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COGNITIVE STRATEGIES AND SKILL ACQUISITION(U) FLORIDA
STATE UNIV TALLAHASSEE MOTOR BEHAVIOR RESOURCE CENTER
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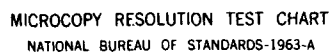
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The invention of this research effort was to determine the cognitive processes involved in the learning of complex motor tasks and strategies that might aid in learning retention and transfer. Eight technical reports were generated to answer different but related questions. —▷ to p. A

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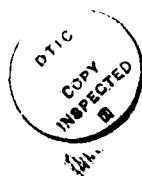
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Many technical problems occurred throughout the duration of the study but were resolved. The first three technical reports were conceptual in nature. A global model of motor behavior was developed, with emphasis on cognitive (control) processes that might be operative in learning and performance. Next, cognitive processes and learner strategies associated with motor learning and performance were identified in relation to processing mechanisms. Then, highly skilled and lesser skilled performers were analyzed as to the way they use strategies.

In the next four technical reports, experiments were summarized in which various strategies were compared as to their effectiveness in helping learners to learn, retain, and transfer. Two different serial positioning tasks, a visual tracking task, and a manipulative procedural were used. Strategies related to imagery, labeling, coding, kinesthesia, rhythm, anticipation, etc., were studied alone and in combination. Different strategies were found to be effective, depending on the task and the purpose (acquisition, retention, or transfer.)

Finally juggling was studied, and modules containing strategies for self-instruction were developed. No significant hardware developments occurred, but it was determined that computer managed tasks offer viable ways of studying learning processes and learner strategies. The interface of computer to task of interest led to increased experimental controls.



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**The Influence of Learner Strategies
on Achievement in Motor Skills**

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INTRODUCTION

The focus of our efforts has been on cognitive processes and learner strategies, and their involvement in the learning and performance of motor skills. A perusal of the recent psychological literature reveals an abundance of studies in which learner strategies are examined in the acquisition of verbal materials. Conceptual and practical concerns are addressed. A plea has been made elsewhere (Singer, 1978) for a similar approach with motor skills.

For instance, from a practical perspective, most training programs emphasize what to do, in terms of content and skills to be mastered. But imposed training often fails to teach learners to think, to evaluate, to develop alternative responses, and to problem solve. Since a limited amount of content can be directed toward specifics within the time appropriated to a typical training program, the question is: What kinds of learner processes can and should be activated, what can the learner learn how to do, in order to generalize to and accommodate future demands?

This question and many others suggest that more needs to be known about the role of cognitive processes in motor performance, and how learners can maximize the involvement or detachment of cognitions during learning/performance. Better strategies should enhance the selection and processing of information, as well as decision making, in acquisition, retention, and transfer situations. The plan in this report is to summarize eight technical reports completed under the contract with ARPA as to (a) the nature of cognitive processes, control, and learner strategies; (b) *related research findings* with regard to the use of strategies in acquisition, retention and transfer situations, (c) the general design of our studies, and (d) the findings.

COGNITIVE PROCESSES AND MOTOR BEHAVIOR

Some form of control can be potentially exerted by the learner/performer from the time information enters the system until it is transformed and responded to in the form of movement activity. A great deal of information processing occurs, possibly under severe time constraints, when people attempt to learn/perform complex motor activities. The desirability of exerting deliberate conscious control will depend on many factors. One of the primary differences between the highly skilled and the lesser skilled is the degree and type of conscious involvement prior to, during, and following motor performance (Singer, Gerson, & Kim, 1979). Therefore, conscious planning, focus, and/or intervention at a particular stage must be determined according to task demands and the capabilities of the person.

The term cognitive processes, or cognitions, has been defined in many ways. Interpretations have varied (e.g., Battig, 1975; Hunt & Lansman, 1975; Norman & Rumelhart, 1975), as have the contexts in which the term has been applied. For purposes here, a cognitive process is defined as a control process, that is self-generated, transient, situationally determined conscious activity a learner uses to organize and to regulate received and transmitted information, and ultimately, behavior.

