DOCUMENT RESUME

ED 257 856 TM 850 319

AUTHOR Cormier, Stephen M.
TITLE Transfer of Training: An Interpretive Review.
INSTITUTION Army Research Inst. for the Behavioral and Social Sciences, Alexandria, Va.
REPORT NO USARIBSS-TR-608.
PUB DATE Jan 84
NOTE 69p.
PUB TYPE Reports - Research/Technical (143) -- Information Analyses (070)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Cognitive Processes; Educational Research; *Job Training; Learning Strategies; *Military Personnel; Military Training; Program Evaluation; Psychomotor Skills; Schemata (Cognition); Training Methods; Training Objectives; *Transfer of Training
IDENTIFIERS Army; List Differentiation Hypothesis; Proactive Interference

ABSTRACT

Information processing and memorial processes that have been identified by contemporary research as important factors in human learning and cognitive activity are shown to provide a basis for explaining and predicting transfer of training effects. Four major factors are discussed in separate sections: the relationship between retrieval cues and encoded information; study-phase retrieval; organizational strategies; and performance automatization. A fifth section briefly discusses the relevance of information processing factors to proactive interference phenomena. These information processing factors are seen to exert their effect in both the laboratory and in applied settings, providing a potential link between basic and applied research on this topic. The similarities and differences in transfer with verbal as opposed to motoric responses are also considered in light of these information processing concepts. (Author)

ED257856

TM

Technical Report 608

Transfer of Training: An Interpretive Review

Stephen M. Cormier

Training and Simulation Technical Area
Training Research Laboratory

U. S. Army
Research Institute for the Behavioral and Social Sciences

January 1984

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

Technical review by

Joseph D. Hagman
Hilda Wing

NOTICES

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report 608	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TRANSFER OF TRAINING: AN INTERPRETIVE REVIEW		5. TYPE OF REPORT & PERIOD COVERED -- 6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Stephen M. Cormier		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63743 2Q263743A794 5320
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE January 1984 13. NUMBER OF PAGES 68
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) --		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

--

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Transfer of training
Information processing
Motor skills
Cognitive skills

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Information processing and memorial processes that have been identified by contemporary research as important factors in human learning and cognitive activity are shown to provide a basis for explaining and predicting transfer of training effects. Four major factors are discussed in separate sections: the relationship between retrieval cues and encoded information, study-phase retrieval, organizational strategies, and performance automatization. A fifth section briefly discusses the relevance of information processing factors to

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

i SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Item 20 (Continued)

proactive interference phenomena. These information processing factors are seen to exert their effect in both the laboratory and in applied settings, providing a potential link between basic and applied research on this topic. The similarities and differences in transfer with verbal as opposed to motoric responses are also considered in light of these information processing concepts.

Technical Report 608

Transfer of Training: An Interpretive Review

Stephen M. Cormier

Submitted by
Robert J. Seidel, Chief
Training and Simulation Technical Area

Approved as technically adequate
and submitted for publication by
Harold F. O'Neil, Jr., Director
Training Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

January 1984

Army Project Number
2Q263743A794

Education and Training

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Training & Simulation Technical Area (Performance Readiness Team) of the Army Research Institute (ARI) has actively pursued a program of research in support of a systems approach to training. A major focus of this research is to develop the fundamental data and technology necessary to field integrated systems for improving individual job performance. This report summarizes the first step in the development of methods to assess and enhance the transfer of skills from training to the job, or from one task to another. The transfer of training literature is integrated and analyzed in order to derive fundamental principles of transfer. The long term goal is to develop methods for predicting the degree of transfer to be expected after specific training experiences.

EDGAR M. JOHNSON
Technical Director

TRANSFER OF TRAINING: AN INTERPRETIVE REVIEW

EXECUTIVE SUMMARY

Requirements:

As part of a major program on individual training for combat readiness, to develop a sound information base for Army decisions necessary to insure the effectiveness of training in promoting job proficiency, this review focuses on the transfer of training from one task or skill to another.

Procedure:

This review is based upon a wide variety of data from an extensive literature survey of pertinent research. Although military-related tasks and findings were incorporated whenever possible, some of the experiments cited used tasks having little direct or obvious relationship with skills currently maintained within the Army. In addition, conflicting data and data pertinent to a more detailed understanding of the behavioral consequences (transfer) of training experiences generally were skimmed over to lend coherence to this report. Nevertheless, a number of tentative conclusions do have considerable empirical support.

Findings:

1. Four major information processing factors are identified as important factors in explaining and predicting transfer of training effects: a) the relationship between retrieval cues and encoded information, b) study-phase retrieval, c) organizational strategies, and d) performance automatization.

2. The importance of the relationships between the retrieval cues available during Task 2 performance and the material encoded in Task 1 for transfer of training has been shown in a variety of experimental and applied research paradigms. The conditions under which Task 1 information can be retrieved using cues present in Task 2 are shown to be an important determinant of transfer of training in both verbal and motor learning. Positive transfer is promoted to the extent that the cuing relationships between the transfer task and Task 1 are distinctive and have high redintegrative value.

These considerations are shown to be useful in analyzing applied research, including the potential effectiveness of simulators for aircraft and other mechanical equipment in transfer of training. Variations in simulator fidelity to the transfer environment have led to contradictory and ambiguous results. Analyses of these studies of simulator effectiveness support the idea that the fidelity of a simulator to the actual instrument can be based on those attributes which have high redintegrative value for correct responses. Those attributes which have lower redintegrative value can be modified or eliminated without substantial loss of transfer.

3. The integration of information across successive presentations of related material through a study-phase retrieval process seems to be critical in increasing positive transfer in many situations. The juxtaposition of different events can result in the formation of higher order concepts, as in textual prose comprehension, or can facilitate the abstraction of critical dimensions of task performance and stimulus recognition. This process can be accomplished through the appropriate variation in Task 1 training used to define the critical dimensions. The process seems to be applicable to both verbal and motor transfer as manifested by the effects of variability of practice on later transfer performance. It was also shown to be useful in understanding the relative effectiveness of guidance versus discovery training.

4. Organizational processes are powerful aids to the learning of new information to the extent that the transfer task can be related effectively to the organizational plan or schema in use. A schema can be regarded as a set of procedural and content knowledges concerning a particular domain of material. Schemata can facilitate both verbal and motoric learning. The use of schemata produces several negative effects on transfer. Schema-irrelevant or incongruent information will often be learned less well than if no schema were being used. In addition, transfer material which requires a different schema than the one used in Task 1 will often lead to negative transfer because the person will spend time trying to fit the new information into an inappropriate schema or try to modify the old schema to fit the new material.

5. Automatized performance can occur after extended consistent practice with particular cues or responses. Qualitative and quantitative differences exist between automatized performance and non-automatized performance, both in terms of the effort required to process and respond to cues and in the nature of the performance itself. Changes in the utilization of the cues controlling responding have been shown to occur over the course of training in a variety of tasks. Such changes usually occur in the direction of more efficient stimulus processing or motor performance. As a consequence, transfer can be affected by the relationship of the particular cues utilized in Task 1 and in the transfer task. In addition, the more efficient performance on tasks can permit time sharing activities or the simultaneous performance of two tasks. Automatized per-

formance tends to be highly specific to the elements consistently presented in Task 1. Thus, there may be little transfer to other components that differ in some way from those that have become automatized. In addition, it can be difficult to suppress inappropriate automatized performance in transfer tasks if the controlling cues are presented.

6. Proactive interference (PI) can be interpreted as due to the operation of several of the factors already discussed. Prior learning can proactively interfere with the acquisition and retention of later learning. Failures of list discrimination and reductions in the amount of information encoded about later tasks were shown to be two important factors in the development of PI. Manipulations which increased the differentiation of material between Task 1 and Task 2 often significantly decreased the amount of observed PI. It was shown that perceptual-motor responding exhibits little PI, in contrast to verbal material, possibly because of the greater distinctiveness of motoric responses. In addition, persons seem to encode material on Task 2 more efficiently but also less completely than Task 1 material.

Utilization of Findings:

The conclusions and implications of previous research provide a firm basis for specific, on-going programs to develop procedures that the Army can use to enhance the value of training for job performance.

Table of Contents

TRANSFER OF TRAINING: AN INTERPRETIVE REVIEW

INTRODUCTION

The increasing level of complexity in the activities and tasks required of military personnel in the modern Army necessitates an enhancement in the amount and effectiveness of training for these tasks. However, this increased complexity makes it less likely that training can be on-the-job (OTJ) while still maintaining efficiency and safety. Thus, training will increasingly be conducted in settings which are different from the job environment to a greater or lesser extent.

In these circumstances, a critical question is the degree to which training outside of the job environment actually transfers to the job itself. That is, does training outside of the job result in job performance levels which are comparable or greater than those attainable with OTJ training? Transfer of training can therefore be seen to be an increasingly important consideration in the delivery of training to military personnel. This fact necessitate designing training programs which will have effective transfer to the target job.

In light of these considerations, greater awareness of the training factors which are known to affect transfer is an important objective for those involved in delivering training in the Department of the Army. A better understanding of the factors involved in transfer of training will make it more likely that new training programs will not only cost-effective, but also contribute to enhanced performance of the Army's mission.

Transfer of training refers to the effect of initial task training (i.e., Task 1) on the acquisition of a subsequent transfer task (i.e., Task 2). Three outcomes are possible: Task 1 training can either facilitate (positive transfer), retard (negative transfer) or have no effect on the acquisition of Task 2.

