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Information Processing Capabilities in Performers Differing in Levels of Motor Skill

by

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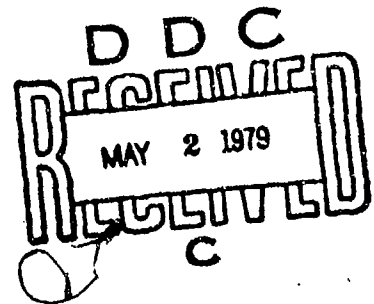


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the motor learning literature were used to make inferences about differences between higher- and lesser-skilled individuals. The dissimilarities noted in strategy usage and processing capabilities serve as a base for techniques that might be used in instructional programs to benefit beginners and those having difficulty in attaining task mastery. Further work is needed in task classification schemes and individual difference analysis to determine more specific guidelines.

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Information Processing Capabilities in Performers
Differing in Levels of Motor Skill

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INTRODUCTION

In the human behaving systems model developed by Singer, Gerson, and Ridsdale (Note 1), skilled performance in complex motor behavior is viewed in part as a reflection of the efficient operation of cognitive processes associated with input, central, and output mechanisms. That is, the various control processes help to determine the ultimate quality of overt motor behavior as a result of the way information is received, managed, and directed from internal and external sources. Thus, individual variations in the operation of sensory, perceptual, memorial, and motor mechanisms contribute to the ultimate skill level which is evidenced by different persons. More specifically, the manner in which a learner utilizes various cognitive processes, in relation to personal capabilities, is one of the major determinants of individual differences in the acquisition of skill (Singer & Gerson, in press).

For example, the stages in the processing of information do not operate as effectively in beginning learners. Thus, the perceptual mechanism, responsible for the filtering of appropriate cues into the system while simultaneously blocking the irrelevant information is not

very efficient. In contrast, the advanced learner is able to abstract the commonality among inputs and employ an effective encoding strategy for recognition of the information (Singer & Gerson, in press). In addition, the beginner may be unaware as to how to use the appropriate control processes for the transmission of information through the various mechanisms of the behaving system, while the advanced performer knows when and where to activate certain cognitive processes, and when to have them operate at a subconscious or what appears to be an automatic level. The skill level which is demonstrated by beginners and highly proficient performers is accountable in part by their differences in using control processes appropriately to process information.

The model of motor behavior explained elsewhere (Singer, Gerson, & Ridsdale, Note 1) and presented in Figure 1 reflects our current thinking about the reception, transmission, and outflow of information. Tables 1 and 2, also prepared in another publication (Singer & Gerson, Note 2) summarize the kinds of cognitive processes and functions that may be associated with motor behavior. Since it is apparent that distinctions in skill level can be associated with the way such processes function during learning and performance, it would be instructive to attempt to determine how they differ. More particularly,

those specific strategies that highly-skilled individuals use when they undertake psychomotor activities need to be identified. In turn, this knowledge would be useful in the design of instructional programs for beginning learners.

Using the mechanisms proposed in Figure 1 and the information provided in Tables 1 and 2 as a departure point, we will summarize the available experimental and conceptual literature as to the major ways in which learner-performers can be distinguished. With Figure 1 as a guideline, we will discuss processing differences between skilled and non-skilled performers as related to these real or hypothesized mechanisms. Direct research and indirect evidence will serve as the basis for the conclusions derived, with verbal learning literature heavily emphasized due to its more abundant presence than motor learning literature in this area. Anyway, we feel and have attempted to make the point elsewhere (Singer, 1978; Singer & Gerson, in press) that there is much commonality between the processes that operate in the learning and performing of both verbal and motor skills.

Sensory Stores

Information from the environment impinges on the organism and is briefly registered in the sensory stores.