However, the person does not totally influence any situation, nor does the reverse probably happen. Whereas behaviorists might lead us to view human behavior as passively controlled by situational dictates, cognitive psychologists would suggest that people actively control their environments. The truth probably lies somewhere in a middle position. Behaviors are not produced without cues or stimuli, and these behaviors are directed accordingly. But all people do not respond similarly to the same events, thereby demonstrating some degree of self-determination. In a sense, then, associationistic behaviors are indeed developed, but in a person's own way.

Mechanisms can be identified that appear to be activated sequentially in stages or in parallel as information is processed leading to complex motoric behavior. A mechanism is defined here as a real or hypothesized "location" or "structure" associated with the nervous system in which specified unique control processes and functions occur. The deliberate use of certain conscious control processes, or the capability of activating certain desirable subconscious control processes, will improve the functional capabilities of one or several of the hypothesized mechanisms in the human behaving system (cf. Belmont & Butterfield, 1977; Butterfield & Dickerson, 1976), such as increasing the capacity of the short-term store by imposing an organizational structure to information being processed in that mechanism (Rigney, 1978). A definite relationship is hypothesized to exist between a particular mechanism and associated cognitive

processes (see Table 1). Although a one-to-one relationship between a mechanism and a cognitive process may exist, it should be realized that several cognitive processes may also be associated with a given mechanism.

The effective operation of a particular control process for a given task reduces the amount of information that must be transmitted through the mechanism associated with it (cf. Butterfield & Dickerson, 1976). Accuracy would be truer and processing quicker than otherwise. Due to the existence of this relationship between cognitions and stages of processing (Trabasso, 1973), the learner is probably capable of developing a hierarchy of processing skills corresponding to each mechanism (Schaeffer, 1975). The hierarchy is based on the complexity of the cognition or processing operations the learner must employ to transform and to transmit information through the system. Thus, as information passes through each stage, the corresponding control processes must be adapted by the learner to meet the changing task requirements, so that information may continue to be transmitted through the system.

To integrate some ideas expressed so far, the learner/performer may invoke cognitive processes to perceive the nature of the task in the context of the environment, to recognize similarities between the present task and previous experiences, and to selectively attend to and to identify the most relevant, yet minimal number of cues necessary for a response to occur. In addition, a person may utilize cognitive processes to enhance goal-expectancy formations, to enhance goal-image formation, or to finalize movement decisions made in the short-term store. Cognitions may be used to permanently store evaluative feedback and causal reasons for a performance outcome for future use, information that will influence future behavior in the same situation. Cognitive processes should be facilitated by the learner's activation and implementation of the appropriate strategies (cf. Kausler, 1974).

LEARNER STRATEGIES AND SKILL ACQUISITION, RETENTION, AND TRANSFER

An effective strategy has been described as the simplest and most efficient means of processing the information inherent in a situation (Newell & Simon, 1972). Rigney (1978) has stated that a strategy may be interpreted as signifying operations and procedures that a learner may use to acquire, to retain, and to retrieve different kinds of knowledge. To Gagné (1974), a strategy is a skill of self-management that the learner acquires to govern the processes of attending, learning, and thinking, while Gagné and Briggs (1974) have suggested that a cognitive strategy is an internally organized skill which governs the learner's own behavior.

A strategy is interpreted here as a self-initiated or externally imposed way of directing information leading to decisions for purposeful behavior. A learner imposes some type of structure on movement information so that it is learned and retrieved more efficiently. Performance is either dependent upon the experimental structuring of the task in which the totality of the relations among the movement cues is emphasized (Gentile & Nacson, 1976), or the subjective organization of the information, in which a structural context corresponding to

TABLE 1

THE CONCEPTUAL RELATIONSHIP OF MECHANISMS, POTENTIAL
COGNITIVE PROCESSES, AND FUNCTIONS IN COMPLEX MOTOR BEHAVIORS

Mechanisms	Cognitive Processes	Functions and Purposes
1. sensory storage*	receive.....	briefly hold information
	transmit.....	forward it to LTS for memory contact or directly to perceptual mechanism

*Cognitive processes do not directly influence sensory storage
but can affect orientation to stimuli.