In the past, predictions of transfer effects on applied settings have been based on the results of basic research in learning performed within the framework of S-R theories of behavior (e.g., Hull, 1921; Osgood, 1949; Thorndike, 1932). This research has provided a relatively straightforward account of transfer based primarily on the strength of interference theory (McGeoch, 1942; Underwood & Postman, 1960).

Despite the early interrelatedness between basic and applied research, there has been an increasing separation between basic research in learning and its application to transfer of training issues encountered in applied settings (cf. Battig, 1978; Deese & Hulse, 1967). This separation is due in part to the theoretical shift from S-R to information processing conceptualizations of behavior. Thus, current research interests are not in transfer of training but in the structures and processes involved in the encoding and retrieval of information during initial task acquisition and retention. It is reasonable to assume, however, that the large volume of recent data has relevance to our understanding of transfer of training even if this has not been its primary focus.

The aim of this paper is to review stimulus processing concepts developed during the last several decades which appear to offer fresh insight into transfer of training results found in basic and applied research. The paper is organized around the effects of four factors viewed as central to the understanding of transfer of training. These factors are: (1) the relationship between retrieval cues and encoded information; (2) study-phase retrieval; (3) organizational strategies; and (4) performance automatization. In the final section, an analysis of proactive interference results will be made which will try to show that certain of these information processing factors are possible underlying causes of interference phenomena. Each factor is discussed in a separate section in which supporting evidence from a variety of sources is provided.

Encoding and Retrieval Processes and Transfer

For Task 1 learning to influence Task 2 acquisition, it is essential for the trainee to retrieve Task 1 information from memory while being trained on Task 2. The present section will discuss cuing relationships established between Tasks 1 and 2 and their influence on the kind and amount of transfer obtained. In other words, how does Task 2 information serve as a retrieval cue for Task 1 material?

At the turn of the century, Thorndike and Woodworth (1901) proposed one of the first, and most durable, theories of transfer. They suggested that transfer from one task to another would occur only if the two tasks contained identical elements. Recent research on encoding and retrieval processes offers new ways of conceptualizing this identical elements view of transfer.

Encoding Specificity

The encoding specificity principle states that no cue can be an effective aid to an item's retrieval unless it has been encoded with that item (Tulving, 1976). Thus, retrieval is dependent on reinstatement of the precise way in which the item was encoded. This principle is assumed to hold true for all testing procedures such as free recall, cued recall, or recognition.

For example, Thomson and Tulving (1970) presented to-be-remembered (TBR) words in the company of weak associate cues during acquisition and then tested recall of the TBR word using a novel (extralist) strong associate cue. As one instance, BLACK was a TBR word encoded with the weak associate train. A strong associate white was then presented to see if it would facilitate the recall of BLACK. It was found that when BLACK had been encoded in the presence of the weak associate train, the strong extralist cue white was a less effective retrieval cue for BLACK than the original weak associate.

It should be noted that encoding specificity has been supported not only with verbal materials but also with motoric responses. A motor response can be acquired under conditions in which one sensory modality (e.g., vision or proprioception) is relied upon during encoding of the TBR criterion movement. Diewart and Stelmach (1977) showed that in this case, reproduction (recall) is most accurate when the same modality is used at the time of performance. Wallace (1977) showed that the limb used during initial training and the direction of movement must also be the same for optimal retrieval (cf. Lee & Hirota, 1980).

Thus, encoding specificity emphasizes both the importance of the encoding context in determining the conditions under which items can be retrieved and the necessity of retrieval cues directly overlapping the information encoded initially. The retrieval cue can be a copy of the TBR item as in recognition, some co-occurring item or some attribute or dimension of the item. This last point is important because it suggests that is is possible to retrieve an item with partial stimulus information.

Researchers have suggested that a stimulus can be conceptualized as a collection of attributes or features (e.g., Smith, Shoben & Rips, 1974; Underwood, 1969). Different contexts can be viewed as biasing different features of the same stimulus. For example, Barclay, Bransford, Franks, McCarrell, and Nitsch (1974) had subjects learn TBR words presented in different sentences which biased their interpretation, e.g., The PIANO was tuned, or The PIANO was lifted, suggesting the piano as either a musical instrument or a heavy object. Recall was better when retrieval cues suggested features that were relevant to the specific encoded aspects of the TBR word as determined by the context. Cues which suggested other aspects of the TBR word were less effective.

Flexser and Tulving (1978) among others have suggested that different stimulus features vary in their redintegrative capacity. Redintegration refers to the capacity of one part of a stimulus complex to re-evoke or cue the entire complex. A stimulus feature which can usually re-evoke the entire stimulus complex can be considered a cue with high redintegrative capacity while a feature which has only a low probability of reinstating the stimulus complex can be considered to have low redintegrative capacity. For example, the first letters of words are typically better cues than are interior letters (Nelson, 1979). The concept of redintegration as applied here to stimulus features is important for two reasons: first, it provides a basis for the effectiveness of partial information in retrieving the TBR item, and second, it helps explain why some features are more effective than others. Variations in the encoding of TBR material will affect the relative salience or importance of the constituent features and this will in turn affect their redintegrative capacity (cf. Horowitz & Manelis, 1972).

Hagman (1978) has provided evidence for different redintegrative values in the cues controlling discrete motor performance. Undergraduates were instructed to learn either a distance or location cue while performing a discrete motor response (moving a wooden element along a wooden bar). The effects of interpolated movements which varied these cuing dimensions on response recall were consistent with the idea that the originally instructed cue had acquired differential importance on cuing the response. Neither repetition nor variation of noninstructed kinesthetic cues had an additional effect on recall unlike the significant effect produced by manipulation of the instructed cue (cf. Adams, 1971; Russell, 1976).

How do these findings and concepts provide a basis for explaining transfer of training results in the applied area? The identical elements approach has generally focused on the correspondence of the S-R associations exhibited in Tasks 1 and 2. However, we can provide a somewhat different perspective by noting the importance of a correspondence between the retrieval information present in Tasks 1 and 2 for the recovery of task relevant material during transfer.

The literature on cued retrieval suggests that stored information is a joint function of the way in which the material was originally encoded and the cues or information available at the time of retrieval. To the extent that the information stored on the first task is encoded in such a way as to be retrievable with the cues available on the transfer task, then we should see positive transfer given similar responses. However, if the encoding of Task 1 material is idiosyncratic, impoverished or otherwise incompatible with the retrieval information present in the transfer task, we should see little or no positive transfer.

In terms of retrieval, the redintegrative value of the available retrieval information is the critical determinant of its effectiveness. Transfer should be highest when the stimulus attributes with the highest redintegrative capacity are present in Task 1 and 2. If a person learns to make a particular response only in the presence of specific stimulus attributes, then, retrieval of the response from memory is highly probable only when those attributes are present. The experimental literature further shows that the stimulus environment cannot be considered as a unitary structure entering into an association with the verbal or motor response component. Instead, certain elements or features of the stimulus can carry a disproportionate weight in the formation of such an association. To the extent that particular cues add little or no redintegrative capacity to retrieve TBR information, they should have minimal effect on transfer.

Cuing Properties of Simulators

The use of simulators to teach trainees how to operate aircraft and other equipment has been an area of research based on the identical elements approach. For example, the airplane simulator is supposed to provide the kind of environment that would be experienced by a pilot in an actual airplane. To the extent that the simulator has a high correspondence (more identical elements) with the actual equipment, it can be said to possess high fidelity.

The transfer effectiveness of simulators is well established (e.g., Valverde, 1973; Lintern, 1980) and as Gerathewohl (1969) has noted, high fidelity simulators specifically have demonstrated their value. Unfortunately, high fidelity simulators are expensive to construct and the amount is usually directly proportional to the degree of fidelity (cf. Adams, 1978). As a result of this cost, much effort has gone into determining how much fidelity is needed, i.e., how far a simulator can deviate from the actual equipment and still produce high positive transfer. From our discussion, we can infer that simulator fidelity can be based on those stimulus attributes which have high redintegrative value for the appropriate response. Those attributes which have lower redintegrative value can be eliminated to reduce cost without significant loss of transfer.

A consideration of these cuing relationships can help to clarify some of the inconsistent research findings related to the degree of fidelity required for simulator utility which have proved refractory to analysis in the identical elements approach. Motion has been a cuing dimension found to exert inconsistent effects on performance (e.g., Jacobs & Roscoe, 1975; Caro, 1979). One reason for this inconsistency is that different kinds of motion (e.g., cockpit motion, rough air simulation, etc.) have different effects. National Air and Space Administration researchers (Rathert, Creer, & Sadoff, 1961) found a significant correlation between increased motion and pilot performance with an unstable or sluggishly responding aircraft. Jacobs & Roscoe (1975) found that motion cues are not useful in transfer to aircraft that are easy to fly, however. Wilcoxon, Davy & Webster (1954) found no significant differences between groups trained with or without rough air motion for basic instrument and radio range procedures. Ruocco, Vitale & Benfari (1965) showed that cockpit motion on a simulated carrier landing task did improve performance as measured by successful landings, altitude error, and time outside the flight path.

Gundry (1977) notes that aircraft motion cues can occur either because of pilot control (e.g., changes in direction or altitude) or because of external forces (e.g., turbulence). He has hypothesized that motion cues may be redundant in the case of pilot-initiated changes not only because the pilot is already alerted to the change but also because aircraft are designed to be as stable and easy to control as possible in normal use. In such a case, other stimulus information is enough to cue the appropriate response. Disturbance induced motion cues, on the other hand, may be more essential to pilot response when other cues (e.g., visual) are inadequate.

