Chapter Five - Conclusion

1.0 INTRODUCTION

Modern world characterized by its scientific and technological progress, vanishing national borders and economic mayhem has led us into a fast paced life. The fast pace of life forces us to be competent into many areas and perform many things at times. In fact this is an age of multi-skilled people and multi-task performance. Obviously the question that comes to mind is do we have capability to do multi-tasking ? Are we, evolutionarily endowed with the mental and physical capacity to do multi-tasking successfully ?

Although human interest and fascination in multiple-task performance dates back to the cradles of civilisation, Psychology which is largely influenced by cognitive paradigm these days, has naturally explored this aspect since its beginning in 1960s. Studies in multiple-task performance has share and overlap its boundaries with studies in attention and reaction time. Even basic philosophical issues about the nature of mind and matter have influenced theorisation in this field. Most used experimental approach to study multiple-task performance is psychological refractory period, which till date has been rampant with equivocal findings, competing theories and conflicting conceptualization.

Meyer and Kieras (1997) proposed a Computational Theory of Executive Cognitive Processes and Multiple-Task Performance. This computational theory accounted for a lot of equivocal findings in psychological refractory period studies. Present research aims at examining assumptions of this theory under different experimental conditions empirically and extends it to truly multiple-task situations.

1.1 THEORIES OF MIND

"There are many specific mental phenomena with which the philosophy of mind is concerned : for example : free will, intention, introspection, mental causation, personal identity, qualia, reasoning, mental content, and consciousness" (Georges Rey, 1998). However, theorization in the field is largely focused on three mental phenomena viz. "consciousness, rationality, and intentionality" (Georges Rey, 1998).

"Emergence in the 1960s of the loose federation of disciplines called 'cognitive science', brought together research from, psychology, linguistics, computer science, neuroscience and a number of subareas of philosophy, such as logic, the philosophy of language, and action theory. In philosophy of mind, these developments led to

Functionalism, according to which mental states are to be characterized in terms of relations they bear among themselves and to inputs and outputs, for example, mediating perception and action in the way that belief and desire characteristically seem to do.

This focus on functional organization brought with it the possibility of multiple realizations : if all that is essential to mental states are the roles they play in a system, then, in principle, mental states, and so minds, could be composed of (or 'realized' by) different substances: some minds might be carbon-based like ours, some might be computer 'brains' in robots of the future, and some might be silicon-based, as in some science fiction stories about 'Martians'. These differences might also cause the minds to be organized in different ways at different levels, an idea that has encouraged the coexistence of the many different disciplines of cognitive science, each studying the mind at often different levels of explanation". (Jackson, Frank & Georges Rey, 1998).

1.2 COMPUTATIONAL THEORY OF MIND (CTM)

Computational approach to mind, as mentioned earlier, considers mental representations and mental computations as two main aspects of mind. "The idea that thinking, and mental processes in general, could be treated in computational terms, was inspired by the successes in the formalization of certain portions of reasoning......It emerges in the work of Newell and Simon, Putnam, Harman, and especially J. Fodor, who has been most explicitly developing the computational-representational theory of thought (CRTT) or the idea that thinking consists in computing upon sentences in a 'Language of Thought'.

Note that, CRTT is not the claim that any computer - even any existing computer - is or has a mind. Rather, it is the claim that a mind is a certain kind of computer, one with specific relations to the environment, which, together, are responsible for its having certain intentional content. It is, in fact, not so much a claim as a research program : the hope is that by understanding the brain as an elaborate computer - or, more realistically, as a complex assemblage of computers - one could ultimately define mental states in terms of the specific computational roles they play in that assemblage. This program is more or less the subject matter of cognitive science" (Georges Rey, 1998).

"There have been three main versions of Computational Theory of Mind, corresponding to three main proposals about the mind's Cognitive architecture. According to the 'classical' theory, particularly associated with Jerry Fodor, the computations take place over representations that possess the kind of logical, syntactic structure captured in standard logical form : representations in a so-called Language of Thought, encoded in our brains. A second proposal, sometimes inspired by F.P. Ramsey's view that beliefs are maps by which we steer, emphasizes the possible role in reasoning of maps and mental Imagery. A third, recently much-discussed proposal is Connectionism, which denies that there are any structured representations at all : the mind/brain consists rather of a vast network of nodes whose different and variable excitation levels explain intelligent Learning. This approach has aroused interest especially among those wary of positing much 'hidden' mental structure not evident in ordinary behaviour" (Jackson, Frank & Georges Rey et al).

Principal assumptions of computational approach are :

1. Key characteristic of mind is intentionality, as defined by Brentano (1874).

2. Mental representations are the stuff that makes up the mind.

3. Intentionality of mental representations require symbols, as symbols are the only known bearers of meaning we know.

4. Mental computations are combining and crunching of symbols or mental representations. Thus mind is a symbol manipulator and cognition is symbol manipulation.

4. Symbols can be combined according to strictly formal rules.

5. The process of combining or crunching of symbol is called computation.

6. Since computations are strictly formal, algorithmic they could be mechanical.

7. As mind is a symbol manipulator, mind is also mechanical or computational.

8. Besides, as mental processes are instantiated in material processes (brain), there is no such things as disembodied or non-physical thoughts.

9. As it is possible to know the way a computer program e.g. Word works, without knowing anything about hardware, similarly it is possible to know how cognition works without studying neurophysiology (wetware).

10. Physical substrates of cognition may be different for different individuals, species and systems and therefore cognition could be realized in any system, not necessarily in mind. Functionalism defines this as multiple realizability. Hence we could study cognitive processes in artificial systems also. Such systems are said to possess artificial intelligence.

11. Artificial intelligence is implemented by Universal Turing Machine which is a general purpose symbol manipulator.

12. Universal Turing Machine executes any specific series of mechanical operations, an algorithm. Such procedures or programs have a cause force i.e. they execute intelligent behaviour by manipulating symbols according to strictly formal rules.

13. As mind is symbol manipulator and symbol manipulation is strictly formal. Contents of mind, meaning or reference to environment are not the subject matter of cognitive science. Computational approach considers that although environment causally affects the body e.g. sensations, we only have to look at the individual system and not its environment. Thus computational approach holds in essence that only processes inside the organism can be studied. In this view psychology 'ends at the skin'.

14. The laws of psychology are intentional. They explain behaviour by citing mental content, the goals and desires an organism has; and that these are implemented in computational mechanisms. The harmonious relationship between the mechanism and meaning is contingent and not necessary. "The computational mechanisms have a causal history of interactions with the world that generally connect current outcome of the syntactic mechanisms with the right behaviour in the environment, that is, preserve the meaning or content of a belief or desire over a series of formal computations.

1.3 MULTIPLE TASK PERFORMANCE

Humanity has always seen multiple-task performance with an awesome wonder. Anecdotes about such performance have been recorded in the history. A classic example in Indian history is that of Haider Ali (father of Tipu Sultan), who has been claimed to be capable of listening to seven people at the same time at his court. Another example is that of Shrimad Rajchandra, the teacher of Gandhiji, who is known for having demonstrated in presence of then British Judges of Bombay Court a yogic skill "शतावधानी", a capacity to do multiple tasks together. Innumerable examples of yogis demonstrating such skills are there in the collective unconscious of Indian mind.

The subject matter has gained more importance in the current milieu which is characterised by technological advancement and demand for highly effective performance especially from modern age executives. This is because a person's ability to cope with such situations depends on how information processing is coordinated across the task at hand, and the success or failure of this coordination can have significant consequences under a variety of real world circumstances. (Meyer & Kieras, 1997).

Intellectual curiosity in multiple-task performance has resulted into a plethora of methodological procedures, empirical findings and theoretical constructs (Atkinson, Hernstein, LIndzey, & Luce, 1988; Damos, 1991; Gopher & Donchin, 1986; Meyer & Kornblum, 1993). Multiple-task performance is generally studied in the Psychological Refractory Period Paradigm. However till date, we do not have any comprehensive theoretical framework for understanding of multiple-task performance (Allport, 1993; Broadbent, 1993).

1.4 PSYCHOLOGICAL REFRACTORY PERIOD

Colman (2001) defines psychological refractory period as "A period following a response to a stimulus during which reaction time to a further stimulus is increased." Whereas Pashler H., Johnston J. C., and Ruthruff E. (2001) define it as "The psychological refractory period (PRP) effect refers to a ubiquitous and often large slowing effect observed when people try to perform two speeded tasks close together in time (each task involving a choice of responses based on a distinct stimulus). While responses to the first-presented stimulus are often little affected by temporal proximity to the second task, responses to the second stimulus are usually slowed as the interval between stimuli is reduced. The increase in second task RTs as the interval between stimuli is reduced in the most commonly used measure of the magnitude of the PRP effect." Telford in (1931) while doing a reaction time study of two consecutive task as given below -

Task 1 (T1)	-	auditory tone	Response 1 (R1)	-	key-press
Task 2 (T2)	-	visual cue	Response 2 (R2)	-	naming

found that if relatively short interval (0.5 second or less) separated the stimulus from the next stimulus for a subsequent response, then the reaction time of the subsequent response i.e. R2 increased relative to ones with a longer interval (1s or more). This was termed as Psychological Refractory Period (PRP). Craik (1948) also reported that manual tracking of moving visual targets produced discrete intermittent responses separated by 0.5 seconds.