2. perceptual mechanism	detect.....	realize existence of signal
	alert.....	anticipate
	selectively attend.....	filter
	recognize.....	analyze features
	match (present cues with stored information)
	make meaning of information
	transmit.....	forward information to STS for action
3. short term storage (STS)	rehearse and process information temporarily.....	retain information for immediate use and decision making
	compare.....	retrieve information from LTS for analysis, decision making, and attributions following feedback
	transform.....	organize (chunk)
	make more functional space available
	provide additional meaning
	appraise situation.....	form performance and goal expectancies
	establish emotional state
	select programs from LTS...	transmit programs to movement generator
	plan program execution.....	determine parameters (location, speed, direction, timing, amplitude, force, effort) in which program is to operate
	transmit information.....	transfer information to long term storage to establish learning

4. long term storage
(LTS)

store information
permanently.....

make information avail-
able for future use,
establish pertinence,
aid in anticipation,
expectancies, and
perception

5. movement generator

initiate program for
motor behavior.....

cue appropriate
musculature to execute
within response
parameters

initiate corollary
discharge.....

alert sensory center of
the brain, anticipate
movement

6. effectors

receive command.....

execute observable
performance

activate feedback
sources

provide information
for future usage
(comparison, recognition)
by making it available
for long term storage

..... provide information to
peripheral organs to help
regulate ongoing
behavior, to adapt
behavior to situational
demands

..... provide information to
influence arousal and
attitudinal states

the learner's cognitive capabilities is imposed on the movement cues. Thus, the development of organizational strategies occurs in one of two ways.

An instructional strategy which is imposed by the instructor on the learner may be designed to help the learner to acquire a skill as quickly as possible, or to facilitate transfer effectiveness or problem solving in the future. While some imposed strategies may increase the rate of initial skill acquisition (Singer & Pease, 1976, 1978), they may not facilitate learning in transfer situations in which no instructor is present (Singer & Gaines, 1975). In the latter case, this can only be achieved when a learner becomes capable of self-generating strategies, whether they have been initially externally-directed or self-generated.

A self-initiated strategy is one in which the learner is capable of determining a procedure which is compatible with personal cognitive capabilities and cognitive style for the learning of a task or a category of related tasks. Strategy choice is partially determined by the particular situation (Bruner, Goodnow, & Austin, 1956), so a sound procedure would appear to be to initially instruct learners in the use of learning strategies if they are ignorant about them. Once a learner comprehends the nature of and the reasons for the use of particular strategies for the acquisition of skill, he or she should be capable of self-generating strategies in related future learning environments.

The learning experience is governed by the use of strategies, which in turn activate conscious and, perhaps subsequently, subconscious processes. The hypothesized relationships would be that situations activate particular strategies that influenced cognitive processes associated with particular mechanisms:

1. A situation activates potential alternative strategies.
2. A particular appropriate strategy influences a corresponding cognitive process.
3. A particular cognitive process is associated with a corresponding mechanism or stage in performance.
4. Situation —→ Strategy —→ Process —→ Mechanism

The learning of a motor skill, or a verbal skill, reflects a problem which must be solved. The behaviors involved in acquiring both types of skills are very similar (Adams, 1971) in that the learner must identify and interpret the problem, utilize strategies to facilitate the processing of information so a plan may be devised which will lead to possible solutions, produce those solutions, and then decide which is the best solution (Posner, 1973).

Some generalizations may be made about strategies. For instance, strategies characteristically: (1) involve systematic analysis and processing; (2) require repeated attempts at a solution; and (3) involve the development of rules, to be applied to the same or similar situations.

Experts use effective strategies; novices use inefficient strategies. However, even experts may not use the same strategies to the same degree. Likewise, it is possible that different strategies are used by experts and novices. Or, they use the same ones, only the experts apply them more effectively. In this light, it is well-documented that individuals have preferential modes of interpreting and responding, and this premise has led to a body of literature entitled ATI (Aptitude and Treatment Interaction). One type of aptitude is cognitive style or approach to learning, and a particular style may suggest the desirability of the use of one strategy over alternatives.

So far, the nature of cognitive processes and learner strategies has been discussed somewhat descriptively. With regard to experimental findings, pertinent learner strategies have been shown to facilitate the acquisition and retention of verbal skills (e.g., Campione & Brown, 1974) and motor skills (Hagenbeck, 1978; Ho & Shea, 1978; Shea, 1977). The acquisition, storage, and retrieval of verbal information has been facilitated by appropriate learner strategies in many investigations.

