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## The role of cognitive style in the acquisition of process control skills

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**THE ROLE OF COGNITIVE STYLE IN  
THE ACQUISITION OF PROCESS CONTROL SKILLS**

**BY**


**BEBI WALIFA HADIYA RASHEED**

**Masters Thesis**

**(May 1996)**

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# **ABSTRACT**

This thesis examines an aspect of individual differences in learning. It specifically addresses cognitive style and how this affects the acquisition of process control skills.

## **Experiment I**

A first experiment was conducted in order to examine individual differences in the execution of process control tasks. This experiment explored the manner in which subjects acquired skills under two training conditions; oral and written instructions in a simple simulated processing plant. One group of subjects was told the "surface principles" (Concepts Group) which governed the functioning of the plant, whilst a second group was given written instructions (Procedures Group).

There were twenty subjects in each of the groups. In the first group it was found that there was greater retention and transfer when subjects were allowed to construct their own responses. However, in the second group individuals differed in the extent to which they willingly abandoned written procedures and were proficient in handling the uncertainty of response construction.

A major finding was that 80% of the people in the "Procedures Group" chose to ignore the procedures and instead developed their own procedures/strategies based on their inferred knowledge concerning plant operation. A further observation was that the "Concepts Group", who were encouraged to construct their own responses, made fewer errors than the "Procedures Group". Thus it was impossible to infer that different preferences for responding were a function of their thinking styles and not based solely upon methods of instruction.



## Experiment II

It was hypothesised that differences in information processing were due to two types of cognitive styles, namely Field Independence (Fi) and Field Dependence (Fd). A group of subjects was categorised into those who were Fi and those who were Fd. These categories were constructed using results obtained from the Embedded Figures Test (Witkin et al 1954). To test such differences, a second experiment was carried out to observe the manner in which Fi subjects differed from Fd subjects. This experiment required subjects to solve similar processing problems as in Experiment I. The group of subjects was divided into two equal groups in terms of Fi/Fd. One of these groups received knowledge pertaining to the tasks presented so that they understood how the plant functioned. The second group was deprived of such information.

The results showed that, in the first group, giving Fd subjects information did not seem to aid them in solving those tasks presented to them. This was contrary to expectations, since it was expected that Fd subjects would more effectively use the information given as an aid to problems solving than FIs. On the other hand, FIs used information as they wished, ignoring it or not as desired and so developed their own ways of responding. The consequence of this was that FIs were better problem solvers.

The expectation was that information would enhance performance. However, both groups performed equally well, demonstrating again the more effective completion of tasks by those who were Fi.

The conclusion of this thesis is that there is empirical evidence to suggest that the results discussed have valid implications for the selection and training in the field of process control. That is, people could be selected on the basis of where they lie on the Fi/Fd dimension and then trained in an appropriate manner for jobs in the process control field.



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# CHAPTER 1

## 1.0 Introduction

### 1.1 The Aim

This thesis investigates the nature of individual differences in the acquisition and execution of process control skills and individual differences that focus on characteristics or traits along which individual organisms may be shown to differ. Such differences may arise from differences in personality or in intelligence. It will demonstrate that such individual differences (if they exist) may be explained by cognitive style. The cognitive style investigated is the Fi/Fd dimension. These two phrases "Field Independence (and Dependence)" represent a continuum along which perceptions are dependent on (or independent from) cues in the environment (the field). It will also demonstrate that such individual differences may have implications for selection and training. That is, if selectors wish people to be Fi in their mode of problem solving, then it may be appropriate to administer selection tests to discover whether or not people are of the desired cognitive style. Such selection procedures may inevitably require training designers to tailor teaching methods according to the style of selected trainees.

### 1.2 The Issue

Much of the research work carried out into the area of process control skills (that is, the special procedures and drills required to carry out tasks in the chemical, textile and other processing industries) has concentrated on understanding how people learn in general, and carry out their jobs or tasks. Theories of skill acquisition (Anderson, 1982; Fitts 1964) readily acknowledge that people will perform more effectively when given more appropriate knowledge structures and appropriate conditions to convert this knowledge into effective skills. An impression drawn from this



approach is that all people will respond to a given task environment in a similar fashion, or at least one governed by the same rules. Given equal knowledge and conditions of practice, then equal skill will, according to these theories emerge.

The perspective of cognitive style challenges this view. If it could be proved that cognitive style affects the acquisition and execution of process control skills, then it may be possible to infer that such styles, when investigated, may be important factors in selection processes and training within the process control industry.

### **1.3      The Nature Of The Investigation**

It is hypothesised that people in the same context (that is, with equal knowledge available, similar/different tasks etc) in the process control industry will perform in different ways. But it is not possible to infer whether it is the task or the cognitive style which is responsible for such differences in performance.

#### **Experiment I**

The first experiment explores individual choice in the use of information in the execution of process control skills. It is supposed that individual characteristics will account for different responses produced by individuals and that different training methods would have a bearing on such responses. Individual differences are demonstrated by the retention and transfer of information, the number of errors committed and "moves" (that is, pre-determined actions) made whilst carrying out tasks.

#### **Experiment II**

The second experiment investigates the validity of the Fi/Fd dimension in accounting for individual differences in skill acquisition. Based on the results of the Embedded Figures Test, subjects are placed into categories of Fi/Fd. They are then randomly placed within two groups, each of which is a mixture of Fis and Fds. One group receives information



pertaining to the functioning of the plant whilst the other group does not. Evidence demonstrating individual differences includes the number of goals completed and the speed of task completion. Analysis of protocols (that is verbalizations made by subjects of how problems were solved during the course of carrying out tasks) should yield information regarding the use of information via the formation of mental models, the planning and use of strategies and the transfer of information.

**Chapter 2** introduces "Cognitive Style" and "Process Control". A description is made of the various cognitive styles which are involved when related to a hypothetical journey. A description is then made of the nature of process control, that is, the types of industries which exist, identification of automated and manual systems and the skills which an operator would require in order to carry out tasks. Cognitive style is then discussed as applied to process control. It is concluded that predominant cognitive skills may cause individuals to solve processing tasks in idiosyncratic manners.

**Chapter 3** reviews the relevant literature. In order to consider the way that different people process information, it is necessary to consider how the scientific study of individuality arose. This includes the study of personality and intelligence. A review is made of the evidence demonstrating the Fi/Fd dimension in learning and how this demonstrates individuality. Individual differences in performance is often confused by ability and learning environments. This is discussed in terms of the "Aptitude Treatment Interaction Theory". Ackerman's (1988) idea of different classes of abilities being highly correlated with performance at each phase of skill acquisition is also discussed. Chapter 3 provides a review of the different cognitive styles and a table illustrating each with an example applied to process control. It is therefore apparent that there are psychological processes underlying skill acquisition. As such, a review is made of the psychological process underlying skill acquisition and that of process control skills. It is concluded that cognitive style is a psychological process that may underlie process control skill acquisition.



**Chapter 4** discusses important "terms" used in this thesis. In order to state and define the components of skill that will be used, knowledge, concepts, principles, task and distance are defined and discussed according to available literature.

- \* Knowledge is defined in relation to individual differences and as applied to process control. The use of knowledge in the formation of "Mental Models" is also discussed.
- \* A brief review of the study of "concepts" and the use of concepts as a way of acquiring knowledge in process control is discussed.
- \* An explanation of the nature of "principles" and how principles can be used to solve problems which are cognitive in nature is discussed. A discussion of the possible use of principles in learning tasks in the process control industry is made:
- \* A brief discussion of the use of different tasks in illustrating individual differences in learning and a review of the kinds of tasks used in process control is made.
- \* Finally "goal response distance" is defined and illustrated diagrammatically.

**Chapter 5** presents experiments which explore the nature of individual differences in the acquisition of process control skills focusing specifically on:

- \* Transfer of learned skills across tasks and within tasks.
- \* How trainees cope with tasks of different complexities given certain information types.



- \* Retention of skills within tasks and between tasks.

This experiment demonstrates that individuals differ in the manner in which they complete tasks and that this may be due to the type of information presented to them and to their individual cognitive styles.

**Chapter 6** Since part of the argument is that the Fi/Fd dimension is a pertinent factor responsible for differences on a number of performance measures, this is explored through experimentation. This chapter argues that individuals placed at particular points on this dimension will use information in different ways and that this may be reflected in such performance measures as:

- \* The type of strategies which people use to complete tasks.
- \* The speed with which tasks are completed.
- \* The level of detail of "mental models".

Since Fis were found to be superior to Fds in terms of forming more appropriate strategies, forming more detailed mental models, and executing tasks at a faster pace, the argument is that training should eliminate this difference. This chapter, therefore, concludes that there is a need for the development of a specific training method which would help Fds to use information in a more efficient way, so that the acquisition of process control skills is ensured.

**Chapter 7** argues that other methods of training should be adopted which allow all Fd individuals to construct appropriate responses. This chapter also outlines the implications of the research in terms of selection and training, where it is argued that it may be appropriate to select individuals on the basis of where they lie on the Fi/Fd dimension and that training (the presentation of information in training) should be of a type which enables individuals to acquire skills.



It is concluded that although these "definition of terms" are mostly applied to tasks other than process control, their use in experimental work in process control can still be illustrated.



## **CHAPTER 2**

### **2.0 Cognitive Style and Tasks**

#### **2.1 Summary**

This chapter defines and describes how cognitive style may be applied to process control skills. In order to do this, it is first necessary to describe the process control domain and the skills needed in order to carry out tasks.

It is clear that for the successful completion of any given task, there may be skills involved and the operator needs to be cognitively flexible. The conclusion arrived at is that different skills may require different cognitive styles. How an operator copes with a task may be a function of his/her predominant cognitive style.

#### **2.2 Definition of Cognitive Style**

Cognitive style is defined in order to gain a broader understanding of what is meant when this is discussed. Cognitive style is the combination of characteristics used to describe a person's mode of problem solving and is said to influence the manner in which different individuals master and carry out tasks.

The research programme which has been in progress for the longest period of time was initiated by Witkin and his associates in 1950. They suggest the existence of a cognitive style dimension known as the "Field



Independent/Field Dependent" style. Styles are reflected in different ways of processing and acting on information. It has generated widespread interest and stimulated much research by others, partly because of cognition, distinct from intelligence, and partly because this perceptual characteristic links not only with thinking and memorising etc, but also with personality and child rearing. Vernon (1969) has pointed out that Field Independence appears to partake of many other widely accepted human parameters. They are General Intelligence "G" or Spatial Ability "S" factors. Creatively, middle class versus working class, masculine versus feminine.

While definitions of cognitive style tend to vary in emphasis and detail, there are those that tend to incorporate some basic elements. For example, Messick (1976) defined cognitive style in terms of "consistent patterns of organising and processing information", whereas Goldstein and Blackman (1978) refer to cognitive style as "characteristic ways in which individuals conceptually organise the environment". Further, Knox (1977) and Floyd (1976) defined cognitive style as the "individual's typical mode of information processing, as he or she engages in perceiving, remembering, thinking and problem solving".

There are those who emphasise the "borderline" nature of cognitive styles and those who view cognitive styles as a comprehensive dimension that goes beyond the cognitive sphere to overlap with other aspects of the psychology of the individual. For example, Brodzinsky (1982) identified features common to them all. Cognitive styles are characteristic modes of being. They show in perceptual or intellectual activity. They



constitute stable self-consistent forms of adaptation and they form a link between the cognitive and personal/affective spheres.

There are definitions that emphasise cognitive traits such as strategies and procedures for problem solving. For example, Kogan (1971) suggested that whereas the idea of skill is based on performance (a quantitative concept), cognitive style refers to the way in which activity is carried out (a qualitative idea), and later emphasised the "neutrality" of cognitive style, meaning its independence of quantitative interpersonal differences and their associated value judgements (Kogan 1980; Witkin and Goodenough 1981). Brodzinsky (1982) pointed out that skills are "process orientated". They consist of the ways that activity is organised and controlled to attain a goal. Of the dimensions of cognitive style identified, attention has been given to the Field Dependent/Field Independent dimension, on which studies have contributed data relevant to the distinction between style and skill.

Fowler and Murray (1987) maintained that differences in cognitive style are often ignored as they deal with the process itself rather than the result. If cognitive style is a valid concept, then it should be of relevance to the attaining of process control tasks, since these tasks are complex in terms of the information presented and the wide range of options available to the operator in using this information to make decisions.



It is possible that cognitive style may influence various types of behaviours. Such behaviours may include those involved in the process of social interaction, such as, observing, deducing what is relevant and what is not, thus enabling people to deal with isolated objects/events in particular contexts, tolerance of unexpected events etc. One could take each cognitive style in turn and then infer that it is that particular style which enables a person to behave in a particular manner. This means that different cognitive styles may influence different sorts of behaviours and such behaviours may be problem solving or task orientated. To illustrate the presence of a combination of cognitive styles an example is given presenting the task of making a journey by car from London to Edinburgh. Remember that individuals are never always at one pole or the other on a dimension, so that a person who views the journey to Edinburgh as a series of steps may be prone to "serial thinking" as opposed to seeing the journey as an "holistic" enterprise.

Driving from London to Edinburgh will involve travelling along different roads and highways where various levels of traffic will be encountered, as will changes in traffic lights, erratic drivers and events taking place alongside the pavements.

The driver would need full use of his/her sensory perception in order to successfully undertake such a journey. He/she may have to isolate into categories particular routes taken so that he/she can deal with them appropriately. An individual who is capable of coping adequately with this task may be described as being a relatively good **compartmentaler**



(Messick and Kogan, 1963; Wallach and Kogan, 1968) as opposed to an individual who is not so efficient. Furthermore, the driver who can "see" many different ways of getting to Edinburgh may be described as having a **divergent** mode of thinking, whilst the driver who considers only a minimum number of routes would have a **convergent** mode of thinking, (Guildford, 1954).

Whilst driving along the road, it would be necessary to monitor the behaviour of the traffic immediately ahead. The driver whose perceptual processes are those of **constricted control** (he/she is constricted to what is immediately ahead) may be more able to do this than the driver who is easily distracted by pedestrians and events occurring on the periphery of the main event, the ongoing traffic. This person is said to have a **flexible control** perceptual process (Gardener et al. 1960; Jenson and Roher, 1968; Klien, 1974; Santostephano and Paley, 1964).

Immediately ahead, the driver may have the unfortunate experience of seeing a car being driven erratically. The driver who is a **relational conceptualiser** may attribute such behaviour to the possibility that the driver has consumed a great deal of alcohol or is suffering from an illness. However, the individual whose cognitive style is that of an **analytic descriptive** person may actually wish to prove that such behaviour is caused by one or other factor, or both. The evidence would be empirical or based upon a more scientific description (Kogan, 1974). Further, the driver who can differentiate the one car amongst the many behaving abnormally, may be described as an **element articulator**, whilst he or she who sees the odd car as part of a pattern of the other cars on the road is a **form articulator**. This pattern would be viewed against the



background of the road taken to Edinburgh (Messick and Fritzky, 1963; Moss, Wardell and Royce, 1974; Wachtel, 1968; Gardener and Long, 1961). Thus a form articulator may very well be a leveller, someone who blurs the differences between the ongoing cars. Whereas a sharpener, (Gardener et al. 1960; Holtsman and Ramsey, 1971; Israel, 1969) may be more like a field articulator who sees the cars as individual entities.

The person who responds to changes in traffic lights and ongoing traffic, the analytic individual, may be said to be Field Independent (Wilkin et al. 1954, 1962, and 1973). Further, those drivers who can differentiate between similar objects/events based on categories of concepts would have the style of breadth of categorisation (Clayton and Jackson, 1961; Glixman, 1965). It is apparent that these examples involve the individual's mode of information processing as he/she engages in perceiving, remembering, thinking, and problem solving. That is, driving a car would involve perceiving the conditions of the current traffic situation. Problem solving may involve negotiating appropriate routes using a map. Remembering would involve rules for driving. Thinking is obviously involved in all of these. This corresponds with Floyd's (1976), Brodzinsky's (1982) and Knox's (1977) definition of cognitive style. Of course Blackman's (1978) definition is also relevant. People would "differ" in how they "see" the environment. As such they would respond in an individual way, that is, there are "characteristic ways in which individuals organise the environment".



Having looked at the more common and perhaps concrete example of the task of driving a car on a long journey, attention will now be focused on the special tasks involved in the domain of process control.

Bainbridge (1979) pointed out that "process" industries produce products such as paper, electricity, steel and petro-chemicals. Machinery is complex and specification may vary. The process machines within which input materials are converted into products are controlled. The operator may schedule the use of resources by allocating input materials to different machines after comparing alternative plans of action. If the process breaks down he/she may have to identify and correct the fault or control the process to maintain output, despite the fault.

Depending upon the task to be carried out, specific kinds of processes are of diverse concern to the operator. To illustrate this, Beishon (1969) looked at the management of cake baking ovens and Bainbridge (1974) looked at the control of blast furnaces. Woodward pointed out that manufacturing methods in an industry usually pass through three stages of technical advance. There is the small batch and "unit production", the large batch and "mass production" and the continuous flow or "process production".

Rasmussen and Lind (1981) looked at the effects of "abnormal" operating conditions in modern industrial process plants, such as when products are produced "off specification". He discovered that such conditions resulted in the operating and repair staff having to deal with a very complex data-



handling task instead of a simple task. The task of the staff is to select from the information presented by the system, the data relevant to the current goal and to transform this information into a set of manipulations appropriate to reach that goal. The transformation of the data describing the actual state of the system is based upon a set of algorithms describing or modelling "system behaviour", a transformation model making and a skilled operator able to identify operating conditions and to predict the outcome of his/her decisions. Rasmussen maintains that for, industrial plants, the complexity faced by operators is determined by the representation of the internal state of the system as presented by information displayed. Therefore, a major topic in any discussion of safety aspects of modern industrial installations is the complexity of the plant operator's work situation during abnormal plant operation. It is concluded that modern information technology should be used to assist the operator in coping with complexity, by using computers for analyzing disturbances and presenting information by advanced displays.

Automated adjustments and feedback loops handle the inner-loop control. A standardized set of procedures is followed during start up. Once the system is in a steady state, the operator engages in periodic adjustment/timing of the process variables, in order to keep certain parameters within bounds and meet production criteria. Problems, however, occur when the operator then has to hand over his/her task to a colleague on another shift. Kragt and Landeweerd (1974) discovered this, stating that any difficulties encountered by the first operator are communicated in writing or verbally. This may result in the loss of relevant information, which could mean the control of the process is interrupted. The end result of such a break in the process is an escalation



of mechanical difficulties within the process. Therefore, whilst an automated system would necessitate the minimum of interruption from operators, a manually operated system would not.

Moving from the domain of process control to the nature of process control tasks and skills, there is no doubt that process plants and systems are complex. Crossman (1960) outlines the course of process control tasks of which there are many. This includes control, special procedures and drills, routine maintenance, recording and reporting. Other skills are required which are mainly perceptual in nature, for example sensing and perceiving. It is apparent that there is much scope for variations concerning how such processes take place and therefore presents scope for an individual's cognitive style to influence performance. The selection of the many process control tasks will now be examined.

#### 2.4.1 Control

The operator must attend to the signs coming from the plant, such as, noises, smells and vibrations. The controls have to be adjusted to keep the product within specification. The components of the control task may vary in difficulty. At one end of the scale is the task of keeping a single variable at a desired value by direct control. An example of this is maintaining flow by closing/opening a valve. At the other end, an operator may have to maintain a combination of qualities in the product by a balance of conflicting requirements. In many plants, the product is changed from time to time without stopping the process. Then the operator must readjust the process to the new specification in order to waste as little raw material as possible.



Kraght and Landeweerd (1974) found that when the task of the controller is analysed, control requires that the following three components should be present:

- \* Specification and understanding of the future goals of production.
- \* An accurate mental representation of the current state of the process.
- \* An accurate internal model of the dynamics of the process. If there is no internal model, the operator must respond, wait to see what happens, and then respond again.

An operator uses flexible sub-routines when thinking about the task, some of which can be used repeatedly. Identifying the present, predicting the future system states, and choosing a control action are carried out by separate routines. Mental representation of tasks differ from one individual to another. Differences will exist in sub-routines and also in the manner in which readjustment takes place.

#### 2.4.2 Special Procedures and Drills

There are usually set sequences of manipulation to be carried out when starting up or shutting down the plant. They are often rapid and complicated manual operations interspersed with some control activity. If all individual operators remember such sequences in a similar fashion, then tasks may be executed by similar methods. However, operators may differ in how they remember the prescribed procedures. Therefore, there may be differences in the manner in which tasks are executed.



### 2.4.3 Routine Maintenance

The reading of important indicators, gauges, control settings and the results of specific measurements are logged at regular intervals. Any disturbances are noted when they occur. Clearly operators should be skillful in:

- \* Keeping the process running. That is, there should be stabilisation and regulation of conditions.
- \* Adjusting the process to give the best results according to certain criteria, for example, yield and optimisation.
- \* Making changes from one product to another quickly and economically.
- \* Avoiding breakdowns, as far as possible.
- \* Resuming normal running conditions as soon as possible should a breakdown occur, thereby ensuring that loss of material and risk of serious damage is minimised. It is possible that how tasks are executed may be due to what information an individual possesses and how he/she uses such information, all of which may be a function of cognitive style.



Specific perceptual skills which an operator must process are those pointed out by Bainbridge (1979) and may include:

\* **Sensing**

This includes the ability to detect the signs such as noises, which indicate how the plant is running.

\* **Perceiving**

The ability to detect the signs and instrument readings in relation to one another. How such interpretations take place may be a function of differences in cognitive styles.

\* **Predicting**

What is likely to happen in a given situation if controls are left alone.

Other skills which an operator must possess are the ability to select the control action most likely to achieve the desired result, plus the ability to listen and read, write and reason. The operator must also be able to use appropriate verbal expressions in order to communicate information effectively to colleagues.

There are, therefore, many skills required in order to carry out process control tasks which inevitably require knowledge in one form or another. How such knowledge is used to carry out tasks could be a function of where individuals lie on cognitive style dimensions and, indeed, what their dominant cognitive styles are. This area will now be discussed.



Having discussed the application of cognitive style in this wider context, it may be possible to infer that cognitive style can either aid or hinder the process of problem solving, depending upon the task that a person is confronted with. Such tasks may be those of dealing with everyday experiences (as in the driving illustration presented) in terms of processes of differentiation, discrimination, analyzing, tolerance and numerous other processes of perception. These same processes may directly affect how people approach problem solving in process control.

The argument is that individuals tend to vary in their cognitive styles and that different cognitive styles may be required in order to execute different tasks. How individuals perform on such tasks may be a function of where they lie along a particular cognitive style dimension.

For example, consider conceptual articulation, where there are individual differences in the extent to which information is tested in dimensional rather than class terms. That is, an operator, given a set of procedures/heuristics to carry out the operation of a process control plant, may test the usefulness of this information by considering it in its broadest sense. This would be dimensional classification. However, if a classification were to be made in terms of a class distinction then the operator may well test the information by placing particular patterns of knowledge about the plant in specific classes. For example, knowledge about system-states may be placed in classes of either "good", "bad" or "intermediate".



Another example would be that of Complexity versus Simplicity. For certain states of a plant, it is apparent that the operator should lie towards the complex end of the dimension in order to function in an appropriate manner. For example:

- \* The operator should be able to adjust the process to give the best results, according to certain criteria, such as yield, quality and minimum use of power.
- \* The operator should be familiar with the overall purpose and function of the plant.

In the examples given, it is clear that the operator should "hold together" various components of the plant in his/her mind, so that appropriate actions may be taken regarding the execution of process control tasks.

In circumstances where abnormal process control conditions occur, such as with breakdowns, operators may be placed in a situation where they have to bring such conditions back to normal. Different operators may respond in different ways. Whilst some may be "risk-takers" in the manner in which they tackle such a problem, others may be more "cautious".



Two examples of where operators may exhibit risk-taking or caution include the following:

- \* The operator must determine what is likely to happen in a given situation if the controls are left alone. That is, he/she should be able to make predictions. It is conceivable that such predictions may occur as a result of the position on which they lie on a particular dimension. If they are towards the cautious end of the dimension, they may respond in a conservative manner, whilst others may take more risks.
  
- \* The operator must be able to select the control action "most likely" to achieve the desired result in any given set of circumstances and avert unfavourable developments when they threaten. In this example, the key words are "most likely". It is obvious that this implies an element of uncertainty, in that an operator may take the risk of not knowing what the consequences may be.

Conditions imposing risk to a well designed plant may be infrequent. If they occur, the operator will be faced with unfamiliar, multiple tasks to generate routes to search for information and to establish norms and judgements. It is also the case that the operator has to consider the risk of damage to the plant. Therefore, the operator would have to accept and deal with unconventional circumstances. Operators may vary in the extent to which they allow for such "unrealistic" experiences, which is how they may perceive it to be if it is a new experience.



## **2.6      Conclusion**

Different tasks may involve a multitude of sub-tasks. Such sub-tasks may require specific kinds of cognitive styles for correct completion. The predominant cognitive style of an individual may predispose him/her to perform in a particular manner.



## **CHAPTER 3**

### **3.0 Review of the Literature**

#### **3.1 Summary**

The main thrust of this thesis is concerned with individual differences in learning, specifically cognitive style when applied to process control tasks. It is therefore, necessary to examine the nature of these individual differences in learning and cognitive style.

It is possible to demonstrate individual differences through assessment of the use of knowledge, what errors are made etc. These are briefly reviewed in addition to the psychological processes concerned with skill and skill acquisition.

#### **3.2 Introduction**

This chapter reviews the literature which is pertinent to individual differences in learning.

The "Dictionary of Psychology" (1985), has defined individual differences as a "label used for an approach to psychological phenomena that focuses on characteristics or traits along which individual organisms may be shown to differ". The areas which demonstrate individual differences are those of "personality" and "intelligence".

##### **3.2.1 Personality**

There are eight theories which account for this area:

- i. **Type Theories.** The oldest of these is described by Hippocrates, who hypothesised four basic temperaments. They are "choleric", "sanguine", "melancholic" and "phlegmatic". It is assumed that



each individual is a representation of a particular balance of these basic elements. The most complete topological theory was that of W.H. Sheldon (1954). He argued that body types are intimately related to personality development. Carl Jung's (1906) approach, although belonging under the psychoanalytical theories, is sometimes bracketed as a type theory, because of his emphasis upon classifying individuals according to types. For example, introvert versus extravert.

- ii. **Trait Theories.** All theories of this kind operate on the assumption that personality is a compendium of traits or characteristic ways which affect behaving, thinking, feeling, reacting, etc. Techniques of factor analysis have been used in an attempt to isolate underlying dimensions of personality. Kittell's (1957) theory is based on a set of source traits that are assumed to exist in relative amounts in each individual and are the "real structural influences underlying personality".

The type and trait approaches compliment each other. Type theories are primarily concerned with that which is common among individuals. Trait theories focus on that which differentiates them.

- iii. **Psychodynamic and Psychoanalytic Theories.** A multitude of approaches is clustered here including the theories of Freud (1936) and Jung (1906), and the social psychological theories of Alder (1973), Fromm (1941) and Horney (1926). They all contain an important common core idea. That is, that personality is characterised by the notion of "integration". Emphasis is placed upon developmental factors, with the assumption that the adult personality evolves gradually over time, depending on the manner in which the integration of factors develop.



- iv. **Behaviourism.** The focus here has been on the extension of learning theory to the study of personality, that is, how much of the behavioral consistency that most people display is due to underlying personality types, traits or dynamics. In addition it is concerned with how much is due to the consistencies in the environment and in the contingencies of reinforcement. The points of view, below, look beyond the person for answers and, to some extent, question the usefulness of the term "personality".
- v. **Humanism.** Maslow (1962), Rogers (1951), May (1952) and Frankl (1963) focused upon aspects of "phenomenology". Here, subjective mental experiences are paramount. They also focused on "holism", where reductionism or behaviourism is rejected and on the importance of the drive toward "self actualization". Humanism's main problems concern the difficulty of testing scientifically many of its theoretical notions.
- vi. **Social Learning Theories.** The notion of personality is treated here as those aspects of behaviour that are required in a social context. The leading theorist is Albert Bandura (1977). His position is based on the assumption that although learning is critical, factors other than simple stimulus-response associations and reinforcement contingencies are needed to explain the development of complex social behaviours that make up personality.
- vii. **Situationalism.** Mischel (1968) argued that whatever consistency or behaviour is observable is largely determined by the characteristics of the situation, rather than by any integral personality trait or types. The regularity of behaviour is attributed to the similarities in situations which a person finds himself.



viii. **Interactionism.** Personality emerges from interactions between particular qualities and predispositions and the manner in which the environment influences the ways in which these qualities and behavioural tendencies are displayed.

For points i-iii, personality represents a legitimate theoretical construct. For points iv-viii, it is seen as a secondary factor inferred on the basis of behavioral consistency.

### 3.2.2 Intelligence

Despite many efforts over the years to develop some independent definition of the term, its connotations have remained intertwined with techniques developed for its measurement. Binet (1905), the inventor of the individual "intelligence test", felt that intelligent behaviour would be manifested in such abilities as reasoning, imagination, insight, judgement and adaptability. Others have argued that all such abilities are only manifestations of a single underlying factor, that is, "general factor". Spearman (1927), despaired of the whole notion and called intelligence "a vocal sound, a word with so many meanings that finally it had none".

Before the tests and measurement movement, the term meant "the ability to profit from experience". This implies the ability to behave adaptively, to function successfully within particular environments. Hence, any intelligence test that proves valid will be one that accurately predicts adaptive and successful functioning within specified environments.

Some definitions of intelligence are:-

- \* Binet (1905) "It seems that in intelligence there is a fundamental faculty, the impartment of which is of the utmost importance for practical life. This faculty is called judgement, otherwise called good sense, practical sense, initially, the faculty of adapting one's self to circumstances. To judge well, to comprehend well to reason well....."



- \* Terman (1921) "An individual is intelligent in proportion, as he is able to carry on abstract thinking".
- \* Burt (1955) "Innate, general, cognitive ability".
- \* Wechsler (1944) "The aggregate of the global capacity to act purposefully , think rationally, and to deal effectively with the environment".
- \* Heim (1970) "Intelligent activity consists of grasping the essentials in a situation and responding appropriately to them".
- \* Vernon (1969) "The effective all-round cognitive abilities to comprehend, to grasp relations and reason".

The definitions of Terman, Burt and Vernon all stress the intellectual aspects of the concept. Binet's and Wechsler's definitions are much broader and closer to common-sense. Miles (1957) pointed out that the definition identified by Vernon, "operational", defines intelligence in terms of tests designed to measure it. Like Heim, Ryle (1949) believes that "intelligence" does not denote an entity or an engine inside us causing us to act in particular ways. Instead, he argues that any action can be performed more or less intelligently.

### 3.3 Individual Differences

One way in which individual differences may be demonstrated is through the Field Independent/Field Dependent dimension. These two phases represent a continuum along which an individual may be placed to characterise the extent to which their perceptions are dependent (or independent from) cues in the environment (the field), which is a dimension of cognitive style. Such evidence demonstrating this is that of how people perform on constructed tasks, for example, the use of information, as shown by Witkin et al. (1962/1964). These individual



differences in performance may be due to various abilities and learning environments of the individuals. Thus, one may conclude that individuals of differing abilities may benefit according to the structure of the environments in which learning takes place.

