Task analysis for process-control tasks : the method of Annett et al. applied

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Task analysis for process-control tasks: The method of Annett *et al.* applied

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In order to improve a process-information system, operators' process-control tasks were analysed according to the method of Annett *et al.* (1971). This method, in which tasks are described in a hierarchical way, was developed for training operators to perform their tasks. Adaptation of the method to analyse process-control tasks is described, and its potential applications elsewhere are considered.

An ergonomics project was conducted at the Philips glass factory for TV screens. The project team wanted to design a modern, improved, process-information system, informing the operators of the values of process variables. It was recognized that the design of the new system should be based on both a process analysis and a task analysis. The specific goals of the process analysis are described in the following section. It precedes the task analysis for the following reasons.

The process analysis should result in a description of the production process, giving information about, for example, a furnace and other machines. This information is indispensable for a task analyst, providing knowledge of the factory jargon and of the different operator tasks. Knowledge of operator jargon and their tasks, combined with an acceptance by the operators, are preconditions for successful task analysis interviews conducted in the second part of a study.

The method of Annett *et al.* (1971) was selected for the detailed analysis of operator tasks. The method is described, and its application to our particular case.

PROCESS ANALYSIS

The process analysis should result in a process description, which the task analyst uses to set up the task analysis. It must therefore provide him with information about: the production process and flow in general; the inputs and outputs of subprocesses; technical functioning of machines; factory jargon; what tasks operators have to perform. There are various ways to acquire this information: our method was based on the project goal. The new process-information system should present the operator with the necessary information in order to improve process control, yielding a better quality and quantity of process output. The method for the analysis required that the production process be divided into several subprocesses, e.g. mixing sand and soda; melting; pressing; polishing. The following questions were posed about the subprocesses: what demands are made by the production staff or quality control department on the *output* variables, with regard to quantity, quality and energy?; in what way are these demands met by (a) adjusting *input* variables, and (b) adjusting *process* variables?

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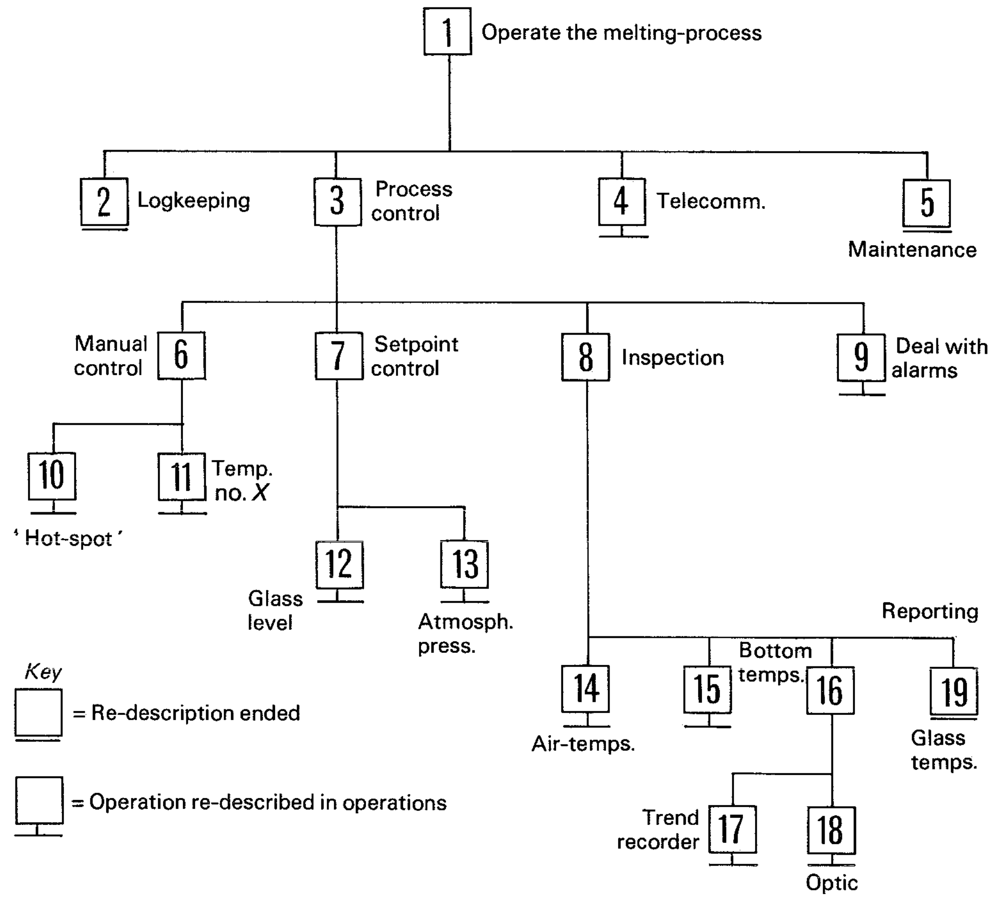