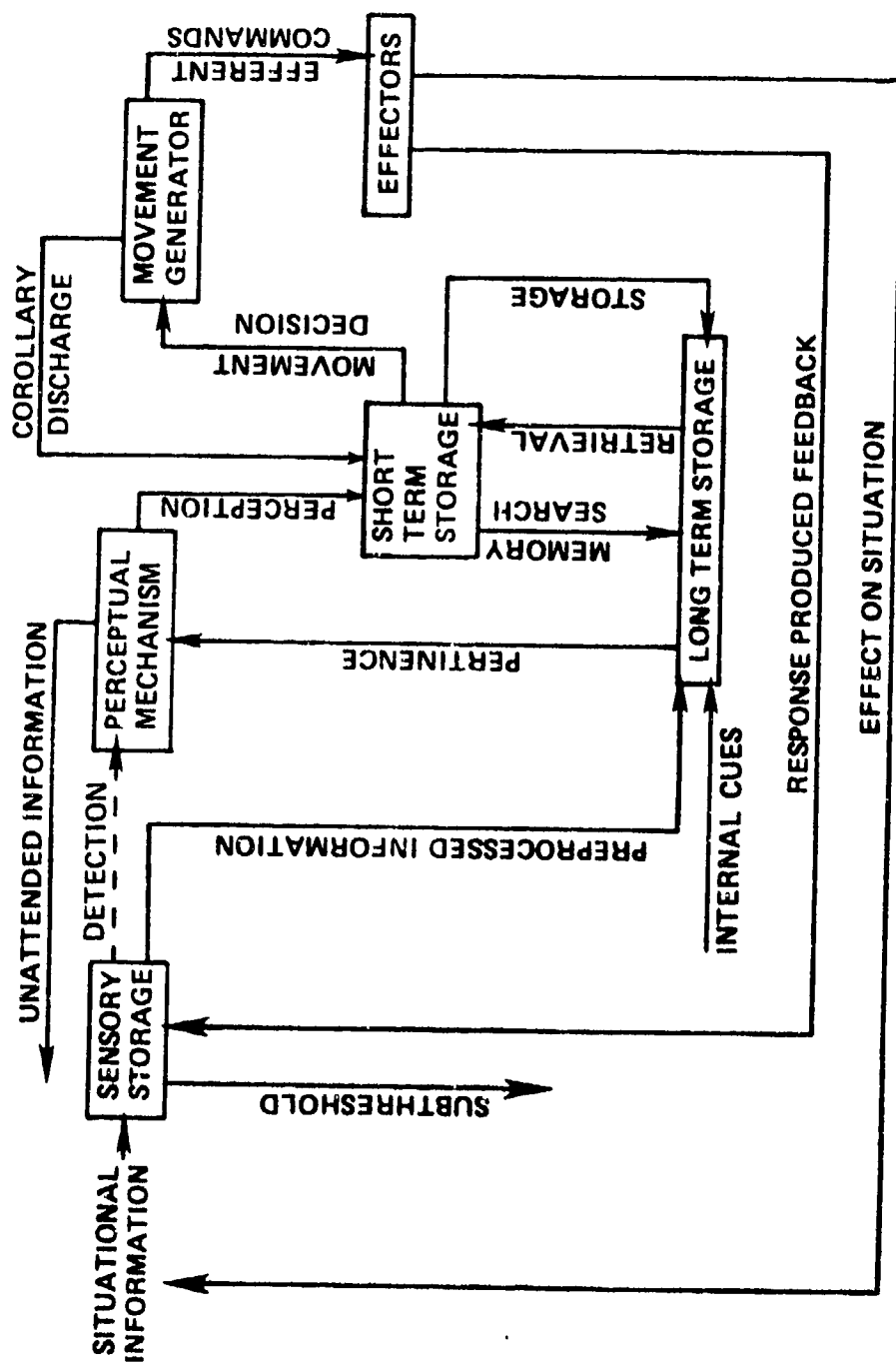


Figure 1. A conceptualization of information processing and motor behavior.

Table 1

The Conceptual Relationship of Mechanisms, Potential
Cognitive Processes, and Functions in Complex Motor Behaviors

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

Table 1 (cont.)

<u>Mechanisms</u>	<u>Cognitive Processes</u>	<u>Functions and Purposes</u>
4. long term storage (LTS)	store information permanently.....	make information available 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

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

Table 2

Explanations of Potential* Cognitive Activities
and Functions in the Performance of Complex Motor Behaviors

<u>Cognitive Activities</u>	<u>Function</u>
1. convert instructional information	transform sensory information for movement representation
2. analyze relationships	recognize similarities between present and past tasks, situations, and experiences (transfer)
3. retrieve information	facilitate recall and recognition, and interpretations and decisions
4. understand task goals	form goal-image of intended performance
5. select cues	identify most relevant and minimal cues at any given time
6. establish personal goals and expectations	form performance expectancies
7. concentrate	focus attention, broad or narrow, depending on task demands
8. maintain optimal arousal (motivational) state	demonstrate conscious control over emotions where necessary
9. analyze nature of task	use fixed or adaptive behaviors as required
10. mentally rehearse prior to and/or after performance	strengthen images and potential motoric responses
11. adapt to stress	use control over emotions and environment where appropriate
12. analyze outcomes of decisions	consider costs and payoffs

Table 2 (cont.)