### **3.4 Individual Difference in Learning**

Learning is a hypothetical construct. It cannot be directly observed, but can only be inferred from observable behaviour. For example, if a person's performance on a task at Time 1 differs in any way from performance on a task at Time 2, it is possible to infer that learning has taken place. Learning implies a fairly permanent change in a person's behavioural performance. To call behavioural change a case of learning, the change must be linked to past experience of some kind. Coon (1983) defines learning as "a relatively permanent change in behaviour due to past experience". Kimble (1961) defines learning as a "relatively permanent change in behavioral potential which accompanies experience, but which is not the result of simple growth factors or of reversible influences such as fatigue or hunger". Kimble's definition has one advantage over Coon's, in that it implies a distinction between learning and performance.

Howe (1980) regards learning as "a biological device that functions to protect the human individual and to extend his capacities. Learning is neither independent of, nor separate from, several other abilities, in particular memory and perception". According to Howe, learning is also cumulative. That is, what is learned at any given time is influenced by previous learning. Most instances of learning take the form of adaptive changes, whereby effectiveness in dealing with the environment is increased.



The implication of the contextualist world view for the study of human individuality, is that psychological types or styles are not fixed traits but stable traits. That is, stable and enduring patterns of human individuality arise from patterns of transactions between the individual and his environment. Genetic determinants express themselves through processes of maturation. These are innately determined sequences of growth or bodily changes which are independent of the environment. Examples include "motor development". The Empiricists maintained that all our knowledge and abilities are acquired through experience. The interactionists viewpoint is that it is possible to be born with capacities to perceive the world in certain ways, but stimulation and environmental influences are crucial in determining how and whether these capacities develop. Different perceptual abilities may be more or less affected by genetic and environmental factors.

Thorndike (1914) pointed to experiments which showed that equal learning opportunities seems to increase differences. Kincaid (1925), also, reviewed studies on the effects of practice and individual differences. He concluded that experimental investigations yield varying answers to the question of whether individual differences increase or decrease as a result of additional equal amounts of practice. Investigators have been concerned with the possibility that Field Independents, adopting a participant role in the learning process, would be likely to impose a mnemonic structure, or to reorganise associative material for more effective storage and retrieval. It was pointed out by Rosencrans (1955) and Witkin et al (1962/1964) that Field Independents should be less susceptible to interference effects because of their selective participation in organising the material. This is called "cognitive restructuring".

Work has been done on a variety of tests of verbal learning using paradigms of paired associates, Berent (1972), Shapson (1969), Watchel (1968). For example, Grippen and Ohnmacht (1972) taught their subjects to label pictures with nonsense word response in a paired associate paradigm. Each picture was an example of a concept. In a subsequent



transfer test, the subjects learned to use the word responses to new picture examples of the concepts. Field Independents learned to generalise to object and design concepts more readily than Field Dependents. In contrast to Field Dependents, the evidence suggests that most Field Independents prefer to learn general principles rather than specific information, Heath (1964), Stidman (1966). However, it was pointed out by Carter (1969), Grieve and Davis (1971), that Field Dependents are at least as able as Field Independents in the acquisition of information. Further, in a study by Gardner et al. (1959), relationships between performances on the Embedded Figures Test, the Rod and Frames Test, with performances on the Free Association Test suggests that extreme Field Articulators (see page 39) may be relatively adept at selecting associations from their internal complexes of possible associations.

If tasks are completed, such as Process Control Tasks, it is suggested that problem solving may take a form which reflects that of what the person already knows of such systems (that is, problem solving is dependent upon relevant associations made in a previous situation).

### **3.5 Individual Difference in Relation to Field Independence/Field Dependence**

When confronted with a process control task, it is often necessary for operators to respond in an appropriate manner (that is, with accuracy) and also within a specified time period (that is, with speed). It is argued that the manner in which operators respond may be a function of their cognitive styles. For example, Simon et al. (1974) studied the performance of groups consisting of Field Independent/Field Dependent subjects on a task involving the assembling of squares from component parts. They showed that groups comprising the Field Independent subjects performed the tasks faster. The conclusion was that differences in processing may produce different rates of retention of material which may be illustrated by recall tasks.



Individuals differ with respect to what they already know, that is, their past experience. Kyllöhen et al (1988) showed that breadth of declarative knowledge, as indicated by performance on vocabulary tests and general knowledge surveys, predicts the speed with which a person will learn facts or associations. This is because learning novel concepts is a matter of integrating those concepts into an existing knowledge base. This agrees with Bartlett's (1932) findings that low knowledge students have more difficulty than high knowledge students in integrating new concepts.

This thesis used constructed tasks, not only to show that there are individual differences, but also to make a common base of comparison among subjects. Prescribed training methods are used in order to show that even though people are subjected to the same set of events, individual differences will exist within the two domains of experiments conducted. The sort of evidence necessary to demonstrate the role of individual differences in learning and in the execution of process control skills includes speed and accuracy, the use of appropriate knowledge and different kinds of errors.

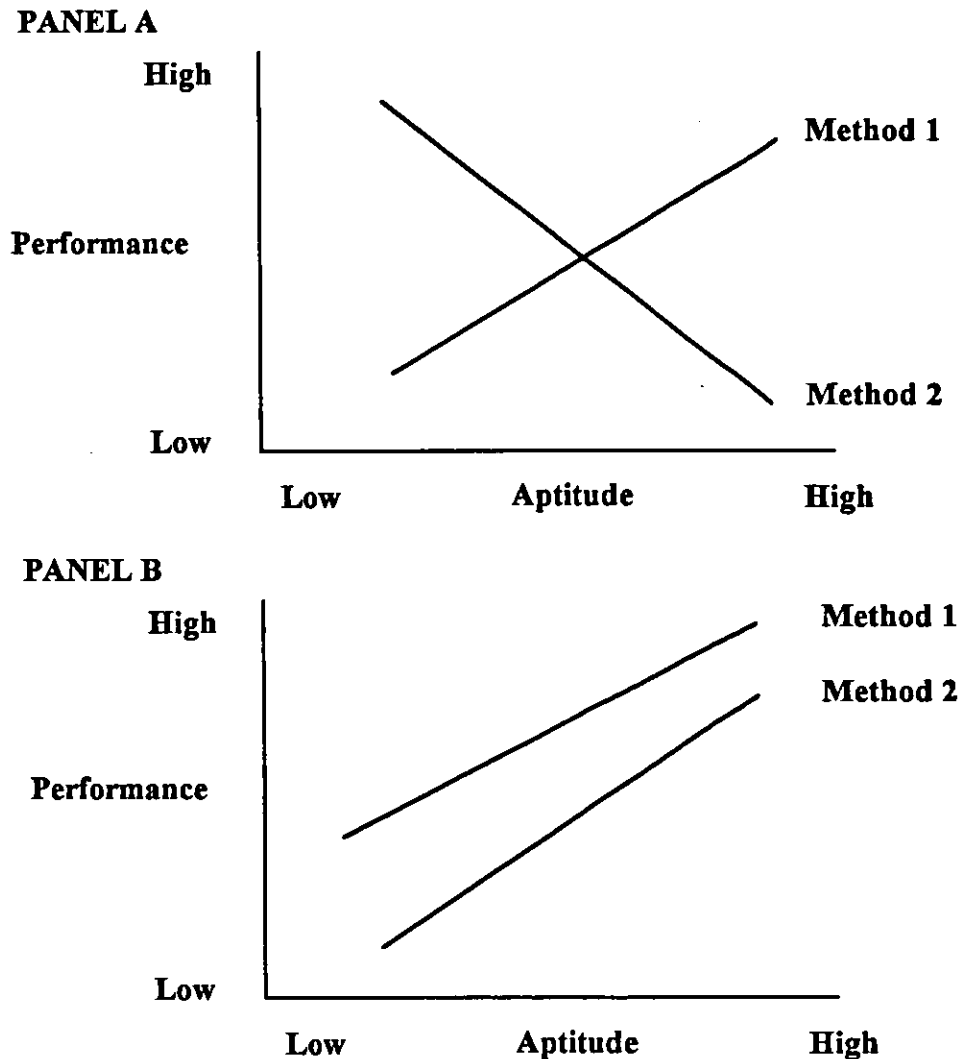
### 3.6 Aptitude - Treatment Interaction (ATI) Theory

Cronbach and Snow (1977) defined "aptitude" as any characteristic of trainees that determines their ability to profit from instruction. Cronbach (1957,1975) defined "aptitude - treatment interaction" as "any situation when two (or more) treatments have differential impact on individuals of differing levels on some trait".

Panel A shows a disordinal interaction. Panel B shows an ordinal interaction, that is, Panel A shows a significant interaction between performance and aptitude. Panel B shows a significant main effect for aptitude and performance, with no interactional effect.



**Figure 3.1**  
**Hypothetical Regressions of Aptitude on Performance**  
**Under Two Training Methods**



The notion that there is no single training approach that is optimal for every trainee is one implication from the ATI perspective.

### 3.6.1 Panel A

Figure 3.1 shows that persons of low level of hypothetical aptitude benefit most when given Training Method 1. Those of high levels of the same hypothetical aptitude benefit most when given Training Method 2.



### 3.6.2 Panel B

This type of "ordinal" interaction is important when the more effective training programme Training Method 1 comes at a higher cost of implementation than the less effective training programme Training Method 2. That is, when the more expensive training programme Method 1 cannot be universally used, it would be most cost effective to administer that training to those persons who are low on the hypothetical aptitude scale.

Snow (1989) pointed out that the degree of structure in the learning environment determines which persons will benefit most from instruction. A selection procedure that allowed only high ability applicants to enter the training programme is not sufficient for establishing a single best learning environment. This is because effective and motivational variables interact with structure to determine learning outcomes. ATIs suggest that a maximally effective training technology must be predicted on a multifaceted perspective, that is, one that incorporates knowledge about the interactions between training methods and the aptitudes, cognitive, conative and affective.

Ackerman (1988) found that tasks which are not complex may bypass the first phase of skill acquisition and so become associated with perceptual speed abilities rather than spatial, verbal and numerical abilities. On the other hand, novel and complex tasks determine the initial degree of association between spatial, verbal and numerical abilities and individual differences on task performance.

The implication of the theory is that the determinants of individual differences in performance are dynamic, that is, different classes of abilities are most highly correlated with performance at each phase of skill acquisition.



### 3.7 Cognitive Style as a Function of Skill Acquisition

It is argued that cognitive style plays an important role in the acquisition of process control skills (that is, within a task environment). Although ability may be an important factor in skill acquisition, it is assumed that cognitive style is not confounded by this. That is, the effect of cognitive style and ability can be separated in a definite way in experimental work, so that their effects can be independently ascertained.

In order to illustrate that cognitive skill plays an important role in the acquisition of process control skills, a review is made of the different cognitive styles (see Table 3.1 page 40). The nature of skill is defined and the psychological process underlying skill acquisition is reviewed. From this, it may be possible to ascertain how the factors of cognitive style, skill and the psychology of skill acquisition are interlinked and play an important part in individual differences in behaviour under certain learning conditions.

#### 3.7.1 Dimension of Cognitive Style

Table 3.1 sets out a range of different cognitive styles, identified in the literature, showing illustrations of the possible relevance to process control tasks. The table defines the sixteen different dimensions including, breadth categorisation, compartmentalisation, conceptual articulation (see pages 41-46).

Each dimension is defined in the second column. For example, breadth of categorisation is defined as "individual differences in the tendency to categorise perceived similarities in terms of differentiated concepts".

Contained within the third column are descriptions of examples of each dimension. Each example is written with the notion that at some time in an operator's life he would be confronted with tasks or a combination of the dimensions listed.



The column headed "measurement" describes ways currently available which are used to measure the dimensions. Therefore, where the dimension is that of Tolerance of Unrealistic Experiences (see page 42), the measurements used could be one of three; the most widely used being the "Rorschach Test". Where "none" is recorded in the measurement column, this means that there are no known tests which are currently available for that dimension.

The final column lists the key references. Thus the key reference dimension for the Field Independence (Fi) versus Field Dependence (Fd) is Witkin et al (1954, 1962, 1963).



**Table 3.1**

**Dimensions of Cognitive Style and Their  
Implication for Process Control**



Dimension	Definition	Example	Measurement	Key References
Breadth of Categorization	Individual differences in the tendency to categorize perceived similarities in terms of many differentiated concepts or dimensions.	If an operator were to categorize a group of systems belonging to one category as opposed to another, it would be necessary to differentiate systems along certain concepts, such as type of product.	None	Clayton & Jackson (1961) Glixman (1965)
Compartmentalisation	Consistent tendencies to isolate ideas and objects into discrete, relatively rigid categories.	An operator may isolate the components of a chemical processing plant in terms of discrete categories of types of products, types of chemical systems, type of mixing plants, etc.	None	Messick & Kogan (1963) Wallach & Kogan (1968)
Conceptual Articulation	Individual differences in the extent to which stimuli or items of information are tested in dimensional rather than class terms.	If an operator were given a set of procedures to carry out the operator of a process control plant he/she may test the usefulness of such information by considering it in its broadest sense. Otherwise he/she may classify such information in terms of certain classes, for example, the function of tanks.	None	Bieri (1960)  Schroder, Driver & Strenfert (1967) Signell (1966)



Dimension	Definition	Example	Measurement	Key References
Cognitive Complexity vs Simplicity	Individual differences in the tendency to construe the world and the world of social behaviour.	An operator may view the breakdown of a plant as being due to a specific fault and then test for this accordingly; whereas others may view the problem as being due to a more complex interaction of various parts of the plant which has produced the stated fault. The former may be termed cognitive simplicity, but the latter could be described as cognitive complexity.	None	Harvey et al (1961) Paneck (1978)
Constricted vs Flexible control	Individual differences in susceptibility to distraction and cognitive interference.	The extent to which an individual restricts attention to relevant cues and actively inhibits competing responses.	Colour Word Test Size Estimation Test Free Association Test	Gardner et al (1960) Jensen & Roher (1968) Klein (1954) Santostefano & Paley (1964)
Converging vs Diverging	This represents the degree of an individual's relative reliance upon convergent thinking (pointing toward logical conclusions and conventionally best outcomes). This is contrasted with divergent thinking. (This is pointed toward variety and quantity of output).	In this case where an operator may have to interpret the data print out of a systems failure, a divergent thinker may produce a number of answers, but a convergent thinker may just produce an answer for the cause of such a failure.	Embedded Figures Test (EFT) Matching Familiar Test	Guildford (1956)



Dimension	Definition	Example	Measurement	Key References
Conceptualising Styles	Individual consistences in the utilisation of particular kinds of stimulus properties and relationships as bases for forming concepts.	<p><u>Relational Conceptualising</u> If a person were to perceive 2 stimuli that of a stirrer and a tank of liquid, it might be possible to relate the function of the stirrer to that of mixing the liquids.</p> <p><u>Analytic - Descriptive</u> If an operator were to describe a process control system as beautifully integrated (descriptive), the question arises as to what it is about the system which makes it beautifully integrated (analysis).</p>	Conceptual Style Test Sigel Conceptual Styles Test Sigel Object Categorisation Test	Kogan (1974)
Field Articulation	<p><u>Element</u> articulation involves the articulation of discrete elements from a background pattern.</p> <p><u>Form</u> articulation highlights large figural elements against a patterned background.</p>	<p><u>Element Articulation</u> An operator who perceives a 'red alarm' against a background of similarly coloured signals.</p> <p><u>Form Articulation</u> An operator who perceives a group of alarm lights as a meaningful unit against a background of other signals.</p>	Embedded Figures Test (EFT) Rod and Frames Test (RFT)	Messick and Fritzky (1963) Moss, Wardell & Royce (1974) Wachtel (1968) Gardner and Long (1961)



Dimension	Definition	Example	Measurement	Key References
Field Independence (Fi) vs Field Dependence (Fd)	A consistent mode of approaching the environment in an analytical as opposed to global terms. The Fi pole includes competence in analytic functioning. The Fd pole reflects less competence.	An operator who notices an error in a computer printout of a process control function will lie towards the Fi pole more than one who does not.	EFT RFT BAT	Witkin et al (1954; 1962; 1973)
Levelling vs Sharpening	Concerns reliable individual variations in assimilation in memory.	A leveller may associate a 2-way valve and a 1-way valve as being similar and may blur distinct functions between them. A sharpener would tend to differentiate between the two on a functional basis.	Time Error Tests Schematizing Test	Gardner et al (1960) Holtzman & Ramsay (1971) Israel (1969)
Reflection vs Impulsivity	Individual inconsistencies in the speed and adequacy with which alternative hypotheses are formulated and information processed.	If an operator were confronted with a particular fault, he/she may ponder on all the possibilities of the causes of the fault before taking a particular course of action.  <u>Reflectivity</u> - But an impulsive individual may try to rectify the situation with the first thoughts which come to mind.	Matching Familiar Figures Test.	Block, Block & Harrington (1974) Kagan & Messer (1975) Kagan, et al (1964) Yando & Kagan (1968)



Dimension	Definition	Example	Measurement	Key References
Serialism vs Holism	This is a tendency to approach things in a linear, step by step fashion, as against a tendency to begin with the whole.	If an operator were to approach an input/output communication programme in a serial fashion, it might be that he/she may 'fail' to grasp the 'overall' meaning of such a programme unless it is approached by a holistic method of thinking.	None	
Scanning	Individuality in the extensiveness and intensity of attention deployment, leading to individual variations in vividness and the span of awareness.	<p>If an operator were to view a control panel, he/she may focus on particular parts of the panel that is related to the liquid levels of the tank. He/she would also be expected to be aware of other measurements.</p> <p>The association with <u>isolation</u> suggests that scanning may occur in the service of information seeking, as in the concern with exactness to offset doubt and uncertainty.</p>	Estimation Tests	Gardner, Jackson & Messick (1960)



Dimension	Definition	Example	Measurement	Key References
Risk taking vs Cautiousness	Consistent individual differences in a person's willingness to take chances and achieve desired goals as opposed to a tendency to seek certainty and to avoid exposure to risky situations.	In an emergency shut down situation an operator is not sure of the procedures which should be followed in order to bring the system back to normal. Instead of doing nothing (an extreme part of cautiousness), he/she may exhibit evasive action by taking risky action.	None	Kogan & Morgan (1969) Kogan & Wallach (1964, 1967) Slovic (1962)
Sensory Modality Preference	This is a tendency to use kinaesthetic visual or auditory modes for experiencing the world.	The use of visual/auditory modes for monitoring systems.	None	
Tolerance for Unrealistic Experience	Dimension of differential readiness to accept perceptions and ideas at variance with conventional experience.	If a fault has occurred which is outside the experience of some operators, a person who cannot accept such an occurrence may lie towards the intolerant pole of the dimension; whereas those who can accept such an experience may lie towards the 'tolerance' poles.	PHI Phenomena Rorschach Test Aniseikonic Lenses Test	Gardner et al (1960) Klein & Schlesinger (1951)



### 3.8

#### Some Psychological Processes Underlying Process Control

Beishon (1969), pointed out that the operator's training needs to build up their knowledge of the process, the task, and their own thinking activities. This starts at a simple level of basic understanding and practical strategy, then builds up to more complex levels through different types of knowledge. For example, Marshall et al (1981) postulated that if the operator understands the general properties of valve, he may generalise this knowledge to other items in the same category.

Bainbridge (1992) pointed out, for example, that in the operator's main thinking activities, review of product demands and the planning of future activities, the operator uses various types of knowledge these include:

- \* The physical structure of the plant.
- \* Product targets, plant constraints.
- \* Interface ----, process plant constraints.
- \* Process state ----, response required associations.
- \* Cause ----. Effect relations.
- \* Dynamic "mental models" of how parts of the plant change over time.
- \* Actions available and their effects.
- \* Typical sequences of events in the process.

The above types of knowledge could be condensed into two distinct types:

- \* Knowledge of general statements about the process. For example, cause-effect relations of production targets. This knowledge is used in predicting, planning, describing and explaining and can be conveyed in sentences, diagrams or simulations.



- \* Knowledge of the feel of the process, the patterns on the interface, and the gains and lags in the process response to changes. This knowledge is used in interpreting the state of the process, and in operating it. This sort of knowledge cannot be described fully in words, but can only be learned by direct experience.

Card et al. (1980) pointed out that the most severe constraint on behaviour arises from the limited capacity of working memory. Smaller tasks generally require less working memory for their performance than larger tasks. It is suggested that this is the reason people break larger tasks into smaller ones. Bainbridge (1975) postulated that operators have in their heads the results of making predictions and decisions.

Craik (1979) suggested that the more processing for "meaning" that some data received, the more effectively they are remembered. Bainbridge (1978) argued that such conditions would not support the acquisition of knowledge and thinking skills needed in abnormal conditions, if information is presented so successfully that the individual does not have to think about it. Bainbridge (1979) also argued that an operator who is able to think about the processes involved would be more flexible in his approach and also have more successful long term storage (due to more effective encoding at the initial stages).

Landa (1966) dealt in detail with learning by means of algorithmic instructions, an exact description of the sequence of elementary operations for the solution of arbitrary tasks belonging to a definite type in solving geometrical and grammatical tasks in school. These studies are relevant, because it is sometimes the case that operators may be called upon to solve multiple tasks in process control industries, of which an algorithmic mode of thinking may be a distinct advantage. However, an algorithmic mode of thinking may be restricted in that it may not allow an operator to be cognitively flexible across various tasks encountered in process control.



Fogel (1961), on the other hand, differentiated between a wide range of possible decision processes. He differentiated between deduction and inductive decision making, that is: Deductive Decision Making would involve inferring something about the system, for example process control. This influence would be based on events which have preceded the present state of the system. That is, it is necessary to be sure that the decision made would have the same result as on previous occasions. Thus, we would need to know something about the present state of the system as well as events preceding that present state. However, an inductive decision (that is, to bring about) would involve a search for the causative factor according to the consequence and any directing rule.

It is apparent then, that the operator may be called upon to perform most elements of process control tasks. How he performs may be a function of the type of knowledge available to him. An important factor is that cognitive style may be reflected in the manner with which people acquire new skills, particularly where the task of acquiring new information can be viewed as an instance of solving problems and also where psychological characteristics of skills is a function of cognitive style and the type of information supplied to the trainee.

Bainbridge (1979), for instance, argued that an operator who found out how to control a plant for himself used a set of propositions about possible process behaviour from which he generated strategies to try. Her conclusion was that an operator will only be able to generate new strategies from unusual situations if he has adequate knowledge of the process and that efficient retrieval from long term memory depends on the frequency of use. But, in order to use information efficiently, it would need to be processed for meaning. Research on human memory, for example, Craik (1979), suggests that the more processing for meaning that some data receives the more effectively the data is remembered.



### 3.9

#### Psychological Processes Underlying Skill Acquisition

Skills can be defined as:

- \* Practical knowledge, in combination with ability, cleverness, and expertness.
- \* To have discrimination or knowledge especially in a specified matter.
- \* Reason as a faculty of mind, the power of discrimination (Longmans Dictionary of Contemporary English).

However, from a psychological point of view, Welford (1968) pointed out that:

- \* A skill is any series of mental or physical acts executed in such a way as to demonstrate complete control by the executor.
- \* Complete control depends on the building up of co-ordinated activity involving different senses, mental abilities, and muscles.

There are several related uses of the word skill. It is possible to talk about a skill in the sense of driving a car, typing or fencing. Someone may be described as having a skill, or being skilled at performing a particular task, in the sense of being proficient or good at it. Highly skilled people are often only vaguely aware of what they do and are usually not conscious of the part played by various sensory modes in regulating their activity.

Fitts (1964) outlined three main stages in skill acquisition. They are:

- \* Cognitive stage - the learner makes an initial approximation of skill, based upon background knowledge and observation of instruction.



- \* In the associative stage, performance is refined through elimination of errors.
- \* In the autonomous stage, skilled performance is well established, but continues to improve up to a certain optimal level.

Winklegreen (1979) pointed out that when a person first learns to drive a car everything seems complicated. He may react slowly to each stimulus situation, but gradually the person learns to react more appropriately, in less time and with less effort. According to the increasing strength hypothesis, retrieval becomes less conscious because it gets faster. It gets faster because the original chain of association gets stronger. According to the "short circuiting" hypothesis, automatization occurs because the subject acquires a second shorter chain of associations that link the stimulus to response through a lower and, it is suggested, a less conscious level of coding in the mind.

Anderson (1982) offered an explanation of the three main stages outlined by Fitts, by providing three analogous stages of his own:

- \* The declarative stage (analogous to the cognitive stage) refers to verbal rules of facts regarding a task.
- \* The knowledge compilation stage (associative stage).
- \* The procedural stage (autonomous stage) where knowledge is compiled into procedures and performance becomes relatively automatic.

Anderson's conclusion was that instruction might guide the development of the necessary declarative knowledge and its subsequent proceduralisation and tuning. For example, when teaching beginners, it is necessary to build from initial knowledge structures. This might be accomplished by assessing and using prior knowledge. Anderson contended that instructional emphasis should encourage



discrimination, generalisations of productions leading to more robust, flexible and organised schema which allows the individual to perform under a variety of conditions.

### **3.10 Conclusion**

Individual differences in terms of "personality" and "intelligence" are well documented. However, it is not clear how ability correlates or does not correlate with the two. The "Aptitude Treatment Interaction Theory" attempts to clarify issues. Apart from ability, personality and intelligence, cognitive style may account for individual differences in learning. This is a psychological process, as are other processes, for example, memory. They are all underlying factors predisposing skill acquisition. The essential role that cognitive style may play is hypothetically demonstrated in Table 3.1).



# CHAPTER 4

## 4.0 Terminology

### 4.1 Summary

This chapter defines the terms to be used in later chapters, especially the experimental work reported in chapters five and six. The terms used are:

- |               |             |
|---------------|-------------|
| 1. Principles | 2. Task     |
| 3. Knowledge  | 4. Distance |

Literature taken from different areas of Psychology is used, in order to illustrate the different uses of the first three terms. They are also discussed in relation to Process Control. The term "distance" is rather idiosyncratic. There is no literature available in Psychology which uses this term. Because of this it is also defined in some detail.

### 4.2 Introduction

In order to state and define the components of skill that will be used in later studies, it is apparent that the concepts knowledge, principles, task and distance should be defined and discussed according to available literature.

When operators are faced with process control tasks, it is often the case that they should have knowledge available to them in order to carry out these tasks. Such knowledge may be in the form of procedures, heuristics and mnemonics. Individual differences in task completion may be due to the different types and nature of knowledge available to individual operators. Knowledge may be represented in various forms which include the formation of "mental models".



Depending upon the type and knowledge, whether verbal or spatial acquired during training, it might be that people develop prototypical models of the plant. It is conceivable that these mental models assist human reasoning in a variety of ways. These can be used as inference engines to predict the behaviour of physical systems. They can also be used to produce explanations and justifications. Further, they can serve as mnemonic devices to facilitate memory. It is therefore important to understand how people learn and reason about physical systems. It may then be possible to formulate a detailed model which accounts for a large portion of the subject's reasoning behaviour (Williams et al. 1986); in other words the type of model etc.

The type of model which is formed might be a composite of the amount and kind of knowledge a person has acquired during training. However, the problem which the experimenter faces is that of elicitation of such prototypical models from people who may not be able to verbally communicate such information. Such mental models may provide a basis for the design of a more effective programme.

The use and attainment of concepts and principles are also important, for they can be used as important tools to train operators to solve process control tasks. For this reason, they are considered in some detail in this chapter.

It is apparent that the nature of the task may have some bearing upon how knowledge is deployed. That is, tasks of different "distances" (the physical distance between goal-sets in a task) may require different sets of knowledge elements. So, the idiosyncratic term of "distance" is also considered in some detail in this chapter.



### 4.3 Knowledge

#### 4.3.1 Definition of Knowledge

Knowledge may be described as representations of facts (including generalisations) and concepts organised for future use (including problem solving). There is "useless" knowledge, such as which is the "third, thirteenth, longest river in the world"? On the other hand, there is knowledge that transcends what is necessary for immediate survival. It is useful to distinguish "knowing how" from "knowing what".

Duncan and Praetorius (1987) reported that it is possible to distinguish between two sorts of knowledge or expertise.

There is knowledge which is declarative, implicit, reportable. It is knowledge in the sense of being knowledgeable, well informed and knowing that something is the case. For example, which nations fought which battles in the "Hundred Years War, or the blood chemistry changes following secretion of steroid hormones by the adrenal cortex.

Then there is knowledge which is implicit, or tacit, not easily reportable; knowing how to do something, that is procedural knowledge.

This distinction between two sorts of knowledge or expertise leads to two closely related observations, namely, the relative accessibility of "procedural" knowledge.

Knowledge includes the skills of knowing how to make effective use of individual facts and generalisations. When appropriately organised, it allows us to transfer experience from the past to the future, to predict and control events and to invent new futures. It is, thus, a crucial component of intelligence.



#### 4.3.2 Ways in Which Knowledge is Acquired

There is knowledge by acquaintance which is "what we derive from sense". For Russel (1914) when this knowledge is expressed in language and organised by common sense or science, we have knowledge by description. Theories of perception, however, have blurred Russel's distinction, by suggesting that there is no direct knowledge by the senses, but that perceptions are essentially descriptions of the object world. This follows from the view that perception is knowledge based and depends upon (unconscious) influence, as suggested by Hermann Von Helmholtz.

Philosophers have held that to know that something is the case, entails a true belief that that thing is the case. Beliefs will be some sort of a structure purporting to represent reality, found within the minds (brains) of human beings. These structures will stand in various naturalistic (world view) relations to the states of affairs which they purport to represent. For example, some of these relations may be such that, if a belief has such a relation to the world, it is not simply belief but it is knowledge. Three suggestions about the nature of these relations are considered.

It is clear that we are equipped by nature with certain reliable "channels" for the receipt of information. We gain knowledge of the current state of the physical world, including our own bodily state, by means of our senses. We gain knowledge of our own current state of mind by means of introspection. We do not acquire knowledge by memory, but memory is a reliable means of conserving it. If we restrict ourselves to simple, "self-evident" steps we can by reasoning acquire knowledge in such fields as logic and mathematics. This suggestion has met with the difficulty that it is possible to have cases of true belief acquired and/or conserved in these ordinary ways, but for these beliefs not to be cases of knowledge. For example, a person may begin by knowing that a certain telephone number is 328-6693. At a later time, as a result of alterations in the person's memory trace, he comes to believe firmly, but falsely, that the number is 382-6963. The memory trace continues to alter and by chance,



the next alteration reinstates the original. Here is a case of true belief, yielded by memory, which is not accounted for as a case of knowledge.

Another suggestion is that when a state of affairs brings it about that we only believe that, that state of affairs obtains, then and only then do we have knowledge. For example, "there is a bird in the tree". This state of affairs acts upon my sense organs, and as a casual consequence, I come to know that there is a bird in the tree.

Cases can be conceived where a state of affairs brings about a belief that that state of affairs obtains, but where we would deny that the case was one of knowledge. Consider, a man whose nervous system is so deranged that any sharp sensory stimulus makes him believe that he hears a loud sound. Bright lights, a strong smell, a blow, all have this effect. Now let the stimulus be a loud sound. He will believe that he hears a loud sound, but it is clear that he does not know it.

A final suggestion is this. For example, a reliable thermometer or a watch in good working order supplies a good model for this situation. If such a thermometer or such a watch, placed in a normal environment, gives a certain "reading" (which corresponds to a belief), then, given the actual laws of nature, it must be the case that this reading is correct. So, one who knows is one whose belief stands to the world in the same way that the thermometer reading stands to the actual temperature or the watch reading stands to the actual time. That is, his belief constitutes Knowledge.