Fig. 1. A hierarchical diagram in similar format to that of Annett: tasks of an operator in a colour TV glass factory.

These two questions were the starting-points of interviews with glass technologists and other staff members. The task analyst must carry out these interviews himself. The resulting process description contained enough information to meet the above-mentioned goals (Piso, 1979). It could also be used for training operators and introducing them to their tasks. An example, illustrating the contents of the description, is as follows:

Subprocess melting (simplified):

Output quality — temperature. . . °C
homogeneous glass
no small bubbles
no stones or threads

Input quality — the way in which the input materials are put in the furnace influences the flow pattern and thus the homogeneity

Process quality — try to maintain a certain temperature curve in the furnace; this curve influences the flow patterns of the glass bulk

The temperature should therefore be kept constant. This is done by the operator. He regulates the total gas flow at a control console.

TASK ANALYSIS

The method of Annett and colleagues

Annett's (1971) method is based on two principles:

(1) tasks can be described in terms of their objectives or end-products;

(2) task analysis is the process of diagnosing the plan that is needed to achieve a stated goal.

The plan that leads to the ' highest ' goal consists of a hierarchy of subplans and subgoals. These goals can be reached by carrying out certain operations, which are in turn the goals for ' lower ' operations in the hierarchy. A task can therefore be shown as a diagram with a hierarchy of goals, subgoals, operations and suboperations. Figure 1 represents such a hierarchy that has been set up using this method in a glass factory.

More information about the tasks, such as a description of operations, is recorded in tabular format of the kind shown in Fig. 2. An operation is further divided (in Annett's terms ' re-described ') into suboperations, when, according to the analyst, the operator is incapable of carrying out this operation to a ' desired standard ' so that primary goals are not reached. This standard is called ' $P \times C$ ', in which: P = the probability that the goal will not be achieved; C = the cost, when this goal is not achieved after the task has been performed.

The method was originally developed for training purposes. Therefore, in practical terms: tasks are subdivided until the operator-trainee knows how to carry out these tasks; or tasks are described until the ' training demands ' have become clear.

Application of the method

Annett's method was selected for use in our case study, because it was developed for and applied to operator-process situations (Duncan, 1974). Two great advantages of the method are the hierarchical concept and the associated diagrams, although Shepherd (1976) has reported that the method has not been applied often. He suggested that the poorly designed tabular format (Fig. 2) was one of the causes, and therefore designed a new format (Fig. 3) in order to arrange the information in a clearer way.

No.	Description of operation and training notes	I or F	A	Re-described
1	Operate the melting-process. **R.** A two-day training programme ' off the job '	–	X	2–5
$\frac{2}{1,1}$	Logkeeping			=
$\frac{3}{1,2}$	Process control. **R.** Several variables under control	–	X	6–9
$\frac{4}{1,3}$	Telecommunication (here not further described)			
$\frac{5}{1,4}$	Simple maintenance. Provide registration instruments with ink, paper, etc.			–
$\frac{6}{3,1}$	Manual control. **R.** Instructions not clear	–	X	10–11
$\frac{10}{6,1}$	Control ' hot-spot '. **R**		X	20–34 (see Fig. 4)

Fig. 2. The tabular format of Annett, applied to the tasks in Fig. 1.

Key

1st column: $\frac{6}{3,1}$ means operation 6 is the first suboperation of operation 3;

2nd column: **R** means operation Re-described;

3rd column: I,F means that there is an Input or Feedback problem;

4th column: X means Action problem;

5th column: 10–11 means $P \times C$ too high; = means $P \times C$ acceptable; — means training demands known.