This intermittency was confirmed by Vince (1948). This led Craik to speculate that "the time lag is caused by the building up of some single computing process which then discharges down the motor nerves .....new sensory impulses entering the brain while this central computing process is going on would either disturb it or be hindered from disturbing it by some 'switching system' ....there is a minimum interval within which successive stimuli can not be responded to."

1.5 A TYPICAL EXPERIMENTAL DESIGN FOR PRP

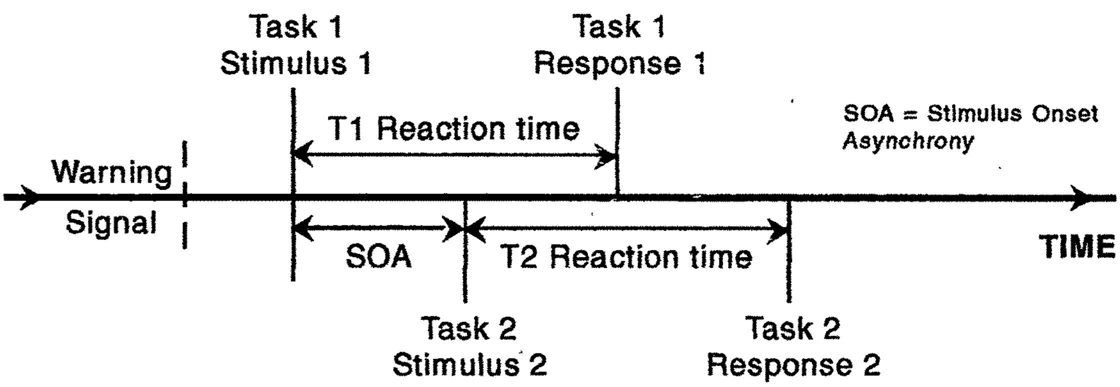

Fig. 2 A typical PRP experiment procedure

"The PRP procedure involves a series of discrete test trials (see figure 2). On each trial, a warning signal is followed by a stimulus (e.g. a visual letter or auditory tone) for the first of two tasks. In response to it, a participant must react quickly and accurately (e.g. by pressing a finger key or saying a word). Soon after the Task 1 stimulus, there is another stimulus for the second task. The sensory modality and semantic category of the Task 2 stimulus may or may not differ from those of the Task 1 stimulus. The time between the two stimuli is the Stimulus Onset Asynchrony (SOA), which typically ranges from 0 to 1 second. In response to the Task 2 stimulus, the participant again must react quickly and accurately. The effector used to make the Task 2 response may or may not differ from that for the Task 1 response. In any case, instructions for the PRP procedure typically state that Task 1 should have higher priority than Task 2 : they also may urge participants to make the Task 1 response first. RTs are measured to determine how much Task 1 actually interferes with the performance of Task 2.

Variations of PRP experiment design would consider following as variables -

1. Tasks could be of Simple Reaction Time or Choice Reaction Time

2. Tasks could be such that they have Stimulus-Response compatibility e.g. stimulus presentation on right side and response with right hand.

3. Tasks could vary in Sensory modality e.g. one task with auditory stimulus and another with visual stimulus.

4. Tasks could vary in Stimulus-Response numerosity e.g. response in terms of multiple tapping or single tapping, or stimulus could be one or more than one.

5. Effectors used in responding could vary e.g. hand, speech etc.

6. Task priorities in responding e.g. Pashler (1984) instructed the subject "to respond as quickly as possible to both tasks in the two-task blocks, with the restriction that the first stimulus must be responded to before the second. Similarly in an another study Pashler and Johnston (1989) instructed subjects to "respond as quickly as possible to the first stimulus.

1.6 FINDINGS OF PRP AND RELATED EXPERIMENTS

1. Task 2 Reaction Time is higher at short SOA than at long SOA. (Davis, 1956, 1957; Vince, 1949; Welford, 1959).

2. The slope of the PRP curve equalled -1 at short SOAs; that is for each unit of time that the SOA decreased, the Task 2 reaction time correspondingly increased. (Davis, 1956, 1957; Vince, 1949; Welford, 1959).

3. PRP effect at zero SOA equalled the mean Task 1 RT.

4. At zero SOA PRP effect has not always equalled mean Task 1 reaction time but significantly less also. (Karlin & Kestenbaum, 1968).

5. Studies have shown that subjects can notice significant amount of semantic

information in unattended auditory messages. Thus, stimulus identification could perhaps proceed in parallel also.

6. PRP effect and reaction time are function of difficulty of response selection of Task 1 i.e. *as response-selection difficulty of Task 1 decreases, PRP effect* decreases. If Task 1 involves very simple response or no response, PRP effect becomes null.

7. PRP effect and reaction time are function of Task 1 S-R numerosity. When Task 1 S-R pairs increases PRP effect and Task 1 reaction time increases.

8. PRP effect and reaction time are function of S-R compatibility of Task 1. When Task 1 stimulus-response incompatibility is increased Task 1 reaction time and PRP effect increases.

9. Task 1 S-R compatibility effects are additive with the factors related to stimulus identification stage (stimulus legibility) and movement production stage (response probability).

10. Response selection stage has been found to be the locus of Task 1 S-R compatibility *effects and S-R numerosity effects. Such effects are generally found to be* interactive.

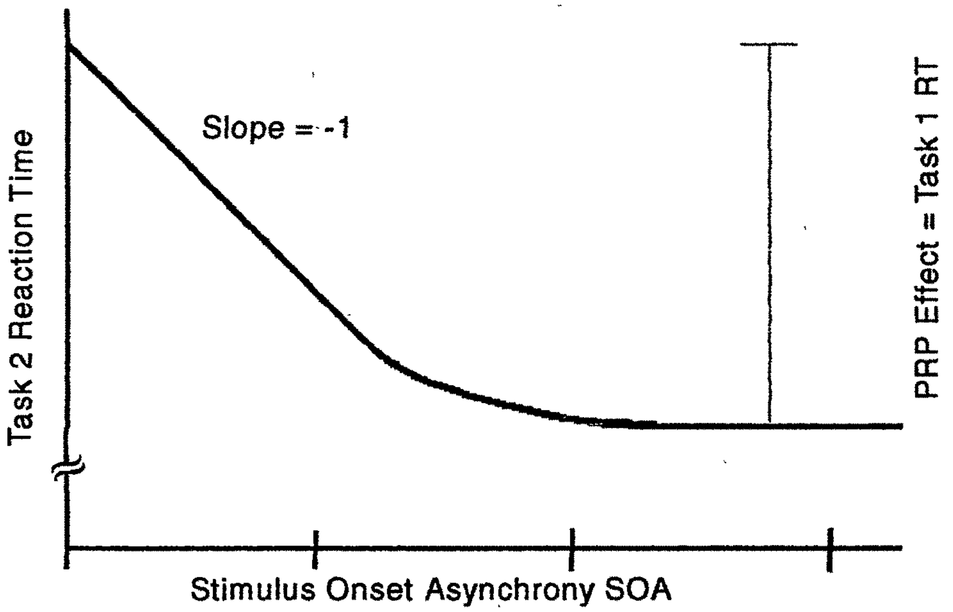

Fig. 3 A typical PRP curve

11. PRP effect and reaction time are function of difficulty of response selection of Task 2. There is an interaction effect between SOA and Task 2 response selection difficulty. Task 2 RTs at long SOA are greater under choice RT condition than under simple RT condition whereas no difference occurs between Task 2 RTs for both these conditions at short SOA. PRP effect is less in Task 2 choice RT in comparison to Task 2 simple RT.

12. SOA and S-R numerosity have additive effects on Task 2 RTs i.e. the difference between Task 2 RTs involving simple reaction and choice reaction were same at both short SOA and long SOA.

13. SOA and factors that influence Task 2 response selection have been found to have additive effects.

13. Task 2 factors have indirect effects on Task 1 performance. Participants are sometimes faster at performing a given task alone than at performing it as the first of two tasks (Gottsdanker, Broadbent, & Van Sant, 1963; Herman & Kantowitz, 1970).

14. Task 1 RTs sometimes increases with the number of S-R pairs in Task 2 (Karlin & Kestenbaum, 1968; Smith, 1969).

15. Occasionally, Task 1 RTs increase when SOAs are short rather than long (Gottsdanker & Way, 1966).

16. Generally, for any factor that influences a Task 2 stage of processing before the locus of the bottleneck, its effects on Task 2 RTs should interact with those of the SOA. For any factor that influences the bottleneck stage or other subsequent stages of Task 2, its effects on Task 2 RTs should be additive with those of the SOA.

17. Difficulty insensitivity : Varying the nominal difficulty of a primary task has little or no effect on participants' performance of a concurrent secondary task (e.g. primary visual manual choice reaction along with secondary digit cancellation task or visual manual tracking task).