#### 4.3.3 Knowledge in Individual Differences

Kyllonen et al. (1988) pointed out that "procedural" knowledge is related to, and hard to differentiate from, working memory capacity. They argued that people differ in their procedural knowledge, that is, good learners internalise useful and general problem solving heuristics, whilst bad learners can report that they know a particular problem solving



heuristic, yet not be able to apply that heuristic in problem solving without being aware that they are doing so.

Turning to "declarative" knowledge, Shute and Kyllonen (1990) pointed out that having declarative knowledge gives the learner an initial edge, but that advantage does not necessarily maintain over the duration of the training experience. Bartlett (1932) argued that low - knowledge students have more difficulty than high - knowledge students integrating a new concept because of their lack of knowledge.

Kyllonen and Tirre (1988) further argued that studies of paired -associated learning have shown that breadth of declarative knowledge, as indicated by performance on vocabulary tests and general knowledge surveys, predicts the speed with which a person will learn new facts or associations. It is argued that the reason for this is that learning new concepts is a matter of integrating those concepts into an existing knowledge base.

In support of this, they may conclude from these various experiments/trials that individuals differ with respect to what they already know and that such differences are prognostic of future success in instructional and training situations. For example, a student with five years of programming experience is a better bet to succeed on a programming course than a student with no programming experience.

#### 4.3.4 Knowledge In Process Control

Knowledge could be in the form of theory. Theory has been used to train people for electronics fault finding. For example, Williams and Whitmore (1959) observed that trainees' knowledge of electronics theory was at its highest following training. However, this knowledge deteriorated during the following three years. Atwood (1974) and Brigham and Laios (1975) showed that the teaching of plant structure and function has beneficial effects.



Knowledge in the form of procedures has been used as training material. This technique was employed by Duncan (1977),(1974) and Duncan and Gray (1974) to provide operators with the means to fault-find process plants. This approach was popular because a solution was guaranteed. However, there are problems with such a method. For instance, specification of branching procedures has the limitation that an algorithm will only distinguish the set of conditions which have been foreseen. If an unforeseen event has occurred, the operator is not helped by algorithmic procedures.

Knowledge in the form of "heuristics" have also been used as training material. Reason (1987) argued that heuristic strategies would have to be employed where diagnostic problems are not amenable to algorithmic solutions.

The trainer may have at his/her disposal various ways of manipulating different kinds of information so that he/she may achieve a desired result. It is therefore possible to think of knowledge in the training context as being used strategically.

For example, information could be withheld and trainees could be coerced to use rules learnt on previous occasions. For example, Marshall et al. (1978) found that there is evidence that when presented information is withheld subjects can later transfer to problem solving with information which has been presented in the original task.

Knowledge could also be used as a form of feedback and so encourage performance. For instance, Duncan (1977) was interested in the effects of informing the subject when he asked a redundant question, an extra question, or made a premature diagnosis of a fault. This is known as the "functional context method" where beneficial effects on training time were observed. However, Duncan and Gray (1975) have pointed out that the validity of these studies is called into question, since the same survey



data were not used for experimental and control groups, except in Hitchcock's (1960) study.

#### 4.4 Definition Of A Mental Model

Central to the conception of mental model, as was noted by Williams, Hollow and Stevens (1986), is the notion of an autonomous object. A mental model is a collection of "connected autonomous objects". An autonomous object is a mental object with an explicit representation of state, an explicit representation of its topological connections to other objects, and a set of internal parameters. Associated with each autonomous object is a set of rules which modify its parameters and specify behaviour.

Mental Models can be thought of as knowledge structures. It is conceivable that these can be schema based (a generic knowledge structure that exists in long term memory). It includes the learner's perception of the task demands and task performance. It could also be that the knowledge that one has of a domain affects the types of models constructed and the type of problem that can be solved. For example, it is apparent that operators who view, for example, the flow of water through a pipe as analogous to that of electricity flow may be more able to solve certain problems more accurately than a group who may use the analogy to a moving crowd of objects. That is, analogies which are far removed from certain conceptualisations may hinder mental model formation.

Nevertheless, on a general level one may differentiate between the following models:

- \* Concepts, relations and categories.
- \* Decision, task orientated models.
- \* Algorithms, methods and strategies.



The first type of mental model contains knowledge inherent in language, that is, concepts such as liquid etc, which a task in a small chemical plant may contain. The second type of mental model is connected to decision making in terms of utility function, allowed actions and system model. For instance, if an operator were to decide whether or not a particular action should be made such as "opening a valve", it is evident that the mental model connected to decision making would be employed. However, a third type of model comprises general algorithms and models for problem solving. For instance, an operator may have in his/her mind the rules and a general model of how one may occur during the operation of a plant.

On a gross level, there may be types of knowledge available to an operator for him/her to use so as to construct a mental model of one form or another including the following:

- \* **Knowledge Of Plant Layout** which is defined by two features. They are the names of the parts of the plant and their localities in accordance with the system list and the localisation of these parts.
- \* **Component Knowledge** which includes some components which are found in large numbers all over the plant. These include pumps and valves. The knowledge of components is defined by these features. They are a function of the components, its construction, its capacity and limitation.
- \* **System Knowledge** which is the theoretical knowledge of each system of the plant. This can be divided into function, construction, flow and feed.
- \* **Process Knowledge** which is theoretical and practical. It is defined by control functions related to the process functions and critical parameters related to the different states and state transitions.



- \* **Knowledge On Localising And Identifying Disturbances** through a system of analytical approach. It is possible to work oneself down from a model of functional meaning through models of abstract function, functional structure and physical function to physical form, that is, down to the nuts and bolts.

#### **4.5 Concepts**

In the seventeenth century Locke proposed that we store a "concept" which is abstracted from our individual experience. Berkeley supposed that Locke intended that we had an image or picture of the universal (for example a universal triangle) which is separate from other individual triangles. Bourne (1966) pointed out that a concept has been formed when a human subject shows the ability to respond to a series of different events with the same label or action. One can conclude that a concept often involves a common element which characterises the instances.

One of the earliest studies of such concepts was that by Hull (1920). He used a large number of Chinese letters. Each group of letters had a particular visual sign in common. In some of the forms the sign was obvious and isolated from the rest. On other forms it was embedded in the network of strokes. Subjects were given the task of memorising long lists of letters so that they could produce a name each time a letter appeared. The lists were arranged so that all forms with one sign were given the same name. Over many trials, subjects were able to classify new letters as well as ones they had seen before.

It is possible to conclude from Hull's study that the task did not instruct the subjects to look for common elements. Knowing the common element did not lead to good performance, unless the common element was shown in the context of individual forms which had to be recognised. Variability of experience was important because the subjects did better when they saw a greater variety of patterns.



Hull's experiment goes a small way toward helping us to understand how one uses past experience in trying to recognise a new pattern. One limitation of his study is that Hull chose to base the classification of new letters as well as old ones on a single common element for each concept. This is not typical of real pattern recognition. That is, when a person recognises a hand written letter as an "A" or a four footed animal as a "dog", there is no single common characteristic he can point to as the crucial identifying sign.

Plato emphasises the hierarchial nature of many processes by which humans impose order upon their world. For example, iconic concepts involve the combining of different perceptual experiences into an overall trace system that allows recognition of a stimulus, or in its absence, to represent it to ourselves. Symbolism imposes new conceptual organisations upon stored information which differ from the actual objects experienced.

In dealing with iconic concepts, the unit of analysis is the object perceived. However, it is possible to disassemble objects into the component attributes which constitute them. For example, a face could be viewed in terms of colour or size. Disassembling objects would allow us to make comparisons among things which are physically quite different. Thus, the ability to separate the dimensions of perceptual object underlines the human capacity for complicated analogies and judgements.

Medin and Smith (1981) describe two types of concepts. They are "classical" and "probabilistic". If we talk of the common properties of a concept and if every property in the concept were true of every possible instance, it would be called a "classical concept". For example, the concept of apple consists of properties shown by most apples. That is they grow on trees, are round, edible, have seeds, and possess distinctive colours. Knowledge of these properties has an impact on how we deal with the objects around us. For instance, having perceived some visible properties of an object as something round, red and on a tree, we assign



it to the concept of an apple. This then enables us to infer properties that are not visible, namely that the apple has seeds and is edible. In contrast, a probabilistic concept is one in which the visible properties do not enable us to infer properties that are not visible, for example, the concept of a "bird". Even though most people's concept of a bird includes the properties of flying and chirping, not all birds fly (ostriches and penguins do not) and not all birds chirp (ducks and chickens do not). Medin and Smith (1981) pointed out that most of our everyday concepts seem to be probabilistic.

Consider the concept of a "two way diverting valve". Every instance of this concept may have the properties of being a metal, of being a particular shape and one in which it may be possible to divert liquid in one direction or another. An example of a probabilistic concept in the process control context is that of a "product". Even though most people's concept of a product includes properties of being a certain shape, size, texture etc, it is evident that not all products may be of this nature, as they may take the form of gases.

How people acquire these probabilistic concepts may be due to the particular way in which the experimenter or trainer chooses to impart knowledge to the subjects or trainees and it is likely to relate to cognitive style. People may also have already acquired concepts which they bring to bear on tasks. For example, Witten et al. (1988), pointed out that when a person learns a new concept, he gains knowledge that can be used in a rich variety of ways. For example, people with an engineering background have already acquired knowledge/concepts about systems and, as such, they may bring to bear this knowledge to complete tasks.

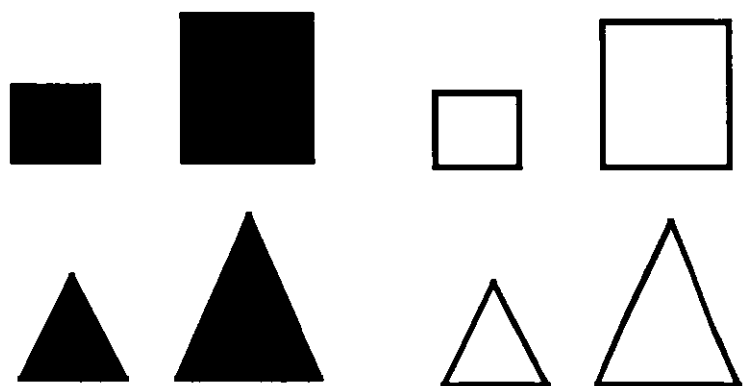
Learning any concept entails the learner generating hypotheses and then testing them. If a concept consists of a number of dimensions, the cycle of hypothesis generation and testing will take longer to complete. Hypothesis testing in learning concepts is, therefore, relevant and so must be considered.



Hypothesis testing is best illustrated by the following example (presented by Bourne, Dominowsky and Loftus in 1979) of an experiment in which adults learn new classical concepts.

The subjects may be shown a series of geometric forms that vary in shape, colour and size.

**Figure 4.1**  
**Geometric Forms**  
**Various Shapes, Colours and Sizes**



The experimenter may arbitrarily decide that the concept TEP is a large, red form. In this case, two of the forms are TEPs and six are non TEPs. In the experiment, each of these eight forms is presented and the subject guesses whether the form is a TEP or a non TEP. The experimenter then provides the correct answer. The experimenter keeps cycling through the eight forms in random order until the subject classifies every form correctly. The number of errors made in mastering the concept is a measure of its difficulty. However, this type of testing may open the doors for various biases to enter in. Snyder and Swann (1978), believed that the most prevalent bias is our tendency to emphasise cases that support our hypothesis and to play down those that refute it. In order to illustrate this, Snyder and Swann proposed the following example:



Supposing that on meeting a young woman, you hit on the hypothesis that she is an introvert. In this case, you would be using hypothesis testing with a probabilistic concept. You may ask her questions that tend to confirm your hypothesis like "Do you enjoy taking walks alone?" or "Do you spend a lot of time at the library?" Positive answers will make you confident that she is an introvert. But, you probably will not ask her questions that might disprove your hypothesis, like "do you enjoy going to parties?" A positive answer would not fit with her being an introvert. That is, you selectively seek evidence to support your hypothesis and fail to ask the critical question that might disprove it.

Considering hypothesis testing within the process control context, a trainer may decide that every "instance" of the newly invented concept such as "tap" is a large black form. The trainee's task is to discover the properties of "Tap". If they are given different forms, the subject may guess whether each is a "Tap" and the trainer tells them whether or not they are correct. This may allow trainees to generate hypotheses about which dimensions are relevant. However, if they come across a figure that fits their hypothesis and not the experimenters, they may abandon their current hypothesis and generate a new one. The result is that there is an opening for all sorts of bias to enter in.

As Snyder and Swann (1978) have pointed out, there is a tendency to emphasise cases that support the hypothesis and play down those that refute it. Suppose that a trainee meets a novel fault in a processing system, he/she may think that it requires one mode of solution as opposed to another for reasons only known to him/her. The trainee may ask questions or perform actions that tend to confirm his/her hypothesis. For example, if the trainer of a process control plant states that the system has a faulty valve, the trainee may ask questions such as "has the valve any relevance to what is happening to the system?" or he/she may actually attempt to solve the problem by manipulating the valve.



The belief is that positive answers may make the trainee confident that the valve is faulty. In seeking evidence to support his/her hypothesis, the trainee may fail to ask the critical questions which might disprove it. Although hypothesis testing seems to be the major strategy for acquiring classical concepts, where every instance must have every property mentioned in the concept. An example is the concept of a bachelor; every instance must have the properties of being adult, male and unmarried. Other strategies come into play in acquiring probabilistic concepts. However, what people may learn about a concept are its instances or "exemplars". However, any item that is similar to the one of the learned exemplars will be classified as an instance of the concept. It is now possible to consider learning by exemplars.

Mervis and Pani (1981) pointed out that although hypothesis testing seems to be the major strategy for acquiring classical concepts, other strategies come into play in acquiring probabilistic concepts, especially when the learner is a child. Often what children learn about a concept are its most typical instances or exemplars. Any item that is sufficiently similar to one of the learned exemplars will also be classified as an instance of the concept. To illustrate, consider a young child's concept of furniture which might consist of only the most common instance, for example table and chair. The child could use the exemplar strategy to classify many other instances of the concept, such as desk and sofa, because they are so similar to the learned exemplars. But, the child may not correctly classify instances of the concept that look different from the learned exemplars, such as lamp and bookshelf. When learning is based on exemplars, typical instances will fare well, but untypical ones may not even be included in the concept.

To illustrate this within the Process Control Context, consider an operator's concept of systems. It might consist of typical integrating systems such as a nuclear power plant. The operator could use the exemplar strategy to classify many other instances of the concept (systems), such as textile mill industries and cheese processing plants,



because they are similar to the learned examples. However, an operator may not correctly classify instances of a concept that look different from examples such as "farm". In order to correctly conceptualise the "whole" of a system, it is evident that the operator should combine the concepts involved in "systems".

#### **4.6 Principles**

The Dictionary of Psychology (1985), defines "Principle" as a general, basic maxim. It is a fundamental truth. It is a generally accepted rule of procedure, particularly a scientific procedure. There are some fine distinctions between principles, canons, rules and laws which are drawn. Law should be reserved for cases in which the uniformity and validity are beyond doubt, while the other terms serve for more problematical cases. In actual usage the connotations of these terms overlap. Distinctions often become academic.

In order to define the use of principles within Psychology, three examples have been chosen from Cognitive Psychology. The first illustrates the use of principle of second order isomerism. This principle suggests that iconic memories preserve the spatial relationships of the individual percepts which produced them.

The assimilation of the "particular" into the "general" has important consequences for human memory and thought. It reduces the probability that we will be able to remember the exact details of what we have seen before. It provides an economical storage system which can deal with a multitude of individual experiences without overloading the memory. It gives an internal reference system and code with which to think. The internal reference for such judgements is the visual category formed from our past experience.



An experiment by Shepard and Chipman (1970) shows how it is possible to study the relationships among internal representations. Shepard chose fifteen American States of the Union, of roughly the same size. He then made two decks of cards. In one deck each card consisted of the "names" of a pair of States, while the other deck had outline "drawings" of the same pairs. Subjects rated the similarity in shape of each pair of States. They first made ratings using only the name deck, so that the comparison rested upon stored information. Then they made the same ratings from the picture deck. The results showed a very high correlation between the two sets of ratings.

Shepard and Chipman argued that the relationship among internal representations of information concerning the shape of the States was the same as that which held among the corresponding external objects. This corresponds with the principle of second order isomorphism. This principle does not contend that internal iconic representations resemble the external events in any direct way. This view would conflict with many findings that the Nervous System stores not literal copies of experience, but abstracted representations of it.

A second principle is that of "Clark's principle of Congruence". Clark (1969) reasoned that it is easier to answer questions which use the same form. If propositions contain the word "high", questions will be easiest to understand if they involve words such as "highest" rather than "lowest". The study used to illustrate this is that of the coordination of visual and verbal codes. This raises the question of individual differences in the efficiency with which people can use such codes. Anecdotal data suggests that some people prefer to think in the linguistic mode, whilst others prefer visual representations.

In the study of memory, some attention has been paid to the coordination of the visual and linguistic systems. The problems which have been studied are two and three term series reasoning problems. Examples from the Psychology of Memory have been chosen, because of their relative



significance to the solutions of process control tasks. That is, memory may be involved in such problem solving processes.

**Table 4.1**  
**Some Two-Term Series Problems and the Mean Times**  
**Required for their Solution**

Form Of Problem	Analysis	Form of Question		Mean
		<u>Better</u>	<u>Worse</u>	
A better than B	A is good/B is good	.61	.68	.64
B is worse than A	A is bad/B is bad	1.00	.62	.81
A not as bad as B	A is bad/B is bad	1.73	1.58	1.66
B not as good as A	A is good/B is good	1.17	1.47	1.32

Adapted from Clark H. H. Linguistic process in deductive reasoning. Psychological Review, 1969, 76, 387 - 404.

Huttenlocher (1968) studied such "memory" problems with children. Children constructed piles of blocks in accordance with her instructions. She reasoned that if subjects constructed a mental picture, they would do best if the subject of the final statement was one which they had not yet placed in the picture. This predicted that it would be easier to solve "B is better than C and A is better than B", than it would be to solve "A is better than B and B is better than C". In the first sentence A, which is not in the first proposition, is the subject of the second proposition, while in the second sentence B, which is already placed, is the subject of the second proposition. Huttenlocher found evidence in favour of the prediction for both children and adults.

Clark suggested that each proposition has an underlying structure. The basic problem is solved when the underlying interpretations produce an orderly set which allows direct comparison. He relied upon a distinction between words like "good", "high" and "happy" which provide the positive end of the scale. Words like "bad", "low" and "sad" provide the



negative end of the scale. Clark reasoned that it is easier to answer questions which use the same form that has been used in the proposition. This principle has been applied to the analysis of the two-term problems shown in the diagram. For example, the proposition that A is better than B is interpreted by the subject in terms of the "good" scale, with A higher than B on the scale. Any series interpreted in terms of "good" will be easier to deal with than any series interpreted in terms of "bad". Using Clark's principle of congruence, it is possible to predict the form of questions which will be easier. These predictions held up well in the overall solution times.

Another example to do with memory of the use of principles in Cognitive Psychology was proposed by Restle and Brown (1970) "Degree Of Organisation Principle". He argued that the better we can organise new material and relate it to existing knowledge, the better it will be remembered.

For example, a person may have knowledge of the road routes of the area in which he/she lives. Suppose that one day some of the routes were altered because there was an accident. Further suppose that the same person wishes to visit his/her Grandmother nearby. Based on Restle and Brown's (1970) argument, the negotiation of the new route would not pose such a difficult problem because he/she already had knowledge of the area as it was in its original state.

#### 4.6.1 The Use of Principles In Process Control

There is no evidence to date of Principles having been used as a source of training Process Control Operators. But, it is obvious from the literature that knowledge in one form or another has been used. Such knowledge may take the form of Heuristics. These are general rules. They have been used by Duncan et al. (1975) for scanning panels and then considering the possibility of symptoms referred back by the process. Knowledge may also take the form of Algorithms. These are elaborations with branching structures and have been used by Duncan (1974,1977),



Horabin et al. (1967) to train process Control Operators. It is apparent that principles are not Heuristics or Algorithms or form any part of them. But, it is not clear that Principles do not form any part of Theory. Theory was used by Landeweerd (1971) to train operators in relation to plant structure and function. Williams and Whitmore (1959); Bryan (1965) have also used theory to train operators to fault find mechanical problems. It is possible to argue that within any theory, that there may be a number of Principles present.

It is also possible to argue that the Withheld Method of training may involve the learner or operator deriving certain Principles from fault finding, or problem solving. Essentially, the Withheld Method ensures that trainees apply a "rule", in which they learn to locate which of possible sub systems corresponding to areas on a panel contains a failure (Marshall and Duncan 1978; Marshall 1981).

Further Duncan and Gray (1975) have argued that at any stage in fault diagnosis, there is a set of faults consistent with the information gleaned by the diagnostician known as the Consistent Fault Set (CFS). Premature diagnosis refers to a number of diagnoses attempted when the CFS is 1. Redundant questions are the number of questions asked in the fault diagnosis sequence which does not reduce the CFS. Extra questions are those asked when the CFS is size 1. Duncan (1977) contended that a trainee learning fault diagnosis should be informed of the above terms during the problem solving process. It is possible that such a process may involve the use or derivation of Principles.

#### **4.7 Tasks**

According to the "Dictionary of Psychology (1985), task is defined as something that needs to be done. It is an act that one must accomplish. It is used for simple physical movements as well as for life goals. It covers personal tasks set by an individual or external demands established by others. It is possible to distinguish between **task demands** and **task**



oriented. Task demand, applies to those aspects of a particular task which, implicitly or explicitly, require of the individual the use of particular actions/patterns of thinking or feeling in order to accomplish the goal of the task. Task oriented, refers to characteristic of persons who tend to focus their attention and energy towards the fulfilment of a given task. The task oriented individual is goal directed and less concerned with the affective or aesthetic aspects of a task than with its completion.

Tasks are generally used in Psychology in order to derive principles, theories etc. and are normally set within the format of an experiment. The use of tasks is relevant in many areas of Psychology. First of all their use in chosen areas of Psychology will be discussed, their use in Process Control and then their use together with the cognitive style of Field Independence/Field Dependence as an underlying factor in the experimental work.

In the area of Psychology, known as memory, there are three separate but interrelated processes. They are registration, storage and retrieval. Memory, like learning, is a hypothetical construct and the way in which it is studied is through testing the subjects' ability to retrieve. Learning corresponds to the retrieval aspect of memory. Storage may seem not to have occurred (no learning) but, as tested by recognition, storage (and hence learning) might be demonstrated. A number of tasks have been used in demonstrating learning and memory. The usage of some of these will be discussed.

The normal laboratory procedure for studying transfer is as follows:

Experimental Group	Learns A	Learns B	Tested on B
Control Group		Learns B	Tested on B

Learning sets represents a special case of a more general phenomenon known as transfer of learning (or training).



In more complex learning situations, transfer may depend on the acquisition of rules or principles that apply to a variety of different circumstances. The notion of "similarity" is a complex one. For instance, in a "mirror drawing" task, practice under one condition, (for example, drawing the outline of a star without the mirror) interferes with performance under the other conditions (drawing image of the star using only the mirror). This produces negative transfer. Tracing patterns of different appearances might seem to constitute dissimilar tasks. In fact, there is considerable positive transfer. It is clear that special tasks are used to demonstrate transfer of learning.

Other tasks have been used to demonstrate learning, especially in the study of "semantic" memory (SM), which has focused on our long term conceptual and linguistic knowledge of the world.

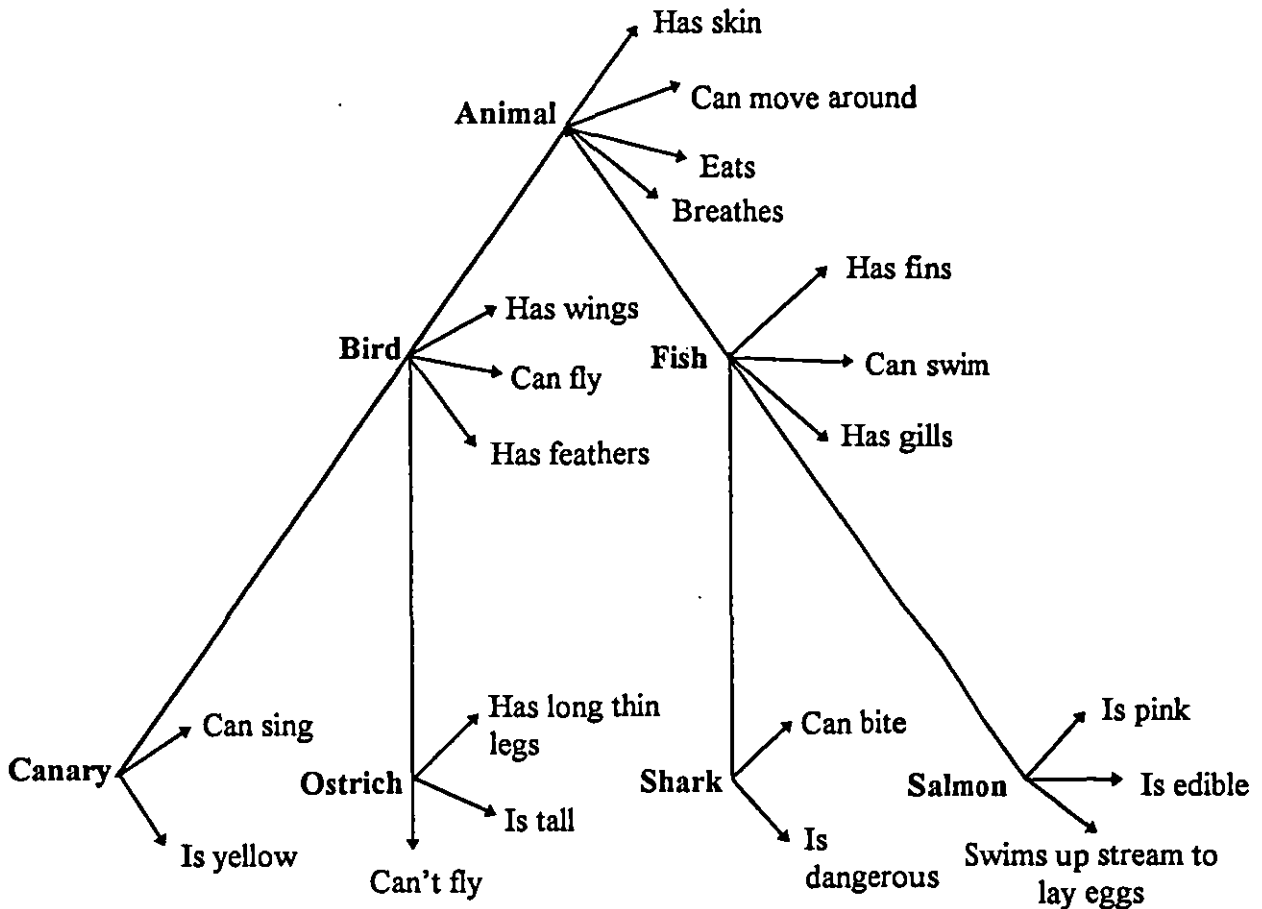
Semantic memory refers to the store of knowledge which underlies cognitive ability. Its capacity is vast. It is impressive by virtue of the speed with which we can retrieve information from it. This suggests that it is highly structured and organised. It is involved in the use of language, problem solving, logical reasoning, answering questions and our ability to understand and predict events based on laws, principles, irregularities etc.

The study of semantic memory had focused on our long term conceptual and linguistic knowledge of the world. One model which has been proposed is the "hierarchical network model" by Collins and Quillian (1969, 1972).



**Figure 4.2**

**Part of the Semantic Memory Network for a 3 Level Hierarchy**  
**(from Collins and Quillian 1969)**



Retrieval Time from Semantic Memory, Journal of Verbal Learning and Verbal Behaviour (1969), 8, pages 240 - 247.

The tasks used by Collins and Quillian were various sentences. Subjects had to judge whether these were true or false, by pressing an appropriate button as quickly as possible. The reaction time was used as a measure of difficulty. The main finding was that the time taken to decide that a statement is true increased as a function of the number of levels the subject had to go through to verify it. Thus, more time was needed to verify "a canary is an animal" than "a canary is a bird", which the model predicts.



Further, Mandler (1967) found that instructions to organise will facilitate learning, even though the subject is not trying to remember the material. The task he used was a pack of 52 cards. Each card had a word printed on it. Subjects were told to place the cards into seven columns.

Half of each group was told to try to remember the words, but not the other half. After five sorting times, recall was tested. Those instructed to organise the cards recalled as many words as subjects instructed to remember them. This suggests that organisation was equivalent to learning.

According to Paivio (1969), probably the most powerful predictor of the ease with which words will be learned is "their concreteness", that is, how easily the word evokes a mental image. Bower (1972) investigated this. The subject's task was to form a mental image of pairs of unrelated nouns (for example, "dog" and "hat") where the two words were interacting in some way. This resulted in better recall than when subjects were instructed merely to memorise the words.

Another area in which the nature of learning has been investigated is that of Perception. However most psychologists regard perceptual abilities as the product of an interaction between genetic factors (nature) and environmental factors (nurture). Some attempts have been made to test the merits of the nativist and empiricist positions.

Most of the evidence comes from the work of Von Senden. In 1932, he reported 65 cases of people who had undergone cataract removal surgery.

Von Senden's original data was taken up by Hebb in 1949. He analyzed the findings in terms of:

- \* **Figural Unity:** the ability to detect the presence of a figure or a stimulus.



- \* **Figural Identity:** being able to name or in some other way identify the object. Hebb concluded that while "Figural Unity" seems to be innate, "Figural Identity" seems to require learning.

It is clear from this selection of studies that different tasks can be used for different purposes in order to demonstrate learning. It is possible to look at the types of tasks which are used to train Process Control Operators.

The arrays may consist of thirty indicators and recorders, some of which are control instruments and an annunciator alarm block. The plant includes unit operations, control loops, and thermal economy systems which produce diagnostic difficulties typical of chemical process plants, for example, symptom masking and symptom referral.

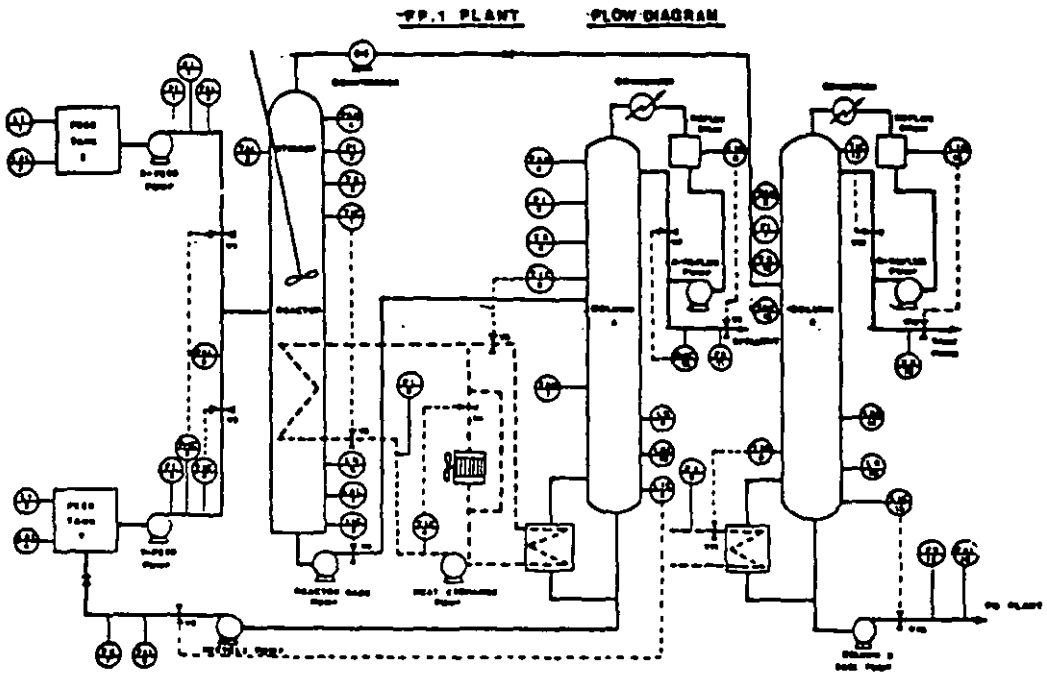
Relief Operators are versatile people who are required to go to a variety of plants on the site and take over the control and fault diagnosis problems of an operator.