<u>Cognitive Process</u>	<u>Function</u>
13. make correct response decisions	consider amplitude, speed, location, distance, and accuracy
14. conserve energy	minimize effort to deter possible fatigue to maximize performance
15. evaluate ongoing performance (feedback) when appropriate and possible	monitor, regulate, and adjust performance
16. evaluate the results of performance (feedback)	use in future decisions in similar activities
17. attribute performance outcomes objectively	influence motivation, expectations, and performance in subsequent similar activities

*Any of these cognitive processes may be activated, depending on the skill level of the person, the nature of the activity, and personal intentions.

If certain characteristics of the information field were anticipated by the performer, then a preattentive analysis might be conducted (Neisser, 1967). This analysis would serve to extract the anticipated features of the stimuli from the total display. The internalization of these features depends on the intensity of the stimuli, the priority or expectancy for receiving the stimuli, and the level at which the stimuli are encoded (Bower, 1975). Individuals differ with regard to the latter two factors.

For instance, Hunt, Lunneborg, and Lewis (1975) reported that students with higher verbal ability were better able to extract more information from a brief visual display than students with low verbal ability. Similarly, Sperling (1960) showed that there was a 15% difference in the amount of available information between the best performer and the worst performer on an iconic memory task. Additionally, Moore and Massaro (1973) found that their best subject correctly identified twice as many items as their worst subject in an auditory identification task. Thus, although the research findings reported here were based on cognitive tasks, the same results may be expected in the psychomotor area, considering that oftentimes no difference exists in the modality of stimulus reception between cognitive and motor tasks. In other words, with the exception of

proprioceptive information, which is primarily associated with psychomotor behaviors, visual and/or auditory signals may be received in both verbal and motor tasks, to be attended to and responded to accordingly.

The sensory stores must function adequately for any information to enter the system without bias; or, for that matter, merely to enter the system. It appears that individuals may differ in the functional utility of the sensory store in two ways. The duration of the store may differ and the speed at which preprocessed inputs contact the LTS may differ, thus leading to a difference in the pertinence levels assigned by the LTS to the preprocessed information (cf. Hunt & Lansman, 1975).

Long-Term Storage (LTS)

Long-term storage contains a knowledge base and representations that are used to establish pertinence levels. The stored memory may be contacted indirectly by environmental cues or directly by internal inputs such as thoughts (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Thatcher & John, 1977). The latter process occurs quite rapidly (Hunt & Lansman, 1975) and can be considered as an important factor in arousing the system to action, especially in the apparent absence of environmental stimuli. The necessity to contact knowledge in the LTS for behavior to occur leads one to

conclude that this mechanism is a repository for learned skills (Marteniuk, 1976). Additionally, the stored information in the LTS serves to provide pertinence values to information that must be transmitted to the perceptual mechanism.

To provide pertinence values to incoming information, the stored representations must include more than just potential behaviors. Due to experience in particular activities, learners develop certain information expectancies that allow them to anticipate stimuli in familiar or near-familiar situations. Anticipatory behaviors of highly skilled performers (Lawther, 1977) result from a more rapid transmission of preprocessed information to the LTS, which leads to the subsequent formation of higher pertinence levels to that information. Appropriate representations of experiences, stored in the LTS, result in different information expectancies when high-skilled performers are compared with those of lesser ability. Beginners lack experience, and thereby lack a proper reference system with which they can recognize and judge new situations as being similar to previous situations. Thus, less skilled performers are unable to activate the desired memory representations, due to their not being present. Consequently, these individuals process information at a slower rate (Fitts & Posner,

1968; Hunt, 1978; Hunt & Lansman, 1975).

Speed of information retrieval from the LTS is a crucial difference between skill levels. With more experience, more situations are encountered and these tend to be recognized at future dates. Similarities between stimuli affect memory access time (Posner & Keele, 1968), and since advanced performers can determine more situations as similar, and yet make just-noticeable difference judgments if necessary, they can activate the proper memory representations to anticipate future incoming stimuli. Additionally, the differences in strategy usage between advanced and novice performers at the time information was originally stored (Love, 1973) leads to variations in LTS access and retrieval times. Thus, experience is one factor that can be used to explain differences in LTS functioning, as experience is probably the major causal element in the determination of what information is to be attended to and recognized.