18. Structural alteration effect : This effect occurs when two circumstances jointly prevail : (a) primary task interference with a secondary task is dramatically reduced by changing which structural components are needed to perform the primary tasks

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and, (b) this change does not increase the primary task's difficulty (e.g. primary task of manual or vocal response to auditory tones and secondary task of visual manual tracking task). Such effects have been obtained by changing primary-task response modality, stimulus modality and mental imagery code.

19. Difficulty-structure uncoupling : This occurs when structural alteration effect reduce the interference between the primary and secondary tasks at the same time as the primary task difficulty actually increases (e.g. primary auditory signal detection task or manual force generation task and secondary visual manual tracking task. This leads to more interference due to easier task than due to difficult task.

20. Perfect Time Sharing : This occurs when neither of two individually demanding tasks interferes with the other during dual-task performance (e.g. simultaneous shadowing of spoken message and playing of piano music from written scores).

1.7 THEORIES OF MULTIPLE-TASK PERFORMANCE

Several modern theoretical perspectives on multiple task performance in PRP paradigm are : (1) Single Channel Hypothesis (2) Perceptual Bottleneck Model (3) Response Selection Model (4) Movement Production Bottleneck Model (5) Unitary Resource Theory, and (6) Multiple Resource Theory. Thus, there are diverse theorisation of multiple task performance leading to diagreeement and confusion. Allport (1993), also stated that -

"What is urgently needed is....a computational theory, in the sense outlined by Marr (1982), of the many different functions of attentional selectivity and control....taking seriously the ideal that attentional functions are of many different kinds, serving a great range of different computational purposes."

To summarize, current status of theorisation in multiple-task performance requires following considerations -

1. Construction of computational models
2. Use of production system formalism
3. Specification of general integrated information-processing architecture
4. Specification of perceptual-motor processors

5. Analysis of executive processes

6. Omission of limited-capacity assumption

Meyer and Kieras (1997) proposed EPIC architecture specifically to implement multiple task performance. Later, in 2001, EPIC was modified to characterize the supervisory functions of executive mental processes.

1.8 EXECUTIVE PROCESS INTERACTIVE CONTROL (EPIC)

"EPIC was introduced for characterizing human performance of concurrent perceptual-motor and cognitive tasks. On the basis of EPIC, computational models may be formulated to simulate multiple-task performance under a variety of circumstances. These models account well for reaction-time data from representative situations such as the psychological refractory-period procedure. EPIC's goodness of fit supports several key conclusions :

(a) At a cognitive level, people can apply distinct sets of production rules simultaneously for executing the procedures of multiple tasks;

(b) People's capacity to process information at "peripheral" perceptual-motor levels is limited;

(c) To cope with such limits and to satisfy task priorities, flexible scheduling strategies are used; and

(d) These strategies are mediated by executive cognitive processes that coordinate concurrent task adaptively.

Formal concepts and algorithms from contemporary computer operating systems can facilitate efforts to precisely characterize the supervisory functions of executive mental processes. In particular, by helping to advance work with the EPIC architecture, a theoretical framework for computational modelling of human multi-task performance, operating system fundamentals provide insights about how people schedule tasks, allocate perceptual-motor resources, and coordinate task processes under both laboratory and real-world conditions. Such insights may lead to discoveries about the acquisition of procedural task knowledge and efficient multi-tasking skills" (Kieras, Meyer, Ballas, & Lauber, 2000).

1.9 FIVE FEATURES OF EPIC

Five heuristic principles of EPIC are (1) Integrated information processing architecture (2) Production system formalism (3) Omission of limited-capacity assumption (4) Emphasis on task strategies and executive processes, and (5) Detailed treatment of perceptual-motor constraints. Details of each principle follows now -

EPIC incorporates known characteristics of human information processing and performance. Figure 6 outlines principal components of EPIC. They consist of several complementary memory stores and processing units that interact with each other hetrarchically. The processing units are implemented as modules of instructions written in LISP, a programming language for symbolic computation in artificial intelligence. EPIC includes basically a long-term memory, working memory, perceptual processors, a cognitive processor, and motor processors. Details of several components are as under -

1. Virtual eye : It is a simulated physical sensor for vision.
2. Virtual ear : It is a simulated physical sensor for hearing.
3. Virtual touch : It is a simulated physical sensor for tactile sensation.
4. Declarative long-term memory : This store contains knowledge expressed as propositions, which embody the gist of the verbal descriptions about when, where, why and how to perform particular tasks.
5. Procedural memory : This memory contains sets of PPS production rules that instantiate procedural knowledge for actually performing the tasks. These rules may be derived through a process of "proceduralization" that converts declarative propositional knowledge to a directly executable form.
6. Working memory : This memory contains symbolic control information needed for testing and applying the production rules stored in procedural memory. Symbolic representations of stimulus inputs and response outputs also are stored in EPIC's working memory for use by the system's production rules. Presently, EPIC's working memory is depicted as a single store that contains various types of functionally distinct information. In other contexts, however, it would be more appropriate to treat working memory as having a number of separate partitions, in each of which the form, amount, and duration of the contents differ from those of the other partitions.

7. Visual processor : It receives inputs from simulated physical eye and sends output to working memory.

8. Auditory processor : It receives inputs from simulated physical ear and sends output to working memory.

9. Tactile processor : It receives inputs from simulated effector organs and sends output to working memory.

10. Cognitive processor : It relies on PPS production rule interpreter, which tests the conditions and executes the actions of production rules in procedural memory.

11. Vocal motor processor : It receives selected symbolic responses from cognitive processor to simulate vocal actions.

12. Manual motor processor : It receives selected symbolic responses from cognitive processor to simulate manual actions.

13. Simulated interaction devices interface between simulated sensors and task environment.

14. Ocular motor processor : It moves EPIC's eyes whose spatial position determines what inputs may enter the visual perceptual processors.

In EPIC task environment sends signals to the simulated interaction devices which in turn sends signals to the virtual physical sensors viz. virtual eye, virtual ear, virtual skin. Virtual physical sensory sends input to visual, auditory and tactile perceptual processor. These perceptual processors sends output to working memory, which is used by a cognitive processor to perform various tasks. The cognitive processor relies on the PPS production-rule interpreter, which tests the conditions and executes the actions of the production rules in procedural memory. Through this interpreter, the cognitive processor selects symbolic responses and sends them to vocal and manual motor processors, which prepare and initiate movements by simulated physical effectors. In addition, there is an ocular motor processor for moving EPIC's eyes, whose spatial position determines what inputs may enter the visual perceptual processor. With its various components, EPIC has capabilities to emulate a broad range of human perceptual-motor and cognitive skills.

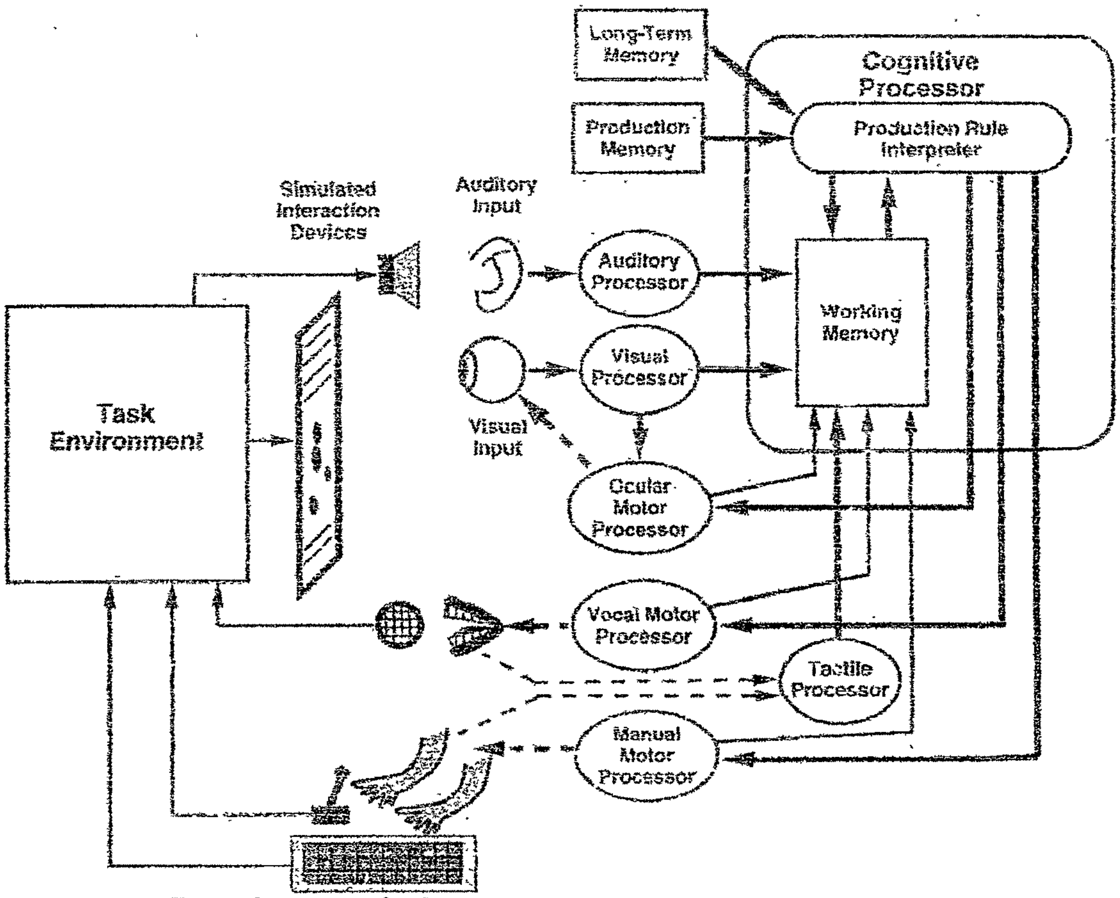


Fig. 6 Overview of information-processing components in the EPIC

2.1 ASSUMPTIONS ABOUT EPIC COMPONENTS

EPIC makes explicit assumptions about the symbolic representations, input-output transformations, and process durations needed to model human performance. The assumptions are guided by the desire to make EPIC parsimonious, precisely specified and consistent with empirical data. Assumed properties of EPIC's perceptual processors, motor processors, working memory and cognitive processor are as summarized in Table 1.