The centralised control room is typical of many continuous process industries. Large and complex arrays of information are displayed on panels of instruments. Such processes, be they oil refineries, nuclear power stations or chemical processes, will rely largely on automatic control systems. The operator's task therefore consists mainly of routine monitoring and logging. However, in the event of a plant breakdown, it is essential that the human operator can use any display information rapidly and efficiently to diagnose the cause of failure, so that he can take remedial action. As automatic control systems become more and more sophisticated, diagnosis of faults within the process may represent a major component of the control room operator's task.



**Figure 4.3**

**Fictitious Chemical Process Plant**



Looking at fault finding in electronic equipment, the key to the effective maintenance of most present day electronic equipment lies in the rapidity with which faults are located once they have occurred. Rulon and Schweiker (1956), have pointed out that fault finding or trouble shooting has been considered an art. The fact that it is regarded by some workers as problem solving (Gagne 1954, Ray 1955), is implicit recognition that the individual finds his own way and does not directly apply previously learned rules.

Bryant et al. (1956) prefers a broad definition of the "task" to include any activity which is directed expressly to the correction of certain classes of malfunctions. Although it is not possible to define the "task" strictly, it is possible to describe the demands of the job, in broad terms. It is essentially a form of searching.

A piece of equipment (for example, electronic equipment) may contain perhaps hundred or thousands of parts. A failure which leads to its



breakdown is caused by a failure of one of these. The job is to locate it as rapidly as possible.

Having considered what "tasks" are in areas of Psychology as well as Process Control, attention will be focused on tasks as used in the special area of "Cognitive Style", examining the Field Independent (Fi)/Field Dependent (Fd) dimension.

Research on stimulus generalisation suggest that Fd people show more generalisation along simple stimulus continua. However, when confronted with more complex stimulus configurations, Fi people appear to show greater positive transfer of training. For example, Messick and Fritzky (1963) used a task in which subjects learned nonsense syllable names of geometric designs and were asked to apply these names to variations of the designs. It was expected and found that Fd subjects would be less effective than Fi subjects at transferring the names to the design variations, because they attached the names to the whole rather than to the parts of the original designs.

Research has also been carried out on the ability to discriminate and synthesise. For example, Gump (1955) found that Fi adults performed better on a picture recognition task than Fd adults. Witkin et al. using similar procedures (defocusing), was unable to replicate Gump's findings when children were used as subjects. They state that the contradictory results may reflect differences in the way children and adults perform on picture recognition tasks. They suggest that Fi children may generate more highly organised and well integrated prerecognition hypotheses than Fd children.

Investigators, for example Fredrick (1967), Rosenfeld (1963), and Shapson (1969) have been concerned with the possibility that Fi people, adopting a participant role in the learning process, would be likely to impose a mnemonic structure or to reorganise associative material for more effective storage and retrieval. Generally speaking, it is assumed



that verbal associations are acquired by a process of reorganisation. Other authors, for example Rosencrans (1955) have suggested that organising associative learning material reduces interference and facilitates learning retention. Such studies have used group tests of paired associates.

#### **4.8      Goal Response Distance**

Since the use of hierarchial tasks analysis is the predominant basis for training in process control tasks and process control is the main thrust of this thesis, it is appropriate to look more closely at "hierarchial task analysis".

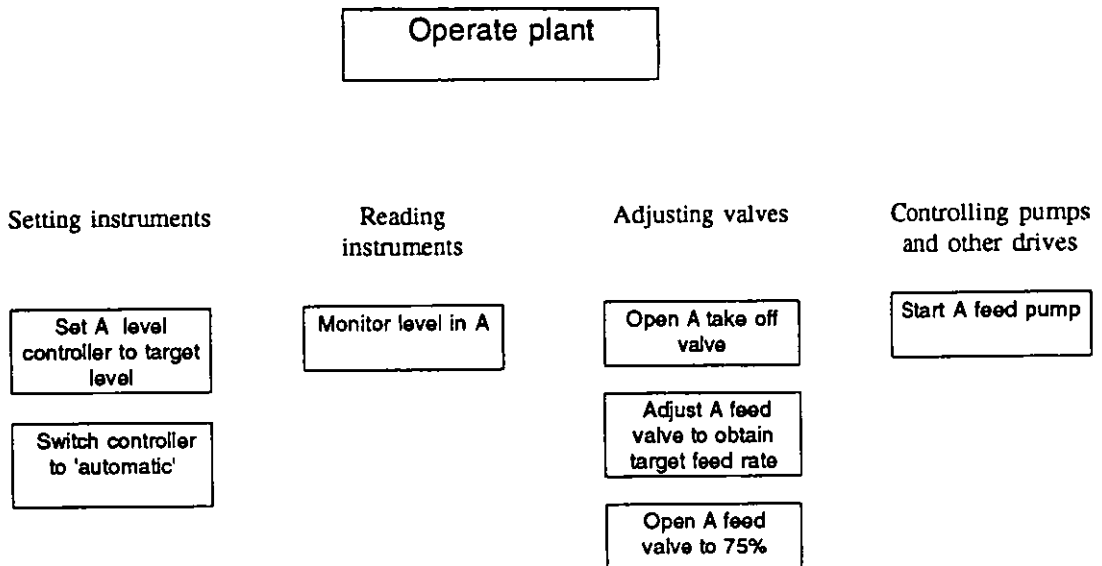
If Hierarchial task analysis is a basis for training, it is possible to consider a variety of "parts", each defined in terms of a particular goal and the set of interfacing activities represented to the operator. For example, in a real plant the operator's goal is to maintain production at a specified rate. The operator does this by using a set of interfacing activities defined in terms of the instruments and controllers available in the control room or out on plant; actions such as starting up pumps, opening valves and reading indicators, see Figure 4.4 overleaf - A small sub-set of some of the basic interfacing actions involved in operating a plant.

In hierarchial task analysis, an overall goal is represented in terms of a number of intermediate levels which ultimately govern the interfacing responses, such as pump and valve operation. An illustration is shown in Figure 4.5 page 78 - A Representative Hierarchial Task Analysis. These immediate goals incorporate, at a higher level, sub-goals such as "start up", "run" or "shut down system". At a lower level there are goal descriptions such as "start up A", "stabilise unit B", while at a lower level still descriptions such as "establish flow to distillation column" will be encountered, which in itself is ultimately described in terms of the interfacing responses referred to earlier.



**Figure 4.4**

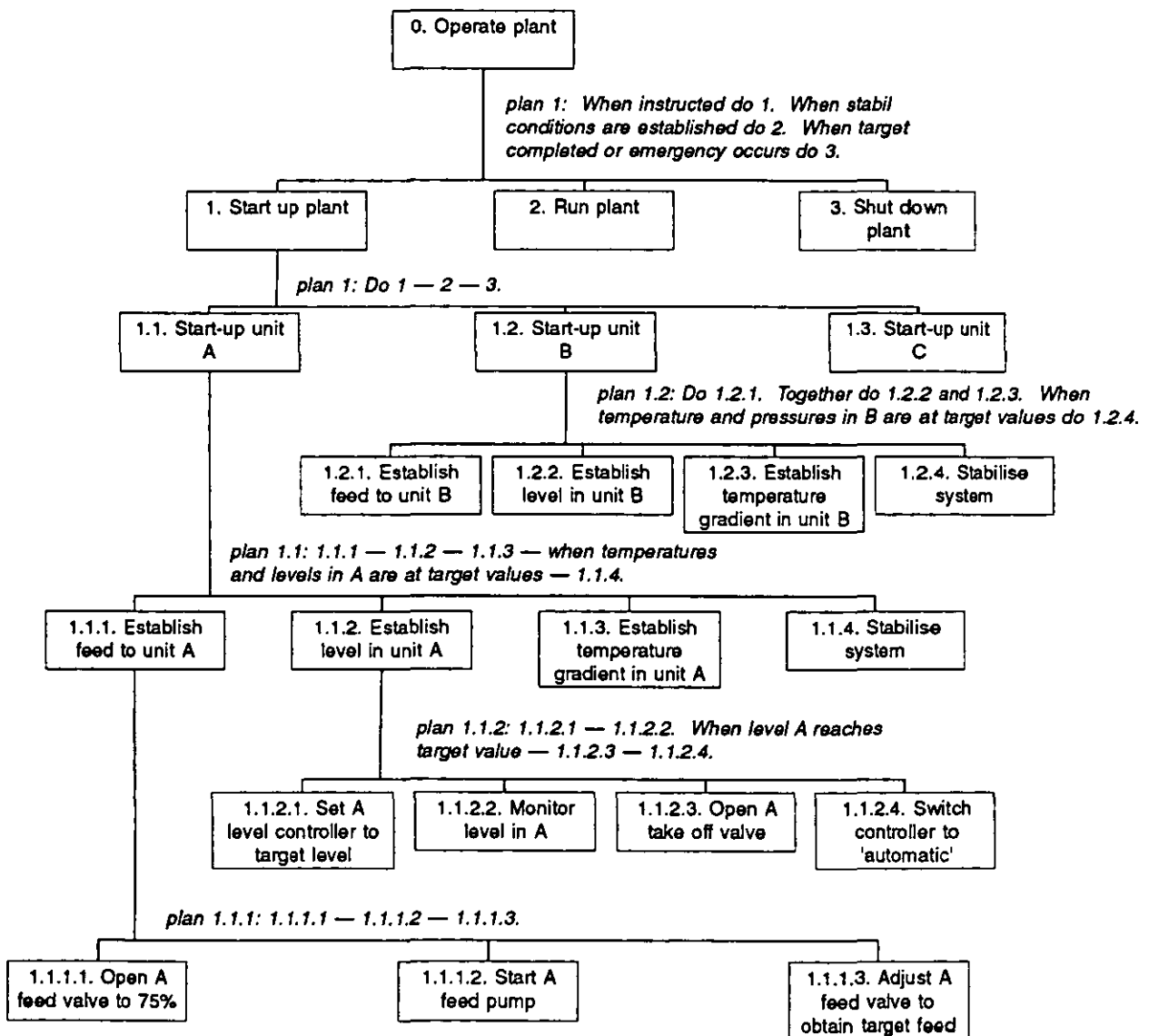
**A small sub-set of some of the basic interfacing actions involved in operating a plant. These represent the sorts of actions that may be taken from within a control room to operate a plant.**



If a hierarchical task analysis had been carried out to reveal these features, it is possible to simplify the challenge presented to the trainee in a variety of ways. Just as the operator, in reality, is set the task of controlling the plant using the interfacing responses, so a trainee is set a task on controlling the plant using the interfacing responses. Thus a trainee is set a task defined in terms of a sub-goal and given a set of responses resources available during that stage of training. The trainee may be set one of many simplified versions of what will be expected in the real task. For example, the trainee could be asked to say how he would "control the overall plant", given the resource of a "button to start up", a "button to run" and a "button to shut down". See Figure 4.6 page 80 - A High Level Simple "Part" Task to Simplify Training. The trainee would therefore acquire some level of skill through this practice, albeit using very crude response resources. At this level, the trainee would learn about when to carry out the main task elements. Learning this would be far easier than having to learn the overall task. It is possible to make



**Figure 4.5**  
**A Representative Hierarchical Task Analysis**



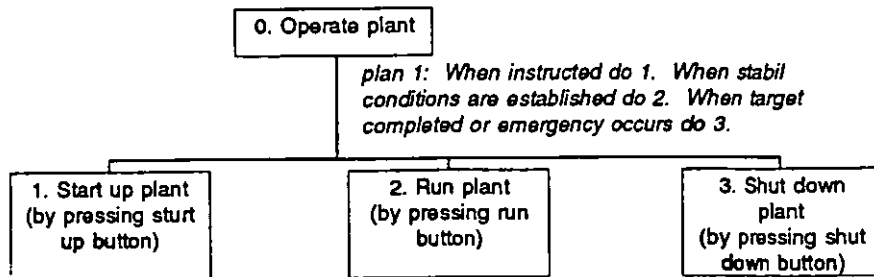


trainee, by setting a low level goal such as "establish feed to a unit A", by providing response resources which would be encountered in the real task. See Figure 4.7 page 80 - A Low Level Simple "Part" Task. In this case, the trainee would learn procedures for feeding a unit by manipulating pumps and valves. It is also possible to provide a substantial number of intermediate tasks. For example, the trainee could be asked to start up a distillation column by using other intermediate goals as shown in Figure 4.8 page 80 - An Intermediate Simple "Part" Task.

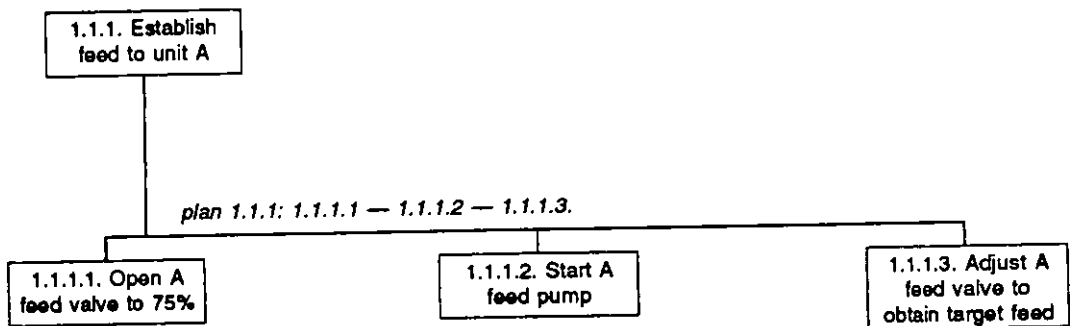
Presumably, each of the tasks set out in Figures 4.6, 4.7 and 4.8 will be easier for the trainee to master than the overall task set out in Figure 4.4. However, it cannot be assumed that any one of these will be any easier than the others even though they are related to each other in the original hierarchy. Figure 4.9 page 82 represents the hierarchy from Figure 4.5. Version A shows the entire hierarchy. In this case, the trainee would be presented with the goal (0) and provided with response facilities (1.1.1.1; 1.1.1.2; 1.1.1.3; 1.1.2.1; 1.1.2.2; 1.1.2.3; 1.1.2.4; 1.1.3; 1.1.4; 1.2.1; 1.2.2; 1.2.3; 1.2.4; 1.3; 2; 3). This will require the trainee to master all the intermediate planning elements of the task, which are not formally shown. Version B is a simplification of version A, offering a lower level goal (1) and fewer response facilities (1.1.1.1; 1.1.1.2; 1.1.1.3; 1.1.2.1; 1.1.2.2; 1.1.2.3; 1.1.2.4; 1.1.3; 1.1.4; 1.2.1; 1.2.2; 1.2.3; 1.2.4; 1.3). There is no basis for simplifying the task, but there are fewer plans from the original analysis to be accommodated, with fewer response facilities. Therefore, it is assumed that version B will be easier. Similarly, version C is easier than version B. By the same argument, version D is simpler still.



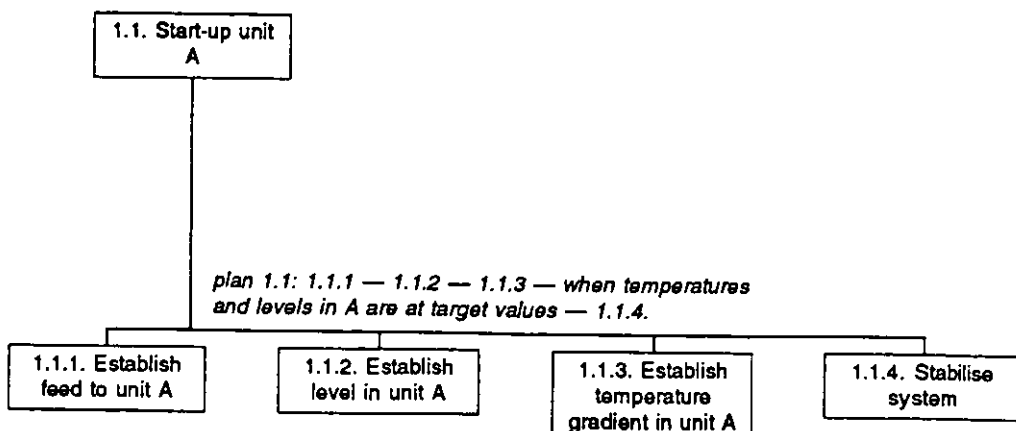
**Figure 4.6**  
**A High Level Simple "Part" Task To Simplify Training**



**Figure 4.7**  
**A Low Level Simple "Part" Task**



**Figure 4.8**  
**An Intermediate Simple "Part" Task**





The term "Goal Response Distance" refers to the relative amount of planning at each respective level, on the grounds that as this decreases, the cognitive demand on the trainee reduces. "Distance" is not simply a function of the number or even type of plans in respective hierarchies. It is simply a relationship between a hierarchy and its constituent hierarchies. No relationship between versions E and F with regard to distance is assumed, because neither encompasses the other. Similarly, it is not assumed that F is simpler than the apparently more complex version B, because neither encompasses the other, although it is assumed that version F is simpler than version A because F is contained within A.

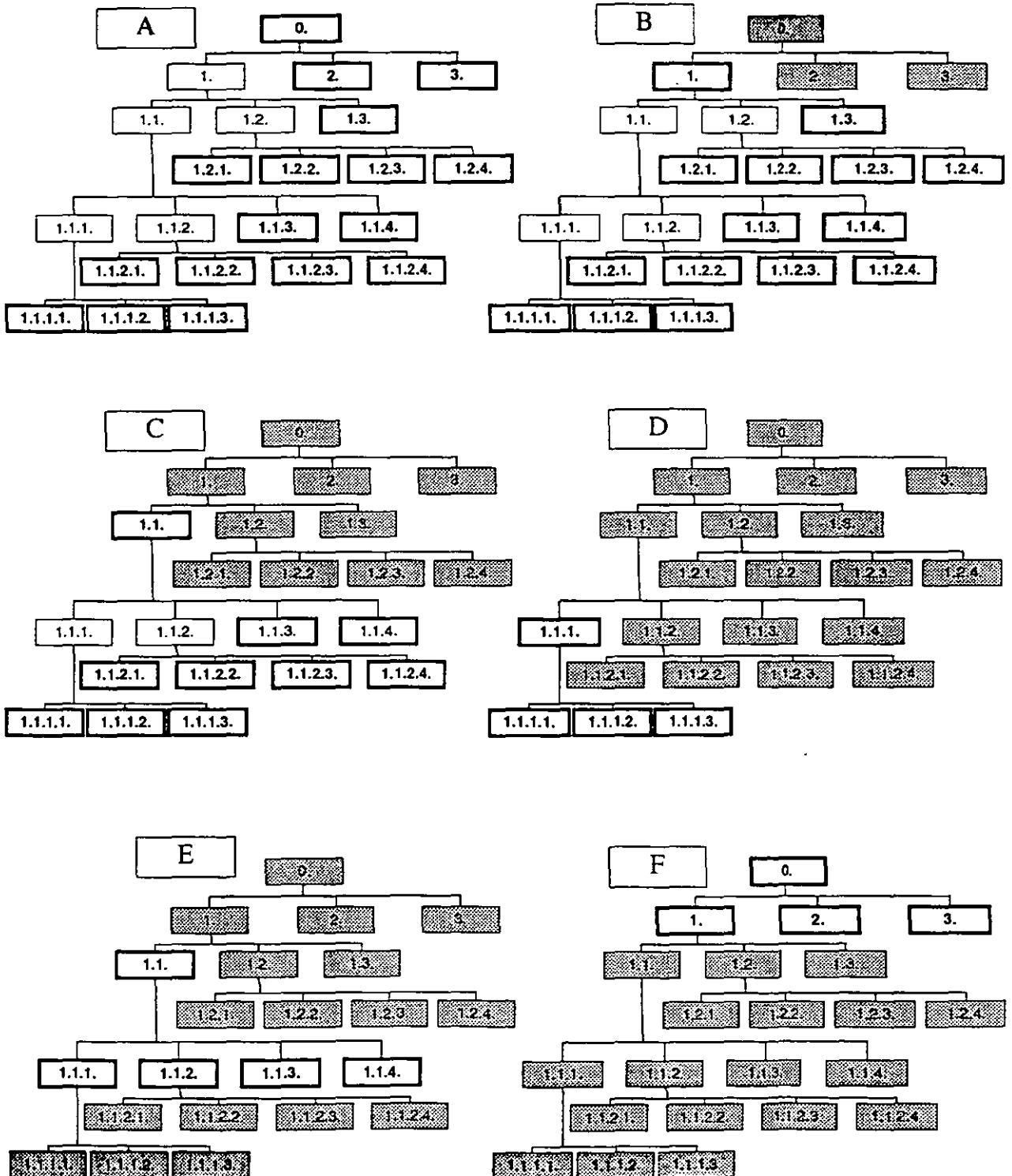
By using this concept of goal response distance, it is possible to select tasks of relative difficulty levels with some confidence, without having to resort to an empirical study to establish task difficulty. This is convenient for the present research and essential in an adaptive training environment where particular task configurations may not have been previously encountered.



**Figure 4.9**

Six Hierarchies which could be presented during training to illustrate different task distances with different levels of difficulty for the trainee.

Shaded boxes represent the parts of the tasks that have been removed for a particular level of training. Bold white boxes represent those elements of the task presented during training (ie goals and response facilities). Fine white boxes are the intermediate levels of the task analysis not explicitly presented as part of the task during training.





It is apparent that Psychology is rich in its discussion of the nature of knowledge and tasks. However, it is not clear how such knowledge and tasks could be fully defined in terms of Process Control. There is some use of the term "Principles" as used in Cognitive Psychology. Again, its use is not fully understood when training Process Control operators is talked about.

As has already been mentioned, "distance" is an idiosyncratic term. When applied to "process control", it has been defined fully so that later studies can be understood, the first of which will now be considered.



## **CHAPTER 5**

### **5.0 Individual Choice in the Use of Information in the Execution of Process Control Tasks**

#### **5.1 Summary**

A study was conducted in order to establish whether or not there are individual differences in the manner with which people acquire process control skills. Using constructed tasks, under two training conditions, performance data were analysed for retention and transfer, errors and strategies used. Two groups of subjects were presented with different training conditions to support the acquisition of a simulated processing skill. In one condition, subjects were presented with a set of explicit procedures to help them complete their task. In the second condition, subjects were given process knowledge, requiring them to construct their own responses.

It was found that while procedures aided the performance of some subjects, it was a hindrance to others. There was greater retention and transfer of information when subjects were allowed to construct their own responses. It was also found that individuals could use information in whatever way they chose. Whilst some developed strategies for tackling a task, others developed strategies during task completion.

The conclusion of the experiments considers reasons for observed differences in performance.



## 5.2 Method

There are various ways of presenting instruction to trainees. These include the presentation of theory, for example the teaching of Physics, Mathematics and Chemistry (Lubbock, 1954). Other techniques include the algorithmic approach where operators follow a prescribed sequence of operations (Horabin et al. 1967) or a set of heuristics (rules of thumb). Knowledge of results has also been considered an important factor in the learning process (Duncan, 1977). Perhaps, the simplest mode of presentation of information is in the form of procedures. One other way of presenting information to trainees is where they are given minimal guidance so providing the opportunity to construct appropriate responses. Such modes of presentation are adopted in Experiment 1.

When trainees are faced with process control tasks, it is apparent that such tasks may be analogous to problem solving situations, where trainees may be invited to adopt certain learning or problem solving modes. The manner in which trainees learn and how much they learn could be a function of the learning environments with which they are confronted. For instance, it was stated by Sharger and Klahr, (1976) that in an instructionless environment there are neither teachers nor books. The only feedback comes from interaction with the subject matter. All information appears within the subject or from observation of the environment. That is, studies have shown (Mayer, 1975; Wertheimer, 1969; Bransford and Johnson, 1973; Newell and Simon, 1972; Scandura, 1977; Goldstein, 1974; Dunker, 1945; Resnick and Glaser, 1976; Katona, 1940) that learning is more efficient in those conditions which facilitate the construction of appropriate responses through discovery, rather than learning a list of procedures.

Scandura (1970) pointed out that, when there is the criteria of initial learning of a few responses, explicit and detailed direction seems to be most effective and efficient. But when the criteria is that of retention and transfer (that is understanding), intermediate direction seems to produce



the best results (Kersh 1958; Katona, 1940). However, Wittrock and Keisler (1965) pointed out that giving specific answers and rules may retard retention and transfer because there is insufficient practice and reinforcement for overtly applying concepts. However, there is a lack of consistent adequate terminology and labels to describe the stimuli employed in these studies. For instance, what is described as intermediate direction in one experiment (Kittel, 1957) may be more directive than what is described as maximum direction (Craig, 1956) in another experiment. Further, what is described as "discovery treatment" (Gagne and Brown, 1961) may involve presenting to trainees the rules, the specific answers to the questions and a second day's rehearsal over the same material that was closely directed the first day.

However, these studies do not indicate that subjects bring their own "psychological equipment" to a task, which would enable them to make sense of it. It is possible that these individual characteristics could account for the different responses produced by people.

### **5.3 Rationale for Experiment 1 - Part 1**

**Aim:** To show that people vary in the manner in which they choose to explore their environments and the consequences of this for learning.

In order to demonstrate that cognitive style has a significant effect on the execution of process control tasks, it is first necessary to demonstrate that there are individual differences between people in the manner with which knowledge is acquired, processed and applied. This is the purpose of the experiment reported here.

Constructed tasks of a small mixer plant are used as environments in which people are given the opportunity to explore. The first experiment is concerned with the manner in which individuals use information. Tasks containing knowledge which is common to each other are presented along



with tasks which do not share knowledge so that if knowledge is a pertinent factor to consider, performance on the latter tasks should vary between individuals. Often trainees are put in a position where they may have to cope with tasks of different distances given that they have different amounts of information and different types available for use. Tasks which share knowledge should therefore be easier for an individual to cope with than those tasks which do not share knowledge.

If trainees are given minimal guidance in the form of information then it is apparent that they may be able to "construct responses" from their repertoire of responses or from information which they are presented with.

Issues to be examined include:

- \* Should tasks be presented to trainees which require knowledge common across several tasks, or would it be better to present tasks which do not share knowledge with each other?
- \* What are the effects of specified instructional material on transfer, the construction of responses and retention?
- \* How is it possible for the instructor to use specified instructional materials in order to help the trainee cope with a given distance task which may be outside his "difficulty" range?

The following hypotheses were formulated:

- i. Individual characteristics would account for different responses produced by individuals.
- ii. There would be a difference in the type/quality of responses made depending upon the sort of instructions used (oral or written).



- iii. Response construction would help the retention and transfer of information.

#### 5.3.1 Subjects

Forty subjects were used. These were undergraduates, postgraduates and research assistants of Loughborough University. Subjects studied included Mathematics, Engineering, Library Studies, Water Transport, Sports, Sciences and English. Subjects ranged in age from 18 to 40 years. The bulk of the subjects were male. More than half of the subjects were from a science background.

#### 5.3.2 Materials

A simulated control panel of a small mixer plant presented on a MacIntosh computer was used to present training tasks and experimental tasks to subjects (see Figure 5.1 and 5.2, pp.89-90). Tasks were video recorded for later analysis.

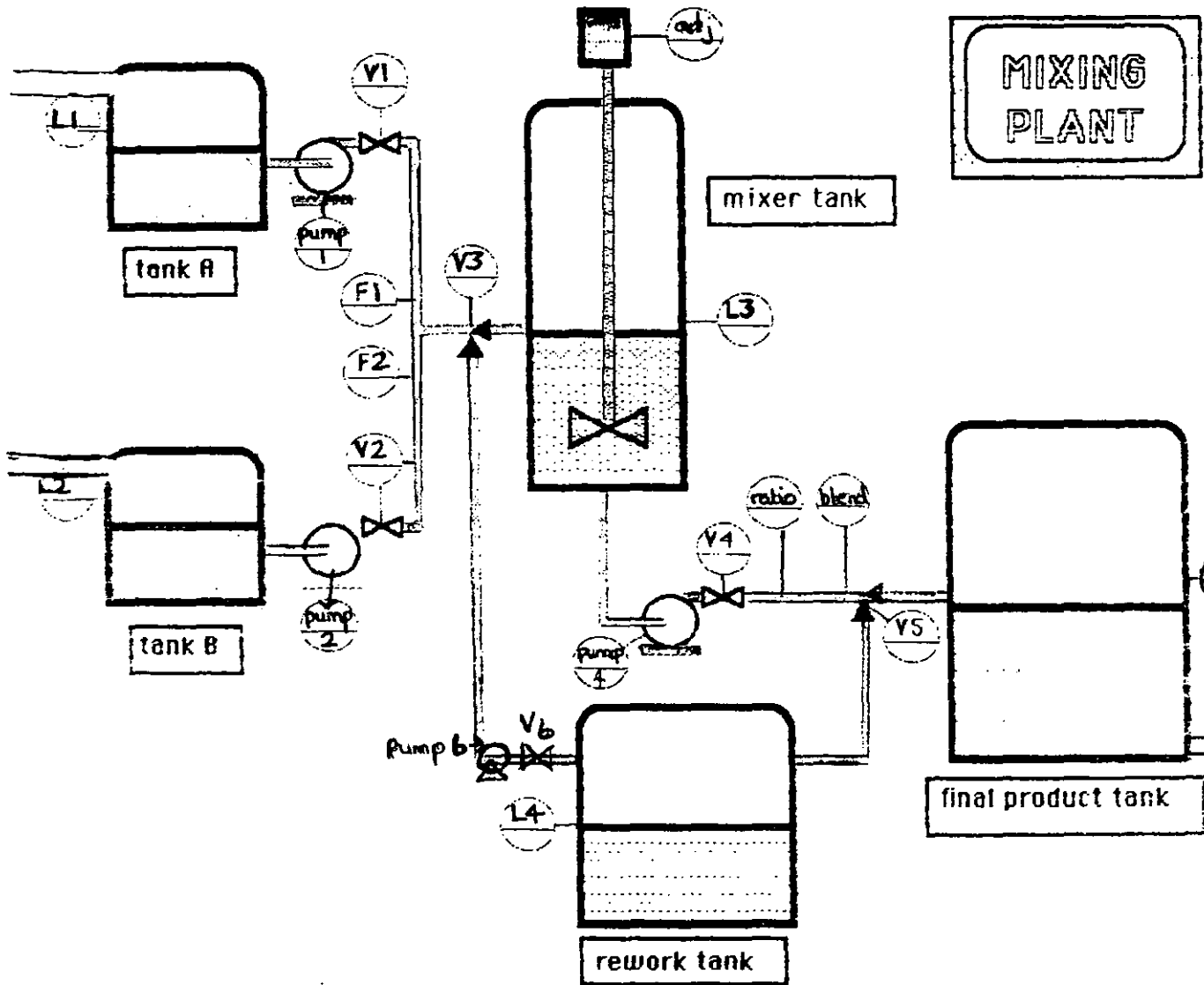
#### 5.3.3 Design

Subjects were randomly allocated into two groups, a "Procedures" and a "Concepts" group. There were 20 subjects in each group. Subjects in each group underwent an initial training session where the principles underlying the functioning of a process control plant and its control panel were introduced (see Tasks Section 5.3.4).

