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Technion - Israel Institute of Technology
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ON THE TRAINING OF TIME SHARING SKILLS: AN ATTENTION VIEWPOINT

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ABSTRACT

Training of time-sharing skills is discussed within an attention framework in which poor time-sharing performance is interpreted to stem from scarcity or inefficient utilization of processing resources. Practice is argued to increase resource availability either by reducing the resource demands of each task, improving coordination, or enhancing the voluntary control on resource allocation. Based on this analysis notions of skill generalizations and implications for the development of training procedures are examined.

One of the most remarkable capabilities of human operators is their ability to learn with practice. The more difficult and complex a task is the greater is the difference between a novice student and a master performer. Performance under time-sharing conditions which is the subject of interest in this brief article most frequently resides on the complex end of the task domain. The large difference between the time-sharing abilities of beginners and trained performers have even led some investigators to argue that findings and theories in this problem area should be categorized into classes based upon these two types of performers, e.g., (Neisser, 1976; Shifrin & Schneider, 1977; Dreyfus, 1979).

Unlike other areas of human performance such as memory capabilities, verbal skills and motor behavior, the study of learning processes in the development of time-sharing skills has very rarely attracted attention as an independent prime topic of investigation. Several studies of this issue were conducted during the 1950's and early 1960's mainly as related to strict views of the human as a single channel processor, (e.g. Baharick, Noble & Fitts, 1954; Baharick & Shelly, 1958; Garvey, 1960). Other studies were indirectly concerned with the notion of time-sharing skills as related to the development of part-whole training techniques, (e.g. Adams, 1960; Fleishman, 1965). In recent years the revival of theoretical and applied interest in the study of workload has drawn attention to the lack of systematic approach and experimental data in this important problem area. Consequently, increased research effort and resource investments have been called to the study of procedures to improve time-sharing skills.

In the present paper we set out from an attention viewpoint in an attempt to outline a general approach to the study of time-sharing skills and examine the implication of such an approach to the development of proper training procedures. Within this framework poor time-sharing performance is interpreted to stem from scarcity of processing resources or inefficient use of existing resources. The major contention is that the development of training procedures to improve time-sharing skills is contigent upon our ability to identify the components of the learning process as related to the demand of concurrently performed tasks for processing resources. Three issues are addressed: a) Effects of practice on resource availability; b) Skill generalization; c) Implications for the development of training procedures.

EFFECTS OF PRACTICE ON RESOURCE AVAILABILITY

a) Reduced Demand for Resources

One view on the role of practice in improved time-sharing performance is that it serves to reduce the resource demands of each of the tasks involved. As the separate demands decrease so does joint demand. Small talk while driving is a common habit which can be easily managed by experienced drivers under a wide variety of driving conditions and topics of conversation. This is, however, an impossible mission for the novice driver. Assuming equal levels of conversation skills (and therefore equal demand for resources) joint performance of the experienced driver can be argued to be better simply because he is required to invest less resources in the task of driving (due to improved prediction capabilities, response

integration, etc., etc.,). To further support this point, imagine now what would happen to this smooth concurrent performance when a sudden traffic problem occurs, or the natural conversation develops into a hot debate on a matter of high personal concern.

The superior level of joint performance of the experienced driver in this example is assumed to result solely from the fact that regular driving demands only small amounts of his resources, so that enough resources are still available for the conductance of conversations. No assumptions are made on interaction between the tasks of driving and talking. In reality, many kinds of interactions may exist. For example, the driver cannot (or better not) use visual cues from the eyes, face and lips of his discussant and is therefore forced to be more attentive to his articulation and intonations. The noise of the engine may force him to raise his own voice, emphasize his articulation and rely more than usual on inner cues to verify his own voice productions. The fact that the conversation appears to flow smoothly in a regular manner provides an indication that good coordination between the tasks has been achieved. Improved coordination with practice is another factor that can affect resource availability, and this is our next topic of discussion.

b) Coordination of Tasks

Coordination in the present context is a general term employed to refer to all processes orginated to resolve or temper conflicts between inputs, outputs or throughputs of tasks under time-sharing conditions. One view on the relationship between coordination and resource availability is that the process of organizing, coordinating, scheduling and allocating resources may require resources by itself (see e.g. Moray, 1967; Logan, 1979). Thus, coordination of time-sharing performance constitutes a task by itself and demands resources. With practice, when consistant strategies of task interweaving are established, coordination requires less resources so that more resources are released to the direct performance of tasks.