2.2 MODELLING HUMAN PERFORMANCE WITH EPIC

To use EPIC for constructing computational models of human performance, two complementary steps are necessary. First, we must consider how various individual tasks might be performed, if our architectural assumptions are correct. Second, we must consider how individual tasks might be coordinated during multiple-task performance.

1. *Single-task performance :* Following steps are involved in modelling single-task performance :

Table 1 EPIC components and their assumed properties

Type of component	Assumed properties
Perceptual Processors	Operations are parallel and asynchronous. Stimulus identities sent to working memory. Transmission times depend on modality, intensity and discriminability.
Motor Processors	Response identities received as inputs. Movement features prepared for physical outputs. Feature preparation done serially with set time increments. Advance feature preparation done for anticipated responses. Movement initiation done after feature preparation. Efference copies of motoric representations sent to working memory.
Cognitive Processors	Programmed with production rules (if condition, then action). Rules interpreted by parsimonious production system. Conditions refer to goals, steps, and notes on working memory. Step in conditions govern flow of control. Complex conflict-resolution criteria and spreading activation not used. Actions regulate working memory and perceptual motor processors. Cyclic operation with set mean cycle duration. No limit on number of rules being tested and applied simultaneously.
Working Memory	Contents consists of goals, steps, and notes. Contents used and managed by cognitive processor. Capacity and duration sufficient for performance in PRP procedure.

a. Analyze the information-processing requirements of each task at hand;

b. Specify a set of production rules to be used by EPIC's cognitive processor in performing the task;

c. Specify the initial contents of working memory;

d. Specify stimulus inputs from the external environment that get the task started;

Following constraints are imposed on modelling :

a. The properties of EPIC's cognitive, perceptual, and motor processors remain the same across all tasks;

b. The production rules used to program the cognitive processor may differ across tasks. But within a task, these rules remain constant unless an explicit learning algorithm is included to describe practice effects;

c. Rationality principle i.e. production rules to be specified as per the goals of the tasks and instructions that people receive about how to achieve them

d. Production rules are specified such that they can mimic basic factor effects on RTs.

a. Stimulus numerosity effects could be brought about by changing the number of production-rule steps and hence the number of cognitive-processor cycles, that take place during each trial depending on the levels of relevant task factors;

b. S-R repetition effects are achieved by repetition-bypass feature such that whenever the same stimulus occurs again on the next trial, the same response as before is selected immediately for it;

c. S-R compatibility effect is achieved by producing a stimulus identity code through perceptual processor, whose features are isomorphic to ones used by a motor processor for programming response movements. Consequently, the cognitive processor may pass this code directly to the motor processor, reducing the processor cycles taken for response selection and thereby decreasing overall RT.

Through the same approach, it is also possible to characterize other factor effects, including ones that stem from stimulus probability and response competition (stroop effect).

2. *Multiple-task performance :* For multiple-task performance it is necessary to specify how the functions performed by the distinct sets of production rules for each of two or more concurrent tasks are coordinated. For every task to be completed properly, there must be some supervisory control to ensure that the tasks' production-rule sets do not try to use the same physical sensors (e.g. eye) or effectors (e.g. hands) simultaneously in conflicting ways. Also supervisory control is needed to ensure that performance obeys instructions about relative task priorities. This is achieved by -

a. Executive processes : The executive processes maintain task priorities and coordinate progress on concurrent tasks through various types of supervisory control. For example, they insert and delete task goals in working memory, direct the eyes to look at one place or another in visual space, send selected responses either to motor processors or working memory, and prepare movement features of anticipated responses, all depending on the current context and task instructions. Such executive functions are performed by additional sets of production rules distinct from those for the individual tasks. As executive processes are specified in form of production rules set whose format and application parallel the rules sets used to perform individual tasks they have a considerable architectural homogeneity. Executive processes have some additional important properties such as -

a. They do not contain procedural knowledge sufficient to perform any individual task;

b. They do not modify the individual tasks' production rules;

c. They coordinate progress on individual tasks only by manipulating goals and notes in working memory;

d. They may change as a function of particular task combinations, priorities, experimental paradigms, and subjective strategies;

e. They allow the production-rule sets for individual tasks to be used across a variety of multiple-task situations.

b. Scheduling algorithm : Performance of concurrent tasks may be coordinated through various scheduling algorithms such as lockout scheduling or interleaved scheduling.

a. Lockout scheduling : Under such schedules tasks are performed one by one in strict sequence; each successive task remains entirely suspended (i.e. locked out) until its turn for processing comes. This progression is achieved by having the executive process insert and delete the tasks' main goals one after another in working memory. Cross-task coordination then has much the same temporal character as under the global single channel hypothesis, but the seriality of performance stems from option supervisory control rather than from one task inherently blocking another task's entry into a single information-processing channel.

Lockout scheduling has the virtue of being simple and easy to implement. It requires minimal executive process and provides a type of coordination that novice multiple-task performers might favour because of its conservative nature, which eliminates potential conflicts over access to perceptual-motor components. However, lockout scheduling has disadvantages too. It precludes highly efficient multiple-task performance because no temporal overlap is allowed in the performance of two or more tasks even though such overlap might be possible from the standpoint of available system resources.

b. Interleaved scheduling : Under it some of the component processes for multiple tasks are allowed to proceed concurrently; an individual task is suspended only during minimal time periods when unavoidable conflicts with competing tasks might otherwise occur. This requires a more complex executive process whose production rules are highly specific to particular task combinations. Consequently, a major contribution of practice at multiple-task performance may involve enabling a shift from lockout scheduling to fully interleaved scheduling.

2.3 PROTOCOL FOR SIMULATIONS WITH SRD MODEL

To demonstrate the applicability of the SRD model and its EPIC information-processing architecture, they are used in computer simulations of representative past studies with the PRP procedure. This allows detailed quantitative comparisons between simulated RTs produced by the model and empirical RTs obtained across various experimental contexts. Although good fits between the simulated and empirical RTs do not prove definitively that the model is correct, they at least establish it as a serious theoretical contender.

Before simulations began, software modules were programmed for each component of the EPIC architecture, including its perceptual processors, motor processors, cognitive processor and memory stores. These modules have been written in the LISP programming language and embody EPIC's basic assumptions in executable form. The functional properties of the architecture have remained the same throughout the simulations, just as real participants' underlying perceptual-motor and cognitive mechanisms presumably do during typical laboratory testing.

a. <u>*Steps in each simulation :*</u> Each simulation involves several steps. Together, these steps are analogous to ones that an experimenter would take in trying to replicate an actual empirical study using human participants.