The subjects of each group were randomly allocated to one of four conditions (see Table 5.2). There were five subjects in each condition. For Condition 1 the subjects were given a "small distance" task and then a "large distance" task. For Condition 2, the subjects were given a "large distance" task and then a "small distance" task. For Condition 3, the subjects were given a "small distance" task and then another task which shared "knowledge" with the small distance task. For Condition 4 subjects



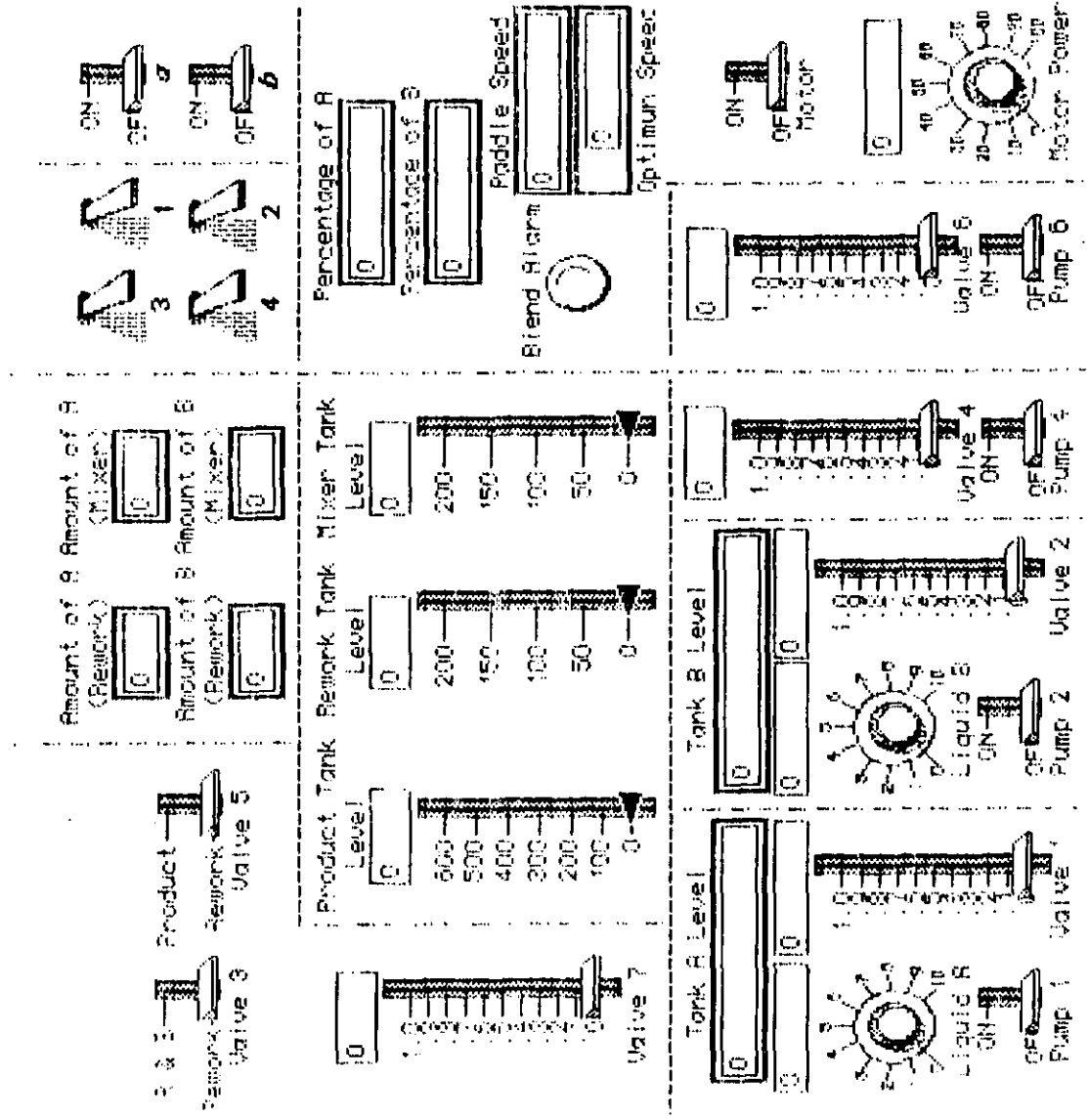
**Figure 5.1**  
**Mixing Plant**





**Figure 5.2**

**Mixing Plant Panel**





were given a "small distance" task and then a task which did not share "knowledge" with the "small distance" task. The same "small distance" task was used in all conditions.

Group 1 (the Procedures Group) differed from Group 2 (the Concepts Group) in that they were presented with explicit procedures of how to perform the first task, that is the small distance task in Condition 1, the large distance task in Condition 2, the small distance task in Condition 3 and the small distance task in Condition 4.

**Table 5.1**

**Experimental Design for Experiment 1 - Part 1**

	1	2	3	4
Procedures Group	Small distance task and then large distance.  N = 5	Large distance task and then small distance.  N = 5	Small distance and then task that shared knowledge with the small distance task.  N = 5	Small distance and then task which did not share knowledge with the small distance task.  N = 5
Concepts Group	N = 5	N = 5	N = 5	N = 5

#### 5.3.4 General Description of Experiment Using Tasks

Instructions were given to all subjects, so as to help them to understand the nature of what they would be confronted with in the main tasks. Various elements of the system were introduced to the subjects to investigate:

- \* The function of the input and output valve.
- \* The function of the pump.
- \* The interrelationship between two tanks.
- \* The function of diverting valve.
- \* The function of the motor and paddle.



Tasks were given to subjects as specified in the conditions for each group. Performance was measured in terms of errors, transfer of information and speed of completion of tasks. Approximately one week later the subjects were presented with two additional tasks which they had not seen before.

However, each task involved similar elements to those that subjects were presented within the previous session.

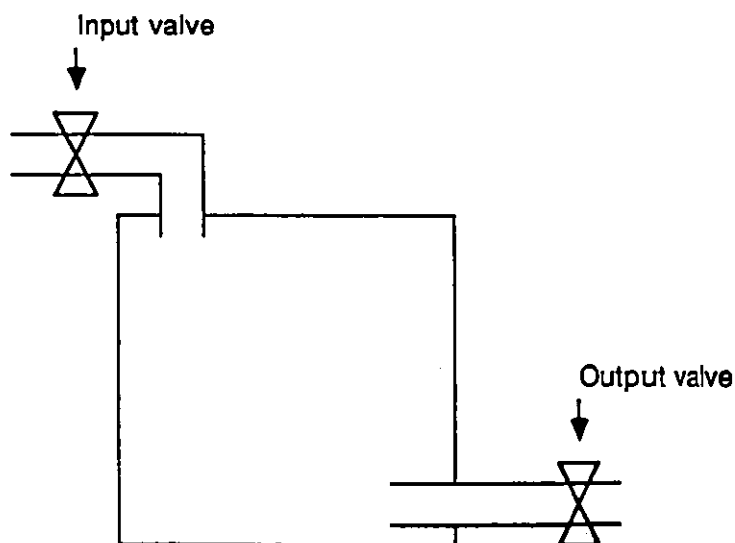
Altogether there were three steps in the experiment:

- \* Presentation of training tasks
- \* Presentation of main tasks
- \* One week later, presentation of the retention tasks.

#### **The Function of the Input and Output Valve**

The mixer tank level is dependent upon the amount of liquid input and output. If the input is greater than the output, then the level of liquid in the tank will continue to rise.

You may want to test this and then observe the results by graphical means. You may want to relate the diagram below with the panel on the screen.

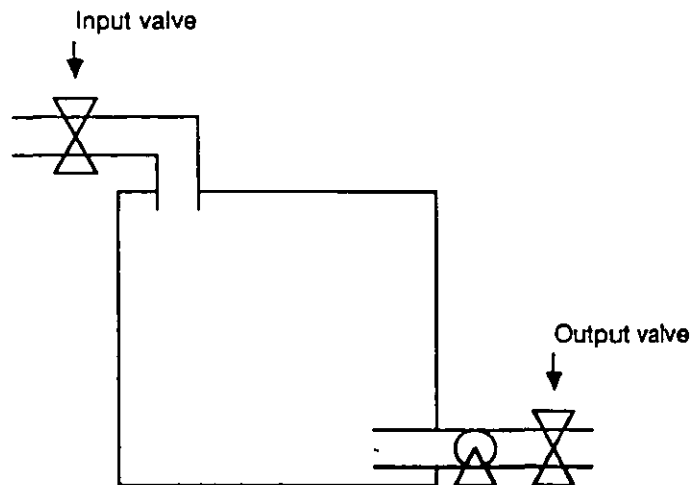


**Task 1:** Using the input and output valve, adjust the tank between 50 and 60 units and then maintain it at this level.



### The Function of the Pump

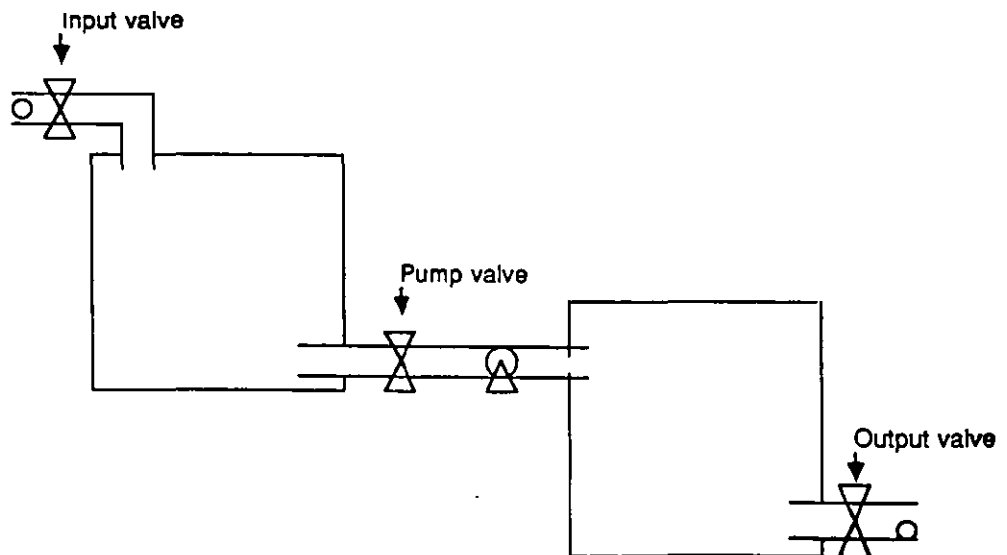
It is not sufficient to open a valve and allow liquid to flow into a tank. It is also necessary to have a pump. This propels the liquid from the tank. However, the valve must be opened before the pump when a task is to be completed.



**Task 2:** Using the output valve, pump and input valve, adjust the tank level to 60 units and then decrease the tank level to 30 units of liquid.

### The Interrelationship Between Two Tanks

There is a dynamic relationship between two tanks. This means that changing the level of liquid in one tank may influence the level of liquid in the other if pumps and valves are kept open.

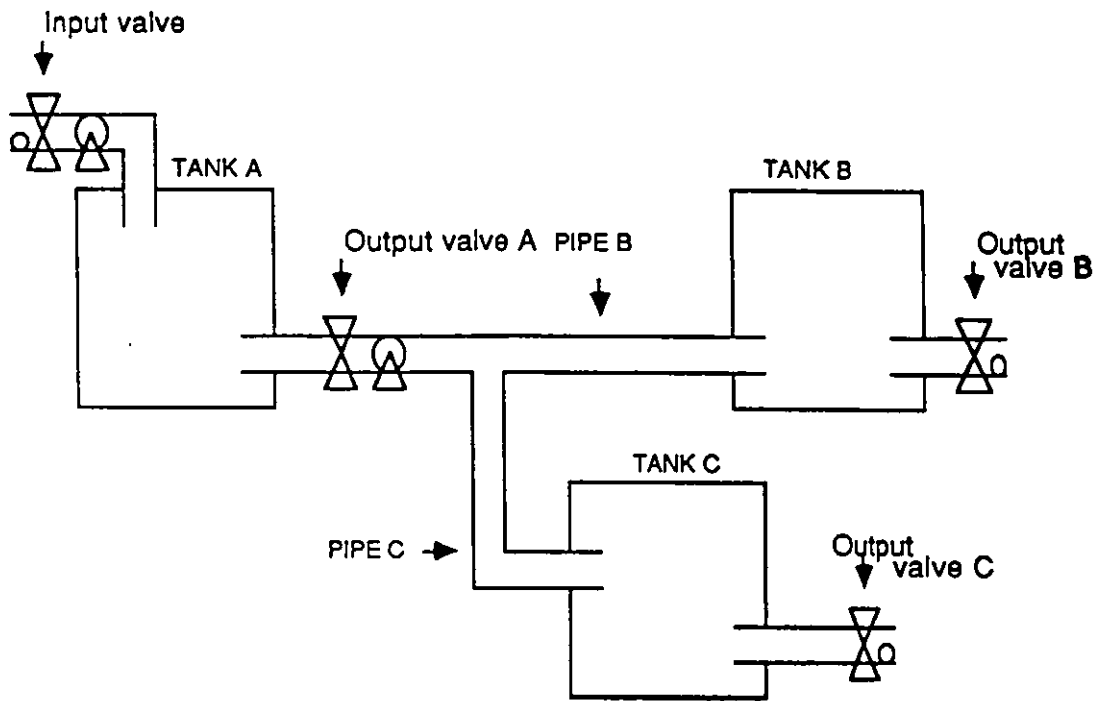


**Task 3:** It is the case that the criterion level for these two tanks is 60 units. However, one tank holds 80 units of liquid and the other tank holds 90 units of liquid. Adjust the tank levels so that both are to criterion.



### The Function of the Diverting Valve

The diverting valve has the effect of either directing liquid to Tanks B or C. It is therefore possible to change the level of liquid in Tanks B or C by using this valve.

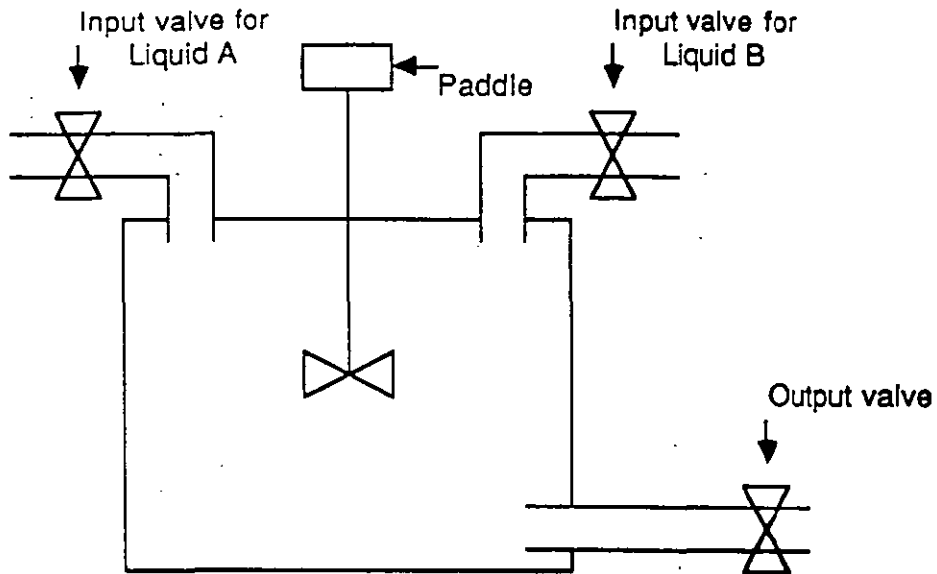


**Task 4:** The criterion level for these tanks is 40 units of liquid. However, as you will notice, all tanks are not to criterion level.

### The Function of the Motor Power and Paddle

The motor power has the effect of varying the rate of the paddle speed. An increase in the level of liquid in the mixer tank should be accompanied by a decrease in the paddle speed, because the liquid in the mixer tank is resident for a longer period and rapid mixing is no longer essential.





**Task 5:** Example 1 demonstrates the latter effect. Given that the optimum paddle speed is 50.00; your task is to mix 16 units of A and 15 units of B.

### Main Tasks

i. **Small Distance Task** - (as defined in Chapter 4)

The blend arm is activated. The task is to deactivate the alarm by making various adjustments. Once the liquid is mixed it should then be diverted to the product tank.

ii. **Large Distance Task** - (as defined in Chapter 4)

The system has been cut short in a run. This is the reason why there are various readings in front of you. Instead of making 600 units of liquid, ie 83% of A and 17% of B; the task is to make 100 units of liquid (40% of A and 60% of B). This must be of the correct blend. The liquid must then be diverted to the appropriate tank.



- iii. **Task which Shared Knowledge with the Small Distance Task** - For an unknown reason liquid is not flowing into the final product tank. There has been a build up of liquid in the mixer tank. This has exceeded 180.80 units. For this reason the paddle has ceased to function. Remedy the situation so that 100 units of the product is made given that the optimum paddle speed for 100 units of liquid is 50.00.
- iv. **Task which Did Not Share Knowledge with the Small Distance Task** - Before start-up the plant is in a state where there is nothing in the mixer tank. There is a lot of liquid in the rework tank and 25 units of liquid in the final product tank. The task is to make 100 units of liquid product using the liquid in the rework tank, after which there must be systematic shut down of the plant.

### **Retention Tasks**

- i. The product tank is full. The mixer tank is also full and the paddle has stopped. Diagnose the cause of this and restart the plant so that it is possible to mix liquid in the ratio of 5:1.
- ii. There is no liquid in Tank A but there is liquid in Tank B. There is less than 20 units of liquid in the mixer tank. This is off specification. Mix 70 units of liquid in the ratio of 4:2.

### **5.3.5 Procedure for the Training Exercise**

All subjects were given the "Principles" outlining the "Mixer Plant".

"The plant will mix two liquids together of a specified ratio and blend. The ratio is normally 5 units of liquid from Tank A and 1 unit from Tank B, ie 5:1.



Anything that is off specification, ie of the incorrect ratio and blend will contaminate the whole batch. It is therefore important to anticipate changes from the desired state as early as possible and then switch the product to the rework tank.

Valves 1, 2, 4, 6 and 7 are control valves. They may be opened on the whole range of 0 to 100%. Valve 3 and Valve 5 are diverting valves. They can only be opened or closed.

All pumps and paddle are electrical. Experience has shown that pumps should be turned on only when the intake pipe is full. The paddle should only be turned on when it is covered with liquid. If the pumps and paddle are put on first, then they may disintegrate due to the energy derived from their own rotation. The paddle speed can be adjusted along a range of 0-100%. If feed rate (the deliverance of liquid from Tanks A and B to the mixer tank) is raised, the rate of the paddle has also to be raised.

In conjunction with the above, the experimenter points to the paper outline of the Plant. Subjects are further instructed "Relate this diagram to the Control Panel on the MacIntosh's screen".

The diagrams were presented to subjects for 15 minutes. During this period of time they were not allowed to do anything except look at the diagrams.

Five examples of the types of tasks that subjects would encounter during the main experimental session served as a training mechanism. Subjects were instructed thus:

"For the first example, I have placed some literature in front of you which incorporates a diagram (the experimenter points to the material in question). This is directly related to what you see on the screen. You have 10 minutes to study the material, after which you are to carry out the



task at the end of the page (the experimenter points to the task). Have you any questions? If you require help whilst completing the first task, feel free to ask".

Instructions along similar lines were given for all examples, except Examples 3 and 4, where subjects were asked to formulate their own approach to particular tasks.

#### **5.3.5.1 Group 1 (Procedures Group)**

"I have placed a set of procedures in front of you. These relate to the various perturbations on the screen. You have about 10 to 15 minutes to study the materials after which I will remove the procedures from your view. These are the two tasks (the experimenter presents the two tasks to the subjects). You may spend 30 minutes on each. For the second task, there will be no procedures. You may not ask me questions relating to how to perform the task in question."

##### **Procedures for Each Task**

1. Read the optimum paddle speed.
2. Increase the motor power as required.
3. Deactivate the blend alarm.
4. Open Pump 3 and Valve 3.
5. Move the switch of Valve 5 to the product tank.
6. Direct liquid from the mixer tank to the product tank.

##### **Large Distance Task**

1. Check Tanks A and B.
2. Move Valve 3 to A and B.
3. Move Valve 5 to the Product Tank.
4. Check that Valve 1 and 2 are open.
5. Check that Pump 1 and 2 are open.
6. Adjust Valve 1, so as to increase the level of Tank A by 40%.
7. Adjust Valve 2, so as to increase the level of Tank B by 60%.
8. Increase the motor power for the paddle.



9. Check that the paddle speed has exceeded the optimum speed.
10. Switch on Valve 4 and Pump 4.
11. Check the readings of the Product Tank.

#### **Shared Knowledge Task**

1. Move the dial of Valve 3 to the Rework Tank.
2. Close Pumps 1 and 2 and Valves 1 and 2.
3. Divert liquid to the Rework Tank until the level falls to 100 units.
4. Check the blend alarm.
5. Increase the motor power as necessary.
6. Move the dial of Valve 5 to Product.
7. Open Pump 4 and Valve 4.
8. Divert all liquid from the Mixer Tank to the Product Tank.

#### **Does Not Share Knowledge Task**

1. Switch on the Rework Valve and Pump.
2. Switch on paddle when the level of liquid is above 20 units.
3. Increase the motor power.
4. Direct Valve 5 to the Product Tank.
5. Switch off Pump 1 and Valve 1.
6. Switch off Pump 2 and Valve 2.
7. Switch off the Rework Valve and Pump.

#### **5.3.5.2 Group 2 (Concepts Group)**

"The perturbations that you see on the screen need to be resolved to a particular state (the experimenter points to the Control Panel). Here is some information relating to this required state and what is happening on the screen. You have 30 minutes to bring the Control Panel to the required condition. During this 30 minutes you may ask me questions relating to the task, but only when you feel that it is absolutely necessary. For the second task, you may not request information from me. You may start when you wish."

Tasks were presented according to the conditions prescribed in the Design.



### 5.3.6 Measurements

During the above tasks, the following measurements were taken:

- \* **Speed**

A stopwatch was used to time how long it took subjects to complete each task from beginning to end. How fast a task is completed may tell us something of the nature of how knowledge is organised and the extent to which there is transfer of information.

- \* **Accuracy**

This is how correctly a subject can complete a task given sets of instructions and other information. A measurement such as this may tell us something about the nature by which sequences of activities are organised.

- \* **Errors**

An error is a blunder or a mistake. When an operator is confronted with a simulated processing problem, he in the process of problem solving may commit a number of errors. The nature of such errors may tell us something of the processes of problem solving by individuals, that is, how they use knowledge.

- \* **Use of Knowledge**

This relates to how subjects collate, integrate and make use of knowledge acquired during task completion. This is measured through the transfer of principles. It is conceivable that the nature of such transfer may be dependent upon the type of knowledge which is imparted to trainees.



**\* Transfer and Retention**

One measure of the efficiency of learning a particular skill is the extent to which that skill is retained after a specific period of time. It is desirable that the knowledge which is retained is used in a similar skill. That is, there is transfer of knowledge.

**5.3.7 Experiment 1 - Results**

This section presents the results of a comparison between the two experimental groups. As a generalisation, the conceptual way of training seemed to be the most effective in producing efficient performance. This was especially obvious with tasks that shared information with one another (that is, the Small Distance Task and another task) as opposed to those which did not share knowledge (that is, the Small Distance Task and another task which bore no relationship to one another). Further, those people who were trained by the conceptual mode (Group 2) seemed to be more efficient in utilising principles and were able to cope with large distance tasks. Nevertheless, the Concepts Group was slower in carrying out tasks; presumably because they had little information to guide their responses. However, it is important to note that some people in the Procedure Group who were presented with procedures chose not to use them, whilst others did. Therefore it appeared that people differed in the way in which they responded to simulated processing problems.

**5.3.7.1 The Use of Principles**

Generally speaking mastering tasks requires that principles should be understood.

It is possible to document the type of principles governing the tasks used and their related concepts.



It is possible to measure/record the number of principles observed by a subject by making note of his/her motor/hand actions. From such actions it may be possible to infer whether or not a subject has the necessary knowledge which is a prerequisite for the construction of a principle.

The principles used are as follows:

1. The ratio, that is, the percentage of A and the percentage of B could be adjusted by making various valve adjustments.
2. If the mixer tank is full, the percentage of A and B will not change, since the mixer tank will not accept any more liquid.
3. Valves 1, 2, 4, 6, and 7 are control valves; they direct liquid in one direction only.
4. Valves 5 and 3 are diverting valves. Valve 3 can either direct liquid to the rework tank or the mixer tank. Valve 5 can either direct liquid to the product tank or the rework tank.
5. Control valves can be opened in a range of 0 - 100%. Diverting valves can only be switched from one direction to another.
6. The extent to which the valve is opened is not proportional to the amount of liquid that passes through it. But it is related to the rate at which liquid flows through it.
7. Because the pump and paddle are electrical, they can only be switched on when they are in contact with liquid.
8. The motor power increases the rate of the paddle.
9. Paddle speed decreases if the level of the tank increases.



10. If the tank level rises above 180.80 units, then the paddle speed will drop to 0.
11. If the paddle speed is above the optimum speed, then the two liquids are mixed appropriately.
12. If the paddle speed is below the optimum speed , then the blend alarm is activated.
13. The blend alarm can be deactivated by increasing the motor power or decreasing the level of liquid in the mixer tank.
14. Liquid can only be diverted from the rework tank to the final product tank via the mixer tank.
15. The pump propels liquid forward.

#### 5.3.7.2 Concepts

- |                    |   |
|--------------------|---|
| a. Ratio           | k. Electrical Devices                                       |
| b. Pump            | l. Relationship of paddle speed to motor power.             |
| c. Paddle          | m. Relationship of paddle speed to level of liquid in tank. |
| d. Control Valve   | n. Cyclical nature of plant mixer - rework and vice versa.  |
| e. Diverting Valve | o. Relationship of paddle speed to optimum speed.           |
| f. Blend           | p. Relationship between rate of input and out put.          |
| g. Rework Tank     |   |
| h. Product Tank    |   |
| i. Mixer Tank      |   |
| j. Indicator       |   |



### 5.3.7.3 Principles and Concepts Associated with Each Task

<b>Small Distance</b>	Principle	- 3,4,5,7,9,11,12,13,15
	Concept	- a,b,c,d,e,f,h,i,j,l,m,o,q
<b>Large Distance</b>	Principle	- 1,2 4,3,4,5,6,7,8,9,10,11,12,13,14,15
	Concept	- a,b,c,d,e,f,g,h,i,j,l,m,n,o,p,q
<b>Shared Knowledge</b>	Principle	- 1,2,4,6,10,11,12,13
	Concept	- c,d,e,f,h,g,i,j,l,m,n,o
<b>Did not Share Knowledge</b>		
	Principle	- 3,4,5,6,7
	Concept	- e,g,h,i,k
<b>Retention Task 1</b>	Principle	- 1,2,3,4,5,6,10
	Concept	- a,b,d,e,h,i,j,q,m
<b>Retention Task 2</b>	Principle	- 1,3,4,5,15,16
	Concept	- a,d,e,g,h,i,j,p,q

For reasons of classification S-L denotes that a small distance task is presented first and then a large distance task. L-S denotes that a large distance task is presented first and then a small distance task.

For each subject, the number of principles used was counted. Each score was converted into a percentage. All calculations used these percentages. A 2 x (Procedures/Concepts) x 2 (Condition 1 - Procedures/Condition 2 - concepts) repeated measures Anova - on one factor showed that type of training has no significant effect on the number of principles used. However, there was a significant effect of condition on the number of principles used S-L.  $F = 47.108$ ;  $F_{crit} = 3.42$ ;  $P < 0.05$ . There was also a significant interaction between condition and type of training,  $F = 49.605$ ;  $F_{crit} = 3.42$ ;  $P < 0.05$ . A repeated measures Anova was also performed using scores from Condition 2 L-S. (See Table 5.3).



**Table 5.2**  
**Mean Percentage Principles Used for the Distances,**  
**Small and Large in Condition 1**

	Small Distance	Large Distance
Procedure Group	100	75
Concept Group	100	82

**Table 5.3**  
**Anova Summary**

Factor 1 = Procedures/Concepts  
Factor 2 = small - large

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	61.25	1	61.25	0.1772
Factor 2	2311.25	1	2311.25	47.108
Interaction	2433.75	1	2433.75	49.605
WSE	392.50	8	49.063	
BSE	2765.00	8	345.63	
Total	7963.75	19		

A significant effect of condition on the number of principles used was evident  $F = 8.6213$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$  (see Table 5.5).



**Table 5.4**

**Mean Percentage Principles Used for the Distances,  
Small and Large in Condition 2**

	Small Distance	Large Distance
Procedures Group	52	100
Concepts Group	78.8	100

**Table 5.5**

**Anova Summary**

Factor 1 = Procedures/Concepts

Factor 2 = Large - Small

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	897.80	1	897.80	1.293
Factor 2	5985.80	1	5985.80	8.621
Interaction	897.80	1	897.80	1.293
WSE	5554.40	8	694.30	
BSE	5554.40	8	694.30	
Total	18890.20	19		

Further a one way independent Anova showed a significant effect of type of training on the number of principles used for the "shared knowledge" and "does not share knowledge" tasks  $F = 9.389$ ;  $F_{crit} = 3.42$ ;  $P < 0.05$ . However, there was no effect of type of task on the number of principles used (see Table 5.7).



**Table 5.6**

**Mean Percentage Principles Used for Tasks that Share Knowledge  
and those that Do Not Share Knowledge**

	Shared Knowledge	Does Not Share Knowledge
Procedures Group	57	83
Concepts Group	100	96

**Table 5.7**

**Anova Summary**

Factor a = Procedures/Concepts

Factor b = Shared Knowledge/Does Not Share Knowledge

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	5650	3		
Factor 1	3920	1	3920	9.389
Factor 2	605	1	605	1.449
Interaction	1125	1	1125	2.695
Within Groups	6680	16	417.5	
Total	12330	19		

### Time

The time that it took each subject to complete as much of the tasks as possible was documented in minutes. Each analysis reported used these times. A 2 way (procedures / concepts) x 2 (small and large distance tasks) repeated measures on one factor showed a significant effect of Condition 1 on the time that each subject spent on a task  $F = 114.38$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$  (see Table 5.9).



**Table 5.8****Mean Time in Minutes to Complete the Small and Large Distance Tasks  
in Condition 1**

	Small Distance	Large Distance
Procedures Group	11.80	28.40
Concepts Group	16.00	29.00

**Table 5.9****Anova Summary**

Factor 1 = Procedures/Concepts

Factor 2 = small - Large

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	28.8	1	28.8	1.179
Factor 2	1095.2	1	1095.2	114.38
Interaction	16.2	1	16.2	1.692
WSE	76.6	8	9.575	1.692
BSE	195.4	8	24.425	

A two way repeated measures on one factor was also performed on Condition 2, that is (L - S ). This revealed a significant effect of condition on time  $F = 13.588$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$ . However, a two way independent Anova showed no effect of type of training or whether a task shares knowledge or not with a small distance task (see Table 5.11).