Perceptual Mechanism

Information that is briefly stored in the sensory registers is transmitted to the LTS as preprocessed information, where it activates appropriate internal representations, if indeed they are present. These memory codes serve to establish the pertinence value of the information as it is forwarded to a hypothesized perceptual

mechanism. The pertinence of a stimulus alerts the learner to anticipate the ordered arrival of information into the perceptual mechanism. At this time, the learner invokes selective attention processes to recognize, identify, and provide meaning to the most relevant information.

Selective attention processes vary among individuals. Not only do attention control processes improve with age (Chi, 1976), based on the amount of "mental effort" (Kahneman, 1973) a person is capable of employing, but skilled performers also possess a better repertoire of strategies for attention than do unskilled performers (Lansman, Note 3; Treisman, 1969). A skilled performer is more capable of choosing the stimuli that convey the most information while disregarding those stimuli that are of little import or that serve as noise to the system (Marteniuk, 1976). Contrarily, unskilled performers tend to concentrate on both relevant and irrelevant stimuli, thereby overloading their channel capacity (Lawther, 1977). In essence, mature non-skilled performers respond similarly to children who behave in an overinclusive manner with respect to selective attention processes (Ross, 1976). In other words, they take in more information than is needed to execute the task correctly.

Skilled performers do not behave in an overinclusive

manner, and therefore, they allocate less of their channel capacity to the task. This leads to an availability of spare capacity that allows these persons to process more information and possibly to engage in parallel processing (e.g., do two tasks simultaneously, anticipate and form potential programs as activity is ongoing). This ability is even more pronounced when the learner becomes familiar with the material so that the selective attention and encoding processes do not demand conscious attention (Kerr, 1973). In contrast, the less-skilled individual does not have any spare capacity available and must attend to information in a serial manner. Serial processing is more time consuming than parallel processing (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Sternberg, 1969), and thus, the rapidity with which a performance can be enacted is reduced. Adequacy of performance in terms of other criteria may be diminished as well.

Performance dissimilarities between skilled and unskilled individuals are also due to the ability of the highly skilled to extract a large amount of information from a minimal amount of cues in the display, while less-skilled individuals are limited in the amount of information they can transmit (Marteniuk, 1976). Moreover, the inequalities can also be attributed to the differential

use of strategies between the two categories of performers. Whiting (1972) has stated that the information attended to by the skilled performer is probably discrepant from that attended to by the unskilled person. The advanced performer focuses on a critical area of the display and is prepared to perceive particular information quickly and accurately. Inexperienced performers, on the other hand, do not usually know what information is important, nor when to attend to it. They tend to fixate their attention on one aspect of the display while other relevant data may be ignored (Marteniuk, 1976; Whiting, 1972).

This apparent ignorance on the part of unskilled performers is predicated on the fact that they appear to have little or no expectations as to what information might be available in the immediate environment. This is especially true with externally paced tasks, where individuals have to respond to situational dictates, often-times occurring in a non-predictable way. Due to their inexperience, unskilled persons are unable to determine the constraints that must be placed on the contextual display so that pertinent information may be processed accurately and efficiently. Advanced performers, however, are capable of monitoring only the important aspects of the display due to their previous experiences in similar

situations, their expectations of the information that should be available, and their anticipation of what they must do when this information becomes available (Norman, 1976).

The ability to correctly anticipate the arrival of input cues speeds up the perceptual process. The differential and more effective use of selective attention strategies (Treisman, 1969) of skilled performers when compared to novices is probably one explanation of divergent performances. Skilled individuals are able to vary attention systematically depending on task demands. Certain skills, such as driving a car, require a broad focus of attention, while other tasks, such as hitting a pitched baseball, demand a narrow focus of attention (Nideffer, 1976). It is the skilled performer who is capable of increasing or decreasing the width of attentional range as dictated by the situation. The result of these advanced strategic selective attention control processes is that only pertinent information is perceived.

As the learner begins to perceive pertinent information, another control process is invoked to render the inputs more meaningful. Recognition, as a cognitive activity, occurs in the hypothesized perceptual mechanism because a person must have some familiarity with information if it is to be transmitted deeper into the

system. Familiarity is based on experience, and highly-skilled individuals will have had more contact with more situations than their less-skilled counterparts. As a result, advanced performers should recognize information at a greater speed and then respond with greater accuracy. This, in fact, is what occurs on both verbal (Hunt, 1978) and motor tasks (Rubin, 1978).