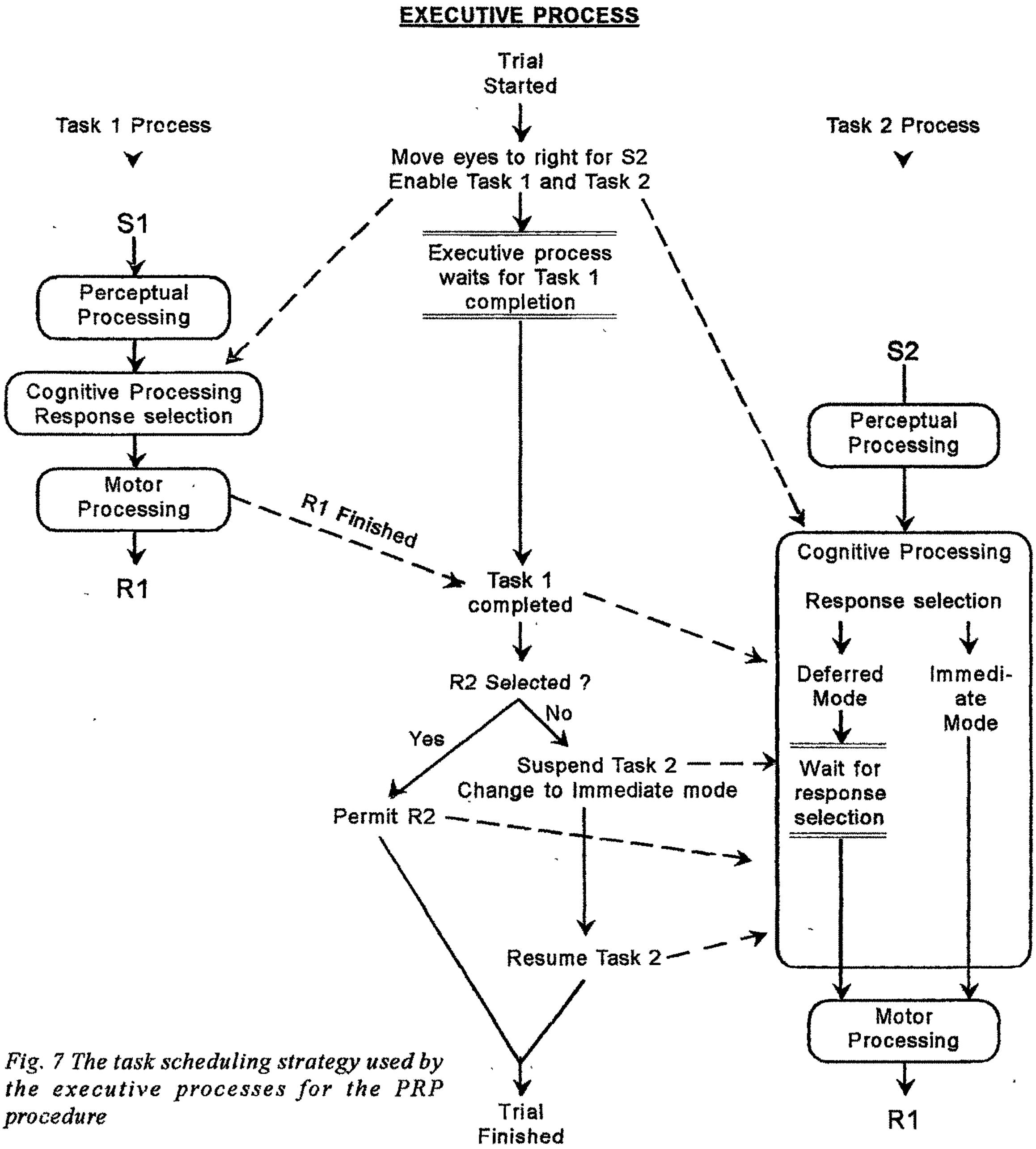


Fig. 7 The task scheduling strategy used by the executive processes for the PRP procedure

1. Selection of empirical PRP study
2. Preparation of environment-simulation program
3. Preparation of executive and task production rules
4. Assignment of numerical parameter values
5. Execution of simulation programs
6. Data analysis

2.4 COGNITIVE AND AFFECTIVE STYLES

In fact while studying individual difference Meyer and Kieras (1997) found that "..Nevertheless, when task 1 is difficult, some people might still adopt a daring scheduling strategy. This prediction follows from several more considerations : (a) regardless of whether task 1 is easy or difficult, EPIC enable various task 2 lockout points and task 1 unlocking events to be used for task scheduling; (b) people differ in the extent to which their performance is routinely cautious or daring; (c) despite strong rewards for cautiousness, some individuals continue to perform daringly." Thus, individual differences may emerge which might be reflective of stylistic performance, which is discussed here below.

Table 4 shows classification of styles

Cognitive Styles	Affective Styles	Cognitive-Affective Styles
Cognitive styles	Tolerance for unconventional or unrealistic experiences	Field articulation
Cognitive complexity	Constricted vs. flexible control	Extensiveness of scanning
Field dependence-independence	Reflection vs. impulsivity	
Category width	Physiognomic vs. literal	
Cognitive integration		
Analytical vs. relational categorizing		
Compartmentalization		
Abstract vs. concrete		
Levelling vs. sharpening		

Of interest here, are the two cognitive styles viz. Conceptual tempo, and Field dependence vs. independence.

1. Conceptual tempo : It is also referred as reflection-impulsivity polarity. Reflectivity is the tendency to consider and reflect on alternative solution, possibilities. Reflective individuals pause to think before beginning a task or making a decision and spend time evaluating their options. Conversely, impulsivity is the tendency to respond impulsively without sufficient forethought. Impulsive individuals quickly offers solutions to problems, without sufficient consideration of the probable accuracy of the solutions.

2. Field dependence-independence : This polar construct is also known as psychological differentiation. It refers to the extent to which a person is dependent versus independent of the organization of the surrounding perceptual field. Evidence suggests a close connection and perhaps an identity between field independence and aspects of intelligence.

Having covered relevant introduction in the field of PRP, EPIC and cognitive style, the discussion now proceeds to the current research.

2.5 PRESENT RESEARCH

Current research is intended to address following four sets of questions -

1. Real life situations actually demand task 2 priorities than task 1 as it is typically designed in PRP experiment. With this change in PRP experiment design -
   - What are the PRP effect and reaction time ?
   - What could be alternative production rules for the same ?
   - Which algebraic equation of SRD model fits in case of such a situation ?
2. Almost all multiple-task experiments generally follow dual-task procedures only.
   - What happens in case of 3 task experimental set up ?
   - How working memory shall become an important parameter in such cases ?
3. If experimental findings focuses on individual differences -
   - How stylistic differences (Field dependence-independence and Reflectivity-impulsivity cognitive-affective styles) shall be related with experimental findings ?
   - How cautious and daring styles shall relate with PRP findings ?
4. If data is analysed in terms of individual performance from trial to trial
   - How much data shall actually fit with SRD model equations ?

- Can such data inform about executive processes ?

Study of this subject matter helps in understanding -

1. Architecture of human information processing system.
2. Structural interface of its components.
3. Capacities of these components.
4. Multiple Task Performance in the given contexts.
5. Principles to facilitate human performance in multiple task situations.
6. Interaction between cognitive and affective processes.
7. Individual differences in multiple-task performance.
8. Fundamental understanding of human information processing.
9. Possibility of construction of scales for selection, placement and training of individuals.
10. Task Designs in such a way so as to gain better performance especially in the context of human factors engineers.

2.6 AIM

The present study explores cognitive-affective processes in multiple-task performance through empirical evidence for Executive Process Interactive Control (EPIC) based Strategic Response Deferement (SRD) model of Psychological Refractory Period (PRP) procedures under varied experimental setup.

3.0 OBJECTIVES

1. To measure PRP effect when primary task is Task 1 and secondary task is Task 2.
2. To measure PRP effect when primary task is Task 2 and secondary task is Task 1.
3. To measure PRP effect under triple task scenario.

4. To compare PRP effects as obtained through objective 1, 2 & 3.

5. To match PRP effects as obtained through objectives 1, 2 & 3 with the EPIC based SRD model of PRP procedure.

6. To match discrete successive choice task effects with the EPIC based SRD model of PRP procedure.

7. To understand the differences in PRP effect among Cautious and Daring individuals and compare them with EPIC based SRD model of PRP procedure.

8. To understand the differences in PRP effect among Field Dependent and Field Independent individuals and compare them with EPIC based SRD model of PRP procedure.

9. To understand the differences in PRP effect among Reflective and Impulsive individuals and compare them with EPIC based SRD model of PRP procedure.

10. To understand the trial-to-trial variations in individual performance under different experimental conditions in context of theoretical formulation of EPIC based SRD model of PRP procedures.

4.0 HYPOTHESES

Based on several objectives above, the following hypotheses are advanced.

1. Repetitive response time shall be more for left hand in comparison to right hand response time.

2. Repetitive response time shall be more for middle finger in comparison to index finger.

3. There will be interaction effect of hand and finger in repetition response time.

4. Second response time of Experiment 3 shall be same as the repetitive response time of the respective stimuli.

5. There will be no significant differences in correct responses for different stimulus display time for all stimuli.

6. Choice reaction times - serial shall be higher than simple reaction time in case of letter stimuli in comparison to digit stimuli.

7. Choice reaction times - repeat stimuli shall be higher than the choice reaction times - serial.

8. Choice reaction times - alternate stimuli shall be higher than the choice reaction times - repeat.

9. PRP effect in T1 priority task shall be as per the standard PRP effect curve.

10. PRP effect shall be different in T2 priority task in comparison to standard PRP effect curve.

11. PRP effect shall be different in subject decision priority task (random) in comparison to standard PRP effect curve.

12. There will be PRP effect in T1 also in triple task trial whenever priority is not T1.

13. There will be PRP effect in T2 and T3 in triple task trial and it will be significantly different from standard PRP effect curve.

5.0 SAMPLE

As this study is a mixed design, and it involves a large collection of data 20 voluntary subjects from Postgraduate classes of Department of Psychology, Faculty of Education & Psychology, M. S. University of Baroda were considered sufficient sample. One subject dropped out due to ill-health and social commitment and so a new subject was recruited in lieu of him. All subjects had more or less similar know-how of computers, normal or corrected-to-normal vision and right-handedness.

