different in the various tasks, varying from a formal model based on training, experience or instructions in routine tasks to models related to detailed physical and technological properties of the system based upon fundamental education in evaluation and decision. It is therefore important to study the nature of the mental models available to the operator and the influence of information coding upon his performance in various tasks to find appropriate means to apply the data conditioning ability of a process computer system.

Suggested Experiments.

Pre programmable task. This is one of the main group of tasks in automated systems. The designer has been able to evaluate the task, but automation has not been considered feasible, and he has therefore furnished the instrumentation with special signals to initiate the response. In such a design there is a need for information of the human response time and reliability. This is investigated in the British experiments using the Horatio equipment suggested by Green (Ref. 5) which records distribution of response time between an artificial warning signal and the operator's response (pressing an acknowledge key). This type of information fits into the British reliability calculating programme NOTED (Ref. 6) and to supply supplementary data it is considered to collect similar data from the DR-3 installation. It is here planned to record detailed data giving true time of occurrence of genuine warning signals and of the operators response to be able to judge the influence of the type of alarm, the operational conditions and the time related to shift periods (Human Alertness Measuring and Logging Equipment, HAMLET).

In the same group of tasks come tracking and regulating tasks as performed by nuclear reactor operators bringing the reactor to power from criticality by manipulating control rods to keep the reactor power at a constant rate of increase. During this task the dynamic properties of the plant are changing and the operator has several secondary tasks of monitoring and manipulating instrument knobs. (Ref. 7)-

As this task is a routine task it is well suited for off-line experiments by means of an analog simulator. It seems possible to use the task to evaluate the role of display coding, as the operator depends upon a set of data, and it is possible to measure quality of response as time spent and integrated mean square deviation from optimal performance by means of the computer.

It is therefore suggested to run a series of simulated start up sequences with the relevant data presented to the operator by individual meters in the conventional way and by integrated displays of different design.

One major difficulty will probably be that the task suggested for experiments, is so easy to perform that quality of performance by trained individuals will show no clear difference in quality, and it should be considered to measure the quality of the display coding in the tracking task by judging the speed of learning the task by untrained individuals, whereas the performance with different types of display coding in tracking task disturbed by secondary tasks (monitoring, meter switching e.a.) may be measured by trained subjects.

<u>Unforeseen tasks, evaluation.</u>

Detection, identification and decision are tasks which are all characterised by inter-comparison of data in special patterns, but the mental transformation models utilized by the operator varies greatly.

Evaluation of operator model will be attempted by analysis of tape recordings made by trouble shooting technicians "thinking loud". A preliminary analysis of the first few cases seems to indicate that a classification can be made according to different mental models (a probabilistic model based upon experience, a formal model based upon normal state data from manuals or experience, and a physical model of the failed system created from fundamental understanding and state data). Correlation with published classifications (Ref.8) is interesting, as the procedures (problem solving) relevant in our context seem to fall in the category "unsystematic" in the report referred to because these investigations are based upon a classification of the manipulations of the trouble shooters with no reference to his mental activities.

It is further planned to make off-line experiments with isolated, well defined evaluation situations by means of simulated systems with various display coding. These experiments will be based upon situations and subsystem extracted from the analysis performed during the design of the complete experimental computer controlled instrumentation designed for the DR-2 reactor (Ref. 9), which is considered to involve two complex operator situations to allow real performance measurements, but to be an excellent base for formulation of relevant isolated experiments.

The initial experiments will attempt to evaluate the difference between conventional meter panels and integrated (C.R.T.) displays in detection and identification tasks, in which the number of successful performances or the accuracy of judgement can be measured At the present stage of the work, the models needed for coding of the integrated displays seems to have the following four main categories:

1) Purely abstract models which only need information coded in easily reognizable patterns. This type is suited for monitoring tasks (detection). Suitable as an example will be data represented by indicators in a straight line to indicate deviation from normal operation.