A major problem in the investigation of motor recognition processes is that they are examined via short-term memory (Newell, 1976; Zelaznik, Shapiro, & Newell, in press). While Newell and his colleagues have found evidence for motor recognition memory, they do not consider it as a perceptual process (Singer & Gerson, in press; Singer et al., Note 1). Perhaps motor recognition is both a perceptual and a short-term memory process, depending on time delays and situations. If recognition is a perceptual process, involving an extended retention interval, then advanced performers should be superior to beginners due to the experience of the former group. If recognition is mainly a short-term memory process, and the retention interval delay is brief, then no performance differences should occur. Finally, if this process is a combined perceptual and short-term memory activity, then performance differences may or may not occur (cf. Zelaznik et al., in press). In any case, recognition, as a control

process, provides meaning to information so that it may be better organized in the short-term store for rehearsal.

Short-Term Storage (STS)

Information that was rendered meaningful in the perceptual mechanism is transmitted to the short-term store. It is in this mechanism that most of the information transformations occur. Additionally, most of the processing differences among individuals can be identified as occurring in the STS. The performance variability that may be noted, both between and within individuals, is often due to the differential use and effectiveness of strategies for the organization of information (Battig, 1975).

When learners are of the same developmental stage, variations in processing abilities have been speculated not to be due to differences in structural capacity (Chi, 1976). Rather, these differences occur in the functional utilization of the short-term store; i.e., the strategies a learner uses to process information. The divergence in performance that is evidenced between high- and low-skilled learners is due in part to strategy usage (Singer & Gerson, in press). Better (adaptable) learners are more capable of shifting from an old, less efficient strategy to a new, more appropriate strategy during the course of skill acquisition (Mondani & Battig, 1973;

Singer, 1978; Singer & Gerson, Note 1).

This conclusion is in agreement with the one made by Hunt, Frost, and Lunneborg (1973), who stated that highly-skilled individuals are more likely to invoke a unique, or perhaps a modified strategy as new items are entered into the STS. The improved coding of these items at the time of storage enables advanced learners to evidence superior performances at the time of testing (Love, 1973). This is very similar to the notion that elaborate or enriched encoding during storage will lead to better performance at a later date (Craik & Lockhart, 1972; Craik & Tulving, 1975).

The initial phase of information storage occurs in the STS. Therefore, it can be assumed that strategy usage will have the greatest effect on this mechanism, and that any performance differences based on the use of the short-term store are due to variability in strategy usage. In support of this, Hunt (Hunt, 1978; Hunt & Lansman, 1975) has stated that performance differences between high- and low-skilled individuals on certain memory tasks, e.g., digit span, were due to the use of different strategies. Similarly, Housner & Hoffman (Note 4) reached the same conclusions using a limb positioning motor short-term memory task. Consequently, the ability of a learner to devise and implement appropriate

strategies for handling information apparently determines the level of subsequent performance on both verbal and motor short-term memory tasks.

Divergent performances between persons of varying degrees of skill level are due to differences in the implementation of strategies and control processes (Chi, 1976; Singer & Gerson, in press). This result has been found consistently in memory scanning tasks when high- and low-verbal performers were compared (Goldberg, Schwartz, & Stewart, 1977; Hunt, Lunneborg, & Lewis, 1975). High-verbal individuals were always superior to low-verbal performers in the speed with which they searched the short-term store. If these speed differences are actually due, in part, to the complexity of the information to be retrieved (Goldberg et al., 1975; Hunt, 1978), then differential strategy usage at the time of storage may be used to explain these results (Sternberg, 1966). Furthermore, it may be assumed that similar results would occur in a motor skill situation.

The conclusion is partially supported by the "encoding specificity principle" (Tulving & Thomson, 1973), which states that the retrieval cue must be stored at the time of encoding so that recall performance may occur quickly and accurately. While much support has been found for this principle in studies of verbal learning, partial

results of verbal tasks, it has been assumed that the same conclusions are applicable to motor skills (Singer & Gerson, in press). In fact, several researchers (e.g., Moody, 1967) have provided evidence that performance differences between high- and low-skilled individuals on a motor short-term memory task were due to discrepant strategy usage.

Housner and Hoffman (Note 4) showed that high-visual imagers were able to reproduce limb position end locations better than low-visual imagers. The movement reproduction superiority was evidenced over retention intervals that included either an interfering activity or a task rehearsal activity (imaging). The consistent results across all conditions were attributed to differences in the ability of the two groups to utilize the designated strategy.