No.	Task component—operation or plan	Reason for stopping	Remarks
1	*Operate the melting-process* *P* 1. A two-day training programme ' off the job ' - - - - - - - - - - - - - - 2. Logkeeping 3. Process control 4. Telecommunication 5. Maintenance		
2	*Logkeeping* *P* 2. No training	$P \times C$ acceptable	Explanation by showing the logs ' on the job '
3	*Process control* *P* 3. Several variables under control - - - - - - - - - - - - - - 6. Manual control 7. Setpoint control 8. Inspection 9. Deal with alarms		

Fig. 3. The tabular format of Shepherd, applied to the tasks in Fig. 1.

Annett *et al.*'s method and Shepherd's contribution were designed to be used for training purposes. In extending their method for other purposes, the following questions have to be answered:

(a) What task information should be gathered and described?

(b) How should this information be collected?

(c) Suppose the specific task aspects are defined, how can we set up a hierarchical diagram of the tasks?

(d) What level of description is necessary? (Is the ' $P \times C$ ' criterion applicable?)

These questions are not too difficult to answer when tasks are analysed for developing training programmes, since the training expert will play an important role in providing the task information and drawing up the diagrams. However, analysing tasks using Annett's hierarchical concept for other purposes can be achieved only after a proper answer to each of the above questions has been given.

We formulated answers to the questions in order to analyse process-control tasks of glass-furnace operators. Our application was successful, and might be useful to others who want to use Annett's method for their special purposes and to solve their unique problems.

METHOD

The answers to the first two questions are presented under the heading, *information collection*. The way to set up a *hierarchy* and to determine the *level of description* are dealt with in two subsequent sections.

Information collection

Our task analysis had to reveal how the operators control the different process variables. Their control performance influences the quality of the output (see the section on process analysis, above). The analysis was consequently restricted to the so-called ' control tasks ', e.g. manual or setpoint control of temperatures, gasflows, etc. Routine checks or standard procedures are not dealt with in this study, although they would be important in developing training programmes.

One of the features of control tasks is the recognition of a ' control loop '. This loop, known from cybernetics and psychology (S–O–R model), can be divided into: perception →decision →operation/action →evaluation/feedback. According to McCormick (1979) these elements can be distinguished in all tasks, not only those in process control. The control-loop model was used to formulate the following questions:

(1) What is the *goal* of the control task, i.e. what defects in a TV screen does one try to avoid?

(2) What *information* does the operator use for his decision to act, e.g. trend indicators or product inspection?

(3) When and under what conditions does the operator *decide* to take action, e.g. at what value of a variable does he change a setpoint?

(4) How is this (control) *action* carried out, e.g. a sequence of operations on the control panel?

(5) What are the *consequences* of his action? How does the operator receive feedback and how does he react afterwards?

Furthermore, three task aspects were considered to be important in this case study:

(6) How *often* will the task be carried out?

(7) *Who* will carry out the task?—e.g. the operator is assisted by his foreman.

(8) What kind of *problems* can occur?—e.g. the knobs for setpoint changes are too small and sensitive.

The eight questions were the start-questions of semi-structured interviews with experienced operators. As previously mentioned, the process analysis had helped to specify the different ' control tasks ' performed by the operators.

Design of diagrams and tabular formats

The task information collected above should now be schematized in a hierarchical diagram. Two constraints were made on the diagram in our study: that it should give a well-ordered hierarchical picture of a task; and that the collected information had to be easily transferred into the diagram. We therefore designed a hierarchy for all control tasks, based on the ' control-loop model ' and questions (1) to (8). This is presented in Fig. 4.

At the top of Fig. 4 the goals of the control task are plotted. For example, the goals of the ' hot-spot task ' are to avoid small bubbles and to make homogeneous glass. These goals are the result of the answers to question (1) in the previous section. In the production of TV glass one can easily cause various defects in a screen by means of a single control task. For this reason, more than one goal could often be identified.