2) Functional models representing the physical relation between data in the set describing a situation or a subsystem. These may be based upon mathematical models of plant response, and may, as suggested by Wohl (Ref. 10), be based upon graphic methods like those utilized in textbooks or graphical design methods to clarify relations between data describing physical processes. This type may be advantageous in the task of identifying the abnormal system.

3) Models closely related to the technological anatomy of the plant as they are used in flow diagrams and "mimic" displays also used in the conventional control systems. this type probably will be mostly suited in the decision task, where the operation evaluates his counter measures, and he may need support when judging the appropriate manipulations. (Examples for DR-2 system are given in Ref. 10).

4) Finally special abstract models may come into use, when special systematic procedures exist (preplanned procedures or general methods). The display may support logical administration of checks performed by the

operator, as suggested by Wohl (Ref. 10) or logical reasoning in general (Ref. 12).

It should be considered that the operator have to identify failures in the instruments as well as failures in the process, and experience from accidents indicates that the operators have a tendency not to trust information from the instrumentation, when a very improbable but maybe risky condition is indicated, and therefore displays for detection and identification should preferably be based upon primary measuring data, and the model thus rather represented by the lay out of data presented than by computer calculation of derived data.

15-4-69.

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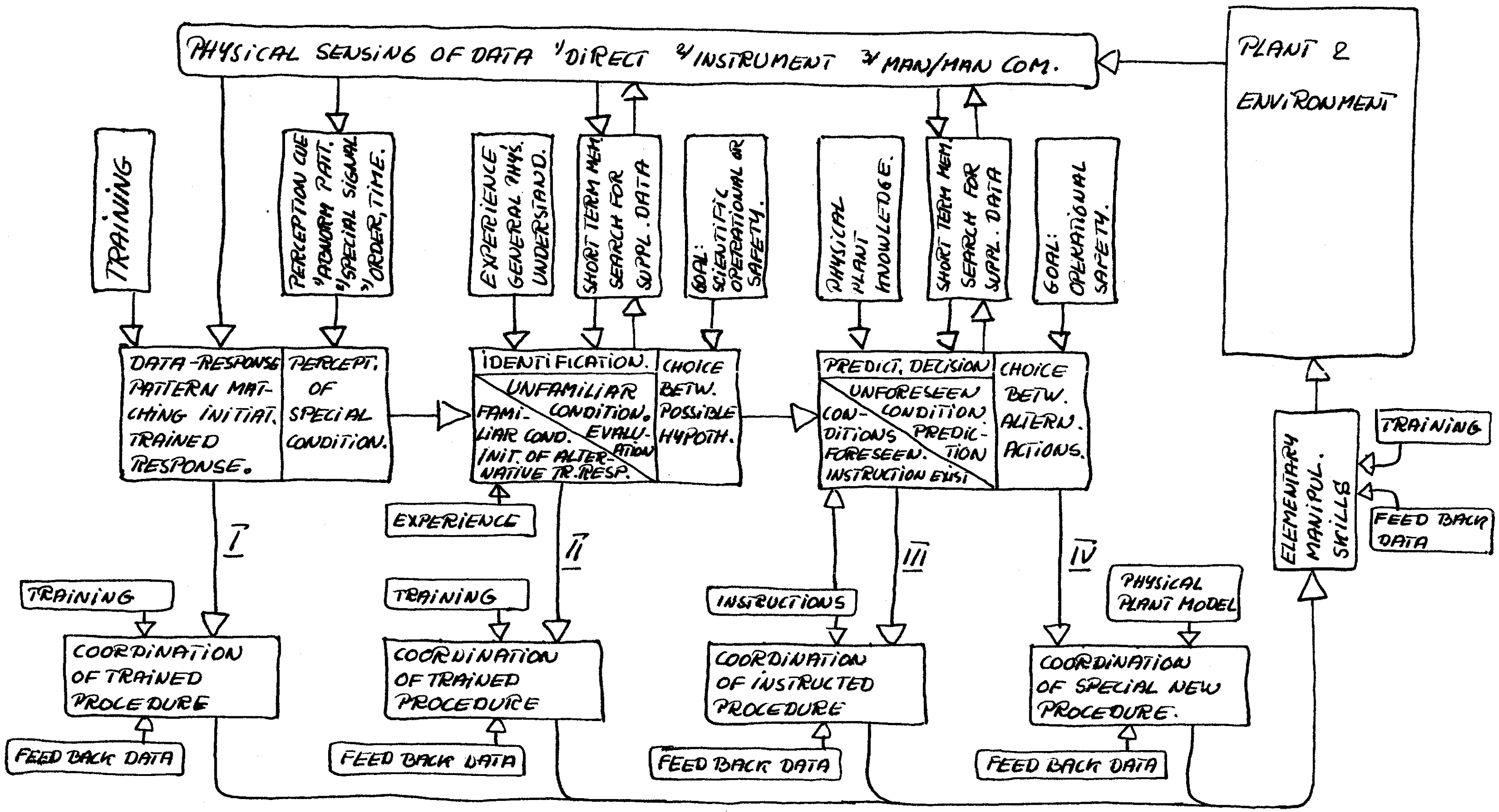
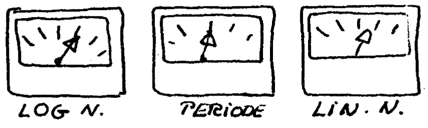
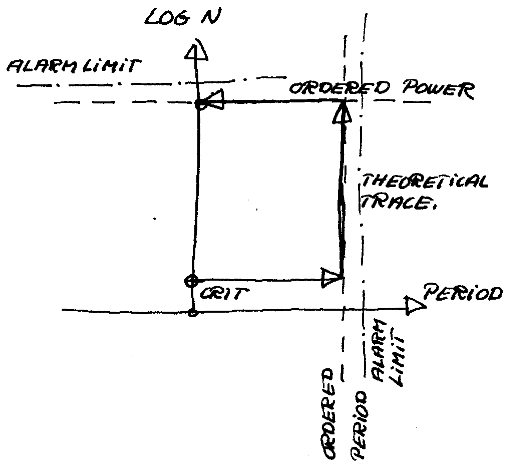