It is clear that strategy usage in the short-term store is a determinant of short-term memory performance, whether the task is verbal or motoric in nature. The greater ability of highly-skilled individuals to handle, manipulate, and organize information in this mechanism leads to a more efficient performance. This is most evident when motor skills are investigated, as performers must quickly process information and decide on which movements must be made, in what direction, with what speed,

confirmation of the premise has also occurred in motor learning situations (Diewert & Stelmach, 1978; Gentile & Nacson, 1976), especially when one considers the basic procedures of a motor short-term memory experiment (see Stelmach, 1974, for a review). Additionally, Hunt (1978) has concluded that high-verbal performers manipulate information better than low-verbal performers due to the more appropriate use of strategies by the former group. This reasoning can be extended by attributing greater organizational characteristics to the strategies of highly-skilled individuals (Gentile & Nacson, 1976) that would enable these persons to encode all the necessary information at the time of storage. Consequently, most or all potential retrieval cues would also be stored, and this should lead to superior performance on a later test.

Other performance differences have also been found between high- and low-skilled performers on various verbal short-term memory tasks (see Hunt, 1978, for a review). These differences have almost ubiquitously been attributed to variations in strategy usage, regardless of the subject population studied (Belmont & Butterfield, 1971; Bower, 1975; Brown, Campione, & Murphy, 1974; Flavell & Wellman, 1977; Hunt, 1978; Hunt et al., 1973, 1975). Although these conclusions are based on the

and with what parts of the body. While advanced performers are able to move efficiently with a minimum expenditure of effort, beginners tend to move in a less efficient manner. After consideration is given to differences in physical capabilities and mechanical techniques, performance differences result from the ability of the highly skilled to form a base of well-organized information in the STS through the use of appropriate rehearsal strategies and then to select the appropriate motor program.

Before discussing the generation of movement, it must be pointed out that other activities go on as well between the STS and LTS. Expectations of success are dependent on previous successes and failures in similar situations (Gerson, Note 5; Weiner, 1974). Level of expectation and other motivational factors will bear on the kind of processing that goes on in STS (Gerson, 1978; Singer & McCaughan, 1978). Stressors present and individual reactions to them in the form of nonadaptable or coping strategies will also affect processing effectiveness (Nideffer, 1976). In other words, there are many intangibles that can help to facilitate or impede strategy selection and execution with regard to processing control. In turn, strategies are needed to make these intangibles work on behalf of the person. It would appear that the highly-skilled performer, in contrast to the lesser skilled,

uses more effective strategies in controlling and directing emotions, reacting to stressors, and in general, maintaining the appropriate arousal level for the task demands (Singer, 1975). Further, expectations in performance level are reasonably high but realistic.

Movement Generator

The movement generator initiates the performance commands to the effectors in the form of motor programs or plans. These programs were selected in the STS on the basis of decisions made in that mechanism, and then transmitted to the movement generator to be loaded and run off. The decision-making or response-selection process represents differences in skill levels in two ways. The more advanced performers would evidence shorter latencies in the selection process, and they would also engage in less error-correcting behavior than their less-skilled counterparts.

Shorter response-selection latencies are the result of greater successful experiences with a particular situation or movement. Extensive practice of a skill often leads to that action becoming programmed (Schmidt & McCabe, 1976; Shapiro, 1978), as in ballistic movements where speed is important. A movement under programmed control can be executed with greater rapidity than a movement under peripheral control. Peripheral control, which is

most often evidenced by unskilled performers, even in ballistic-type movements, is dependent upon feedback for effective completion. Since movements under feedback control require more time to execute than programmed movements (Keele, 1968), the unskilled performer is unable to enact a number of responses in a short amount of time. While this delay in execution may not lead to performance errors during the initial phase of a motor action, it is highly probable that later aspects of a movement will either be error-filled or not performed at all. This would be due to the unskilled performer being unable to prepare the system to accept the new incoming stimuli for which responses must be formulated.

Of course, a truly programmed (or preprogrammed) response is not always desirable. It implies a degree of automaticity, of sub-conscious control. A reaction to the wrong cue, when under central control, cannot be changed due to conscious intervention until at least .20 to .30 of a second has elapsed (Schmidt, 1975). The peripheral control of movement suggests a slower movement which is amenable to ongoing modifications and adjustments. It might be suggested that the higher-skilled performer has learned how to adapt, like a thermostat, to response demands. Sometimes movement will be placed under central control, other times under peripheral control

Realizing personal limitations, certain situations will elicit movements deliberately under peripheral control in the highly skilled. Obviously, this discussion has deliberately been focused on potentially rapidly-made movements. When movements do not require speed, then both lower- and higher-skilled performers will rely on peripheral feedback for information. However, the strategies used by highly-skilled as to the monitoring of peripheral (e.g., proprioceptive) information differ from the lesser-skilled. In the former case, degree of attention to such information is focused as there is a need, but in the latter case, there probably is more attention given to too much information or else to the less pertinent information. Thus, less-skilled performers would have difficulty successfully completing tasks that demanded fast and accurate responses.