The motion studies mentioned above support two basic conclusions relevant to the current information processing approach. First of all, positive transfer was not a rigid function of the degree of identical elements in Tasks 1 and 2. Similar levels of positive transfer were found despite variations in the level of correspondence between Task 1 and 2. Secondly, some stimulus attributes of the training environment were more important to the retrieval of TBR material than were other attributes. The degree to which a particular stimulus attribute functioned as a retrieval cue for current responding seemed to depend on the nature of the TBR material and the extent to which other retrieval information was available.

These results suggest that it is the specific relationships between the information available at retrieval and the encoded information which is crucial to transfer. In this view, it is not fidelity per se that contributes to high positive transfer; rather it is the presence of retrieval information in Task 2 which has a high redintegrative capacity for the essential Task 1 material. Low fidelity devices should be effective in producing transfer as long as they provide the trainee with the essential cuing relationships between the stimulus attributes of the task environment and the appropriate responses.

Another point that can be made is that even when both a low fidelity and a high fidelity simulator specify the most essential cuing relationships, the low fidelity device may be more effective because it contains fewer inessential elements. The isolation of the most relevant information should provide trainees with simpler encoding requirements in Task 1, and increase the probability of the appropriate acquisition of the TBR material. Improper stimulus encoding is likely when trainees are unfamiliar with the requirements of Task 1 or 2 and when the TBR material is complex (e.g., Ornstein, Nichols, & Flexman, 1954; Caro, 1973).

It should be noted that decreases in simulator fidelity seem most feasible for tasks that require fixed procedures (e.g., Baker, Cook, Warnick & Robinson, 1964; Bernstein & Gonzalez, 1971). For example, Prophet and Boyd (1970) found that a cockpit mockup made of plywood and photographs was about as effective as instruction in the aircraft itself on tasks such as aircraft pre-start-up, start run-up, and shut-down procedures. Grimsley (1969) reported the results of a simulation study which examined variations in Task 1 fidelity on operation of the control panel for the Nike-Hercules guided missile. Low aptitude subjects were trained on either a high fidelity hot panel (physical and functional duplicate), cold panel (physical nonfunctioning duplicate) or low fidelity reproduced panel (full size artist's representation of hot panel). Testing was conducted immediately after training and also four and six weeks later. The results showed no significant difference in training time, initial Task 2 performance, amount retained or retraining time as a function of task fidelity.

On the other hand, tasks in which it is difficult to identify the specific cues which control responding may require more fidelity in the training situation. Salvendy and Pilitsis (1980) developed training simulators to teach suturing techniques to medical students. Three training methods were used: electromechanical, perceptual, and a combination of both. A standard instruction (lecture) group was used as controls. The electromechanical method taught students how to puncture simulated tissue with the aid of a mechanical device which provided auditory and visual information on the correctness of the technique performed. The perceptual method involved watching filmed performance of both expert surgeons and inexperienced medical students. The trainee was instructed to analyze the student's performance by comparing it to that of the surgeon's. The third experimental method was simply a combination of both procedures.

The results showed that the electromechanical and combined electromechanical perceptual groups had the highest transfer performance levels and were essentially equivalent. The perceptual-only group's performance was not significantly different with the control group in the number of good sutures, although instructors did rate their performance as somewhat higher. These results suggest that essential cuing information is provided by the actual performance of the suturing technique which is difficult to impart through alternative (lower fidelity) means.

We can apply the same reasoning to the studies of airplane simulators which showed significant effects of motion on transfer performance. Simulator motion cues seemed to be most crucial to the successful transfer on those tasks in which motion provided information as to the correct response to be performed; information that was not present in the other stimulus information available to the trainee. Thus, motion cues were useful on a carrier landing task (Ruocco et al., 1965) but made little difference on instrument and radio range procedures (Wilcoxon et al., 1954).

Up to now we have considered the effects of cuing relationships on positive transfer, however, it is possible for (inappropriate) cuing relationships to exist between Task 1 and 2 which could lead to zero or negative transfer. One such example would be when relevant Task 1 information has been encoded and retrieved using attributes which are not present on Task 2, e.g., augmented feedback. Augmented feedback, or the use of special cues which provide supplementary or augmented information concerning responding, often facilitates Task 1 performance (e.g., Briggs, 1969; Michelli, 1966). However, its effect on Task 2 performance is much more variable and can produce zero or negative transfer (e.g., Bilodeau, 1952, 1969; Welford, 1968). As Welford (1968) notes, augmented feedback cannot be expected to increase transfer when the subject comes to rely on it for performing the correct response instead of helping the subject to observe and better use inherent task information that will also be available in Task 2. These and the other findings discussed previously highlight the importance of examining and specifying the precise relationship between the retrieval information and the encoded materials present on Tasks 1 and 2.

Although we have examined the importance of cuing relationships in determining transfer through consideration of such phenomena as encoding specificity, we have not specifically discussed ways of manipulating the relationship between cues and TBR material which increase the likelihood of positive transfer. Therefore, we will next consider one line of research which sheds some light on this question.

Distinctiveness of the Cuing Relationship

Distinctiveness and Memory. Basic research of encoding and retrieval processes involved in the initial acquisition of material has highlighted the importance of the distinctiveness and differentiation of cue-TBR-item associations from each other. Items differentiated in memory are more likely to be retrieved given appropriate retrieval information than are items which are not differentiated (cf. Nelson, 1979). An important point raised by Eysenck (1979) is that distinctive material may well tend to be processed better than non-distinctive material.

To the extent that a particular stimulus contains features which are unique or infrequent relative to the set of items from which it has to be discriminated, a retrieval cue containing those features will contact that particular item better than the others (cf. Watkins, 1979). Decreased distinctiveness, for example, in the form of acoustic similarity between letters or words impairs discrimination of such items (Nelson & Rowe, 1969) and words with irregular orthographic patterns are retained better than words that are orthographically common (Hunt & Mitchell, 1978; Zechmeister, 1972).

Stimulus Predifferentiation. One area of transfer research relevant to the issue of stimulus distinctiveness is stimulus predifferentiation (SP). In SP studies analyzing transfer, individuals are typically either simply pre-exposed to stimuli used in the training task (e.g., observation training) or are given training emphasizing their distinctiveness (e.g., labeling training). During SP (Task 1) training the subject learns to differentiate among the task stimuli and it is this knowledge which has to be transferred to the new task; a typical measure of transfer being the facility with which the Task 2 responses are associated with these stimuli. In general, differential responding to different task stimuli would seem to involve keeping the different stimuli distinct in terms of their response implications (cf. Ellis, 1973).

Although some SP transfer research involves motor responding or applied learning, it should be noted that the majority of studies involve more conventional laboratory materials and tasks (e.g., verbal or pictorial learning). Nevertheless, SP as manipulated by labeling training or observational training have been found to accelerate the acquisition of both discriminative verbal (Ellis, 1973) and motor responses (Arnoult, 1957).

Ellis and Muller (1964) studied SP effects using verbal labels for random shapes. Although observation training yielded superior transfer for recognition of simpler six-point shapes, distinctiveness pretraining was superior for 24-point shapes. It should be noted that a large number of trials were provided, allowing for the observation group to locate distinguishing features without the aid of explicit distinctive labels. Ellis and Schaffer (1974) showed somewhat similar results in that predifferentiation training was more effective with stimuli consisting of complex random shapes and letter matrices than it was with CCC trigrams. Similar findings have also been obtained with children (Katz & Zigler, 1969). Labeling of similar stimulus pairs was more effective in terms of transfer with younger rather than older children; the younger children presumably finding the task more difficult. We can, thus, see a general effect of task difficulty on predifferentiation effectiveness.

Price and Slive (1970) have argued that the principal effect of label relevance is to increase the probability that the representation formed at the time of encoding will be matched by the representation given at the time of retrieval. Nagae (1980) has provided independent evidence that the verbal labels do possess an effective discriminating function at encoding. An experiment by Trabasso (1963) highlights the importance of emphasizing relevant features using a concept learning task. Flower patterns were the materials used. Angle of leaf was the relevant dimension and it was emphasized in different ways in different groups (e.g., exaggerating the angle, adding color). The experimental groups learned faster than the control group and transferred use of the relevant feature to a new, harder problem.

Significant transfer effects have been shown as a result of stimulus pretraining with both discrete, discrimination-type (Posner & Keele, 1973) and continuous perceptual motor tasks (Wood & Gerlach, 1974). In the latter study, the focus was on the effects of audiovisual pretraining on a continuous perceptual motor task used in flight simulation. The pretraining consisted of the presentation of specific instruments involved in the criterion task of take-off and controlled climb or descent. Only three states were allowed for each instrument in pretraining, thus, permitting the discrete presentation of the relevant stimuli in the flight task. A first measure of transfer was level off time. Significant increases in performance as a result of stimulus training were found late in transfer task training. A second transfer measure was a combination of two pitch error scores. On this measure, significant differences between conditions were evident only during the early Task 2 trials.

Summary

The importance of the relationships between the retrieval cues available during Task 2 performance and the material encoded in Task 1 for transfer of training has been shown in a variety of experimental and applied research paradigms. The conditions under which Task 1 information can be retrieved using cues present in Task 2 are shown to be an important determinant of transfer of training in both verbal and motor learning. Positive transfer is promoted to the extent that the cuing relationships between the transfer task and Task 1 are distinctive and have high redintegrative value.

These considerations are shown to be useful in analyzing applied research, including the potential effectiveness of simulators for aircraft and other mechanical equipment in transfer of training. Variations in simulator fidelity to the transfer environment have led to contradictory and ambiguous results. Analyses of these studies of simulator effectiveness support the idea that the fidelity of a simulator to the actual instrument can be based on these attributes which have high redintegrative value for correct responses. Those attributes which have lower redintegrative value can be modified or eliminated without substantial loss of transfer. Additionally, the distinctiveness of the cue-TBR-item relationship was shown to be an important factor in transfer studies utilizing stimulus predifferentiation techniques.