6.0 EXPERIMENTAL DESIGN

6.1 Experimental design of present study is mixed one. This is because data has been collected in such a way that they could analysed as Between-subject, Within-subjects as well as Single-subject design. No counterbalancing has been done purposefully. This was done to maximize the systematic effect to maximal. All throughout conditions stimulus conditions were maintained constant.

6.2 Dependent measures :

- Response time
- Response accuracy

6.3 Tasks :

Task 1 : Visual - Manual two-choice task (digital stimuli)

Task 2 : Visual - Manual two-choice task (letter stimuli)

Task 3 : Visual - Manual two-choice task (digital stimuli)

6.4 Stimulus Onset Asynchrony :

- 0.00 sec
- 0.20 sec
- 0.40 sec
- 0.60 sec
- 0.80 sec

6.5 Effectors :

- Right index finger for digit '4'
- Right middle finger for digit '5'
- Left index finger for letter 'd'
- Left middle finger for letter 'f'

6.6 Sequence of experiments :

1. Experiment 1 - Stimulus Identification
2. Experiment 2 - Repetitive Response

3. Experiment 3 - Simple Reaction Time

   - Single response

   - Double response

4. Experiment 4 - Discrete Successive Choice Reaction Time

   - Serial

   - Reverse

   - Alternative

5. Experiment 5 - Discrete Concurrent Two Choice Reaction Time

   - Dual Task

   - Triple task

6. Experiment 6 - Matched Figure Test

7. Experiment 7 - Embedded Figure Test

7.0 PROCEDURE

Each experiment was simulated and conducted on computer through a Visual Basic program. The program Access files for data storage. The flow of simulation was left to the subject's control. Details of each program has been attached herewith in Appendices. Details of each experiment follow -

7.1 Experiment 1 - Stimulus Identification

Complete experiment was simulated on computer. The flow of simulation was left with the subject. The experimenter was just supposed to supervise the occurrence of experimentation. Whole experiment was completed in eleven screens. Before beginning the experiment, the experimenter could set the stimulus display time as the per the standard series.

The first screen was a welcome screen, wherein a respondent was welcome, informed and thanked for participation in the experiment. On pressing 'next' the respondent could move to screen two which asked respondent to fill relevant basic information such as name, birth date, age, gender, and class.

Next screen gave detailed instructions to the subject about the procedure and checked whether instruction was properly understood. On pressing 'yes' the subject was shown example screen, which displayed 5 rectangles, four of which contained digit '4', '5' and letters 'd', 'f' in the centre respectively, and a blank rectangle. This was followed by a 'get ready' screen with a fixation dot in the centre. When respondent pressed 'enter' a blank screen appeared and in the centre any of the five stimulus rectangle was displayed for prefixed display time. Afterwards the respondent was shown response screen wherein five rectangles were again shown and asked to click the rectangle which was displayed on the screen. This was followed by a feedback screen. Subsequently the respondent was again displayed 'get ready' screen with a fixation dot and the next trial continued upto the end of a block.

Presentation of rectangles was completely randomized. Each rectangle was displayed 50 times and in all 250 rectangles were displayed in one block. Ten such blocks were presented in the range of 90 - 10 msec display time. Between each block respondent was given a rest period as per the need of the respondent.

7.2 Experiment 2 - Repetitive Response

Complete experiment was simulated on computer. The flow of simulation was left with the subject. The experimenter was just supposed to supervise the occurrence of experimentation. Whole experiment was completed in seven screens. The first screen was a welcome screen, wherein a respondent was welcome, informed and thanked for participation in the experiment. On pressing 'next' the respondent could move to screen two which asked to fill respondent relevant basic information such as name, birth date, age, gender, and class.

Third screen consisted of the experimental instruction for respondent explaining to him / her about what was expected to be done. This screen was followed by 'get ready screen' wherein subject was asked to check the position of his finger and hand on appropriate key. The next screen instructed the subject to 'start'. With the first key press, the 'start' screen was removed and the screen started displaying the letter or digit pressed by the subject. During the experiment, the subject was supposed to press repeatedly a key as per instruction 100 times. The program recorded each key press time, accuracy of key press and other respondent related details. In all respondent pressed following four keys in the same order for 100 times.

1. Type '4' with right-hand index finger
2. Type '5' with right-hand middle finger
3. Type 'f' with left-hand index finger
4. Type 'd' with left-hand middle finger

Program kept count of 100 key press and stopped the key press on 100th count. In case of wrong key press by mistake, maximum upto 10 corrections were allowed by taking count upto 110. Subsequently, the subject was given feedback about his / her mean repetitive response time. Then the procedure continued for remaining three stimuli in same manner. Finally, the respondent was thanked again for participating in the experiment.

7.3 Experiment 3 - Simple Reaction Time - Single response & Double response

Essential simulation followed similar screens. In this experiment the respondent were shown each digit and letter along with blank screen one after the other. Stimulus presentation was as given below :

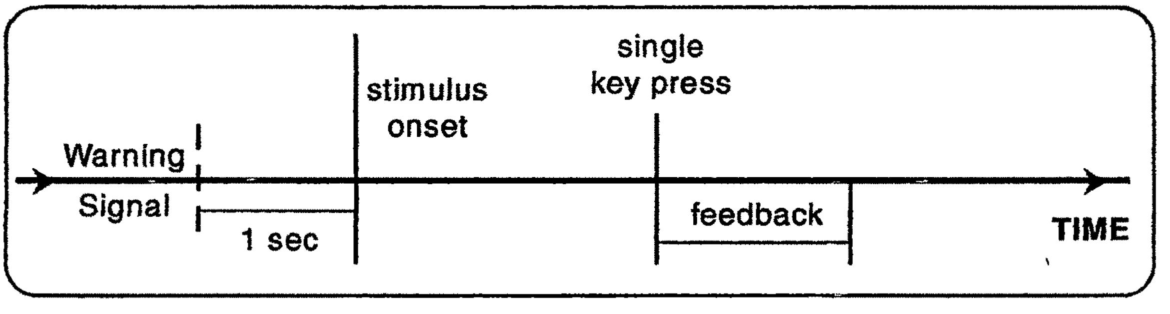
Stimulus	*No. of trials*	*Response*	*Effector*
4 + blank screen	(50+25)	4 on numeric pad	right hand index finger
5 + blank screen	(50+25)	5 on numeric pad	right hand middle finger
d + blank screen	(50+25)	d on alphabetic pad	left hand middle finger
f + blank screen	(50+25)	f on alphabetic pad	left hand index finger

The respondent was supposed to press appropriate key once with appropriate finger as quickly as possible. The program recorded response time, response accuracy and other details. This was considered as one block.

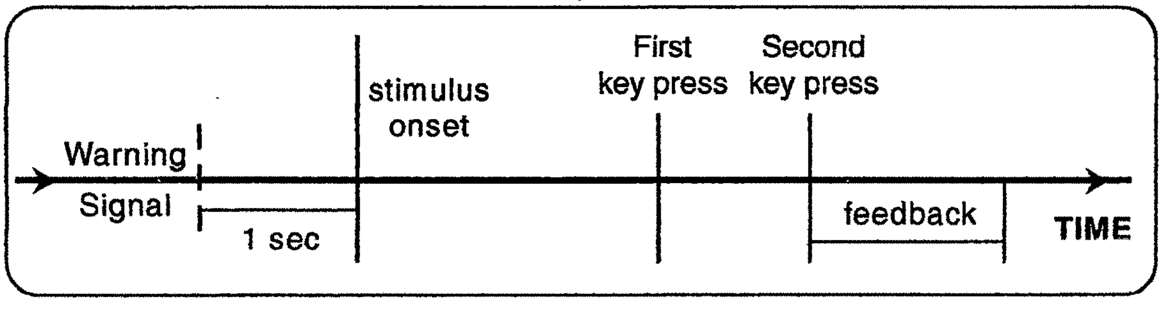
Subsequently another block with the same procedure was followed. Only difference was that the subject was to press the response key twice as quickly as possible.

Schematic representation of the experimental procedure is as given below.