Responses which must be formulated and enacted with great accuracy and speed need to be well-learned, and therefore, come under program control. As the result of extensive practice, the skilled performer establishes a repertoire of programmable movement subroutines and action plans (Newell, 1978) that can be performed without much conscious attention (Marteniuk, 1976). These subroutines are controlled at a lower level (Gentile, 1972), and the executive is then capable of attending to other relevant situational inputs.

Glencross (1977) substantiated this point by stating that the higher centers of control operate in a closed-loop fashion, utilizing feedback and other information to make comparisons and modifications in the motor programs. The programs represent a lower-order, open loop method of control, initiated to carry out movements. Any activity that goes on for a reasonable period of time would probably activate both open loop and closed loop control from occasion to occasion. Klapp (1978) reaffirms Glencross' position, as he also recognizes the existence of hybrid systems of control in which both programmed and feedback control operate. After discussing mechanical and human systems, he concludes that "most systems at some level of analysis must be regarded as hybrid systems" (Klapp, 1978, p. 231). The skilled performer, then, has developed adaptive strategies and component skills, enabling the potential shift to occur in a hybrid control system.

In contrast with skilled performers, novice performers have not received as much practice with a variety of movements, or perhaps even a particular movement. Therefore, their actions cannot be under programmed control. Rather, unskilled performers operate in a closed-loop fashion (Adams, 1971, 1976) regardless of task demands, and their higher control centers are occupied

with attending to the movement. As such, these performers cannot decide on the next movement in the sequence until the current one is completed. Thus, their performances tend to take an extended period of time, and this results in more errors occurring in the latter stages of movement sequences because the necessary response has not even been selected.

This difficulty can lead to errors in response selection (Schmidt, 1976), where the wrong response is chosen because the environment was misperceived. That is not to say that skilled performers do not commit errors in response selection, also. The difference is that the advanced performers are better prepared than the novice to choose the correct response due to greater experience with the task, more skills, and a greater capability to use appropriate strategies. However, regardless of experience, another type of performance error can occur, and at any skill level. These are errors in response execution, and they result from the musculature incorrectly exacting the movement commands. Once again, due to extended practice, highly-skilled individuals will tend to commit less of these errors than will their less-skilled counterparts.

The control of both types of errors, selection and execution, involves the integrated functioning of all of

the mechanisms: sensory storage, the perceptual mechanism, the LTS, the STS, the movement generator, and the effectors. Decisions for the selection of responses are made in the STS and are sequenced in the appropriate order in the movement generator. If an incorrect decision is made, or the programs are sequenced in anything but the proper order, then a performance error must occur. Similarly, if the programs are loaded correctly, but the movement generator incorrectly selects the musculature to perform the movement, then an error in execution will result. The difference in performance that is evidenced between high and low skilled individuals is related to the amount of program control (Schmidt & McCabe, 1976), and then to the latency with which either selection or execution errors can be corrected.

Effectors

The effectors of concern here are the receptors in the muscles, tendons, and ligaments, associated with particular limbs, that are responsible for carrying out the movement commands. If the commands are accurate and precise, then the effectors simply execute the movement. If the commands are incorrect in any aspect, then observable performance will be inappropriate. Considering the two possible errors that a performer may make, selection and execution, the effectors are most responsible

for correcting errors in response execution.

The correction of response execution errors by the effectors can be carried out through reflexive control within the muscle spindle. Smith (1976) stated that the gamma fibers within the spindle receive information that the sequence of muscular contractions is not proceeding according to plan. The gamma system, then, reflexively excites or inhibits the appropriate motor-neuron that controls the extrafusal fibers responsible for the contraction. In this way, execution errors, and even the slightest mismatch between input and output, are corrected and control of the movement may revert back to the motor program so that movement can be completed as planned.

The correction of response execution errors would occur more rapidly in advanced performers than in less-skilled individuals. The extensive amount of practice and the continuous adaptation of strategies that is necessary to achieve a high level of skill must repeatedly involve the cognitive control processes and the muscles necessary to perform a movement in an efficient manner. The gamma system of the advanced performer should be more highly tuned to detect and to correct response execution errors as compared to the same system in a novice because the cortical centers have planned the movement

more effectively. Thus, at all levels of skill, there is a system to ensure that the movement is being carried out as planned, and this system is more highly developed in the advanced performer.