The sequence perception →decision →action →evaluation is used to divide a task into three phases: a *pre-phase*, an *action phase*, and an *evaluation phase*. The pre-phase is split up into an ' operation ' called perception and one called decision. The ' perception task ' consists of the use of several information sources by the operator—see question (2), and the ' decision task ' refers to question (3). The action phase can be split up into a sequence of operations, the number of which depends on the particular task—with reference to question (4). The evaluation phase is the cognition of information about the consequences of the action (' feedback '). Only when necessary was an ' action ' or ' perception ' carried out, e.g. a small correction of a variable. Information about this evaluation was gathered by posing question (5). This ' basic ' hierarchical diagram in Fig. 4 gives a clear picture of the control task, permitting the most essential aspects of such a task to be readily seen.

A detailed description of the task can be reflected in a table. Shepherd's tabular format was used for this purpose. Information collected by means of questions (6), (7) and (8) can be stored in this format, in the column headed ' Remarks ' (see Figs 3 and 5).

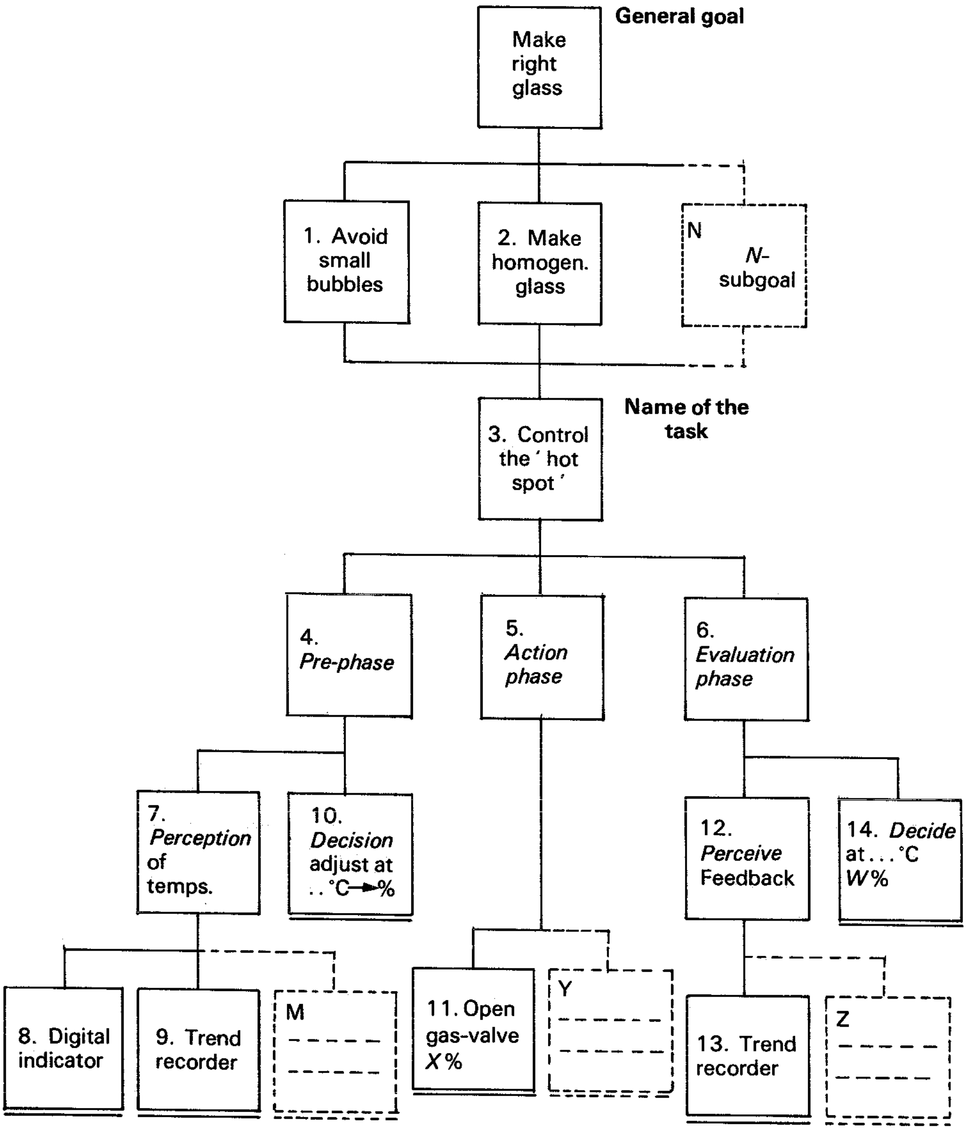

Fig. 4. A hierarchical diagram of a process-control task. Annett's method modified and applied to the task: control the 'hot-spot' (operation no. 10 in Fig. 1).