**Table 5.10**

**Mean Times (in Minutes) to Complete the Small and Large Distance Tasks in Condition 2**

	Small Distance	Large Distance
Procedures Group	18	27
Concepts Group	18.8	28.4

**Table 5.11**

**Anova Summary**

Factor 1 = Procedures/Concepts

Factor 2 = Large - Small

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	6.05	1	6.05	0.214
Factor 2	432.45	1	432.45	13.588
Interaction	3.45	1	3.45	0.1084
WSE	254.6	8	31.825	
BSE	226.4	8	28.3	
Total	922.95	19		

### Counting Of Errors

An overall strategy of achieving the main goal is outlined for each task. From this overall strategy, sub-goals are pinpointed. There are a number of different ways by which a sub-goal could be attained. A move that is incompatible with the achievement of a particular sub-goal is counted as an error. For example:



#### 5.3.7.4 Results for All Tasks

A 2 (Procedures/Concepts) x (Task 2/Conditions 1, 2, 3, 4) independent Anova was performed. There was a significant effect of type of training on the number of errors committed.  $F = 47.334$ ;  $F_{crit} = 2.32$ ;  $P < 0.05$ . That is, the procedure group produced more errors. There was also a significant effect of task type on the number of errors committed  $F = 117.44$ ;  $F_{crit} = 2.32$ ;  $P < 0.05$ . That is, the "large distance" task produced more errors. Further, there was a significant interaction of task type and training method on the variance  $F = 48.98$ ;  $F_{crit} = 2.32$ ;  $P < 0.05$  (see Table 5.13).

**Table 5.12**

**Mean Number of Errors Produced for the Four Conditions**

	Conditions			
	1	2	3	4
Procedures Group	2.0	3.0	6.2	9.0
Concepts Group	5.8	1.4	2.4	7.8

**Table 5.13**

**Anova Summary**

Factor a = Procedures/Concepts  
Factor b = Conditions 1,2,3,4

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	1221.1	7		
Factor a	270.4	1	270.4	47.334
Factor b	670.9	3	223.633	117.44
Interaction	279.8	3	93.267	48.98
Within Groups	182.8	32	5.7125	
Total	1403.9			



### Counting of Errors

All analysis in this section used the repeated measures Anova on one factor. There was a significant effect of task on the number of errors produced  $F = 22.56$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$  (see Table 5.15).

**Table 5.14**

**Mean Number Of Errors Produced For Task 1 and Task 2 in Condition 1**

	Task 1	Task 2
Procedures Group	3.6	5.4
Concepts Group	3.2	5.2

**Table 5.15**

### **Anova Summary**

Factor 1 = Procedures/Concepts

Factor 2 = Task 1, Task 2

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	0.45	1	0.45	0.044
Factor 2	18.05	1	18.05	22.56
WSE	6.40	8	0.80	
BSE	81.60	8	10.20	
Total	106.55	19		



### Condition 2

There was a significant interaction between the tasks and type of training  
 $F = 9.6$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$ .

**Table 5.16**

**Mean Number of Errors Produced for Task 1 and Task 2  
in Condition 2**

	Task 1	Task 2
Procedures Group	3.2	5.0
Concepts Group	4.4	3.8

**Table 5.17**

### **Anova Summary**

Factor 1 = Procedures/Concepts

Factor 2 = Task 1, Task 2

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	0.00	1	0.00	0.00
Factor 2	1.8	1	1.8	2.4
Interaction	7.2	1	7.2	9.6
WSE	6.0	8	0.75	
BSE	46.8	8	5.85	
Total	61.8	19		

### Condition 3

A significant effect was found for the type of training that subjects received on the number of errors produced  $F = 8.571$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$ . There was also a significant effect of task type on the number of errors produced  $F = 7.692$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$  (see Table 5.19).



**Table 5.18**

**Mean Number of Errors Produced for Task 1 and Task 2  
in Condition 3**

	Task 1	Task 2
Procedures Group	3.6	6.4
Concepts Group	1.4	2.6

**Table 5.19**

**Anova Summary**

Factor 1 = Procedures/Concepts  
Factor 2 = Task 1, Task 2

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	45.00	1	45.00	8.571
Factor 2	20.00	1	20.00	7.692
Interaction	3.2	1	3.2	1.462
WSE	20.8	8	2.6	
BSE	42.00	8	5.25	
Total	131.00	19		

**Condition 4**

A significant effect of task type on the number of errors produced  $F = 6.667$ ;  $F_{crit} = 3.44$ ;  $P < 0.05$  (see Table 5.21).

**Table 5.20**

**Mean Number of Errors Produced for Task 1 and Task 2  
in Condition 4**

	Task 1	Task 2
Procedures Group	1.2	2.2
Concepts Group	0.8	1.8



**Table 5.21**

**Anova Summary**

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	0.8	1	0.8	1.231
Factor 2	5.0	1	5.0	6.667
Interaction	0.00	1	0.00	0.00
WSE	6.0	8	0.75	
BSE	5.2	8	0.65	
Total	17.0	19		

Time

Conditions 1 and 2

Two way repeated measures (S - L, L - S)  $\times$  2 (Task 1, Task 2) showed no significant effect of condition on the time that each subject spent on Task 1 and Task 2 (for either the Procedures or the Concepts Group).

Conditions 3 and 4

Many tasks in this condition were not completed. It is therefore problematic to apply tests of comparison. However, the means indicate that the Concepts Group spent longer than the Procedures Group on Task 1: 20.00 minutes (Condition 3), 18.33 minutes (Condition 4) and for Task 2: 29 minutes (Condition 3), and 19.5 minutes (Condition 4).

**5.3.7.5** Construction of Responses

All the possible responses that were perceived to be constructed from incomplete knowledge was documented for Conditions 1 and 4. The reasons for this being:

- \* A small distance task does not provide all of the knowledge necessary to carry out a large distance task.



- \* Subjects would not have prior knowledge of tasks of which they have had no experience.

The percentage of responses that each subject constructed for each of the tasks in Group 1 and 2 was calculated. A 2(Condition 1/Condition 4) x 2 (Procedures/Concepts) Anova were performed. There was no significant effect of task type or training on the number of responses constructed. Also there was no significant interaction of task type and training on the number of responses constructed. This was contrary to expectations, since it was expected that the Concepts Group would produce greater numbers of construction of responses.

#### 5.3.7.6 Retention

It is evident that although the Procedures Group produced a greater number of errors than the Concepts Group in Condition 3 and 4, the Procedures Group retained a greater percentage of principles.

#### Principles

Inspection of means indicate that it was justifiable to carry out correlated "t" tests instead of Anova. A correlated "t" test showed no significant difference between the number of principles remembered in the two tasks for Condition 2 (Group 2)  $t = 0.816$ ;  $P < 0.05$ . However, for Condition 3, there were significant effects of:

- \* Type of training on the percentage of principles remembered  $F = 42.95$ ;  $F \text{ crit} = 3.44$ ;  $P < 0.05$ .
- \* Type of task on the percentage of principles remembered  $F = 20.753$ ;  $F \text{ crit} = 3.44$ ;  $P < 0.05$
- \* There was also a significant interaction of task and type of training on the percentage of principles remembered  $F = 20.753$ ;  $F \text{ crit} = 3.44$ ;  $P < 0.05$  (see Table 5.23).



**Table 5.22**  
**Mean Percentage of Principles Used for Task 1**  
**and Task 2 In Condition 3**

	Small Distance	Large Distance
Procedures Group	100	100
Concepts Group	91	50

**Table 5.23**  
**Anova Summary**  
**Condition 3**  
**Factor 1 = Procedures/Concepts**  
**Factor 2 = Task 1, Task 2**

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	4351.25	1	4351.25	42.975
Factor 2	2101.25	1	2101.25	20.753
Interaction	810.00	8	101.25	
WSE	810.00	8	101.25	
BSE	810.00	8	101.25	
Total	10173.75	19		

A two way repeated measures (on one factor) showed a significant interaction between the type of training and tasks on the percentage of principles remembered for Condition 4.



Experiment 1 showed that different people responded to simulated processing problems in different ways. However, an element of this thesis is concerned with investigating the issue of what causes such individual differences. This experiment proposes that it is the type of "task" which is responsible for observed differences in strategic moves. The complexity of the task may be a determining factor governing moves. For instance, the options of a three tank system is double that of a two tank system and one may be confronted with more alternatives of completing a task in a three tank system compared with a two tank system. That is, the three tank system has more information inherent in it compared with a two tank system. Different people process information at different levels and approach tasks in their idiosyncratic ways.

Greeno et al. (1979); Rabinowitz and Chi (1987) suggest that some learners may approach a task with a preconceived notion as to what strategies would be appropriate. Campbell et al. (1976), Earley and Perry (1987) pointed out that a specific goal encourages the development of task relevant plans. But a general goal does not have a specific performance level about which to think. On the other hand, algorithmic tasks have their paths to solutions well mapped out and straight forward. Operations are performed with a method to solve all problems of a particular class. An example of this is simple mathematical problems for which there are specific rules to be followed that guarantee a successful solution. However, heuristic tasks require people to discover which operations are relevant for solution. But, there may be no single way of solving the problem to guarantee success. There may also be ambiguity about how to go about solving the problem. McGraw (1978) cited serial number problems as an example of an heuristic task. This involved working out the relationship between two numbers in a series of numbers. This experiment investigates the nature of problem solving when subjects are presented with tasks where specific rules for them are not outlined.



This experiment investigates the nature of problem solving when subjects are presented with tasks where specific rules for them are not outlined.

#### 5.4.1 Hypotheses

The hypotheses based on the assumption that there would be transfer of information across tasks were:

- \* The type of tasks will determine the kinds of moves or strategies which people will choose to deploy.
- \* Strategy development will be dependent upon experience with the initial task.
- \* Subsequent tasks will be easier to complete.

#### 5.4.2 Method

Subjects devised modes of attack for the completion of two tasks. Some rules for the categorisation of tasks were formulated. This was based on the perceived level of complexity. The simpler task was presented first to subjects:

#### 5.4.3 Subjects

Forty subjects from Loughborough University performed both tasks. These subjects were not the same as the other subjects used in Experiment 1. The subjects studied different subjects. These included English, Engineering subjects, Library Studies and Mathematics. Subjects ranged in age from 18 to 30 years.



#### 5.4.4 Materials

Simulations of two tank and three tank systems in the form of pumps, valves, tanks and indicators were presented to subjects. Subjects were also presented with paper diagrams of these.

#### 5.4.5 Design

A two tank system and a three tank system was presented to subjects. In the two tank system, one of the tanks contained liquid above criterion. However, the three tank system had two tanks which contained liquid above and one of which contained liquid below criterion. The task was to bring these two tanks back to criterion, so that all tanks matched. It was possible to manipulate the valves and pumps so that hypothetical liquid levels could be adjusted in each tank.

#### 5.4.6 Procedure

Subjects were asked to resolve abnormal liquid levels in a two tank and a three tank system. They were instructed not to ask questions which were directly related to the manner in which the tasks could be carried out.



#### 5.4.7 Results

Each move that subjects made was recorded as a code.

Code	Meaning	
0	No Changes	
1	Increase Valve	X
2	Decrease Valve	X
3	Close Valve	X
4	Increase Valve	Y
5	Decrease Valve	Y
6	Close Valve	Y
7	Increase Valve	Z
8	Decrease Valve	Z
9	Close Valve	Z

There was more than one way of achieving the goal. Each set of movements was examined. Those moves that were incompatible with achieving the overall goal of adjusting tank levels to criterion were counted as "incompatible moves". An incompatible move is one in which the person does not complete the task due to moves which would not lead to the achievement of the goal. However, a compatible move is one which allows the individual to complete the task.

For example, if an individual were to open a valve and leave a pump shut when diverting liquid away instead of opening both, this would be counted as incompatible. A compatible move would be counted as one in which both the pump and valve were left open when diverting liquid away.

Correlated "t" tests showed that there was no significant difference between the times taken to complete Task 1 and Task 2. However, there was a significant difference between the total number of moves taken to complete Task 1 compared with Task 2.

$$t = 8.736 \quad P < 0.05$$



**Mean Moves**

**Task 1 = 38.35**

**Task 2 = 16.575**

A significant difference was also found between the number of incompatible moves for Task 1 and Task 2.

$t = 9.653; P < 0.05.$

**Mean Moves**

**Task 1 = 16.475**

**Task 2 = 1.4**



## **5.5. Conclusions**

- \* This is essentially a pilot study which seeks to explore the extent to which there are individual differences in problem solving of process control tasks. The study uses the notion of "distance" in order to construct appropriate tasks.
- \* Subjects in the Concepts Group (ie given minimal guidance of how to solve task) performed better than subjects who were not given such guidance. It is concluded that, because subjects in the Concepts Group were allowed to "construct their own responses" compared with the Procedures Group, this was a factor for their superior performance.
- \* There were subjects who could use knowledge in the form of Procedures or Principles in an appropriate manner, whilst others could not.
- \* Subjects tended to use strategies which they found appropriate at the time. These may be well thought out, or not, that is, ones based on "trial and error" alone.
- \* These experiments point out that there are individual differences in problem solving of process control tasks. These differences may be ones of a perceptual nature and are therefore cognitive in element. It is postulated that a dimension of cognitive style, that is, the Field Independent/Field Dependent dimension is responsible for these differences. An exploration of this is made in Chapter 6.
- \* Individuals abandoned procedures if they wished. They resorted to responding based on whatever information they had acquired.



- \* Whilst, for some, incompatible moves become less frequent as problem solving progressed, for others, incompatible moves appeared to be consistent from start to finish. It is therefore apparent that the manner with which individuals approach tasks are due to differences in strategy of movements.
- \* People did not repeat moves which caused errors when completing the first task. That is, learning took place.
- \* In the second experiment, subjects spent approximately equal time on both tasks. Having completed Task 1, the second task was not so problematic as it could have been, had subjects not had the initial experience with the simpler task. That is, due to a "transfer" effect, the second task was completed in approximately the same time as the first.
- \* Tasks which shared knowledge produced fewer errors than those which did not. This was especially evident with the "conceptual mode of training". Training people by this method was effective if their initial experience in training was one in which there was a logical build up of concepts from one task to the next. That is, there was greater retention and transfer of knowledge by the conceptual mode of training than by the procedural mode.



## **CHAPTER 6**

### **6.0 The Validity of Field Dependency In Accounting For Individual Difference In Skill Acquisition**

#### **6.1 Summary**

Following the conclusions from Chapter 5, that individuals use information in different ways when acquiring a cognitive skill. This chapter reports a study investigating whether individual learning styles can be predicted by an individual's score on a test of "field dependency".

All subjects from the experiments were asked to complete an Embedded Figures Test (Witkin et al. 1971). Scores derived from this enabled individuals to be placed into appropriate categories. Subjects were also asked to study the diagram of a simple processing plant. Subjects who had previously been classified as Fi or Fd were then randomly placed into either Condition 1 or 2.

Subjects in Condition 1 (experimental group) received no information (ie. no verbal or written instructions) prior to the carrying out of two tasks. However, subjects in Condition 2 (control group) received information prior to task completion.

Performance measures included the number of goals completed, the speed with which tasks were completed, the type of mental models formed, the types of strategies which Field Independents and Field Dependents could develop and the extent to which there is transfer of information.



It was found that field independents seem to be able to make appropriate use of information (that is, use information according to what benefited them most), whilst Field Dependents were unable to do so. This is illustrated by the finding that the Field Independent's mental models were more detailed than the Field Dependent's (that is more structured models were formed around the system by the Field Independents). The Field Independents were also quicker in the execution of tasks. This seemed to be a function of the fact that whilst Field Independent's seemed to formulate appropriate strategies and were able to transfer information, Field Dependents were unable to do so.

## **6.2      Method**

Chapter 5 pointed out that individuals use information in different ways, when they acquire process control skills. But, it is assumed that individual learning styles can be predicted by an individual's score on a test of field dependency. However, using the assumption of Anderson's and Fitts's stages in skilled development (where the skills become finely tuned to the task in question), there are a number of factors which could influence the effectiveness with which each stage is accomplished by the individual. The factor of individual differences can bear differently on separate stages and cause various levels of attainment to be achieved by individuals.

Anderson (1982) provided a framework for understanding observations made by Fitts (1964) on the development of skills. The three main stages are: i. Cognitive; ii. Associative; iii. Autonomous.

- i.      In the Cognitive stage, the learner makes an initial approximation of skill. This is based on background knowledge and observation of instruction. Differences in prior knowledge, may affect the reaction times of individual



responses to processing problems. Conceptual nodes may be formed between the knowledge which may be part of these tasks and the prior knowledge which people may have. For example, engineers may be more proficient than artists in the execution of process control tasks, since they may have had the experience of similar systems before (Glaser, 1984; Minsky, 1975; Schank, 1982; Potts et al. 1989; Clifton and Slowiaszek, 1981; Corbett, 1977). Also, there may be differences amongst engineers in the extent to which an initial approximation to a skill is made, as there would be amongst artists.

- ii. In the Associative stage, performance is refined through the elimination of errors. That is, refinement may be achieved at a faster pace by those familiar with the task. For example, engineers who are familiar with systems may be more proficient in the elimination of errors when confronted with process control tasks than artists.
- iii. In the Autonomous stage, skilled performance is well established, but this continues to improve. Improvement may continue at a faster pace and also on a steady continuum by individuals who have had prior experience with similar tasks or those whose learning styles facilitate such improvement.



Once a skill has been acquired, with practice, the skill may become less complicated to execute. This is known as automisation. Such processes may be a function of the capacity of an individual to process information, That is, different people may differ on this dimension.

Anderson (1982) divides the course of learning into three parts. They are the "declarative stage", the "knowledge compilation stage" and the "procedural stage".

Declarative knowledge refers to verbal rules or facts regarding a task. For example, an operator may be faced with the facts of how to switch on a mixer tank. The conversion of slow declarative knowledge into faster compiled procedures occurs in the second stage of acquisition known as knowledge compilation. Compiled procedures (the procedural stage) are relatively automatic. Anderson contended that instructional emphasis should encourage discrimination and generalisations of productions, leading to more robust, flexible and organised schemata. This enables the individuals to perform under a variety of conditions.

Depending upon the different ways in which people organise and encode information, that is, represent knowledge, certain plans may be formulated as opposed to theirs. As a result, this may determine the type of problem solving strategies that are deployed. But, as a planning aid, written instructions may be an obstacle to the structuring of action. By giving the impression that they make up a plan, instructions may give users the feeling that no planning is necessary for implementation. The action sequence may be described, the goal structure is not explicit and the rationale is never presented.



### 6.3

#### Rationale for Experiment 2

It was pointed out by Heath (1964) and Stidman (1966) that Field Independents seem to be better than Field Dependents in the transfer of information, the imposition of structure on disorganised information (Nebelkopf and Dreyer, 1970) and the ability to break set ways of approaching tasks (Hritzuk and Taylor, 1973). That is, how individuals use information in responding to learning conditions may be predicted by deducing where they lie on the Fi/Fd dimension. In order to demonstrate this, it would be necessary to obtain scores which would place individuals on appropriate points along the Fi/Fd scale. One method available for such an endeavour is the Embedded Figures Test (EFT). In order to make appropriate comparisons between Fis and Fds and their use of information, it is necessary to divide subjects into two groups, one group to be given information and the other no information.

#### 6.3.1

##### Hypothesis

Several hypotheses were constructed. These were based on the assumptions that Fis and Fds would differ on a number of factors. Such factors are:

H0: There will be no difference between Fis and Fds in the number of sub-goals/goals completed.

H1: Fis will complete more sub-goals/goals than Fds.

H0: There will be no difference between Fis and Fds in the speed with which tasks are completed.

H1: Fis will be faster in the completion of tasks.

H0: There will be no difference between Fis and Fds in the types of mental models formed.

H1: Fis will form more detailed mental models than Fds.



H0: There will be no difference between Fis and Fds in the types of strategies used to complete tasks.

H1: Fis will use fewer "trial and error" and more well thought out strategies eg. "means end" strategies.

H0: There will be no difference between Fis and Fds in the "transfer" of information.

H1: Fis will be better able to "transfer" information.

It is also argued that any differences observed in verbalizations etc. may be due to whether or not people are supplied with external sources of information.

Further, it was hypothesised that differences between subjects may be a function of whether information is presented in written form or a spatial form (as in diagrams etc.)

### 6.3.2 Subjects

Forty-three subjects took part from Loughborough University. Of the twenty three Fis, twenty one were from engineering undergraduate and post-graduate background. That is, they were studying civil engineering, electronics engineering, water transport and other types of engineering at the university.

The other two in this category were studying English at an undergraduate level. The age range of these students was 18-30. Subjects were categorised as Field Independents or Field Dependents according to scores obtained from the Embedded Figures Test (EFT).

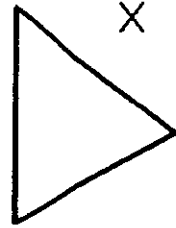
### 6.3.3 Materials

The EFT is a perceptual test. The subject's task on each trial is to locate a previously seen simple figure within a larger complex form.

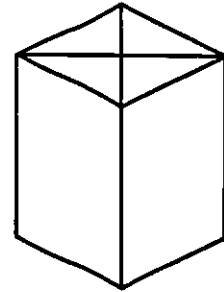


**Figure 6.1**  
**An Embedded Figure**

For example, the simple form



is hidden in the more complex figure



It is necessary to find the simple form in the complex figure and then trace it in pencil/over the lines of the complex figure.

Scores on the EFT reflect the extent of competence at perceptual embedding.

#### 6.3.4 Design

The categories of Field Independents and Field Dependents were divided into two groups. Whilst all of group A (12 Fi, 10 Fd) received no information (that is no written and verbal information related to tasks in question) prior to the completion of two tasks, all of group B (11 Fi, 10 Fd) received information. The two tasks differed in that one was small distance and the other was large distance (that is, there were many more goals to master in the large distance task, as well as greater goal distances



between tasks compared with the smaller distance task). Group A subjects were presented with a "small distance task" first and then a "large distance task"; the reverse was the case for group B. That is, groups were counterbalanced. This controlled for practice effects. There was a recall task one week later. Protocols were recorded concurrently of how tasks were solved.

**Table 6.1**  
**Experimental Design for Experiment 2**

		Small Distance Task	Large Distance Task
A	Information	N = 6	N = 5
	Fi	3F, 3M	3F, 3M
	Information	N = 5	N = 5
	Fd	3F, 2M	3F, 2M
B	No Information	N = 6	N = 6
	Fi	3F, 3M	3F, 3M
	No Information	N = 5	N = 5
	Fd	3F, 2M	3F, 2M

### 6.3.5 Procedure

The examples that were used in experiment 1 were set out on a number of frames using the "labview" package. Each example took a specified number of minutes to "load up". This, plus the time it took to complete tasks took about one hour on most occasions. Therefore, a combination of all the examples was presented on one frame. It was hoped that this would solve the "time" problem, as well as serving as an adequate training session. See Figure 6.1 page 130 - An Embedded Figure.



It was explained to subjects that there were three parts to the experiment, that is, the first part involved completing the EFT, the other two parts involved an initial training session and finally completing the training task.

#### **6.4      Initial Training**

##### **Part 1:**

For the Embedded Figures Test (EFT) subjects were instructed: "Start reading the directions, which include two practice problems for you to do. When you get to the end of the directions please stop. When the subjects finished reading the instructions, they were further instructed "It is necessary to trace all of the lines of the simple form. When I give the signal, turn the page and start the first section. You have two minutes for the seven problems in the first section. Stop when you reach the end of the first section. Ready go ahead". After two minutes, they were instructed to stop whether they had finished or not. They were instructed, "When I give the signal, turn the page and start the second section. You may not finish all of them , but work as quickly and accurately as you can. Ready, go ahead". After five minutes they were asked to stop whether they had finished or not. They were further instructed: "When I give the signal, turn the page and start the third section. You have five minutes for the nine problems in this third section. Ready, go ahead". After five minutes they were instructed to stop whether they had finished or not.

##### **Part 2:**

A description of a small mixer plant in the form of a paper diagram and written material was shown to subjects before the experiment commenced. Subjects' verbalizations of problem solving was tape recorded, whilst the tasks were video recorded.



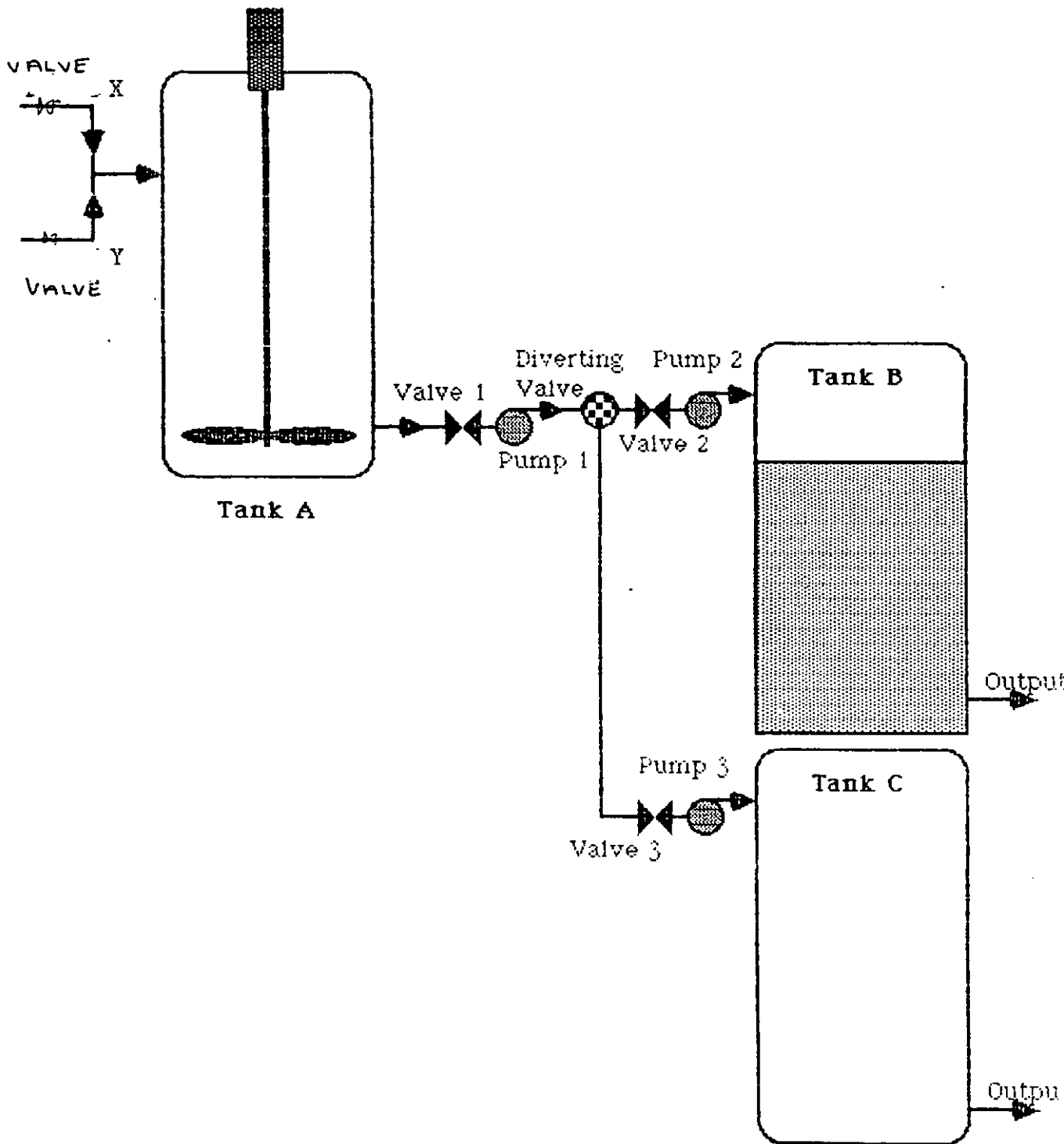
**Part Three:**

In conjunction with Figure 6.2, subjects were presented with the following literature:

- \* It is sufficient to open a valve and allow liquid to flow into a tank. It is also necessary to have a pump. This propels the liquid from the tank. However, it is necessary that the valve is switched on before the pump, when a task is to be completed. Switching on the diverting valve will allow liquid to flow from Tank A to either Tanks B or C. Therefore, it is possible to choose which direction you wish liquid to flow, by using this valve.
- \* The mixer tank level is dependent upon the amount of liquid input and output. Because tanks are directly connected to one another, there is a dynamic relationship between the different tanks. This means that changing the level of liquid in one tank may influence the level of liquid in another tank if valves and pumps remain open.
- \* On the screen in front of you are three tanks with their associated valves etc. Read the information which I have placed in front of you. You have ten minutes to do so. I will ask you to perform the task which is stated at the bottom of the page. Please do not hesitate to ask me for help when it is required by you. Do you understand? You may now start. There is no time limit, but you are advised to be as quick as possible.



**Figure 6.2**  
**Three Tank System**





### 6.5.1 Task

Using input valves and pumps, fill Tank A to 180 units of liquid in the ratio of 4 units of liquid X to 50 units of liquid Y. Notice that the blend alarm is activated. Deactivate the alarm by decreasing the level of liquid in this task. This should be achieved by transferring 40 units of liquid from Tank A to Tank B, and 40 units of liquid from Tank A to Tank C.

Tank B is full, therefore some of this liquid would have to be removed before liquid from Tank A is transferred to Tank B.

### Main Tasks

These were:

#### i. **Small Distance Task**

The mixer tank has 150 units of liquid. We require 200 units of this liquid. 20% of liquid in the tank is off specification. Transfer this liquid to the rework tank. Adjust valves and pumps so that is possible to mix 200 units of liquid. The optimum paddle speed is set at 50 units.

#### ii. **Large Distance Task**

The blend alarm is activated (because the paddle speed is below the optimum speed). There are 600 units of liquid in the product tank and more in the mixer tank. Mix 175 units of liquid in the ratio of 53:47. The liquid should then be transferred to the product tank. The optimum speed is set at 41.00.



**Information Group A** - "On the screen in front of you there are various perturbations of the control panel. Accompanied with this is a set of instructions of how to carry out the task. You are required to study this information for fifteen minutes, after which I will remove it. You will then be required to perform the task. You have a maximum of thirty minutes. If you feel that you cannot finish it within this time, please let me know. After I have removed the information from your view you are to tell me how you think you should do this task. You are to specify what knowledge elements you should use and the consequences of making certain actions. You are to imagine that another person will want to carry out this task based on what you have said, so please try to be as explicit as possible. As you are carrying out this task, I will stop you intermittently. Again you are to imagine that there is someone who has not seen this task before, but is required to carry it out at a later stage. You are to instruct this person how this task should be carried out, according to what you have done. Do you understand? Have you any questions? I will also ask you to describe briefly the system as you "see" it. There are two tasks. You may begin the first task now. There will be no initial instructional steps for the second task".

**No Information Group B** - Subjects were instructed along similar lines to the above, except they were given no instructional steps, that is, detailed information relating to how the first task should be carried out.

**For each subject, the comments recorded were:**

- \* How they think that the task should be solved.
- \* What knowledge elements were used or should be used.
- \* What they thought would be the consequences of making certain moves.



- \* During "problem solving" they were occasionally asked to describe what they had done.

**Recall Task - (This took place one week later)**

The diverting valve V5 is stuck at "rework". This mixer tank contains some liquid that should be diverted to the product tank, but this is impossible. The liquid in this tank is of the correct blend. The rework tank contains some liquid that is off specification, therefore this liquid should be remixed. There is also some liquid in the product tank that is off specification. Therefore, this liquid would need to be removed.