For example, mnemonic techniques, encoding instructions, or instructions in the use of particular strategies (Belmont & Butterfield, 1971; Craik & Lockhart, 1972; Weinstein, 1978) have had positive effects on performance. Most researchers in this area indicate the importance of involving the learner in the development of organizational strategies. Such strategies are helpful to the learner in storing information and retrieving it when desirable. The more frequently investigated techniques, and those that have appeared to demonstrate consistent and significant improvement in the learning process, include rehearsal, chunking, imagery, mnemonics, and elaboration.

Many cognitive strategies have been analyzed by researchers and used successfully by subjects in verbal learning situations. Strategies in the learning of verbal material have been typically characterized as: (1) possessing a heavy cognitive component; (2) serving the ultimate purpose of reducing learner dependence on external cues and maximizing self-directedness in using strategies; (3) a means of controlling the processing of information; (4) an operation that alters data that enters the system, thereby enhancing the meaningfulness of stimuli; and (5) learning techniques that may be generalized in different learning situations and with various types of subject matter. The subsequent effect of strategy usage is to improve the processes involved in learning to learn, retention, and the retrieval of information. Perhaps most important is that these processes appear to be of equal importance for psychomotor behaviors.

In conjunction with motor skill acquisition, imposed strategies have required subjects to: (1) "think about" or "imagine" motor responses or movement patterns; (2) attach verbal labels to each of a series of movements; (3) selectively attend to relevant components of a task; (4) verbally rhythmize a sequence within a movement pattern; (5) organize information so that new learnings can be tied to old learnings, thereby enhancing meaningfulness to novel stimuli; (6) demonstrate comprehension of a skill through the verbal communication of newly acquired knowledge and skills; and (7) use rules which, when acknowledged, allow greater recall of information and/or skills.

While the short-term effects of strategy usage has been reasonably well documented (at least in the verbal area), knowledge of long-range effects is minimal. In fact, there is little supportive evidence that strategies used in one situation are applicable and facilitatory in a future situation (Brown, 1978). However, strategies that enhance skill acquisition and short-term retention also have the potential to transfer to the learning of a skill in a new situation with similar parameters.

Strategy transfer usually cannot occur unless the learning environment includes some reference to the transfer situation (Bransford, Franks, Morris, & Stein, 1978; Campione & Brown, 1974; Morris, Bransford, & Franks, 1977); e.g., the temporal structuring of the components within each task are similar (Keele & Summers, 1976). Another factor that has an influence on strategy generalizability is the compatibility of a particular strategy with a learner's cognitive processing capabilities. If a strategy is effective but incompatible, the learner would tend to reject it in lieu of some other, less efficient strategy. This less efficient strategy may facilitate initial acquisition, but it would probably have a detrimental effect in a transfer situation. The decrement in transfer learning would be the result of the limited applicability of the self-imposed strategy.

To train a person to be aware of the potential to activate strategies for skill acquisition is not sufficient. Externally imposed strategies may produce the same positive effect on immediate learning as will internally generated strategies. The training of this potential must also be geared to the utility of those abilities in future retention and transfer situations (Duncan, 1953). In this way, a person can enter new learning environments, acquire the necessary skills prescribed in that environment, and do so with a minimal amount of external guidance.

For effective transfer to occur, both the instructor and the learner must understand the original training task and the transfer task (Belmont & Butterfield, 1977; Morris et al., 1977). The components of both tasks must be similar enough so the learner is able to determine the relationship between the two tasks. Performance decrements on the transfer task are often due to the trainee's inability to comprehend these relationships, but inferior performance may be due to the differences between the demands of the two tasks which neither the instructor nor the learner realized (Brown, 1978). When transfer is not demonstrated because of differential task requirements, it is not due to a deficiency in the learner's cognitive capabilities. The lack of transfer is a result of the change in the processing activities required by the two tasks (Morris et al., 1977).