Study Phase Retrieval and Transfer

In the previous section, we examined the situation in which Task 2 retrieval information provided access to the relevant information encoded in Task 1. The TBR information was useful in more or less direct fashion for transfer task performance. However, in different circumstances, the information retrieved from Task 1 can be put to other uses. If it is compared and integrated with information that is under study, then a higher order concept or new relation may emerge under appropriate conditions. This use of retrieved information is usually termed study-phase retrieval, in which information in a second task acts as a retrieval cue for Task 1 information necessary for a higher order integration of both items or sets of material (cf. Jacoby, 1974; Hintzman, 1976). It should be noted that this situation falls within the definition of transfer of training in that Task 1 (or item 1) learning influences the way in which the transfer task (or item) is learned (cf. Clark, 1978). In the current section, we will be examining several kinds of transfer phenomena which involve the integration of information over successive occurrences of related material. First, we will examine some of the variables influencing the integration of textual materials. Following this, there will be an extensive analysis of the way in which stimulus and motor variability in Task 1 training promotes transfer and the connection of these phenomena with the operation of an abstractive process based on the integration of information across successive presentations of TBR material.

Textual Integration

One common use of a study-phase retrieval process is in the processing of prose materials as in a textbook. Information from one sentence or passage typically has to be compared or integrated with information from a prior passage. Often, the comprehension of the second passage is dependent on retrieval of the prior encoded material. Thus, the second passage would need to act as a retrieval cue for that information. The relationship between the two passages can be explicit, as in verbatim repetition or directed reference to the other passage, or it can be implied as with anaphoric reference or ellipsis. (An example of an anaphor would be the word so in the sentence: They are going to lunch and so are we.)

For example, Jarvella (1973) asked subjects to recall or recognize either of the final two sentences of a recorded dialogue. There were three conditions of textual integration of the final sentences with prior material: implicit co-reference, explicit co-reference, and novel (unrelated) reference. For full sentences, no co-reference led to significantly worse recall than with either implicit or explicit co-reference. For some recognition judgments, implicit co-reference produced the highest retention; however, for minor paraphrases, the overt co-reference was best. These results suggest that listeners or readers maintain some continuity between successive segments of discourse or text. It is when a current sentence contains primarily new information and is relatively independent of the preceding sentences that the most forgetting of the prior information occurs.

In general, it is the clarity of the reference which is the key factor in producing comprehension or integration (Carpenter & Just, 1977; Haviland & Clark, 1974). For example, Yekovich and Walker (1978) have shown that more repetition of a word is of little help in integrating sentences when a common conceptual representation has not also been identified. A number of specific variables have been shown to be important in promoting reference clarity such as the degree of linguistic correspondence between the cuing and TBR information (Yekovich, Walker, & Blackman, 1979) and whether or not related items occur consecutively in the text (Hayes-Roth & Thorndyke, 1979).

It would be expected that the learning of a second passage containing referents to previous material would be facilitated to the extent that such information could be used in comprehending the transfer material. Haberlandt and Bingham (1978) showed that certain inferences are activated by the first sentence in a set of sentences and that subsequent sentences are processed faster if their content is consistent with these inferences (cf. McKoon & Ratcliff, 1980). Royer and Cable (1975) examined the pattern of subjects' learning involving two passages dealing with scientific material (heat and electricity). For the experimental subjects the initial passage contained either concrete or abstract referents for difficult (abstract) material in the transfer passage. Control subjects received on initial passage unrelated to the transfer material. The subjects in the concrete-abstract condition recalled significantly more of the transfer material than did subjects in the abstract-abstract condition or the control-abstract condition receiving the same second passage. As the authors note, such treatment differences are more likely when the transfer material cannot be easily related to existing knowledge.

Study phase retrieval may be a necessary but not sufficient condition for positive transfer to a second passage, since it is the task specific effects of the study-phase retrieval of encoded information which are important in a particular situation. Campione and Brown (1974) showed that transfer on discrimination problems was affected by the degree to which the training format on different discrimination problems fostered integration of the relevant information (cf. Royer, Perkins, & Konald, 1978; Sullin & Dooling, 1974).

Stimulus Variability and Transfer

The Effects of Task Variation. One of the most studied training factors has been the relative effectiveness of variation or stability of Task 1 training on Task 2 performance (e.g., Hunt, Parente, & Ellis, 1974; Schmidt, 1975). There is increasing evidence that an important factor in the positive transfer often induced by task or item variety in training is the operation of an abstractive process linked with study phase retrieval. The retrieval of relevant information during the performance of the different training tasks would be used for the purpose of comparing and abstracting the existing commonalities or invariant relations which unite them.

The beneficial effects of variety on transfer have been demonstrated in many different types of tasks such as free recall learning (Ellis, Parente, & Walker, 1975), serial learning (Baker, Santa, & Gentry, 1977), motor learning (Schmidt, 1975) and the acquisition of elementary mathematics (Burton, Lemke, & Williams, 1975). Several applied studies have provided evidence for the same transfer benefits from variable conditions of initial training. Lovaas and Simons (1969) noted improved transfer of punishment treatment for self-destructive behavior in retarded children when punishment was administered by several individuals as opposed to only one (cf. Wehman, Abramson, & Norman, 1977). Hagman (in press) examined the effects of training schedule and equipment variety on maintenance tasks retention and transfer (e.g., electrical repairs). Although equipment variety had no effect on basic retention, it did significantly enhance transfer test performance when training was given under spaced conditions (i.e., one day rest pauses).

These and other studies suggest that transfer is enhanced as a result of variation in Task 1 conditions although it should be noted that the degree of learning is an important moderating factor (e.g., Bevan, Dukes, & Avant, 1966). For example, Morrisett and Hovland (1959) examined the individual contributions of degree and variety of Task 1 learning on a discrimination task. The group receiving moderate training and moderate variety of problems was superior to the groups with high original learning and low variety and with low original learning and high variety in that order (cf. Gilbert, Spring, & Sassenrath, 1977).

At this point, we have seen that training variability is a factor with important implications for transfer. The extent to which the effects of training variability can be ascribed to the integration and abstraction of the TBR material over its successive presentations will now be considered.

Concept Formation or Abstraction. In this section we are interested in those transfer studies which examine the way in which subjects integrate information from a number of events to aid abstraction and the formation of simple concepts. Such simple concepts or prototypes are often nonverbal in nature, consisting of geometric or other kinds of figures or patterns which can be varied systematically on particular dimensions.

Posner and Keele (1968) trained subjects to correctly classify four distortions each of four unseen dot pattern prototypes. The subjects were then tested on transfer to patterns consisting of the prototypes they had not previously seen, old previously learned distortions or control patterns which were equated so that they had the same mean variation as the original distortions. In the transfer task, the prototypes were classified into the correct group significantly more often than were any of the equated control patterns. Posner and Keele (1970) used the same test but with a delay of a week interposed between stimulus exemplar presentation and the transfer task. The previously unseen prototypes were "recognized" at least as well as the four presented distortions derived from it. Furthermore, correct classification of the prototype showed no loss over the week while performance on the original patterns suffered significantly. Thus, extraction of information concerning central tendency takes place during original learning of the distorted (varied) patterns and is not thereafter mediated by them. This result suggests that another representation has been formed which represents the abstracted or prototypical knowledge (cf. Salthouse, 1977).

Homa (1978) used figure drawings of ill-defined forms to further investigate this abstractive process. Subjects initially classified 18 different patterns into three categories which contained 3, 6, or 9 members. Following this task, a transfer test was given in which old exemplars, new exemplars, prototype and random patterns were presented for classification. In another experiment, categories were defined in Task 1 by 4, 8, 16, or 32 exemplars, followed by a transfer test which contained unrelated and new patterns based on the categories at each of six distortion levels. In both experiments, prior training on numerous different exemplars enhanced transfer compared with training with a few exemplars.

The importance of variability has also been emphasized in the context of verbal learning (e.g., Martin, 1972; Battig, 1978) although there has been conceptual disagreement as to the basis for its effectiveness in promoting retention and transfer. One viewpoint is that variable encoding can improve retention and transfer because it provides more different ways in which to retrieve the TBR material (Madigan, 1969; Bower, 1972). This account minimizes the importance of an abstractive process involving study-phase retrieval of prior related material and emphasizes the role of multiple, independent representations of the TBR material.

More recent theory and data, however, have provided support for an interpretation more consistent with the findings from the non-verbal prototype studies considered above. The importance of the integration of information across successive variable presentations has been demonstrated by a number of studies of verbal retention. Johnson and Uhl (1976) showed that repeated items which were recognized as having been presented twice, and therefore encoded on the second presentation with reference to the first encoding, were recalled better than those not recognized on the second presentation (cf. Belleza, Winkler, & Andrasik, 1976). A number of studies indicate that variations in the encoding context contribute to retention or inferential reasoning if the different information is all grouped within a common functional representation (e.g., Moeser, 1976; Young & Belleza, 1982).

Nitsch (1977) examined the extent to which different encoding contexts can contribute to positive transfer in verbal concept learning. Novel verbal concepts (e.g., minge-to gang up on someone) were defined by examples that either were derived from one context or a number of varied contexts. Although Task 1 learning was better in the condition using examples from one context, transfer performance to new examples of the concepts in a different context than previously encountered was better after varied context training.