One week later, subjects were instructed - "You are presented with one task today. You have thirty minutes to complete this task. Like last week, you are required to give implicit instructions of how this task should be done when I ask you". The experimenter requested verbalizations before the subject started the task, during completion of the task and also on completion of the task. The experimenter further instructed "I will also ask you to specify how you 'see' the system. Have you any questions? You may start now".

## **6.7 Analysis**

It was evident that Fis were faster in completing all goals/sub-goals. Also the Fis were quicker on the completion of recall tasks. Fis seemed to have benefited more from being presented with information than Fds. This was the case whether subjects were presented with information or not.



In order that it should be possible to compare mental model formation, strategy development etc. between groups and conditions, it was necessary that all protocols should be transcribed. Percentage goal completions, speed of completion tasks, mental model formation and types of strategies developed were recorded and analyzed for each group and each condition.

For purposes of clarification, S-L indicated that a small distance task and then a large distance task is presented to subjects. L-S indicates that a large distance task and then a small distance task is presented to subjects.

The percentage of sub-goals completed for each task was calculated. A 1 (Fi/Fd) x 2 (S-L) analysis of variance was performed. For the "information group" the F<sub>i</sub>s and the F<sub>d</sub>s did not differ significantly in the percentage of sub-goals completed. There was also no interaction between distance and whether a subject was categorised as F<sub>d</sub>/F<sub>i</sub> on the percentage of sub-goals completed. However, a 2 (Fi/Fd) x 1 (L - S) analysis of variance revealed a significant difference between the scores obtained for the F<sub>i</sub>s/F<sub>d</sub>s;  $F = 14.234$ ,  $F_{crit} = 3.18$ ;  $P < 0.05$  (see Table 6.3).

There was no significant effect of distance on the percentage of sub-goals completed. There was also no significant interaction between distance and whether a subject was categorised as F<sub>i</sub>/F<sub>d</sub>.

**Table 6.2**

**Mean Percentage Of Sub-Goals Completed**

	Small Distance	Large Distance
Field Independence	88.833	79.167
Field Dependence	20.00	35.00



**Table 6.3****Anova Summary**

Factor 1 = Fi/Fd

Factor 2 = Large Distance/Small Distance

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	17412.27	1	17412.27	14.243
Factor 2	13.134	1	13.134	0.011
Interaction	829.7	1	829.7	0.695
WSE	10751.67	9	1194.63	
BSE	11010	9	1223.33	
Total	40016.77	2		

For the "no information group" S-L distance condition, there was no significant difference between the Fis and Fds on the percentage of goals completed. Also there was no significant effect of distance and no significant interaction between distance and Fi/Fd. This was also the case for the L-S distance condition.

**Total Speeds****Information Group A**

The speed that it took each subject to carry out each task was calculated. This was achieved by taking the reciprocal of the time in minutes, that is, 100/time in minutes. Therefore, the lower the speed, the slower is the person on that particular task. 2 (S-L) x (Fi/Fd) analysis of variance was performed. There was a significant difference between the means  $F = 6.059$ ;  $F_{crit} = 3.18$ ;  $P < 0.05$  (see Table 6.5).

There was no significant effect of distance on the total speeds and no significant interaction between distance and whether a person is categorised as Fi or Fd.



**Table 6.4**

**Mean Speeds for the Small Distance and Large Distance Tasks  
for both Fis and Fds**

	Small Distance	Large Distance
Field Independence	7.5	3.647
Field Dependence	2.763	1.976

**Table 6.5**

**Anova Summary**

Factor 1 = Fi/Fd

Factor 2 = small - large

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	55.938	1	55.938	6.059
Factor 2	33.26	1	33.26	2.524
Interaction	11.89	1	11.89	0.902
WSE	118.594	9	13.177	
BSE	83.089	9	9.232	
Total	302.77			

A 2(L-S) x 1(Fi/Fd) analysis of variance revealed that there was no significant effect of cognitive style or distance on the total speeds for each subject. Also there was no significant interaction between cognitive style and distance.

**No Information Group B**

Analysis of variance revealed (for both conditions S-L and L-S) that there were no significant effects of cognitive style or distance on the total speeds. Also there was no significant interaction between distance and cognitive style.



### Recall

#### Total Speeds

For the information and no information groups, 2 way analysis of variance, single observation on separate groups was performed. 2 (Fi/Fd) x 2 (S-L, L-S) revealed that there were significant effects of cognitive style on the speed with which subjects completed the task.

#### Information Group A

$F = 9.1933$ ;  $F_{crit} = 4.41$ ;  $P < 0.05$  (see Table 6.7).

**Table 6.6**

**Mean Recall Speeds by Fis and Fds  
in the Small-Large Distance Conditions**

	Fi	Fd
S-L	10.00	3.55
L-S	8.237	3.00

**Table 6.7**

**Anova Summary**

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	197.285	1		
Factor A	187.72	1	187.72	9.1933
Factor B	7.743	1	7.743	0.379
Interaction	1.822	1	1.822	0.082
Within Groups	367.545	18	20.419	
Total	762.115	21		

#### No Information Group B

$F = 8.1707$ ;  $F_{crit} = 3.16$ ,  $P < 0.05$ .



**Table 6.8**  
**Mean Recall Speeds by Fis and Fds in the**  
**Small-Large and Large-Small Distance Conditions**

	Fi	Fd
S-L	6.45	3.4
L-S	11.271	3.022

**Table 6.9**  
**Anova Summary**

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	244.172	3		
Factor A	174.125	1	174.125	8.1707
Factor B	33.205	1	33.205	1.558
Interaction	36.842	1	36.842	1.729
Within Groups	383.594	18	21.311	
Total	871.938			

However, for both groups, there was no significant effect of distance and no significant interaction between distance and cognitive style.

**Information Group A - Speed for Sub-Goals 1, 2, 3 Small Distance Task**

For each condition in each group, the speeds for sub-goals were calculated. These speeds were subjected to two way analysis of variance, with repeated measures on one factor. For the small distance task, where there are three sub-goals, sub-goal 1 was ranked as being the least complex in nature and sub-goal 3 the most complex. For the S-L distance condition, there was no effect of cognitive style on speed or distance. Also, there was no significant interaction between cognitive style and distance on the speeds of completion for these sub-goals. However, for



the L-S distance condition, there was a significant effect of cognitive style on the speeds with which it took people to complete the three sub-goals  $F = 50.017$ ;  $F_{crit} = 2.48$ ;  $P < 0.05$  (see Table 6.11).

**Table 6.10**  
**Mean Speeds for Sub-Goals 1, 2, 3**  
**Large-Small Distance**

	Sub-Goals		
	1	2	3
Field Independence	55.56	15.32	19.05
Field Dependence	0.00	6.67	10.00

**Table 6.11**  
**Anova Summary**

Factor 1 = Large-Small (small distance)  
Factor 2 = 1, 2, 3

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	4879.115	1	4879.115	50.017
Factor 2	2223.85	2	1111.925	1.8139
Interaction	3965.89	2	1982.925	3.235
WSE	9194.81	15	612.987	
BSE	1170.596	12	97.549	
Total	21434.261	32		

Nevertheless, there was no significant effect of distance or interaction between distance and cognitive style.



**No Information Group B - Speed for Sub-Goals, 1, 2, 3 Large Distance Task**

For the L-S distance condition, there was a significant effect of cognitive style on the speed with which subjects completed the sub-goals.  $F = 7.609$ ;  $F_{crit} = 2.62$ ;  $P < 0.05$  (see Table 6.13).

**Table 6.12**  
**Mean Speeds for Sub-Goals 1, 2, 3**

	Sub-Goals		
	1	2	3
Field Independence	42.22	33.055	19.45
Field Dependence	4.00	9.33	8.00

**Table 6.13**  
**Anova Summary**

Factor 1 = Fi/Fd  
Factor 2 = 1, 2, 3 (Large-Small) Small Distance

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	5444.409	1	5444.409	7.609
Factor 2	624.67	2	312.335	0.559
Interaction	99992.886	2	426.443	0.888
WSE	6706.816	12	558.901	
BSE	10733.019	15	715.535	
Total	24501.8	32		

This was also the case for the S-L distance condition  $F = 8.849$ ;  $F_{crit} = 2.62$ ;  $P < 0.05$  (see Table 6.15).



**Table 6.14**  
**Mean Speeds for Sub-Goals 1, 2, 3**

	Sub-Goals		
	1	2	3
Field Independence	36.67	18.61	11.388
Field Dependence	0.00	3.67	4.00

However, for both the L-S, and the S-L distance conditions, there was no significant effect of distance and no significant interaction between cognitive style and distance.

Factor 1 = Fi/Fd

Factor 2 = 1, 2, 3 (Small - Large) Small distance.

**Table 6.15**  
**Anova Summary**

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	3164.44	1	3164.44	8.849
Factor 2	823.46	2	411.73	0.943
Interaction	1260.16	2	630.08	1.444
WSE	5237.58	12	436.465	
BSE	5364.066	15	357.604	
Total	15849.71	32		



Information Group A - Sub-Goals 1, 2, 3 and 4 Large Distance

For the S-L distance condition, there was no effect of cognitive style on the speed with which it took subjects to complete the sub-goals. However, this was not the case for the L-S distance condition. There was a significant effect of cognitive style.  $F = 9.486$ ;  $F_{crit} = 2.28$ ;  $P < 0.05$  (see Table 6.17).

However, there was no significant effect of distance nor was there a significant interaction between the variables for both conditions S-L, L-S.

**Table 6.16**  
**Mean Speeds for Sub-Goals 1, 2, 3 and 4**

	Sub-Goals			
	1	2	3	4
Field Independence	50.00	19.72	12.57	19.44
Field Dependence	14.00	9.00	5.25	2.86

**Table 6.17**  
**Anova Summary**

Factor 1 = Fi/Fd  
Factor 2 = 1, 2, 3 and 4 (Large-Small) Large Distance

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	3400.703	1	3400.703	9.486
Factor 2	4036.046	3	1345.35	3.385
Interaction	1343.589	3	447.863	1.1269
WSE	6358.89	16	397.431	
BSE	7170.25	20	358.513	
Total	22309.478	43		



**No Information Group B for All Sub-Goals in the Large-Small Distance Condition**

For the L-S condition, there was a significant effect of cognitive style on the speed of finishing sub-goals.  $F = 8.817$ ;  $F_{crit} = 2.28$ ;  $P < 0.05$  (see Table 6.19).

**Table 6.18**  
**Mean Speeds for the Completion of Sub-Goals**  
**for The L-S Condition**

	Sub-Goals			
	1	2	3	4
Field Independence	17.78	42.5	14.5	11.95
Field Dependence	9.45	2.00	2.86	5.00

**Table 6.19**  
**Anova Summary**  
Factor 1 = Fi/Fd  
Factor 2 = 1,2,3 and 4 (Large-Small distance) Large Distance

Source of Variation	Sum of Squares	Df	Variance	F
Factor 1	2922.98	1	2922.98	8.817
Factor 2	1680.334	3	560.111	1.296
Interaction	2161.416	3	720.472	1.667
WSE	6917.437	16	432.339	
BSE	6630.55	20	331.528	
Total	20312.717	43		

However, for the S-L distance condition, there was no significant effect of cognitive style. For both the L-S distance condition and the S-L distance condition, there was no significant effect of distance, nor were there significant interactions between distance and cognitive style on the speeds with which these sub-goals were completed.



## Recall

### Percentage of Sub-Goals Completed

Two way Anovas - single observation on separate groups for the information and no information groups 2 (Fi/Fd) x 2 (S-L, L-S) was carried out for the percentage of sub-goals completed. Significant differences were found between Fis and Fds for both groups. That is, for the Information group  $F = 5,045$ ;  $F_{crit} = 3.16$ ;  $P < 0.05$  (see Table 6.21).

**Table 6.20**

**Mean Percentage of Sub-Goals Recalled for each Condition**

	Small-Large Distance	Large-Small Distance
Field Independence	91.67	91.667
Field Dependence	60.00	50.00

**Table 6.21**

### **Anova Summary**

Factor A = Fi/Fd

Factor B = Small-Large; Large-Small

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	7583.34	3		
Factor A	7333.33	3	7333.33	5.045
Factor B	113.636	1	113.636	0.078
Interaction	136.374	1	136.374	0.094
Within Groups	26166.66	18	1453.7033	
Total	33750.21	21		



No information Group B - Sub-Goals Recalled for Each Condition

$F = 8.578$ ,  $F_{crit} = 3.16$ ;  $P < 0.05$ . (see Table 6.23).

**Table 6.22**

**Mean Percentage of Sub-Goals Recalled for Each Condition**

	Small-Large Distance	Large-Small Distance
Field Independence	91.67	100
Field Dependence	60.00	50.00

**Table 6.23**

**Anova Summary**

Factor A = Fi/Fd

Factor B = Small-Large, Large-Small

Source of Variation	Sum of Squares	Df	Variance	F
Between Groups	9553.03	3		
Factor A	9094.69	1	9094.69	8.578
Factor B	0.00	1	0.00	0.00
Interaction	458.34	1	458.43	0.432
Within Groups	19083.33	18	1060.185	
Total	28636.36	21		

**Mental Models**

Using the protocols derived from subjects, an attempt was made to translate the verbal descriptions of the mixer plant into pictorial diagrams (the Key for the diagrams is set out overleaf). Quotations from various people were also noted to illustrate specific points.



<b>Key</b>	<b>MT</b>	<b>=</b>	<b>Mixer Tank</b>	<b>A</b>	<b>=</b>	<b>Liquid A</b>
	<b>PT</b>	<b>=</b>	<b>Product Tank</b>	<b>B</b>	<b>=</b>	<b>Liquid B</b>
	<b>RT</b>	<b>=</b>	<b>Rework Tank</b>			

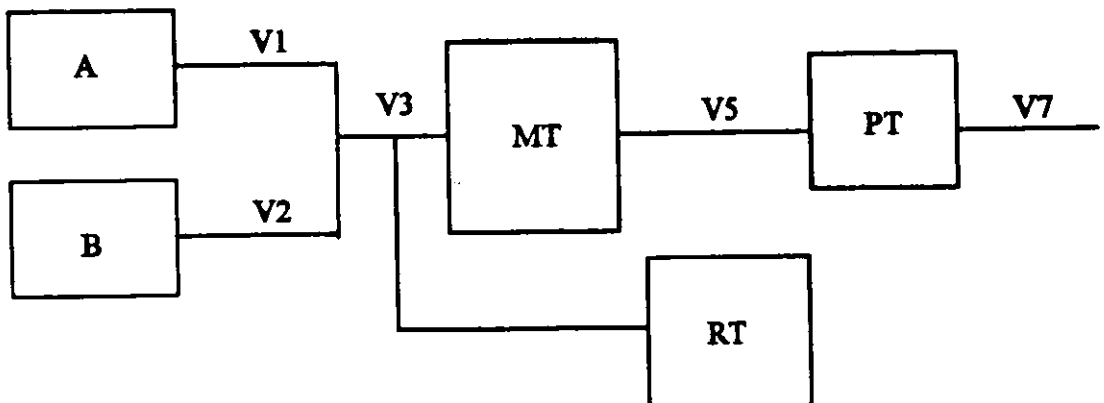
<b>V1</b>	<b>=</b>	<b>Valve 1 (one way)</b>	<b>P1</b>	<b>=</b>	<b>Pump 1</b>
<b>V2</b>	<b>=</b>	<b>Valve 2 (one way)</b>	<b>P2</b>	<b>=</b>	<b>Pump 2</b>
<b>V3</b>	<b>=</b>	<b>Valve 3 (two way diverting)</b>	<b>P3</b>	<b>=</b>	<b>Pump 3</b>
<b>V4</b>	<b>=</b>	<b>Valve 4 (one way)</b>	<b>P4</b>	<b>=</b>	<b>Pump 4</b>
<b>V5</b>	<b>=</b>	<b>Valve 5 (two way diverting)</b>	<b>P5</b>	<b>=</b>	<b>Pump 5</b>
<b>V6</b>	<b>=</b>	<b>Valve 6 (one way)</b>	<b>P6</b>	<b>=</b>	<b>Pump 6</b>
<b>V7</b>	<b>=</b>	<b>Valve 7 (one way)</b>			

### Information Group

#### Mental Models By Fis in the Large-Small Distance Condition

##### **Task 1**

- a) "I did look at the screen and use the instructions. I did relate them to the task. I did it by relating the diagram and seeing how it related and I could then remember it."

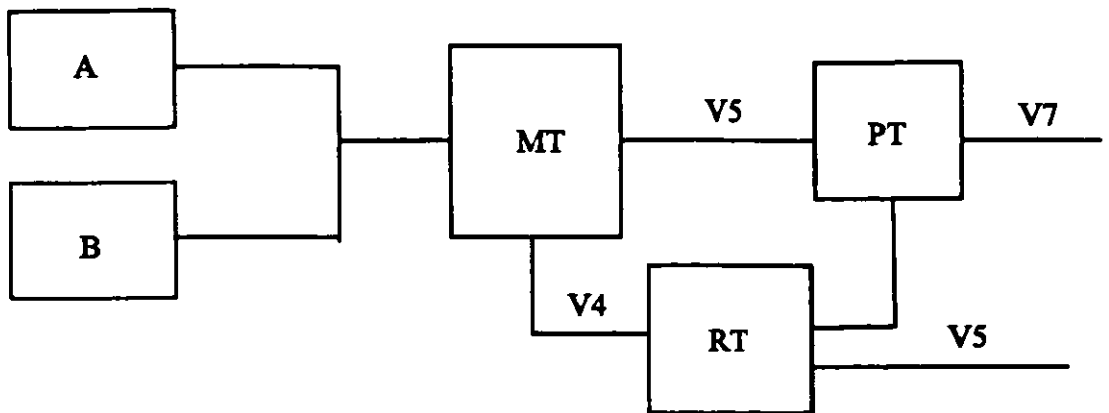


- b) "I remember the system by a combination of manipulating the various combinations of the plant and the diagram."

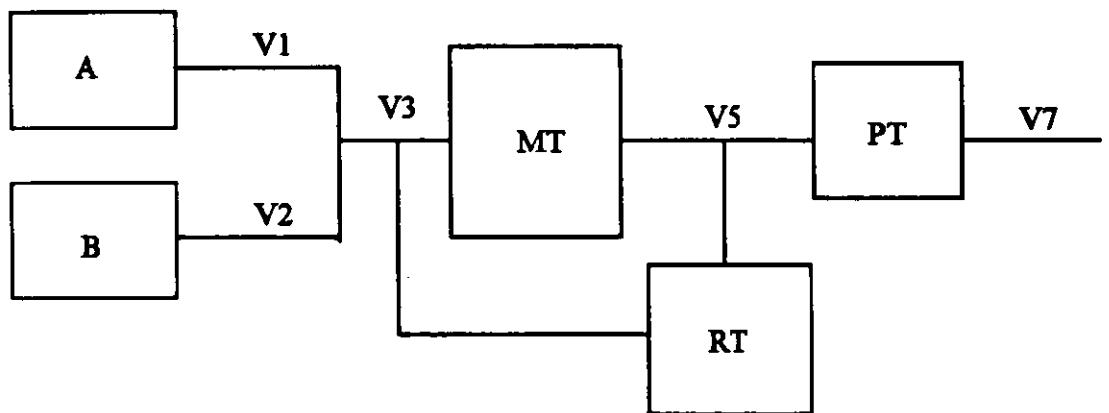


## Task 2

a)



b)

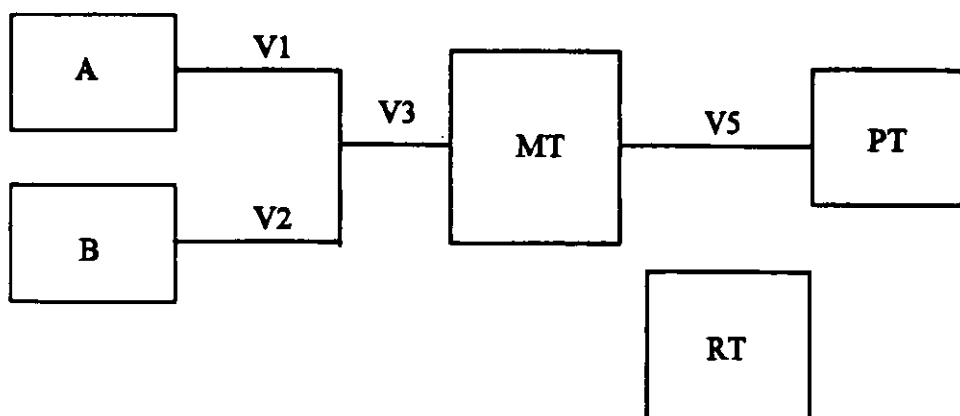


## Information Group

### Mental Models by Fds in the Large-Small Distance Condition

## Task 1

a)





- b) Not changed significantly

### Task 2

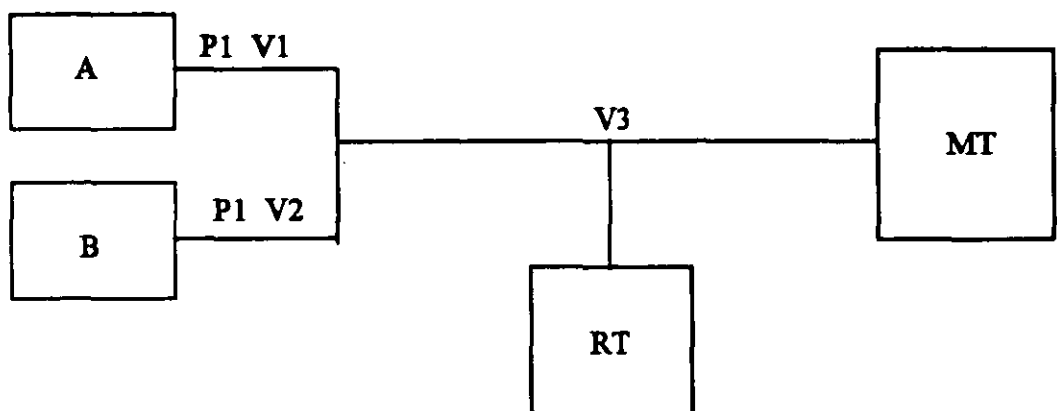
- a) "I am basically using what I see on the screen and nothing else".

### Information Group A

#### Mental Models for Fds in the Small-Large Distance Condition

### Task 1

- a) "I see a basic diagram on a page, not on the screen. The picture is with a number of dials which can be opened and closed."



- b) "Basically, I see it as a drawing of Tank A and B, mixer tank, rework tank and the valves in the same place as before. The only thing is knowing which valves control which tanks and which pumps control which tanks."

### Task 2

- a) "By now I don't really see the system in terms of a picture, but more in terms of the information on the screen, unless it's an area I have not come across before in previous tasks, that is to open Valve 7 and Valve 6. My mind tried to go back to the picture to visualise which valve was which. I decided that Valve 7 was the



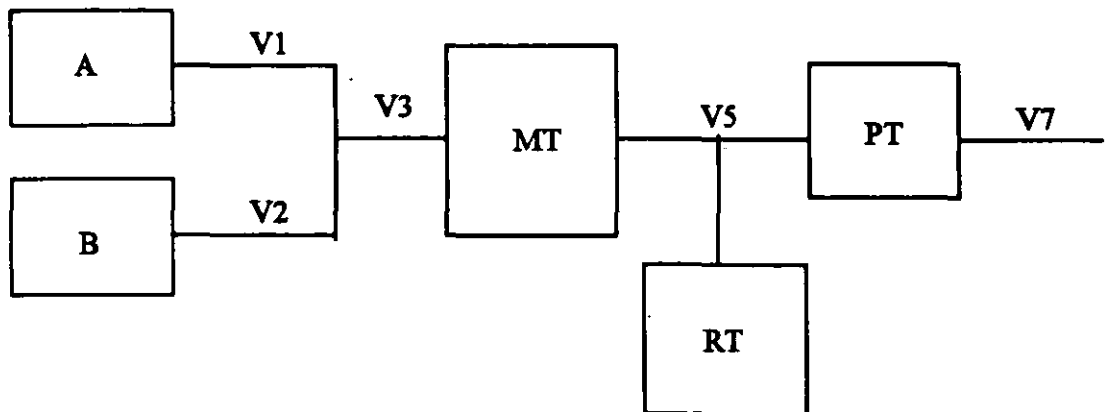
valve to open to take mixture from the product tank and Valve 6 takes liquid from the rework tank. From the actual task itself I did not have such a visualisation. It was a case of relying on the information gained from previous experience with the task. This relies on information on the screen rather than actual picture.

### Information Group A

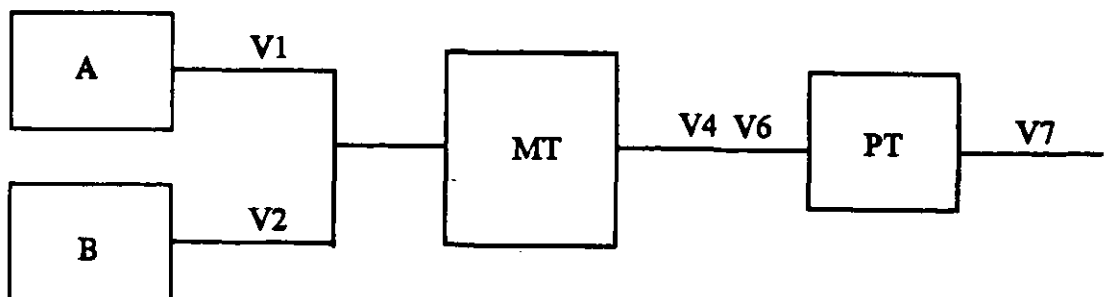
#### Mental Models By Fis Recall Task in the Small-Large Distance Condition

"I can't remember any of the things I read. It was instructions I could use. I didn't think I had to remember. I looked at things, and then worked things out."

a)



b)





**No Information Group B**

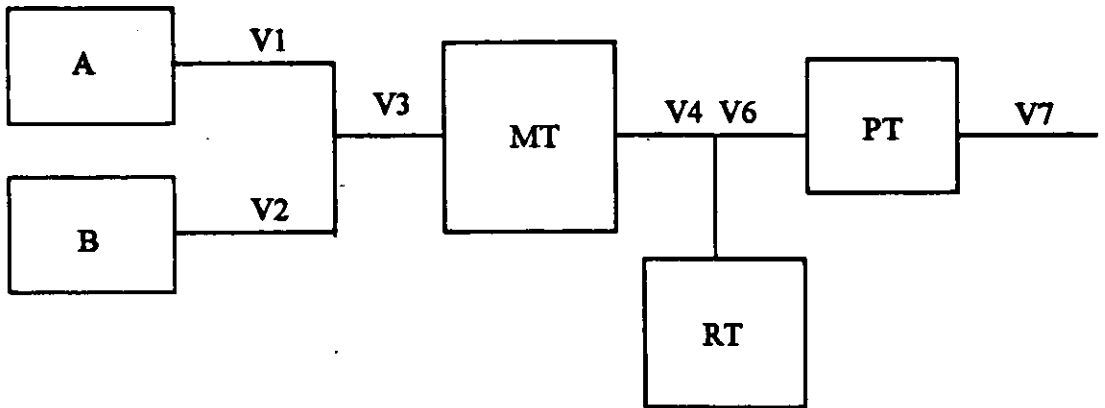
**Mental Models By Fis in the Large-Small Distance Condition**

**Task 1**

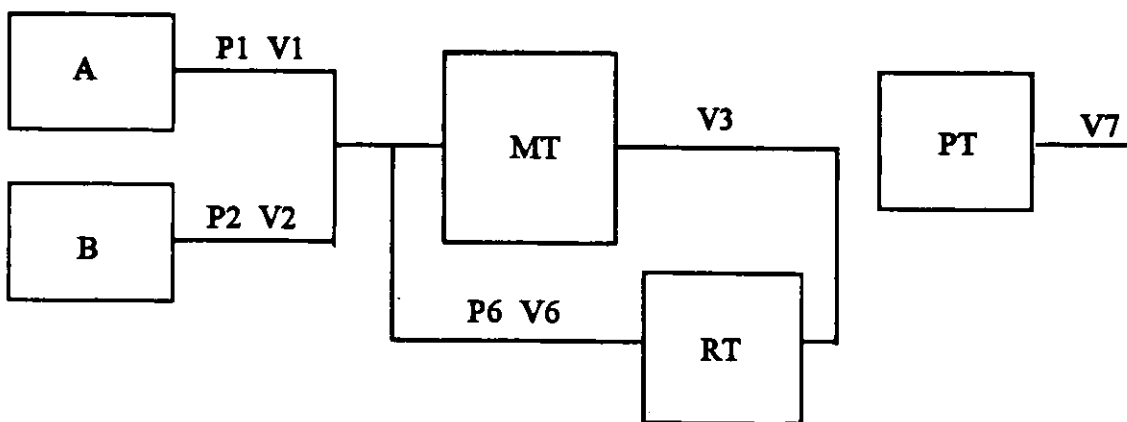
"I see a diagram somewhere in the back of my mind. When I see the panel on the screen, I associate the position with what they do."

**Task 2**

a)



b)





## No Information Group B

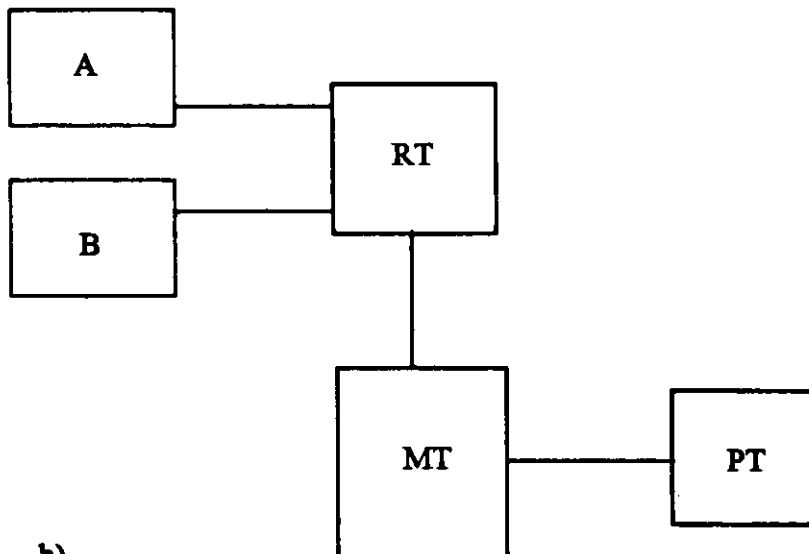
### Mental Models By Fds in the Large-Small Distance Condition

#### Task 1

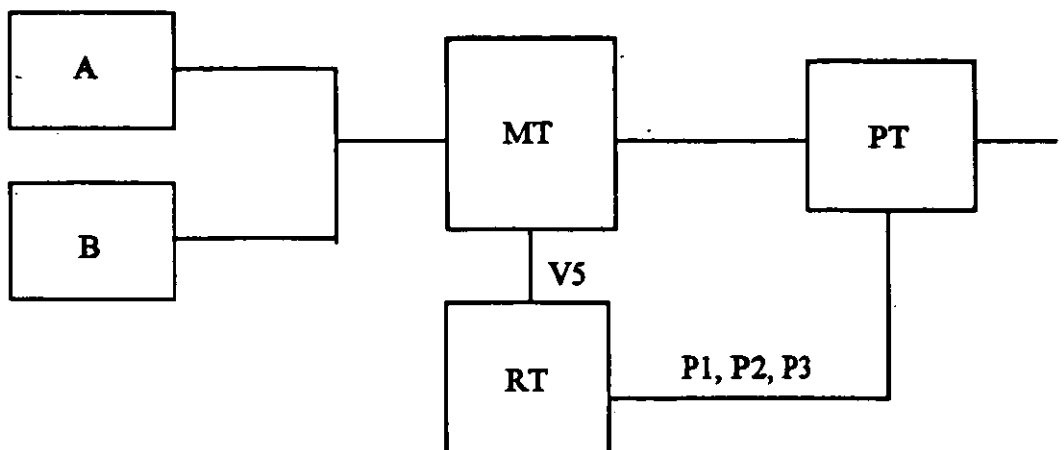
"It is not possible to visualise the system. Everything is set out on a screen and I don't know what the relations are to one another. There is no diagram showing me what it's like. I can't possibly see how you can work that out."