Block 1



Block 2



7.4 Experiment 4 - Discrete Successive Choice Reaction Time

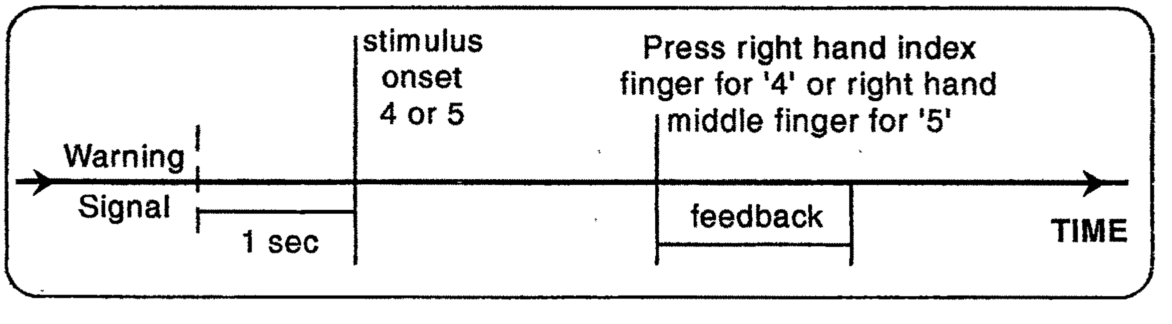
This experiment was conducted in three parts as given below -

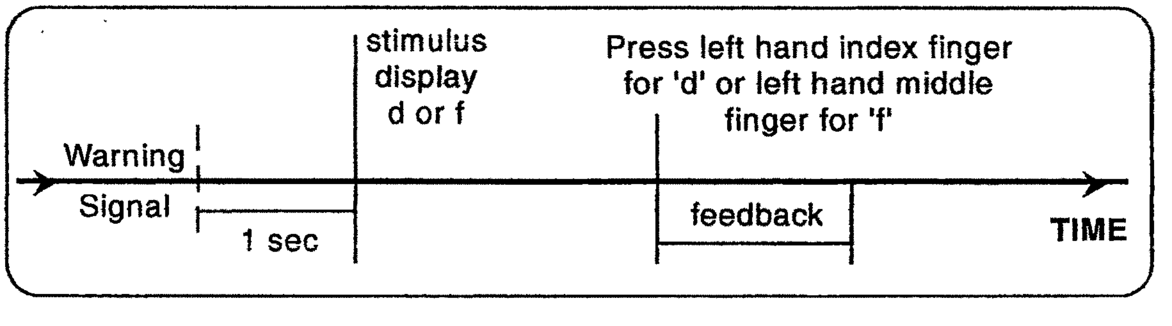
PART I : Discrete Successive Choice Reaction Time - Serial

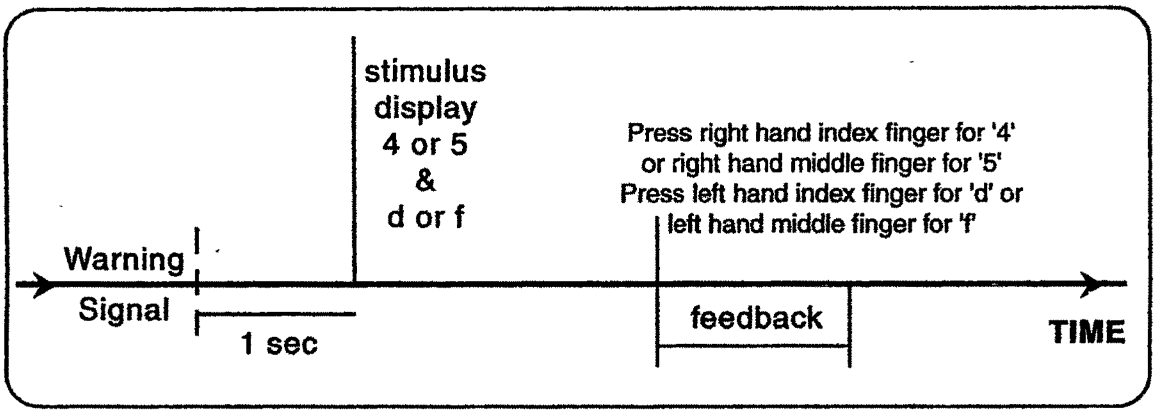
Essential simulation followed similar screens. In this experiment the respondent were shown either digit or letter in serial order. Stimulus presentation was randomized as given below :

Stimulus	*No. of trials*	*Response*	*Effector*
4 + 5	(50+50)	4 on numeric pad	right hand index finger
		5 on numeric pad	right hand middle finger
d + f	(50+50)	d on alphabetic pad	left hand middle finger
		f on alphabetic pad	left hand index finger
4 + 5 + d + f	(50+50+50+50)	4 on numeric pad	right hand index finger
		5 on numeric pad	right hand middle finger
		d on alphabetic pad	left hand middle finger
		f on alphabetic pad	left hand index finger

The. respondent was supposed to respond with appropriate hand and finger as quickly as possible. Schematic presentation of the procedure is as under -





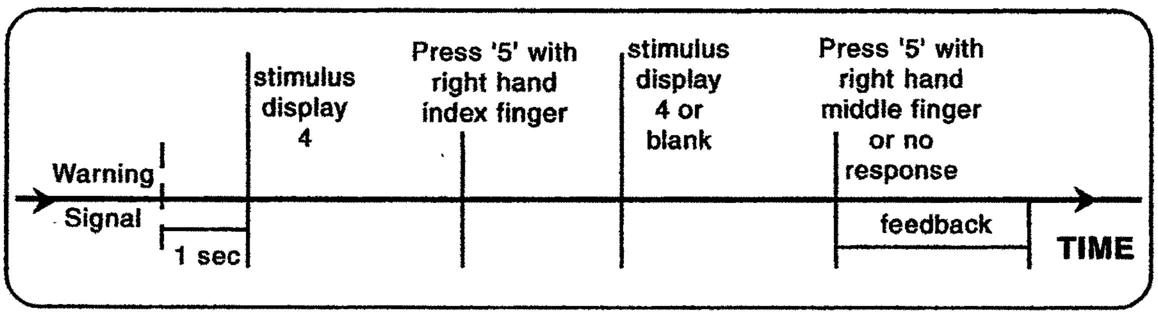


PART II : Discrete Successive Choice Reaction Time - Reverse

Essential simulation followed similar screens. In this experiment the respondent were shown either digit or letter in serial order. Stimulus presentation was randomized and as given below :

Stimulus	*Presentation*	*Response*	*Effector*
4 + 4 or blank	(50 + 25)	5 + 5 on numeric pad	right hand middle finger
5 + 5 or blank	(50 + 25)	4 + 4 on numerical pad	left hand index finger
d + d or blank	(50 + 25)	f + f on alphabetic pad	left hand index finger
f + f or blank	(50 + 25)	d + d on alphabetic pad	left hand middle finger

The respondent was supposed to respond with appropriate hand and finger as quickly as possible. Schematic presentation of the procedure is as under -



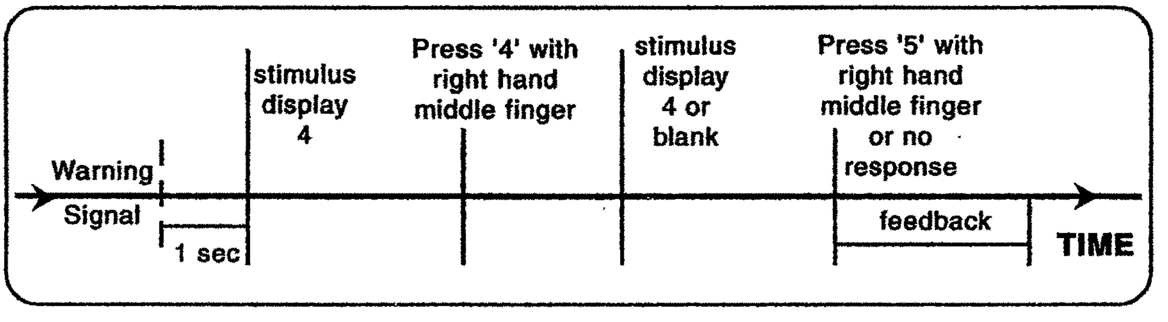
Same procedure was repeated for digit '5' and letters 'd' and 'f'. In this procedure principal difference was that the same stimulus was presented twice in succession and the subject had to respond to both with same response.

PART III : Discrete Successive Choice Reaction Time - Alternate

Essential simulation followed similar screens. In this experiment the respondents were shown either digit or letter in serial order. Stimulus presentation was randomized as given below :

Stimulus	***Presentation***	***Response***	***Effector***
4 + 4 or blank	**(50 + 25)**	**4 + 5 on numeric pad**	**right hand middle finger**
5 + 5 or blank	**(50 + 25)**	**5 + 4 on numerical pad**	**left hand index finger**
d + d or blank	**(50 + 25)**	**d + f on alphabetic pad**	**left hand index finger**
f + f or blank	**(50 + 25)**	**f + d on alphabetic pad**	**left hand middle finger**

The respondent was supposed to respond with appropriate hand and finger as quickly as possible. Schematic presentation of the procedure was as under -



Same procedure was repeated for digit '5 & 4' and letters 'd & f' and 'f & d'. In this procedure principal difference was that the alternate stimulus was presented and the subject had to respond first stimuli with the same response and second stimulus with reverse response.