Another view on the relationship between coordination and resource demands argues that coordination by itself does not require resources, but conflicts and poor coordination between tasks result in waste and inefficient utilization of processing resources. According to this view the essence of coordination is the development of performance stragegies that maximize the returns of resource investments (e.g. Gopher & North, 1977; Navon & Gopher, 1979).

A third notion of task coordination can be offered if a multiple resource view of the human processing system is adapted. In a recent paper (Navon & Gopher, 1979), we propose such a framework to describe the limitations of performance under time-sharing conditions. A multiple resource approach seems to have several advantages over traditional single capacity views. According to this approach the human processing system possess several mechanizms each having its own capacity. Those capacities can at any moment be allocated among several processes, and tasks can overlap to various degrees in their demands for common resources.

In the present context, coordination can be construed as a strive to minimize the overlap in the resource demands of concurrently performed tasks. In other words, it is assumed that alternative strategies can be developed for the performance of the same task in order to minimize the competition for processing resources between this task and another jointly performed task. The changes in the conversation style while driving that were described earlier in this paper provide an example of possible strategic shifts in the relative emphasis on sources of information and modes of vocal behavior developed to protect the concurrent conductance of conversations and driving.

Several authors, (e.g. Neisser, 1976) have argued that with sufficient practice coordination may reach the stage of integration that is, concurrently performed tasks may be integrated to form a new whole, new entity which reduces the total demand for processing resources. At this level the situation ceases to be a time-sharing condition because the separate tasks have lost their independence. This possibility presents an interesting problem to theorists of time-sharing performance, namely: what are the combinations or type of tasks that are more amenable to such interaction and what are the tasks that will remain independent even after prolonged practice. A detailed discussion of this point is beyond the scope of this paper, some candidates for comparison may be: integral and separable dimensions of perception, discrete vs continuous tasks, externally paced and self paced tasks, rhythm compatability, etc., etc.

c) Voluntary Control on Resource Allocation

What is the extent of the operator's ability to voluntarily control the allocation of his processing resources?
How sensitive are operators to the efficiency of their resource investments?
Can operators be trained to improve the management of their resources and be sensitized to the consequences of voluntary allocation?

Extensive experimental evidence has been accumulated to show that selective attendance is an active process which is influenced by motivation, biases and utility considerations. The operator is not passively submitted to task demands but actively engages in selection and determination of preferred courses of action. However, little is known on the extent to which conscious allocation policy can be recruited to maximize the efficiency of resource utilization in concurrent task performance. For example, can operators be meaningfully instructed to devote 95 percent of their resources to one task and only 5 percent to another; can they change proportions to 80/20, 70/30 or reverse them upon request. If performance criteria is set to maximize the marginal efficiency of every unit of invested processing resources, can operators wisely manage their resource allocation among tasks? The importance of providing adequate answers to these questions in the context of training and development of time sharing skills is obvious.

Several studies conducted in recent years by this author in collaboration with other investigators provided encouraging demonstrations of the ability of human operators to control their resources, (North & Gopher, 1976; Gopher & North, 1977; Wickens & Gopher, 1977, Gopher & Navon, in press). A doctoral dissertation recently completed in our laboratory by Michael Brickner (in preparation) directly tested the influence of instructed variations in resource allocation on the training of time-sharing skills. The results of this work yielded strong support to the potential power of improved voluntary control in the development of time-sharing skills.

Brickner compared concurrent performance of pursuit tracking with a letter typing task. In three different groups of subjects the priority of tasks remained equal and constant throughout training, or varied dynamically requiring subjects to change the allocation of their resources between the two tasks. Subjects trained under variable priority conditions achieved better levels of joint performance at the end of the training period. In addition, this group was superior in its ability to protect performance when transferred to a new condition in which unexpected variations in task difficulty were introduced on the two tasks and subjects were instructed to maintain fixed levels of performance. These instructions could only be observed if resources were properly shifted from the performance of one task to the other, to compensate for the changes in difficulty. A similar pattern of results was obtained in a second experiment in which a self paced letter typing task was paired with either a self paced or an externally paced binary classification of digits. These results suggest that human operators can control the allocation of their resources but may have only limited experience or knowledge on the efficiency of their allocation. Spontaneous allocation if not properly instructed may be suboptimal. Brickner's results emphasize the importance of pursuing the research on the voluntary control of resources and its role in improved time sharing capabilities.