Battig (1978) has argued that increased contextual interference (variability) during learning of TBR material can lead to improved retention or transfer, particularly when subjects are tested under changed conditions. Such interference would make irrelevant contextual information, which cannot be functionally grouped into a common representation, less likely to be retrieved along with the TBR item. Thus, the TBR item becomes abstracted or decontextualized. One way of producing interference between irrelevant contextual attributes would be to increase the variability of an item's contextual presentation; the stable attributes would gain associative strength relative to those attributes which are constantly being varied.

For example, Hiew (1977) reported improved retention and transfer in verbal rule-learning following training under variable contextual conditions.

These studies support the idea that subjects, when sensitive to the occurrence of related or similar TBR material across different presentations, can integrate new material with that already in memory into a common representation. Stimulus variability aids transfer by exerting an effect on this process in two ways: it provides a means by which the subject can distinguish relevant from irrelevant attributes (abstraction) and enhances the probability that additional relevant attributes will be encoded into the functional representation of the TBR item. The integration of the new material with that already in memory would necessitate some form of a study phase retrieval process.

Motor Variability and Transfer

The Effects of Task Variation. Variation of the exemplars or tasks used to provide motoric training displays transfer effects similar to those seen with verbal or cognitive tasks (e.g., McCracken & Stelmach, 1977). It has been argued that motor schemata (prototypes) are best formed through variable practice (e.g., Schmidt, 1975), although we should qualify this statement by noting that abstraction will occur only to the extent that such variability does not preclude invariances in the stimulus or motoric parameters (cf. Zelaznik, Shapiro, & Newell, 1978).

Variable practice has been shown to produce increased transfer in situations outside the normal range of practice (Newell & Shapiro, 1976) and to more persistent transfer performance on tasks within the range of original practice (Williams & Rodney, 1978). Moxley (1974) showed similar effects using a complex motor task with children as subjects. Wrisberg and Ragsdale (1979) showed that high variability of the stimulus conditions cuing the performance of a discrete button press response reduced error scores relative to low variability training.

In a study by Shea and Morgan (1979) Task 1 training conducted under variable contextual conditions showed increased transfer to a second task. The largest transfer effect was found on the transfer task of greatest complexity. However, it should be noted that while transfer was improved, initial acquisition of the first task was impaired by high contextual variability conditions (cf. Dunham, 1977). These results mirror those found in verbal learning (e.g., Nitsch, 1977).

There is broad evidence that variability of motor practice on Task 1 is beneficial if the trainee is acquiring a motor skill performed in a relatively stable environment (e.g., throwing objects at fixed targets).

This type of task has been termed a closed skill by Poulton (1958). Typically, studies of this kind have either varied spatial components of the task such as target location (Husek & Reeve, 1979; Kelso & Norman, 1978), position of the trainee with respect to a fixed target (Moxley, 1979), movement velocity (McCracken & Stelmach, 1977), or movement time (Newell & Shapiro, 1976).

Less evidence is available on the effects of varied practice on open skill acquisition and transfer in which the response must be changed according to the particular momentary circumstances (e.g., throwing at a moving target). The Wrisberg and Ragsdale study did show that training with varied stimulus velocities facilitated transfer to a situation with a new response condition. However, response variability _per se_ was not manipulated.

Guidance vs. Discovery Training. A discrete area of perceptual motor research on the effects of training variability has been the investigation of the relative effectiveness of guidance versus discovery training. Under a guidance learning procedure, trainees are shown or told the correct response in a given situation. In contrast, a discovery learning procedure encourages trainees to self-discover the correct response by way of a trial and error process.

In general, guidance has been reported to be either as effective (Prather and Berry, 1970) or more effective (Singer and Gaines, 1975; Singer and Pease, 1976) than discovery training in promoting Task 1 learning. Transfer results, however, have not been as straightforward. For example, some researchers have found that transfer task performance after guidance training is either equal to (Bilodeau and Bilodeau, 1958; Holding, 1959) or greater than it is after discovery training (MacRae and Holding, 1965, 1966) and that this superiority increases as the transfer task becomes more complex (Holding and MacRae, 1966). In contrast, other researchers have found that transfer is better after discovery training than after guidance training (e.g., Prather, 1971; Singer & Gaines, 1975; Singer & Pease, 1976).

The relative effects of guidance and discovery training appear to be a function of whether or not subjects experience alternative movements (i.e., variability) during training. Usually, under guidance training only the to-be-learned movement is performed. This lack of experiencing alternative responses promotes learning by eliminating errors and increasing the performance of the TBR movement (Adams & Dijkstra, 1966; Prather, Berry, & Bermudez, 1972). By practicing the correct response subjects develop an accurate memorial representation of the TBR movement. However, when a new response is to be performed, such learning may not transfer readily to the new situation.

Annett (1959) has argued that practicing only the correct response detracts from the subject's ability to discriminate it from among similar alternatives. This inability to discriminate one response from another impedes transfer task learning. In support of this notion, MacRae and Holding (1965) have shown that subjects who perform guided alternative movements during training show improved final task performance compared with subjects who were only trained on the single, to-be-learned movement. Thus, better transfer from discovery learning methods may be due to the alternative movements performed during the training task. Even in one of the studies cited previously to reveal the benefits of guidance on transfer (Bilodeau and Bilodeau, 1958), subjects were able to experience a limited degree of alternative movements during guidance training. This experience may have caused the effective transfer. Thus, as suggested by Holding (1965), it appears as though knowledge of the correct response is incomplete if there is no opportunity to define it against similar incorrect alternatives.

The relationship of this line of research to both the abstractive process and the encoding specificity studies would seem to be a promising area to investigate. Guidance training essentially relies on the correspondence of the encoded Task 1 information with particular retrieval cues that are expected to be present in the transfer task. This method is successful to the extent that the expected retrieval conditions can be presumed to be consistently in effect in the transfer task. Similar effects have been shown in the encoding specificity studies in which items encoded with respect to one particular cue become more difficult to retrieve when that cue is not present at the time of retrieval.

With more complex transfer conditions, the discovery method may be more likely to lead to positive transfer if it promotes the abstraction of the most task relevant information through the variations in initial training conditions (whether subject or experimenter generated). The operation of abstractive processes in the integration of successive experiences may play a critical role because errors help define the critical dimensions of successful performance in situations in which these elements are not easily specified to the trainee. In addition, if the information that will be present in the transfer task cannot be precisely specified there can be value in learning what information can safely be ignored. In other words, contextual variability in training insulates transfer performance from the negative effects of irrelevant contextual change between Task 1 and 2.

Summary

The integration of information across successive instances of related information presentation through study phase retrieval seems to be a critical process in increasing positive transfer to novel tasks and information.

The juxtaposition of different events can result in the formation of higher order concepts, as in textual prose comprehension, or can facilitate the abstraction of critical dimensions of task performance and stimulus recognition. This process can be accomplished through the appropriate variation in initial training used to define the critical dimensions. The process seems to be applicable to both verbal and motor transfer as manifested by the effects of variability of practice on later performance in transfer. It was also shown to be useful in understanding the relative effectiveness of guidance versus discovery training.

Organizational Strategies and Transfer

The discussion of abstractive processes and information integration contained in the previous section provides a natural introduction to the present topic which concerns the effect of organizational strategies on transfer of training (cf. Tulving and Donaldson, 1972). To the extent that previous learning provides a framework for the categorization and interpretation of new material, then transfer should be facilitated. As we shall see, organizational variables can be a powerful influence on the learning of new but related tasks; however, the effect is not inevitably positive. If the transfer task does not meet the organizational criteria that were previously established, then negative transfer can occur.

Organization and Learning

It has long been noted that short-term memory (STM) places limitations on the information processing capacity of an individual at any given time. Techniques that can pack extra information or increase the retrieval efficiency of items processed through STM should increase the total amount of information that can be processed in usable form (Miller, 1956; Watkins, 1979). For example, the appropriate organization of items containing some common attribute should reduce the number of retrieval cues needed to make contact with the traces, if they are encoded so that the common feature is made salient.

Empirical evidence for the connection between organizational strategies and increased recall of word or number lists has been available for some time (e.g., Bousfield, 1953; Cohen, 1963; Birnbaum, 1975), at least where clear and distinct categorical relationships exist between the target items. Organization seems to exert its effect through the linking of multiple items to higher order control elements or categories. However, the categories themselves are treated as any other item in memory would be (Cohen 1963; Tulving & Pearlstone, 1966).

The same kind of organizational effects can be seen with prose passages as well as word lists. Buschke and Schaier (1979) showed that text-based story recall involved the retrieval of distinct memory units which are clustered together. Th. recall units correspond with the propositional units of the story and the organization of recall corresponds to the propositional structure. Thus, story recall involves the recall of propositional units organized by a story schema (cf. Thorndyke, 1977). Thus, there seem to be parallels in the organizational strategies used with prose materials with that of word lists, indicating their general mnemonic utility. One other indication of this generality is the apparent equivalence of instructions to organize materials and instructions to recall (Mandler, 1967).

Schemata and Transfer

Schemata are generally defined as integrated sets of procedural and content knowledges concerning a particular domain which guide the encoding of new information and enhance its retention. The concept of the schema and its use in processing new information has been proposed by a large number of researchers (e.g., Anderson, Kline, & Beasley, 1979; Bobrow & Norman, 1975). In a real sense, the use of schemata or other organizational strategies can often be regarded as a transfer variable even when Task 1 learning is considered, since typically the schema or organizational framework has already been acquired before its effect is measured on Task 1.