SCHEMATIC DIAGRAM OF OPERATOR PERFORMANCE.

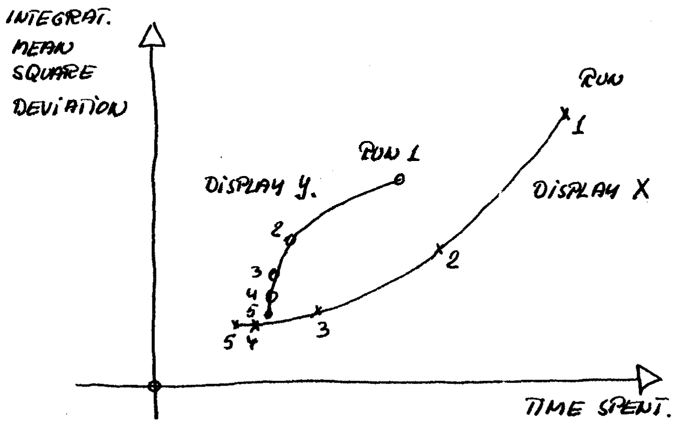
FIG. 1.



CONVENTIONAL METER DISPLAY OF LOG. AND LIN. POWER AND RATE OF CHANGE OF POWER.



SIMPLE INTEGRATED DISPLAY.