#### Task 2

a)



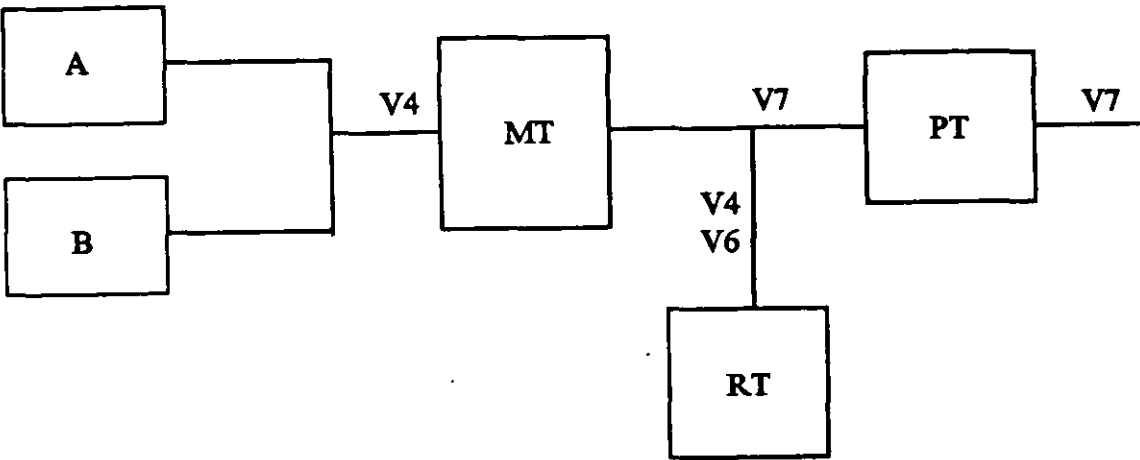
b)



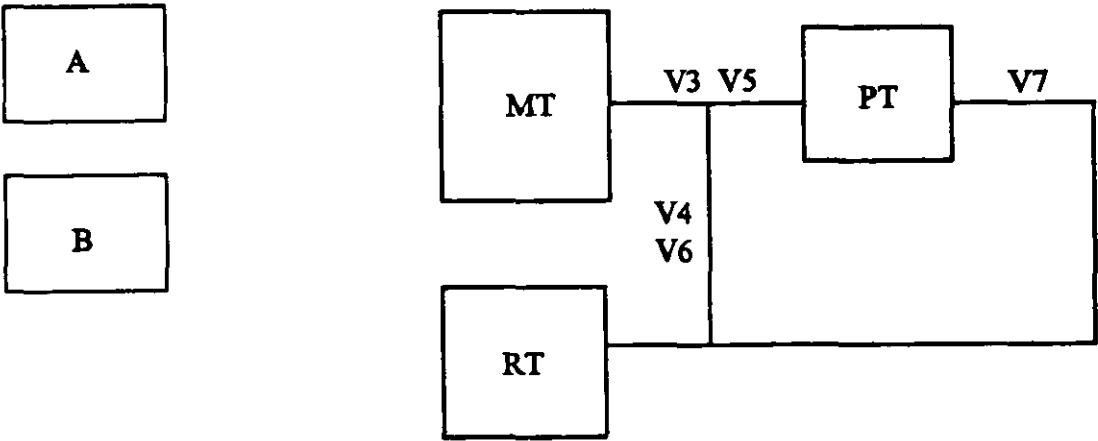


**No Information Group B**  
**Mental Models By Fds in the Small-Large Distance Condition**

**Task 1**



**Task 2**

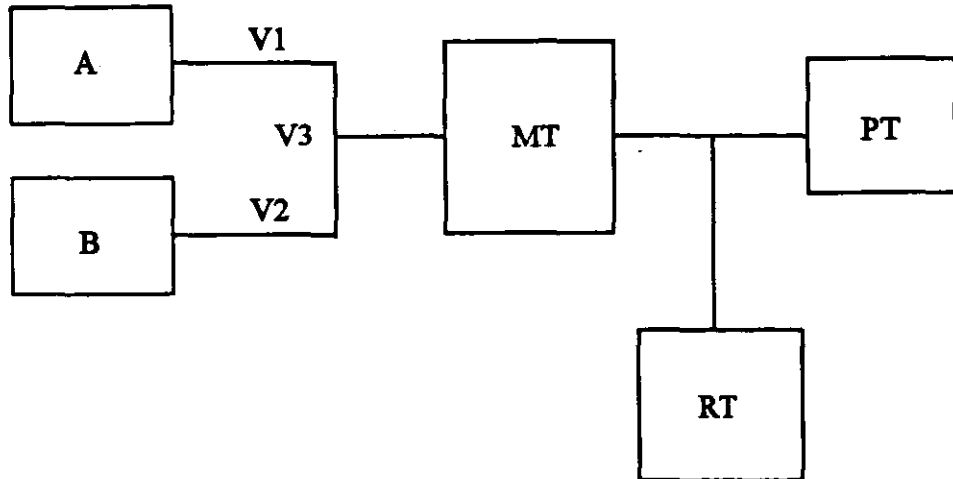




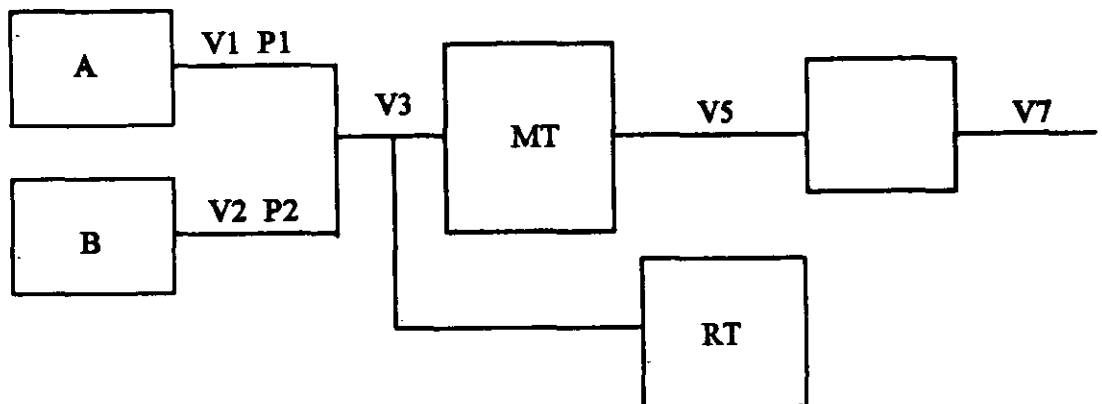
**No Information Group B**

**Mental Models by FIs in the Small-Large Distance Condition**

a)



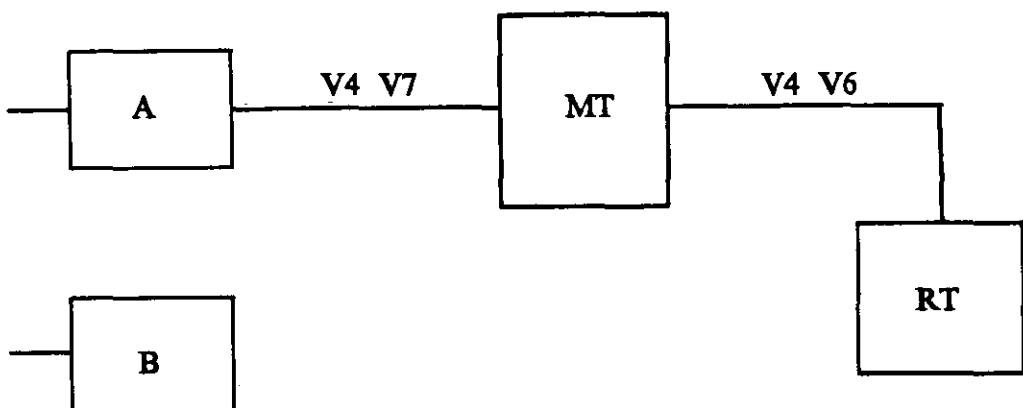
b)



**No Information Group B**

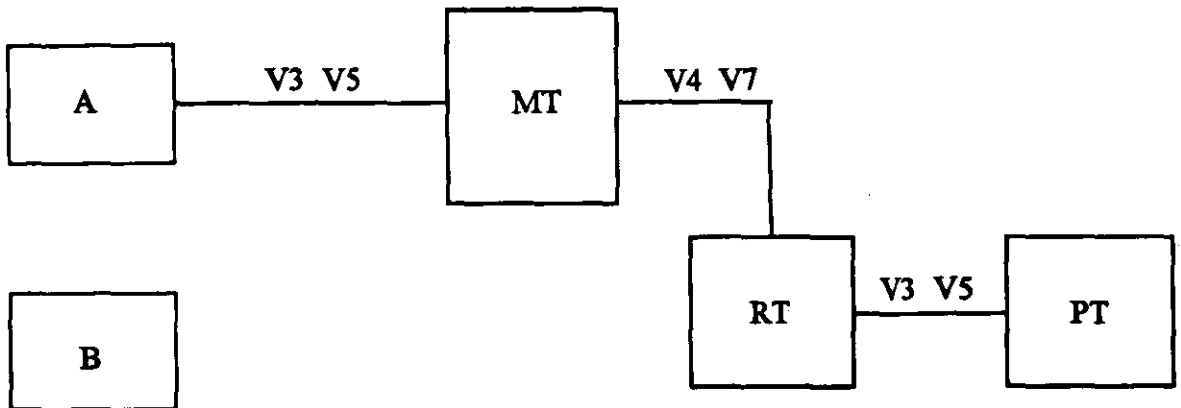
**Mental Models by Fds Recall in the Small-Large Distance Condition**

a)





b)

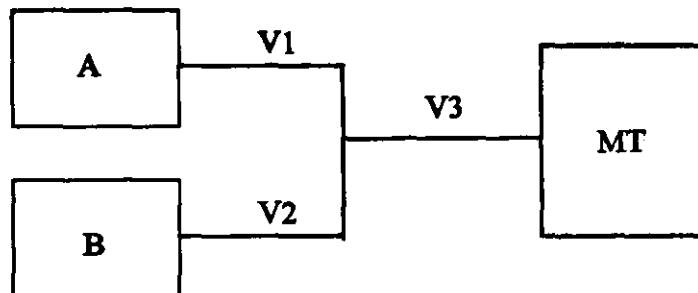


**No Information Group B**

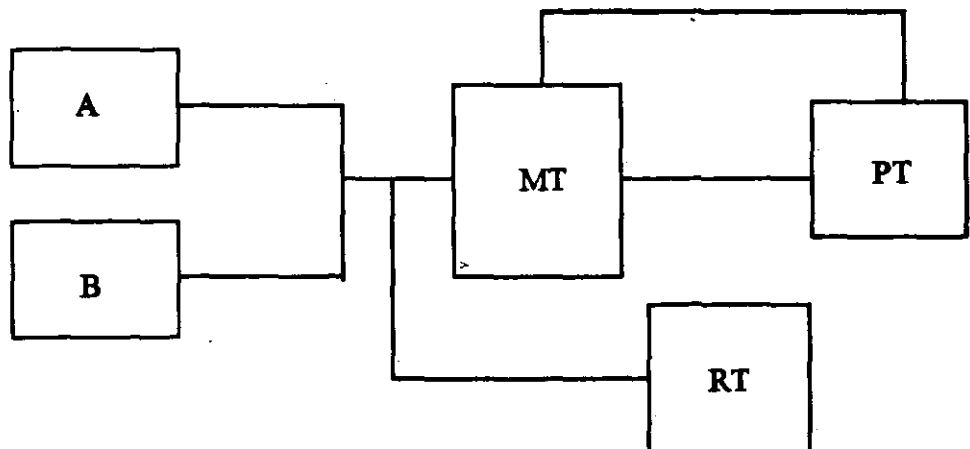
**Mental Models by Fds Recall in the Small-Large Distance Condition**

"I have a picture fixed in my mind of where the tanks are but not the valves."

a)



b)





It was hypothesised that differences in problem solving strategies may be due to differences in cognitive styles between Fi and Fd individuals. The types of strategies which different people employ included the following:-

- \* A means end strategy consists of searching for transformations which reduce the differences between the current state and the goal.
- \* Another strategy orients towards promising paths and this helps avoid exploration of doubtful ones.
- \* Knowledge can be prior information. This may involve transfer, since the individual can transfer knowledge of a procedure to a new situation. However, this is associated with a device identical to the one in the new problem.
- \* Knowledge from another domain can be used to tackle a new problem. This is analogy.
- \* Trial and error strategies consist of searching for paths in each stated space, leading to a goal. Such strategies are often implemented where transfer and analogy are unfeasible, when the subject is unfamiliar with the problem.
- \* A programme production strategy can draw on plans of procedures and state representations.
- \* A focusing strategy is one used to test one hypothesis at a time and gradually reduces the number of the hypotheses by elimination of spurious ones.



- \* Scanning strategy is used to test several hypotheses at a time. A new hypothesis is entertained only when the current hypothesis is rejected.
- \* A serialist strategy is one for learning or problem solving, which involves tackling a problem or field study in small units. Later, it involves joining the results together to form a complete picture. If the serialist is asked to explain a particular concept, he produces the line of argument which was presented to him.

Examples are taken from the tasks completed in order to illustrate the range of strategies used in problem solving.

**Information Group A - Field Dependent Subject**  
**Large to Small Distance Condition (Task 1)**

Verbalisations were recorded and transcribed.

**Subject:** "I think that Valve 4 should be closed, because we want 175 units in the mixer tank. Set the valves of liquid A and liquid B equal. Have equal ratios of Valve 1 and Valve 2. Let it be in the mixer tank. Mix it at that rate. See the percentage of A and B. We can keep changing values of Tank A and B. Once mixed, open Valve 4 and lead it to the product tank."

**Experimenter:** "What have you learnt."

**Subject:** "Valve 6 actually takes liquid from the rework tank to the mixer tank. Valve 4 takes it from the mixer tank. A lot depends on Valve 5."

"I am not scared of making errors because I can undo them."



This example shows that the subject has tried to use a "means end strategy" approach. He has orientated himself towards promising paths and has used a "serialist" approach of tackling the problem in small units. He has also used or is able to use forms of "trial and error".

#### **Information Group A - Field Independent Subject**

##### **Large to Small Distance Condition (Task 1)**

**Subject:** "The main goal is to transfer 175 units of liquid in the ratio of 53:47 in the final product. You will do this in mixing Tanks A and B by opening valves and pumps. Then transfer this through Valves 3, 4, 5 and 6 to the final tank. I have not got the correct ratio for the mixer tank level. I have got to transfer liquid to the product tank. Valve 7 controls the amount of product in the tank. Valve 4 affects the amount of liquid in the mixer which affects the percentage ratio. I am trying to get the correct ratio by opening Valve 4 and put pumps on A and B."

The subject has tried to test one hypothesis at a time and has "focused" on particular points for testing, that is, a "focus strategy" was used.

A "Chi - Squared Test" was used in order to find out if there were significant differences in the range of choices/strategies used by individuals in different conditions.

#### **Information Group A (Fi/Fd)**

No significant differences were found between the two conditions of S-L, L-S for the Fis and Fds. A significant difference was found between the Fis and Fds in the L-S distance conditions  $X^2 = 28.32$ ;  $X^2 \text{ crit} = 28.32$ ;  $P < 0.05$ . But there was no significant difference between Fds and Fis in the S-L distance condition.



**No Information Group B - Field Dependent Subject**  
**Large to Small Distance Condition (Task 2)**

**Subject:** "Liquid from different tanks should be mixed in order to make up the expected ratio. The volume should fit into the product tank. 175 units should be mixed. There should be room for liquid in the product tank."

This example shows that a "scanning" strategy is employed. The subject is considering several hypotheses at a time.

**No Information Group B (Fi/Fd)**

No significant difference was found between the Field Independents and the Field Dependents for the S-L condition and the L-S condition.

**6.9 Conclusion**

- \* Fis were generally more efficient in both tasks than Fds in the manner with which they structured information. This was reflected in their fairly rapid completion of tasks. It may be argued that this could be the result of their greater analytical and structuring abilities which enabled them to plan courses of action and strategies for achieving the goals. That is, they could adapt organised knowledge to intended tasks.
- \* The Fis completed both more sub-goals and more complex sub-goals. It could be argued that this may be due to the possibility that they were more proficient in compiling responses.



**This can be stated as a number of points:**

- i. It is apparent that if trial and error did not seem to produce results, the Fis would construct a plan. They would then try to be more selective in the type of hypothesis which they tested.**
- ii. Fds tended not to have coherent plans.**
- iii. Peripheral aspects of the system were mainly dealt with by Fds. They seemed to be unable to construct feasible plans around the main item.**

**i - iii are observations made from the protocol data.**



## **CHAPTER 7**

### **7.0 General Discussion and Conclusions Concerning the Interaction Between Field Dependency/Independence and Training Methods**

#### **7.1 Summary**

Some of the pertinent conclusions reached from arguments and experiments are discussed. Based on the results of such findings, it is supposed that it might be possible to consider the design of appropriate training regimes for Field Independents and Field Dependents respectively. It is concluded that findings may have implications for operator selection and training.

Various methodological problems are considered. Such problems include intrinsic biases in the design of experimental material, biases in samples taken and the difficulty of extrapolating findings to real life situations (ecological validity). Other factors include the subjective nature with which some information was identified. It is concluded that findings may have implications for operator selection and training.

#### **7.2 Introduction**

During experimentation, the intention was to set out control variables and conduct experiments under stringent laboratory conditions, ie conditions where there is relatively little experimenter bias and where appropriate use is made of tests and measures of performance. However, this is not always possible and there are experimentation difficulties with complex tasks, such as process control, even simple simulated ones. In these tasks, operators may switch between a number of strategies, especially where individual differences are called into play. Therefore, to examine



aspects of behaviour associated with complex issues such as cognitive style in process control there is serious risk of compromising straight forward experimental design. However, it is felt that despite these problems, the general findings are robust and justify drawing a number of recommendations. Following the discussion of methodological problems, the chapter will draw out the major findings from the research.

### **7.3      General Discussions of Major Findings**

The hypotheses stated that individuals having acquired knowledge from small distance tasks, would be speedier in mastering a large distance task. Also tasks which share knowledge with another would be easier to cope with than those which do not share knowledge. It is postulated that the manner with which tasks are completed would be a function of whether people are trained "conceptually" or by "procedural mode".

#### **Results indicate that:**

Tasks which share knowledge produced fewer errors than those which did not. This is especially evident with the "conceptual mode of training". Training people by this method was effective if their initial experience in training was one in which there was a logical build up of concepts from one task to the next. That is, there was greater retention and transfer of knowledge by the conceptual mode of training than by the procedural mode.

- \*      The conceptual mode of training did not differ significantly from the procedural method in the times that it took the trainees to complete all tasks in all conditions (see pages 108 and 109).
- \*      The procedures group elicited a greater proportion of errors than the concepts group (see pages 109 to 113). The concepts group was therefore more efficient than the procedurally trained group.



It could be that the conceptually trained group was more involved in thinking that problem through, whilst the procedural group merely performed on the basis of trial and error. However, both groups achieved the stated end goal in approximately equivalent times.

- \* The concepts groups exhibited greater transfer of information in the "L-S distance" conditions and on tasks which do not share knowledge. However, this was not the case for recall tasks in conditions where tasks "shared information" and the "S-L distance" condition. This may be due to the possibility that when individuals are faced with intrinsically difficult problems to solve, they tend to employ transfer strategies.

**The second part of Experiment 1 (an exploration of problem solving strategies.**

- \* Whilst, for some, incompatible moves become less frequent as problem solving progressed, for others, incompatible moves appeared to be consistent from start to finish. It is, therefore, apparent that the manner with which individuals approach tasks is due to differences in strategy for movements.
- \* People did not repeat moves which caused errors when completing the first task. That is, learning took place.
- \* Subjects spent approximately equal amounts of time on both tasks. Having completed task 1, the second task was not so problematic as it could have been, had subjects not had the initial experience with the simpler task. That is, due to a "transfer" effect, the second task was completed in approximately the same time as the first.



It can be concluded that "task type" influences problem solving strategies and that people differ in their modes of problem solving given the same information.

Why this should be so was investigated in the second experiment. It was argued that individual differences are highlighted through the mediums of the Fi/Fd dimension. That is, the manner of information processing and the abstraction of information to make decisions can influence the way in which skills are acquired.

The Field independents were quicker in eliciting responses in recall tasks. This suggests that information gained through experience with tasks was better encoded by Field Independents than Field Dependents. Support for this arises from the work of Meshorer (1969); Davis (1967); Fredrick (1967). It was also observed that individuals varied on the extent of "transfer" of acquired knowledge in the different conditions.

It is apparent that extrinsic information functioned as a planning aid for Field Independents and Field Dependents. However, the two groups differed in the nature of the plans constructed. A plan is a covert, mental, hierarchial operation that is assumed to exist "inside the head". Field Independents were better able to make use of plans in order to develop relevant strategies which led to solutions of problems.

Although, it is possible to point out that some extrinsic information is better than none, as a training method, it is conceivable that the benefit of such information may vary among individuals. That this, one has to find out how much information should be available to field independents (along the stated dimension of Fi/Fd), in order for them to be able to use such information efficiently. This may necessitate the formulation of pilot studies.



Field independents and field dependents differed in their spatial representation of systems. Field independents were better able to use information to form detailed spatial representations of the mixer plant. It might be that field independents are more endowed with "spatial ability" than field dependents. Therefore, if one were to present information to such people, it is assumed that this should be in a pictorial form, which might be more readily assimilated than written information. This requires more research.

It was evident that people tended to change the way in which they saw the system at various points. Specifically, Fis tended to have a more detailed picture in terms of where valves were and the spatial location of the tanks.

However, this picture changed as individuals became familiar with the system. That is, by manipulating the various components of the system, an understanding was gained of specific elements. This added to their conceptual understanding of the whole and thus appeared in further descriptions. The Fds were less detailed in any descriptions that they produced. However, as they progressed through tasks, the descriptions were not noticeably different in nature.

It was also evident that whether people were given information or not, did not have an appreciable effect on the quality of descriptions that were produced by the Fds. Descriptions produced by the Fds in the information condition were less accurate than the no information condition. In fact a number of Fd people pointed out that the information added to their "confusion". However, the Fis made more use of the information presented to them. Also, whether people were presented with a large distance task first or last did not seem to be a major factor in descriptions. What seemed most relevant was whether people were Fis or Fds

It was not apparent that some extrinsic information is better than none as a training method. However, it appears from this study that the benefit of such information may vary among individuals. One has therefore to



deduce how much information should be available to Field independents (along the stated dimension of Field Independence/Field Dependence) in order for them to use such information efficiently. Again this may necessitate the design of some pilot studies. If one were to design a training methodology, it may necessitate to consider the following: Whether information should be in a pictorial, spatial or a written form; if in a written form, it would be necessary to decide what format such instructions should take, that is, whether information should be presented as procedures or as theory.

From observations of videos and verbalizations, it was evident that subjects were aware of what they had done, what hypotheses were being tested, and the required conclusions. However, for the Fds, this was not so obvious. Once Fds had some idea of what they wanted to do, it was not so easy for the group of subjects to translate any verbalisable knowledge into actual performance (see pages 158-159). Initially, the written instructions were useful to the Fds, in that promising moves were made. But it was evident that this confused many, because when deviations occurred from the required paths, trying to remember the instructions was not fruitful since they did not provide solutions. Indeed, it was pointed out by subjects that. "I used the information initially, but I decided to abandon it because it all became a bit confusing; I tried to use the information, but now I have resorted to trial and error".

It was voiced by some people that it becomes very much like "driving a car" (that is at a skill based level). However, the notion is that once cognition is at this level ie. automatic, it is no longer verbalisable, Anderson (1985). But in this study, subjects could talk about what they had done and their reasons. This supports Berry and Broadbent's (1984) findings; that is, as subjects become more familiar or expert with a task, then knowledge becomes verbalisable and accessible.



Matthews et al. (1988) also pointed out that people have no separate knowledge bases to guide their behaviour in tasks. One source is their conceptual representation or mental model; the second, an independent source of information on subject's memory for past sequences of events to the task.

In conclusion, it is possible to postulate that subjects do not have two knowledge sources as shown by Matthews et al. (1988) and Estes (1979) but, the conceptual representation of the plant is a result of the subject's memory for past sequences of events i.e. they are an integral part of each other.

#### **7.4      Methodological Problems**

##### **A:      The Relevance of Laboratory Research to Applied Research**

It is the purpose of different experimental designs to control subject variables, but the variability of human beings makes them difficult to study. It is not possible to predict how an individual may behave when he is put into a controlled laboratory situation. It is not possible to be sure that the way in which people behave in the laboratory is an accurate indication of how they behave outside in real life, that is, it may lack ecological validity.

Individuals may differ in their relative motivation to complete tasks. Whilst some may view the task as being part of a relevant study worthy of completion, others may not hold such a view, and would therefore be less motivated to complete it.

##### **B:      The Relevance of Students as Subjects**

The subjects used for the experiments were student volunteers from Loughborough University. Miller (1967) estimated that 90% of American experiments used college students. He pointed out that there is no reason to believe that college students are typical



of any group, in terms of gender, age, personality and social class background. It has not been possible to separate our educational background from EFT scores.

**C: Bias of Experimental Material**

The mixer pant and control panel were constructed on the basis of assuming that it might be possible to teach individuals, irrespective of their educational background, how to use the system. However, the system may have been biased in the sense that such a model may be more easily understood by people with some scientific knowledge, because, the intrinsic nature of the task has logical principles associated with it. There is a need for some understanding of proportions, flow systems, and the cognitive skills of analysis, computation, approximations, application of knowledge to a physical system and seeing logical connections between disparate elements. As such, the experimental material may have been biased towards people of the field independent pole.

**D: The Problem of Attribution of Performance Differences to a Factor**

It is possible to argue that the results may be incidental, that is, they may be due to some other factor other than the Fi/Fd dimension. Other cognitive styles may have prevailed during problem solving which were not accounted for. For example, it is possible that cautiousness versus risk taking may be responsible for the manner in which individuals chose to complete process control tasks. However, this seems to be a major problem in any factor type experiments when an inference is drawn about some general psychological principle.



Based on arguments by Wallach and Kogan (1965) and Watson (1991) there are two distinct dimensions of impulsivity. Whereas impulsivity may involve lack of thought and in non analytic (a description of field dependency), it may also involve an element of changeability and flexibility (a description of field independency).

However, observations from these three experiments support the point made by Kogan et al. (1964) that "impulsive children are apt to settle on the wrong conclusion in an inferential method". This may foster the development of feelings of inadequacy. It is conceivable that since these impulsively derived hypotheses are apt to be incorrect, a child who encounters a series of humiliating failures would eventually withdraw from any involvement.

#### 7.4.1 Conclusion

In order to be sure that findings can be attributed to various population types, it would be necessary to be sure that the methodologies used are sound and appropriate. However, various experimental problems have been outlined and the usefulness of using experiments might be questioned.

Although there may be arguments for not doing the experiments, there may also be strong arguments for conducting them; one being that a start has to be made somewhere, given that this is a rather complicated methodological area of study.

#### 7.5 Implications of Results and Conclusions

Individual differences might be catered for when prospective operators are selected and are trained for a particular job/jobs in the process control field. Thus, it would be necessary to provide different sets of information, so that different people can take advantage of their cognitive styles.



### **Matching the Cognitive style of the trainer with the trainee**

In teaching, training or learning, it is the case that knowledge about cognitive styles offers several possibilities especially in combination between trainee population types and trainers/trainees. That is, if it is possible to assess where an individual lies on the field independent/field dependent dimension, it may be possible to train him accordingly. For example, homogenous groupings of trainees may foster the deployment of certain training methods as opposed to others.

### **Instructional Design Based on Cognitive Style**

The present study has focused on the role of extrinsic information upon the acquisition of simulated processing skills. Different tasks require different styles. Therefore if one were to devise an instructional method, it would be necessary to consider the requirements of the tasks, as well as the cognitive styles of the operators concerned.

#### **7.5.1 Stages**

- i. Decide whether the individual is Fi/Fd and where on this dimension he lies.
- ii. Deduce the level of "impulsivity" of the individual. A test could be used, for example, that used by Kogan (1965) and Watson (1991).
- iii. Decide upon the type of "distance" tasks which should be presented to a trainee of a particular cognitive style.

The trainer should decide what type of instructional material should be presented to individuals, if they lie on particular points on the Fi/Fd dimension and if they are of a particular level of impulsivity.



The trainer may also have to decide when and how feedback should be given, and what form this feedback should take.

Finally, it is important to decide upon ways in which performance could be assessed.

### 7.5.2 Other Implications

- \* While much of this discussion has focused on the means of adapting training to cognitive style of the individual learner, it has also emerged that for people high on the Fd dimension, adapting training remains problematic and, therefore, such people are likely to be successful process operators whatever training regime is adopted. This emphasises cognitive style as an important field for investigation regarding process operator selection. In particular, the research suggests the Fi/Fd dimension is an important determinant of success in selection of operators.
- \* It is conceivable that individuals from different backgrounds may interpret problem solving situations in different ways. That is, different cultural backgrounds may influence the capacity for monitoring one's own behaviour, the value associated with generalising from practice, and the competence in specific skills related to the media most prevalent in one's background and culture. It is apparent that there is a need for investigation upon the acquisition, transfer and retention of process control skills, as there is no evidence to date.
- \* It might be the case that the type of tasks, as well as the personality of individuals, may be pertinent factors, influencing the manner with which process control skills are acquired. If anxiety is one factor which is independent of cognitive style, it



may be necessary to investigate the extent of such a factor as a prevailing dimension in performance, as there is no available evidence.

- \* In a society such as <sup>the UK</sup> ~~this~~, males are often expected to be the problem solvers and to take the lead. Such qualities exhibited by females are sometimes regarded negatively. It is possible that this may have the effect of encouraging females to have negative attitudes to problem solving. If such attitudes are embedded in a prospective operator by the time she is eighteen, the question arises as to what could the trainer could do in order to eliminate or reduce this. An investigation of this issue may have implications across a broad range of problem solving situations. ✕

## 7.6 Conclusions

The main findings were:

- \* It would be necessary to provide different sets of information so that different people may take advantage of their particular cognitive styles.
- \* Learning situations should be designed so as to enable or permit people to learn according to their cognitive style. This is without the constraints imposed by a rigid learning method.
- \* The idea of matching the cognitive style of the trainer with the trainee is fairly common. But it is quite easy to get this wrong. Simulation training entails providing a rich set of training facilities. In this case, people may be supported according to their individual cognitive styles.



- \* It is not certain that a technology will ever be achieved/developed where it is possible to categorise the individual so that his precise method of learning is understood and training can be tailored to his needs.



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