Positive Effects. As we would expect from the studies of organizational strategies considered in the previous section, the use of schemata can enhance positive transfer to the acquisition of new, but relevant information (cf. Frase, 1975). A study by Chiesi, Spilich, & Voss (1979) provides a good example of the facilitated learning of domain relevant information associated with the use of an appropriate schema. Subjects with different levels of baseball knowledge were given passages of domain relevant information and then tested on retention of the new information. High-knowledge subjects had a higher probability of recognizing the TBR material, particularly when such information was important in terms of their other domain-relevant knowledge. In addition, these subjects needed less contextual information to make correct recognition judgments than did low-knowledge subjects and were superior at recalling event sequences. This latter effect was due to their greater capacity to relate successive segments of input information.

Studies of expert chess players have shown that they possess a high capacity to retain novel arrangements of chess pieces on the chessboard that are consistent with the general requirements of sound play. However, their memory for random arrangements of the chess pieces is no better than the non-expert subject (Chase and Simon, 1973). These studies suggest a close connection, incidentally, between the usefulness of a schema in a particular situation and its capacity to aid study phase retrieval of relevant information while new information is being processed.

One line of research into this question has been the examination of the effects of advance organizers, pre-questions, and other organizational aids in the learning of new educational material. The purpose of these various procedures is to provide the trainee with a schema which can be used to facilitate the integration and comprehension of the material. Advance organizers provide abstract higher order information relative to the passages to be learned (cf. Ausubel and Fitzgerald, 1962; Ausubel, 1977). The objective is to permit the hierarchical organization of less inclusive concepts and information encountered in the text under appropriate super-ordinate concepts.

For example Mayer and Bromage (1980) had subjects read a text concerning a new computer programming language. One group was provided with an advance organizer passage which provided a higher level framework for interpreting the new material while another group was given the organizer after reading the text. The advance organizer group demonstrated higher recall of conceptual idea units and made more novel inferences. The after group did score higher on the recall of technical idea units however. Similar results have been reported using television instruction (Nugent, Tipton & Brooks, 1980) or oral instruction (Alexander, Frankiewicz & Williams, 1972).

Negative findings concerning the usefulness of advance organizers have also been reported (e.g., Graber, Means, & Johnston, 1972). This is not particularly surprising given the complexity of the relation between schemata which are essentially as novel to the subject at the time of their presentation as the target material itself. In real-life situations, schemata would more generally be built up over a relatively extended period of experience with a particular domain of material.

Negative Effects. Although schemas have been shown to facilitate acquisition of new material in a variety of situations, such positive transfer is not invariable. With respect to the organizational strategies discussed in the previous section, one consistent finding has been that while information consistent with the schema does show facilitated learning, incidental- or schema-incongruent material is actually learned less well than it would be in the absence of the schema. For example, Dee-Lucas and DiVesta (1980) examined subjects' acquisition of textual material presented in different contexts, i.e., with topic sentences, headings, related sentences or unrelated sentences. Subjects either generated these contexts or had them provided. The organization of the materials, particularly when generated by the subject, resulted in organization-relevant information being learned well, but at the expense of incidental information. The presentation of cues or instructional objectives has the same effect on relevant versus incidental (or cue-irrelevant) learning (Rothkoph & Koether, 1978; Frase & Kreitzberg, 1975).

Interestingly, research on the transfer of problem solving behavior shows similar effects when the problems are organized to promote a particular problem solving method. For example, facilitated learning can occur when subjects are given a series of related problems of graded difficulty proceeding from simple to complex (Sweller, 1976). However, a deficit in problem solving termed "Einstelling" (failure to appropriately change a mental set or schema) can occur when a simple but different problem is substituted for the last of a series of related problems. Sweller and Gee (1978) showed that such negative transfer could be abolished by providing the subject with a clear change in the perceptual cues between the last different problem and the previous problems. In other words, the subject is alerted that the schema that has been used may no longer be appropriate (cf. Weisberg, DiCamillo, & Phillips, 1978).

Motor Schemata

Schema concepts have been applied to motoric behavior as well as to verbal-symbolic materials although the definition of the term necessarily is somewhat different in certain details (e.g., Schmidt, 1975; Newell & Shapiro, 1976; Pew, 1974). Motor schemata refer to a class of actions and the abstract prototype increment of that class which supplies the essential response invariants to each action within the class. According to Schmidt (1975) the schema contains information about the initial conditions, response specifications, response outcome, and sensory consequences of the movement.

Evidence for generalized motoric patterns has been obtained with a number of different types of movements. Shapiro, Zernicke, Gregor, & Dostel (1981) reported that walking behavior displays a number of invariant elements from instance to instance, particularly in the relative timing of particular movements. Similar invariant timing relationships have been found in typing (Terzuolo & Viviani, 1979) and lever rotation (Shapiro, 1976). For example, in typing, the relative timing between letters in a word is constant for professional typists, regardless of the context of the word and the speed with which the word is typed (cf. Turvey, 1977).

Zelaznik, Shapiro, and Newell (1978) provided evidence that subjects develop a rule relating sensory consequence to outcome which is then used to generate a reference for correct performance. For example, if subjects generate a motor recognition schema rather than simply storing all feedback traces separately, then the subjects receiving varied relevant experience should have better transfer performance than those receiving constant experience. In Task 1, subjects experienced movement produced auditory feedback by listening to the taped sound of a rapid timing task, in which rods were moved on a linear trackway. Then, they were were tested on transfer to the actual timing task. The transfer results showed that subjects who received listening experience with the criterion movement time did not exhibit lower error scores than did subjects who received a narrow or wide range of listening experience without ever hearing the criterion movement time. In addition, performance deteriorated over trials with the constant experience group while the variable groups maintained their performance throughout the trials (cf. Kelso & Norman, 1977; McCracken & Stelmach, 1977).

Livesey and Laszlo (1979), in studying discrete tracking tasks, have suggested that the strategy adopted in the first task is important to the degree of transfer obtained. This point is relevant to the observation that organization or schemata facilitate transfer on congruent tasks but retard such performance on incongruent tasks. Fumato (1981) gave experimental groups two tracking tasks, one of which involved far and near movements at short regular intervals while the other involved such movements at irregular, longer intervals of practice. Positive transfer was observed from the irregular to the regular conditions but not vice versa because the strategy used for the regular task could not be applied to the irregular task. This was not the case in the irregular to the regular condition.

Part-Whole Transfer

In this section we will consider the impact of organizational variables on part-whole transfer. As we found previously with other paradigms, organization can have positive or negative effects on part-whole transfer. Incompatible organization between the initial part learning (Task 1) and the whole task (Task 2) can lead to negative transfer while compatible organization promotes transfer.

Tasks themselves can be said to be organized if their parts blend together into an integrated whole such as in simulated flying of an aircraft or aiming a rifle. A task is called unorganized when its parts constitute self-contained independent subdivisions such as in maintenance tasks. Naylor and Briggs (1963) showed that when a task is highly organized, any attempt to divide it up into parts tends to destroy the continuity of individual actions and therefore part training can result in negative transfer to the whole task. For an unorganized task in which parts are independent, this is not a problem, at least when task difficulty is sufficient to justify training one part at a time (Briggs & Waters, 1958; Singer, 1975).

In general, tasks with low levels of difficulty show a corresponding benefit in whole as opposed to part training, presumably because the organization of the task into some coherent unit is typically made easier in such circumstances. Perhaps for the same underlying reason, adults who are more intelligent and have more task-related experience often show more transfer after whole than part training (McGuigan and McCaslin, 1955). In addition as training continues, whole practice is increasingly likely to result in positive transfer (Naylor, 1962).

The influence of organization in part-whole transfer has been examined more analytically in verbal learning (e.g., Sternberg and Tulving, 1974). Typically, such studies have employed successive word lists which subjects have to free recall. The experimental group learns two lists of words in which the second contains some items from the first list randomly mixed in with the new items. The control group learns two unrelated lists. Tulving (1966) found that although the experimental group recalled more items on the initial trials of List 2 learning, the control group eventually surpassed them. Intuitively, it would be expected that if subjects have already learned half the words of the whole list during List 1 learning, then learning the whole list should be easier than if new words from the whole list were learned in List 1. Tulving argued that subjects grouped words into subjective organizational units during List 1 learning and that these units may not have been applicable to the whole second list. The reorganizational process requires added time and offsets any individual advantage due to the prior learning of specific whole-list words during part-list training (cf. Bower and Lesgold, 1969).

More recent research has shown that the magnitude of the negative transfer can be affected by manipulations which tend to make part-list organization either more or less compatible with the whole list. For example, informing the subjects of the relationships between part and whole lists (Novinski, 1972; Petrich, 1973), using blocked rather than random presentation of part list items during whole list (List 2) learning (Ornstein, 1970) and simultaneous rather than successive part and whole list item presentation (Elmes et al., 1972) all decrease negative transfer. Presumably each procedure allows subjects to maintain or create compatible interlist organizations. On the other hand, the probability of negative transfer increases as degree of part-task learning increases (Elmes, Greener, & Wilkinson, 1972).

Schulze and Gorfein (1976) showed that negative transfer is produced when the subject attempts to include new items into the old organization. When the subject organizes the whole list into separate parts corresponding to old and new items, then positive transfer occurs. It is highly possible that one of the subjects' difficulties lies in discriminating old from new terms (Schwartz and Humphreys, 1973). This may particularly be the case when material is presented in cumulative fashion and there is limited opportunity to organize the part-list material (Rundus, 1978).