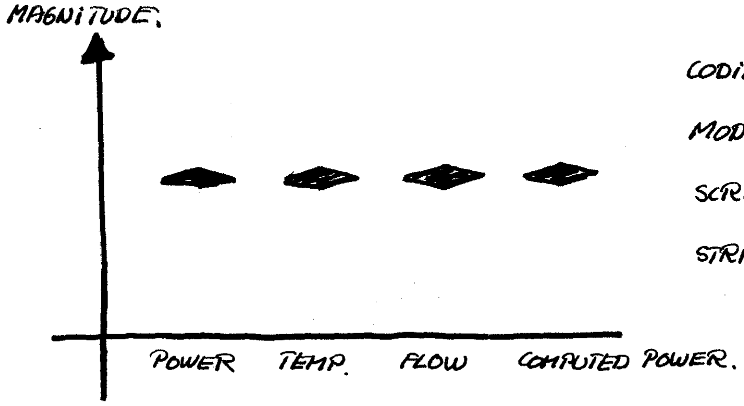
EXPERIMENTAL (HYPOTHETICAL) CURVES FOR JUDGING DISPLAY QUALITY IN TRACKING TASK. BY LEARNING SPEED. UNTRAINED SUBJECTS.

— o —

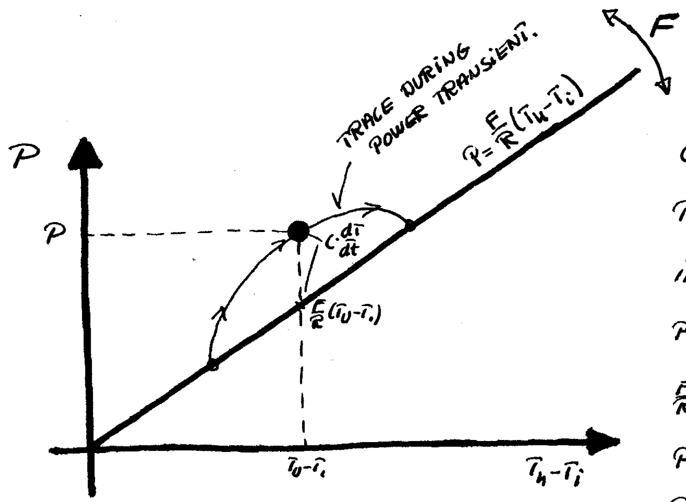
TRACKING QUALITY MEASURED BY LEARNING SPEED OF UNTRAINED SUBJECTS, WITH SIMPLE ISOLATED TRACKING TASK. WHEN SUBJECTS ARE TRAINED PERFORMANCE WITH MULTITASK PERFORMANCE MAY BE TESTED. (TRACKING PLUS INSTRUMENT MANIPULATION (SWITCHING OF ADDITIONAL (LINEAR) METERS.) MONITORING, CONSTRAINTS BY NOISE AND ALARM FUNCTIONS.)

OFF LINE EXPERIMENTS WITH TRAINED OPERATOR PERFORMANCE.

FIG. 2.



CODING TO PURELY FORMAL MODEL: STATE AS PRESCRIBED — INDICATORS IN STRAIGHT LINE.



CODING FROM MATHEMATICAL RELATION $P = C\frac{dT}{dt} + \frac{F}{R}(T_u - T_i)$.

IN STATIONAR STATE INDICATOR $P = f(T_u - T_i)$ should lie on $\frac{F}{R}(T_u - T_i)$ - line.

P = POWER, F = FLOW, R = HEAT RESISTANCE, C = HEAT CAPACITY
T = TEMPERATURES.

BOTH THESE DISPLAYS ARE RELATED TO TEST OF HEAT BALANCE. PRIMARY DATA DISPLAYED. CAN BE MONITORED BY OPERATOR DIRECTLY, BUT PATTERN SHOWS THEIR RELATION.

CODING RELATED TO TECHNICAL LAYOUT OF PLANT TO SUPPORT OPERATORS DECISION & MANIPULATION IS SHOWN FIG 4, WHICH IS TAKEN FROM REF. 11. IT DISPLAY STATUS OF HEAT TRANSFER SYSTEM. INDICATORS ARE:

⚲ BLOWER, FULL SPEED; ⚲ HALF SPEED. ┼ NO FLOW, ┼ FLOW.
⚲ PUMP NOT RUNNING; ⚲ RUNNING. ETC.

CODING OF INTEGRATED DISPLAYS. FIG. 3.