7.5 Experiment 5 - Discrete Concurrent Two Choice Reaction Time

This experiment was conducted in two parts as given below -

PART I : Discrete Concurrent Choice Reaction Time - Dual Task

Essential simulation followed similar screens. In this experiment tasks were defined as -

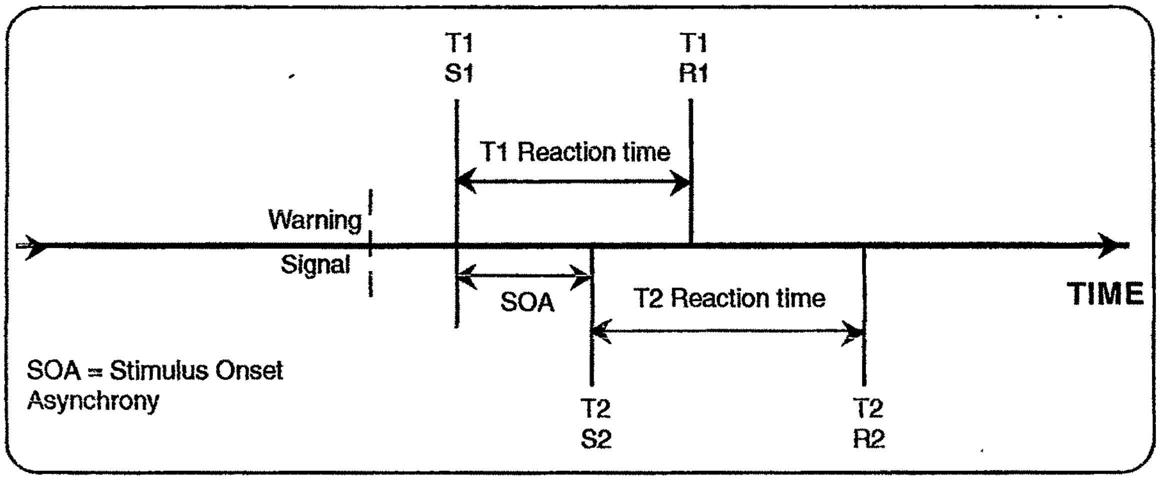
Task 1 - Stimulus 4 or 5 and response key 4 or 5 on numeric key pad

Task 2 - Stimulus d or f and response key d or f on alphanumeric key pad

The respondents were given tasks in the following order :

Task	*No. of trials*	*SOA*	*Task priority*	*Presentation*
T1 & T2	(50+50)	0/200/400/600/800 msec	T1 & T2	Serial
T1 & T2	(50+50)	0/200/400/600/800 msec	T2 & T1	Serial
T1 & T2	(50+50)	0/200/400/600/800 msec	Subject decision	Random

The respondent was supposed to respond with appropriate hand and finger as quickly as possible. Schematic presentation of the procedure was as under -



PART II : Discrete Concurrent Choice Reaction Time - Triple Task

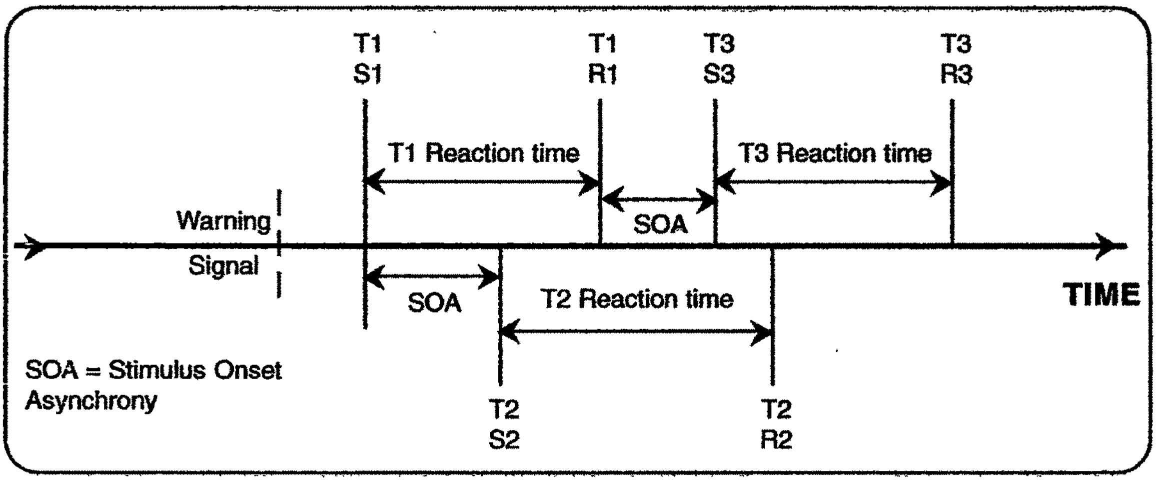
Essential simulation followed similar screens. In this experiment tasks were defined as -

Task 1	-	Stimulus 4 or 5 and response key 4 or 5 on numeric key pad
Task 2	-	Stimulus d or f and response key d or f on alphanumeric key pad
Task 3	-	Same as Task 1 (i.e. stimulus 4 or 5 and response key 4 or 5)

The respondents were given tasks in the following order :

Task	*No. of trials*	*SOA*	*Task priority*	*Presentation*
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T1, T2, T3	Serial
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T1, T3, T2	Serial
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T2, T1, T3	Serial
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T2, T3, T1	Serial
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T3, T1, T2	Serial
T1, T2, T3	(50+50+50)	0/200/400/600/800 msec	T3, T2, T1	Serial

The respondent was supposed to respond with appropriate hand and finger as quickly as possible. Schematic presentation of the procedure is as under -



Same procedure was repeated for different priorities responses (T1T2T3). In this procedure principal difference was of the presentation of T3 also. SOA for T3 was decided as per the mean reaction time of respondent in Part I of the experiment.

7.6 Experiment 6 - Matched Figure Test

In this experiment, simulation of Matched Figure Test was presented to the respondent. The respondent was supposed to match each stimulus figure with the response figure, given along with distracter figures. Response time and response accuracy was recorded by the program.

7.7 Experiment 7 - Embedded Figure Test

In this experiment, simulation of Embedded Figure Test was presented to the subject on computer. The subject was first shown a stimulus figure and then he/she was supposed to find out the same figure hidden into a response figures. The subject was supposed to press a key as soon as he could identify the stimulus figure. The time was recorded for the same. Subsequently the respondent was given grey coloured response figure, wherein he/she was supposed to highlight the hidden stimulus figure. No second thought was allowed while highlighting the figure. Subsequently the subject was shown next stimulus figure. The procedure continued until the end of the test.

8.0 TOOLS

8.1 A Desk Top Computer with

- Intel Pentium IV processor
- LG Studioworks 700E Color Monitor
- Standard Keyboard with 104 keys
- Logitech Optical Mouse

8.2 Computer software for simulation and data storage

- Programming language - Visual Basic 6.0
- Database - MS Access 2000

8.3 Computer software for data analysis

- SPSS 10.0

- MS Excel 2000

9.0 STATISTICAL ANALYSIS

Analysis of data was done using Univariate ANOVA, descriptive statistics and data was reported in form of frequency, percentage and charts.

10.0 MAJOR FINDINGS

Following are the major findings of this research.

1. Repetitive response time is found to be more for left hand in comparison to right hand response time.

2. Repetitive response time is found to be more for middle finger in comparison to index finger.

3. There is interaction effect of hand and finger in repetition response time.

4. Second response time of Experiment 3 has not been found to be same as the repetitive response time of the respective stimuli.

5. Significant differences has been found in correct responses for different stimulus display time for all stimuli.

6. Choice reaction times - serial is found to be higher than simple reaction time in case of letter stimuli in comparison to digit stimuli.

7. Choice reaction times - repeat stimuli shall be higher than the choice reaction times - serial.

8. Choice reaction times - alternate stimuli shall be higher than the choice reaction times - repeat.

9. PRP effect in T1 priority task has been found to be as per the standard PRP effect curve.

10. Partial PRP effect has been found in T2 priority task in comparison to standard PRP effect curve.

11. Partial PRP has been found in subject decision priority task (random) in comparison to standard PRP effect curve.

12. Partial PRP effect has been found in T1 also in triple task trial whenever priority is not T1.

13. PRP effect has been found in T2 and T3 in triple task trial and it was like standard

PRP effect curve.

14. Absolute and relative featural difficulty of stimuli have emerged as important factor contributing stimulus identification processes.

15. Stimulus display time has interacted with stimulus difficulty as an important contributing towards stimulus identification process.

16. Individual differences have emerged as important factor in stimulus identification and response processes.

17. Differences in PRP effect among Cautious and Daring individuals have been demonstrated.

18. No PRP effect difference has been found among Field Dependent and Field Independent individuals.

19. PRP effect has been observed among Reflective and Impulsive individuals in triple task situation.

20. Trial-to-trial variations in individual performance under different experimental conditions has been demonstrated.

11.0 LIMITATIONS

1. This study was conducted on Pentium processor using Visual Basic program. Measurement of time in such software may have error in range of $\pm$ 5 to $\pm$ 10 ms.

2. Individual data analysis using algebraic equations could not be done as parameter distribution was not available.

3. All subjects in the experiment were right-handed, which might have influenced the findings related to handwise variations.

11.0 SUGGESTIONS

1. Such hierarchical experiment using different stimuli and response pattern should be replicated.

2. As short SOA is very important in parameter estimation, more studies should be done with smaller steps of SOAs (e.g, 20, 40, 60, 80 ms).

3. Results of such studies should simulated in EPIC in order to explore variability in parameter estimation.