In essence, the results of verbal part-whole transfer research show that interference between organizational structures developed during successive part-whole list learning leads to negative transfer. When interference occurs, whole task learning is more effective than part task learning. If interference is prevented, part task learning can be as effective or even more effective than whole task learning. These findings may be a reflection of the general tendency of organization to promote the acquisition of information congruent with the schema being used and retard the acquisition of irrelevant or incongruent information that we saw with the use of advance organizers and other such procedures.

Summary

Organizational processes are powerful aids to the learning of new information to the extent that the transfer task can be related effectively to the organizational plan or schema in use. A schema can be regarded as a set of procedural and content knowledges concerning a particular domain of material. Schemata can facilitate both verbal and motoric learning. The use of schemata produces several negative effects on transfer learning. Schema-irrelevant or incongruent information will often be learned less well than if no schema were being used. In addition, transfer material which requires a different schema than the one used on Task 1 will often lead to negative transfer because the subject will spend time trying to fit the new information into an inappropriate schema or try to modify the old schema to fit the new material.

Automatization of Performance and Transfer

In this section we will examine some of the properties of automatized encoding and responding and their implications for transfer performance. One of the most common findings in the training literature is that increased practice almost always leads to improved performance, in terms of both quality and speed (e.g., Newell & Rosenbloom, 1981). It has been widely suggested that skilled performance is due in large part to a decrease in the total amount of attentional capacity that must be devoted to a task and to an increase in the efficiency of responding through the removal of unnecessary elements (e.g., Adams, 1971; Kahneman, 1973). For the most part we will focus on the stimulus processing aspects of automated performance.

The mechanisms by which reductions in attentional capacity can be made without reducing performance have not been completely specified; however, there is substantial evidence that as stimuli become increasingly familiar, they are more likely to be recognized before entering working or short-term memory. The processing of highly familiar stimuli is believed to occur in what is termed a pre-attentional processing stage (e.g., Egeth, 1977; Shiffrin & Schreider, 1977). Such pre-attentive processing has at most a minimal effect on the available resources of working memory so that the individual can process other information simultaneously without deficit.

There are two implications for transfer performance given the accuracy of the above account. First, there should be a high degree of positive transfer to those stimuli in Task 2 which have become automatized in Task 1. Secondly, the reduction of processing effort to a part of the stimulus environment should permit the performance of more complex tasks whose requirements would overwhelm working memory if all processing had to go through it. At this point, we will now concentrate on the specific characteristics of automatized processing as it is acquired and utilized by the subject.

Characteristics of Automatized Processing

Development of Automatization. Automatized processing seems to develop only under particular conditions. Increasing practice or stimulus familiarity is a necessary but not sufficient condition for automatization to develop. It is critical that there also be consistency of practice or stimulus presentation (Schneider and Fisk, 1982). For example, in visual search experiments in which the subject must look for particular items (targets) in an array or field of irrelevant stimuli, large increases in performance speed are found when the same targets are used consistently over different trials (e.g., Neisser, 1963; Logan, 1979). The occurrence of parallel search and processing of stimuli by subjects is indicated by the findings that set size functions (i.e., the number of targets and the time it takes to find them) tend toward zero as practice becomes extended. On the other hand, if the targets are changed from trial to trial, then automatized encoding does not seem to develop even after prolonged practice (Kristofferson, 1972).

Fisk and Schneider (1981) showed that both qualitative and quantitative differences existed in stimulus processing in consistent as opposed to variable stimulus search conditions. Under vigilance conditions, variable target search was characterized by serial and effortful processing while consistent target search was parallel and easy in the sense that it did not overly tax the resources of working memory. Stimulus detection sensitivities dropped significantly under consistent but not under variable search conditions.

In a recent experiment, Salthouse and Somberg (1982) have shown that while the initially most difficult processing conditions show the greatest improvement in response times, such gains in responding can also be seen in simple tasks of signal detection or visual discrimination. As the authors note, these findings indicate that increases in skill can occur even with very basic information processing activities. Thus, skill acquisition cannot be ascribed entirely to indirect factors such as improvements in the coordination or timing of such elements in the overall task.

Automatization and Changes in Cue Utilization. One consistent finding in the literature concerning the effects of extended practice is that changes in the subject's utilization of various cues controlling responding typically occur over the course of training. For example, in perceptual-motor tasks such as tracking, subjects typically rely heavily on visual cues during initial training. As training progresses, however, more use is made of proprioceptive and other internal cues (Fleishman and Rich, 1963). Trumbo, Ulrich, & Noble (1965) showed that more specific visual cuing enhanced initial learning on a pursuit tracking task but had little effect on the final levels of criterion performance or on delayed (30-day) retention (cf. Johnson, 1981).

Such changes in the cues which control responding or stimulus processing presumably occur in the direction of stimulus attributes which are more useful (i.e., more distinctive and correlated) in identifying the stimulus or directing the response to occur. Kessel and Wickens (1982) showed that monitors of automatic pursuit displays who had prior experience relied upon different perceptual cues in making signal detection responses compared with naive subjects. Koonce (1974) showed that motion cues in simulators were more important to experienced pilots' performance although they did not enhance transfer from the simulator to the aircraft. This effect is probably due to the greater correspondence of the simulator motion cues to the cues pilots use or are familiar with in actually flying the aircraft. Thus, their absence in the simulator can lead to some performance deficits since the pilot must make use of less favored cues. In addition, if we follow the logic of encoding specificity, there will be a less precise match between the encoded characteristics of the memory trace and the available retrieval information.

Christina and Anson (1981) showed that progressively less stimulus feedback from visual or kinaesthetic cues is used as practice is extended for response movements which can be performed on other bases. Visual feedback had a positive effect on learning to initiate a positioning response only during initial acquisition. The subject in this situation could rely on a particular motor program or schema. However, with a response involving movement extent which was less susceptible to control by a motor schema, visual feedback exerted a positive influence on both early and late periods of initial acquisition as well as during transfer (cf. Adams, Gopher, & Lintern, 1977).

As these studies indicate, changes in cue utilization occur over the course of extended practice which can affect transfer under the appropriate circumstances. To the extent that the subject in Task 1 attends more strongly to the most functional stimulus information, transfer should be enhanced to other tasks in which responding can also be controlled by these cues. In addition, the control of responding through the use of proprioceptive or other internal cues would seem to insulate the subject in many situations from variations in the stimulus conditions in which the behavior must be performed.

Stimulus Specificity of Transfer with Automatized Processing

In the previous section we saw how extended practice in appropriate situations could result in changes in cue utilization from exteroceptive to internal sets of cues to control responding. Nevertheless, in many cases, automatized performance still is controlled by the occurrence of specific exteroceptive stimulus information. Thus, the question arises as to the degree to which transfer of automatized training is specific to the stimuli trained in Task 1. Actually, the weight of evidence seems to indicate that the generalizibility of automatized training is somewhat narrower than are other types of Task 1 training.

Schneider and Fisk (Note 1) showed high transfer of automatized processing to stimuli in the same class as the original stimuli. Subjects were trained under consistent conditions to detect words from a particular category such as colors. After extended training, subjects were presented with novel words from the same category and showed high (92%) transfer from the old to the new words (cf. Ross, 1970; Schaffer and LaBerge, 1979).

Nevertheless, the similarities between the original and the transfer task must be substantial, at least on those dimensions that have become automatized, for such positive transfer to be demonstrated. Slight changes in the processing conditions during dual task performance, on which one or both components have been automatized, for example, typically disrupts such performance initially (Schneider, 1982; Logan, 1979). Eberts and Schneider (1980) had subjects detect a sequence of three discrete movements of a line segment. Although automatic processing developed after consistent training to a particular sequence, when the pattern was spatially rotated, the degree of transfer was no greater than after variable training, which does not produce automatized encoding.

There is contradictory evidence on whether automatized processing can be maintained to one component on the transfer task if other components are different from Task 1. For example, conjunction searches, in which a subject must search for a stimulus with two particular attributes (e.g., a red triangle or a green square) do not seem to be automatized to the same degree as searches for stimuli with a single critical dimension (Treisman and Gelade, 1980). On the other hand, Schneider and Fisk (in press) have shown that automatized processing can occur to task components that have consistent requirements even if there are other task components that are not consistent. In general, there seems to be at least an initial deficit in performance even with small changes in the transfer task.

Interestingly, the transfer deficits to different stimuli become greater when stimulus training is extended in Task 1 (Salthouse & Somberg, 1982). This effect suggests that automatized encoding can lead to reduced generalization and positive transfer if extended too long. The automatized processing becomes stimulus-specific to such an extent that almost any stimulus change results in the disruption of such processing (cf. Graboi, 1971; Heimer & Tatz, 1966).

The stimulus specificity of automatized processing can also create more subtle deficits in transfer. Eriksen and Eriksen (1974) showed that reaction times were slowed when irrelevant flanking stimuli were present that were similar to the automatized stimuli even though consistent training occurred only with the latter. The subjects could not stop processing the irrelevant stimuli even when instructed to do so. Shiffrin and Schneider (1977) also found that subjects were unable to stop processing consistently trained stimuli although they were able to do so with variably trained stimuli. In other words, once stimuli or responses become automatized it may be difficult (although not necessarily impossible) to inhibit such processing or responding when conditions chan (cf. Eriksen and Schultz, 1979).

Friedman (1978) presented subjects wit target pictures containing objects which the subject expected or didn't expect to be represented. The subjects had to discriminate the pictures from difficult distractor pictures. Automatized encoding did seem to occur with the expected objects which were apparently processed on the basis of global physical features. On the other hand, unexpected objects elicited more controlled processing;

for example, fixations to unexpected objects were roughly twice as long as to the expected objects. The automatized encoding of expected objects had the negative effect of leading to less detection of missing expected objects or cases in which one expected object was replaced with another expected object. Friedman noted that two events which constitute the same class to the subject may be indistinguishable in automatic encoding (cf. Kolers, 1975).