Until now, the discussion on effector control has centered around the gamma system, a sub-conscious form of movement regulation. As is obvious, effectors also transmit proprioceptive information for conscious recognition and control on many occasions. This information is recycled throughout the system, to be used immediately and/or as an additional input to the knowledge representation base in LTS. Such is the case with visual feedback or other forms of response-produced information (Singer et al., Note 1).

If the task or situation is altered due to performance, input cues change as well. Feedback information can come from the situation or from within the person (Adams, 1976), but if sources are to be consciously attended to, they must be processed through the set of subsystems already explained (cf. Singer et al., Note 1). Strategies for the use of feedback are important, as the advanced skilled performer seems to learn which feedback to pay attention to, and when. Once the act is completed, this information should be stored as a reference base for subsequent activity, and beginners need to learn

organizational strategies to "catalog" this information correctly in storage, to be retrieved when needed. During an activity, feedback information may be abundant, redundant, or relatively absent. Attention to feedback varies between learners, and the need to attend to feedback varies from task to task.

COGNITIVE PROCESSES AND LEARNER STRATEGIES

Difference in skill level may be attributed to many factors, but in this paper, the emphasis was on the processing of information. Stating it simply, the higher-skilled process information more effectively and efficiently. They have learned appropriate strategies to enhance processing at different stages, from the inflow of information to the movement made in response to task demands.

Strategies related to readiness, anticipation, emotional control, concentration, recognition, selective attention, the retrieval of related information, the establishment of performance expectations, the processing of information for later use, the planning and selecting of a motor program for present use, the organization of behaviors, the utilization of response-produced feedback, and other processes, seem to be used more appropriately and effectively in the higher-skilled as compared to their lower-skilled counterparts. Strategies pertinent

to the initiation and maintenance of processes needed to be activated are, depending on the nature of the task, apparently possessed to a greater degree by the more highly skilled. Hence, processing is usually fast and accurate.

Processing can be automatic, as when cue and response parameters are known in advance and relatively simple. Thus, the combinatorial strategy of anticipation, concentration, and motivation operates prior to the onset of the signal (cf. Klapp, 1978; Zelaznik, 1978). As activities become more complex and longer, more strategies need to be activated. Combinations of feedback and program control may operate, requiring the use of relevant strategies for conscious or sub-conscious decision making and execution.

The purpose of this paper was to explore ways in which superior and inferior individuals differ in their use of cognitive processes and strategies in motor skills in general. The emphasis was on self-initiated strategies. Since beginners are trying to improve at what they are doing, a knowledge of what goes on within the superior performer can serve to identify and call attention to the ideal operation of processes and strategies. This is a first step. It should benefit learners and instructors alike. Instructors should encourage learners to learn productive strategies so they can use them by

themselves in the acquisition of skill.

However, much greater precision is needed to make such knowledge more meaningful and applicable. Considerations must be made for (a) type of task, and (b) the cognitive style of the learner (individual difference factors), and we have begun preliminary work in this area (Singer & Gerson, Note 2). Motor task classifications schemes (e.g., Fitts, 1965; Gentile, Higgins, Miller, & Rosen, 1975; Kriefeldt, 1972; Merrill, 1972) are helpful in this regard. In ours, three dimensions have been considered: dominant processing mechanisms that operate prior to, during or after performance, availability of feedback during or after performance, and self-pacing vs. externally-pacing. For example, a task in which the input (sensory-perceptual) mechanisms are primarily active, feedback is only present after the act is completed, and an externally-paced act would suggest the involvement of a particular set of processes, with the need for the implementation of corresponding strategies. In other words, tasks have to be classified in some meaningful manner in order to determine which strategies are most important to consider as influential on pertinent processes.

Likewise, learner differences in preferred styles of learning and responding need to be recognized (e.g., Snow, 1977). For instance, one may do well with imagery

techniques, another with labeling, and another with a kinesthetic awareness strategy to enhance the operations that occur in STM and influence learning/performance. More elaborate training programs are those in which there is sensitivity in instructional approaches to learner differences.

However, as was stated before, the intent in this paper was to identify information-processing differences between people who differ only in respect to skill level, and without concern for the type of motor task. This more general orientation to the area should lead to the development of more specific task-learner considerations, with implications for training and learning. Strategies should be taught to and used by beginners to help promote learning, thereby decreasing trial and error experiences and lengthy practice time.

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