SKILL GENERALIZATION

The analysis of the different way in which practice may affect resource availability in time-sharing performance enable us to address more meaningfully the question of skill generalization. To what extent can skills acquired in one time-sharing situation be generalized to other situations? The question of skill generalization can be considered on several levels. In the most general sense, skills that were developed in one situation should generalize to all other time-sharing conditions. Within a multiple resource framework a more limited view of generalization can be conceived, skill is expected to generalize to all other situations in which the same resources are involved. Generalization may also be linked with the performance of a specific task and skill may transfer to all other time-sharing situations in which this task is employed. All of these alternatives assume at least some degree of skill generalization. Finally, we cannot ignore the possibility that although considerable skill is developed in each specific situation it is unique to that situation and can not be transferred to any other situation.

Of the three types of practice effects that were discussed (i.e. reduced costs of each task; improved coordination and enhanced voluntary control), reduced resource demands of each of the concurrently performed tasks can certainly link with the task specific type of skill generalization and be assumed to transfer to all other situations in which this task is performed. The reduced demands of driving to the experienced driver is equally relevant to concurrent conversation or writing in his personal notebook. It should be noted however, that this is not a real time-sharing skill and does not necessarily require training under time-sharing conditions.

Strategies relevant to the coordination of concurrently performed tasks can vary widely depending on the type of inputs involved, spatial and temporal constraints, the nature of responses and the type of processing tasks. Considering the richness of all possible combinations, generalization at this level can hardly be assumed. Small changes in the conditions of performance may require substantial revision of coordination strategies. Some sense of generality of coordination skills

can be restored if we assume that major types of strategies can be identified and that the total number of such strategies is very limited. Systematic exploration of this possibility still awaits the devotion of risk-taking, industrious researchers.

Improved voluntary control of resources is one faculty of time-sharing skills that has the potential of broader generality. If better control of resources can be taught and the human operator can be trained to become more sensitive to the efficiency of his resource allocation, a knowledge base which has relevance to a wide variety of situations may be acquired. Note however that because resource investments are always evaluated in terms of performance achievement and because resources are differently scaled in the performance of different tasks, direct transition of skills from one task to the other may not be readily observed. Nevertheless experienced operators may be more aware and possess better tools to examine the efficiency of their resource investments and consequently may progress more rapidly during training from the state of novice to the state of expert. Within a framework of multiple resources each of the above general statements should be bounded to the training of a specific resource.

To summarize this discussion of skill generalization we can conclude that there is little reason to believe in the existence of highly general across the board time-sharing capability, although there are several senses in which some degree of generalization can be postulated.

IMPLICATIONS FOR THE DEVELOPMENT OF TRAINING PROCEDURES

Several implications for the development of training procedures to improve time-sharing skills appear to emerge from the analysis presented in this paper, although this analysis is very preliminary and incomplete. One implication is that the development of such skills can benefit very little from an extensive introductory phase of single task training or the interlacement of single task conditions in the course of time-sharing training. Despite the fact that reduced resource demands of each task was presented as one outcome of practice the core of time-sharing skills appears to reside in improved coordination and better control of resource allocation. Furthermore, if different strategies are employed when a task is performed singly or in concurrence with other tasks, extensive single task training may be harmful and introduce rigidity in the transition from single task to time-sharing performance.

The diversity and numerosity of variables that may affect coordination between tasks do not enable specification of recommended procedures to facilitate the development of this skill. Training specialists can try to isolate the major parameters and bottlenecks relevant to this process in every training situation and devote their training efforts to these variables. It may even be useful to try and develop specific feedback techniques to emphasize progress on specific aspects of coordination (for example progress from sequential response alternations between tasks to modes of parallel responses). Additional research on this important process may enable us in the future to develop an arsenal of procedures relevant to major types of coordination problems.

Last but not least is the requirement to develop proper procedures and feedback techniques that would teach operators to allocate their resources in different proportions, and enable them to examine the consequences of allocation in terms of the overall efficiency of joint performance. Joint manipulations of task difficulty and task priorities with augemented feedback indicators as attempted by Gopher & Navon (in press) and Brickner (in preparation) appear to represent steps in the right direction.

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