Level of description

It will always be a problem to decide on the level of description, in terms of the degree of detail in which tasks must be described. Application of Annett's criterion '$P \times C$' seems to be objective, but it is complicated, time-consuming and derived from training-task analyses. A simplified criterion, which indicates the required level of analysis, will more often be used in practice: a task or operation is split into subtasks or suboperations until both the operator and analyst decide that the task or operation is clear to them.

No.	Task, goal, operation description	Remarks	IPC	MI
1	*Avoid small bubbles* 1. When the temperature in the furnace is too low, the chemical reaction is delayed and small bubbles remain in the glass			
2	etc....			
3	*Control the 'hot spot'* 3. The operator must keep the temperature of the air in the middle of the furnace at a certain value - - - - - - - - - - 4. Pre-phase 5. Action phase: regulate total gas flow 6. Evaluation phase	The operator has no assistance for this control task		
4	5,6 ---			
7	*Perception of temperatures* 7. Two information sources were mentioned in the interviews: 8, 9 - - - - - - - - - - 8. Digital temperature indication 9. Trend recorder	—both sources are located on a control panel —operator looks at these temperatures every 10 minutes		

Fig. 5. The tabular format of Shepherd, modified for process control, applied to the operations in Fig. 4.

In our study we put this criterion for process-control tasks into practice as follows. Control tasks were re-described until concrete control actions (e.g. a setpoint change) had become clear to the analyst. In the tabular formats of Annett and Shepherd (Figs 2 and 3) a column about $P \times C$ could thus be omitted, but two other columns were added (see Fig. 5): a ' more information ' (MI) column, in which a sign X indicates that the analyst has too little information to describe the operation properly; an ' important for process control ' (IPC) column, marked when task aspects are important to control the process, for example having a direct influence on rejection of end-products. These two columns were used for a second interview with operators.

DISCUSSION

We are now even more convinced that a useful task analysis is impossible without a preliminary process analysis, carried out by the task analyst himself. The process description is useful to acquire some general knowledge of the production process and factory jargon. It also helps the task analyst to pose meaningful questions about the operator tasks to be analysed.

The method of Annett and colleagues, used as described above, has been applied to 45 operator control tasks with success. The control-loop concept and hence the questions (1) to (8) were valuable in obtaining the information requested. The questions themselves may be rather specific to the problem dealt with in this study, but the control-loop concept and the relation between collected information and the diagram are not. For that reason, we suggest that the following guidelines are very useful in applying Annett's hierarchical method to any purpose.

(a) Try to set up some basic questions about the tasks to be analysed. The S–O–R concept will be helpful in doing this. The contents of these questions will be related to the particular goal of the task analysis.

(b) These questions will be sequentially or hierarchically related. These relationships and their structure form the basis for a hierarchical diagram.

(c) An (interview) questionnaire should be based on these questions and their structure; the collected task information can now be transferred directly into the diagram and tables.

Using the above guidelines, we have succeeded in setting up a hierarchical instruction manual (Piso, 1981).

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REFERENCES

ANNETT, J., DUNCAN, K. D., STAMMERS, R. B. & GRAY, M. J. (1971). *Task Analysis*. Department of Employment Training Information Paper no. 6. London: HMSO.

DUNCAN, K. D. (1974). Analytical techniques in training design. In E. Edwards & F. P. Lees (eds.), *The Human Operator in Process Control*. London: Taylor & Francis.

MCCORMICK, E. J. (1979). *Job Analysis*. New York: AMACOM.

PISO, E. (1979). A situation-analysis in aid of an ergonomical system design. MSc thesis, Eindhoven University of Technology (in Dutch).

PISO, E. (1981). Ergonomic evaluation of control rooms: Two case studies. In *Proceedings VIII, IFAC World Congress*, 24–28 August, Kyoto, Japan. Oxford: Pergamon.

SHEPHERD, A. (1976). An improved tabular format for task analysis. *Journal of Occupational Psychology*, **47**, 93–104.

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