A POSSIBLE RESEARCH ORIENTATION AND METHODOLOGY

The analysis of the effectiveness of various learner strategies in influencing processes associated with the acquisition, retention, and/or transfer of motor skills can be handled in many experimental paradigms. A number of topics need to be addressed. The following list is suggestive but not conclusive:

1. effectiveness of instructor-imposed versus self-generated strategies;
2. effectiveness of different types of strategies for different types of tasks;
3. influence of strategies on acquisition versus retention versus transfer;
4. individual differences (e.g., cognitive styles) and relationship to strategy effect on learning;
5. high versus low-skilled performers and differences in the usage of strategies;
6. the training of low-skilled performers with strategies typically adopted by the highly-skilled;
7. the development of strategy learning modules (self learning) for different categories of tasks;
8. effects of informed choice of multiple strategies on learning.

During the past year, we have been interested in the relative effectiveness of different strategies with three types of tasks. They are computer-managed and are referred to as the Serial Positioning Apparatus (SPA), the Serial Manipulation Apparatus (SMA), a procedural task, and the Visual Tracking Apparatus (VTA). Each makes different demands on subjects and may be considered as representative of three categories of tasks.

Five groups have been used in each experiment: three different strategy groups, an informed choice group, and a control group. Strategies are decided ~~and dependent~~ upon their apparent association with successful performance in the task. The typical design is presented in Figure 1.

In one of the first studies (Singer, Gerson, & Ridsdale, 1979), a curvilinear repositioning apparatus--not computer-managed--was used. Subjects were required to replicate 6 limb movements to predetermined criterion locations. Imagery, kinesthetic emphasis, and labeling were the three strategies selected. Analysis for AE, CE, VE, and percent of correct responses revealed "imagers" to be more accurate and less variable in their responses than the subjects in the four other groups. However, the control subjects performed better than the other three groups, possibly suggesting the importance of implementing strategies that are compatible with individual cognitive styles, or the irrelevance of labeling and kinesthetic emphasis to achievement in this task.

In another study with the same task (Hagenbeck, Singer, & Gerson, 1979), imagery again was found to be the most effective strategy technique. The serial position curve was obtained, with a strong primacy effect and a slight recency effect for the imagery, relevant labeling, and kinesthetic groups.

Questionnaire

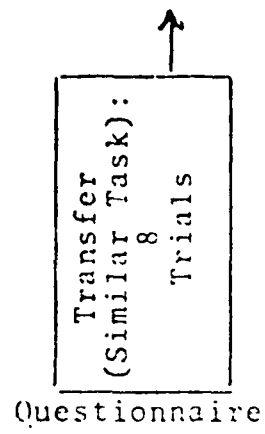


Figure 1. Schematic design of strategy experiments.

Nevertheless, the first two strategies elevated the response scores in the middle positions of the curve significantly more than was the case with the other groups. The indication is that not only will different strategy conditions possibly lead to different levels of skill acquisition, retention, and transfer, but also differential effects on the serial position curve.

The computer-managed tasks have not provided us with clear-cut trends as yet. We have learned that much more time needs to be spent on general instructions orienting the learner to the task as well as to the particular strategy condition. These tasks are quite complex. Information overload or underload must be considered, and we are refining our procedures. With the SMA (described in its earlier form elsewhere by Singer, 1976), imagers performed better than chunking, verbalization, and informed-choice groups on both acquisition and transfer tasks (Singer, Ridsdale, & Korienek, 1979a). No strategy (imagery, rhythmic, or anticipatory) was more effective than the other with the VTA. However, the rhythmic strategy group was superior to the control group in performance (Singer, Ridsdale, & Korienek, 1979b).

With the SPA (Singer, Ridsdale, & Korienek, 1979c), and 10 positions, the typical primacy-recency effect generally exhibited during serial recall was not demonstrated. If anything, performance seemed to become increasingly worse with each position across trials. No performance differences were noted among the groups, the strategies being rhythmic, imagery, and chunking. In spite of such disappointing data, we are quite optimistic that we can redesign our tasks and instructions and produce more interesting data.

Each experiment is not designed to improve the performance in a specific motor skill. Rather, the search is for methods that will enable learners to self-generate problem-solving strategies and techniques in order that success may be realized more readily in categories of skills. The development of analytical and adaptation processes within a learner should lead to the creation of self-instructional environments. If the person possesses the strategies and skills to produce a solution to a problem, then the amount of external guidance necessary for learning is reduced. Additionally, the acquired skill is probably retained to a greater degree since the learner is more involved in the learning experience.

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