These findings suggest that the automatization of processing is characterized by a reduction in the amount of information processed about a given stimulus. Presumably, only those attributes which are most highly correlated with the stimulus are processed. However, if other stimuli are presented which share these attributes but differ on others, there may be a failure to note the change because of the more superficial stimulus analysis which the subject is performing. In other words, there is inappropriate transfer from Task 1 training.

In the next two sections, we will examine the implications that automatized processing holds for two other types of transfer phenomena. First, we will analyze the influence of relative task difficulty on transfer between related tasks; and second, we will take a look at time sharing or dual task performance.

Task Difficulty and Transfer

Transfer between easy and difficult versions of particular tasks is often asymmetric; that is, more positive transfer will be found from one training sequence (easy-difficult or difficult-easy) than from the other. It has been suggested that asymmetrical transfer occurs when some aspects of a task are learned more easily at a particular difficulty level than are other aspects (Leonard, Kormes, Oxendine, & Hesson, 1970).

The way in which a particular task is difficult to perform may be the crucial factor in determining the form and direction of the asymmetrical transfer. In this regard, the concept of changes in cue utilization by the subject as training progresses may provide some insight into these transfer phenomena. Difficult tasks which force the subject during practice to make use of more efficient and relevant cues can act to increase transfer to easier tasks which permit less efficient cue utilization. On the other hand, difficult tasks which simply are beyond the information processing capacities of the subject at the time of acquisition will have no such effect on transfer. In the latter case, more transfer should be seen from an easy to difficult training sequence.

For example, in cross-modal transfer studies, greater transfer from the more difficult task to the easier task is generally found (Von Wright, 1970). Butter (1979) trained 30 boys in a scanning strategy on the (visual) Matching Familiar Figures Test and on the Haptic Matching Test. The latter test is generally considered to be more difficult (Wolfgang, 1971). Subjects who were visually trained exhibited decreased errors only on the Familiar Figures Test and actually showed increased latencies on both tasks. However, haptically trained subjects showed decreased errors on both tasks.

This is not a uniform effect in other situations, however. Boswell and Irion (1975) studied transfer along a difficulty dimension using a rotary pursuit task. More transfer was shown in the training sequence in which training was given at 55 RPM and the final test was at 60 RPM than vice versa. The authors note that the optimal training speed is one that is slightly lower than the test speed because relatively less is learned at the faster speed.

This latter observation is a key point. As Miller (1972) notes, in many tracking tasks there is positive transfer from lower to higher order systems but not vice versa. In lower order systems the person directly moves the indicator while in higher order systems the effect of control movements is on rate or acceleration. In such systems, the effects of movements are not immediately apparent. The difficult higher order systems, if encountered too early, may simply remove the person from the learning condition. In other words, the subject is not able to process the necessary information in any kind of usable form (cf. Cote & Schaefer, 1981).

In the cross-modal studies, however, it seems likely that the more difficult initial conditions act to encourage greater learning by demanding more attentional effort on the part of the subject in a situation in which such additional processing will result in more learning. In these situations, difficult-to-easy transfer is seen because the subject has presumably learned to process the relevant stimulus information more efficiently. Thus, the way in which a particular task is difficult to perform may be the crucial factor in determining the nature of transfer between easy and difficult tasks.

Dual Task Performance

One implication of automatized stimulus processing is that the reduction of attentional resources devoted to one task makes the simultaneous performance of a second task more feasible. In the most favorabl case, a fully automatized task should permit the performance of a second task (not incompatible with the first) without deficits in either of the tasks (cf. Rieck, Ogden, & Anderson, 1980; Eriksen and Spencer, 1969).

There have been several studies showing that after extensive practice dual task performance can display no appreciable deficit on either task, such as reading and dictation (Spelke, Hirst, & Neisser, 1976), flying an airplane while digit cancelling (Colb & DeMaio, 1978) and typing while shadowing prose (Shaffer, 1975). Similar effects have been found in dichotic listening tasks in which subjects wear earphones and different stimuli are simultaneously presented in the different channels. After consistent training, subjects can follow both channels at the same time as long as target stimuli are not simultaneously present (Duncan, 1980). It should be noted that dual task performance on dichotic listening tasks will show decrements if one of the tasks has not become automatized (e.g., Treisman, 1969).

A somewhat different viewpoint of dual task performance is held by some researchers (e.g., Hirst, Spelke, Reaves, Charock, & Neisser, 1980) who argue that time sharing is a specific attentional ability which can be trained in individuals to increase their capacity to engage in dual task performance. Freedle et al., (1968) showed that dual task performance was a function not only of constituent task performance but also of a time sharing attentional ability (cf. Fleishman, 1965; Jennings and Chiles, 1977).

A number of studies have demonstrated improvements in time sharing capacity after training (e.g., Damos, 1977; Gopher and North, 1974, 1977). Gabriel and Burrows (1968) examined the effects of such training in an applied setting. Pilots given time sharing training showed enhanced performance on flying simulation tasks. Reick et al. (1980) showed that in tracking tasks, single task performance contributed little to subsequent dual practice performance. However, dual practice performance was found to be a major determinant of dual task performance.

The extent to which time sharing training is more important to transfer on dual tasks than automatization of one or both of the task components may well depend on the nature of the task. As we saw previously, some tasks have encoding and retrieval characteristics which lend themselves better to part learning than other tasks. As the Freedle et al. study suggests, both factors may be involved in varying degrees in the same task situation.

Summary

Automatized performance can occur after extended consistent practice with particular cues or responses. Qualitative and quantitative differences exist between automatized performance and performance that is not automatized, both in terms of the effect required to process and respond to cues and in the nature of the performance itself. Changes in the utilization of the cues controlling responding have been shown to occur over the course of training in a variety of perceptual-motor tasks, for example. Such changes usually occur in the direction of more efficient stimulus processing or motor performance. As a consequence, transfer can be affected by the relationship of the particular cues utilized in Task 1 and in the transfer task. In addition, the more efficient performance on tasks can permit time sharing activities or the simultaneous performance of two tasks. Automatized performance tends to be highly specific to the elements consistently presented in original training. Thus, there may be little transfer to other elements that differ in some way from those that have become automatized. In addition, it can be difficult to suppress inappropriate automatized performance in transfer environments if the controlling cues are presented.

Proactive Interference and Information Processing

A significant amount of transfer research has been conducted in order to test different interference theories of retention and forgetting, investigating either the retroactive effects of Task 2 learning on Task 1 retention or the proactive effects of Task 1 learning on Task 2 acquisition and retention (Osgood, 1949; Underwood & Postman, 1960). Since we are concerned with the transfer of training, we will concentrate on proactive effects of Task 1 learning on Task 2 acqusition and retention, more specifically, the proactive interference (PI) that can result between the two tasks. It should be emphasized at the outset that the aim of the present section is simply to demonstrate the relevance of some of the information processing factors discussed previously to the phenomenon of PI, and is not a review of interference research *per se*.

PI is generally defined as increases in the time or error rate involved in Task 2 acquisition (i.e., negative transfer) or as increased forgetting of Task 2 material as a result of Task 1 practice. Most of the evidence for PI has been found with verbal materials; very little evidence for negative transfer using motor responses has been found (cf. Bilodeau & Bilodeau, 1961). The motor PI that does occur is often quickly converted into positive transfer. It should be noted, on the other hand, that the degree of positive transfer between different motor tasks is generally not large due to the differences between such tasks (Adams, 1954).

PI is often studied in an A-B, A-D procedure in which different (verbal or motor) responses are successively learned to the same stimulus. The amount of negative transfer is usually assessed by comparing the A-B, A-D group's performance with a control group's performance on an A-B, C-D procedure. Actually, negative transfer is difficult to show if an overall decrement in performance is taken as its definition since the A-B, A-D group often performs better on the A-D list than a control group with no Task 1 learning (cf. Deese & Hulse, 1967; Bilodeau & Bilodeau, 1961).

PI has more meaning as an important factor in applied settings if we define it as the degree to which inappropriate intrusions of previously learned responses occur in the transfer situation (cf. Holding, 1976). In verbal learning, for example in the A-B, A-D paradigm, an intrusion would be to respond with the "B" term while learning the second list in which the "D" term is now appropriate. Intrusive errors can create significant dangers in applied settings if some inappropriate response occurs at a critical moment (e.g., while flying an airplane).

Interestingly, current explanations of PI center around two factors, list differentiation (LD) and encoding deficits, with relationships to some of the information processing factors discussed previously. LD refers to the distinctiveness in memory between what was learned in Task 1 and Task 2. The greater the distinctiveness of the material between the two tasks, the smaller the expected amount of PI. Encoding deficits refers to the possibility that increases in the familiarity or experience with a task lead to changes in the way similar material is encoded.

List Differentiation and PI

As we saw in the first section of the paper, the distinctiveness of the cue-TBR relationship between Task 1 and Task 2 is an important factor in the retrieval of information from memory. To the extent that PI is the result of interference or competition from incompatible responses, manipulations which affect the differentiation of Task 1 and Task 2 should also affect PI levels. Deese and Marder (1957) showed that increases in between list errors were found when a long delay was interposed before final testing after presenting subjects with two lists of words to learn. These errors were presumably due to a decrease in the relative temporal separation between the lists (cf. Belleza and Schirmann, 1975; Runquist and Runquist, 1977). PI is greatly reduced when Task 1 learning is widely distributed over time (Underwood and Ekstrand, 1966; 1967). This finding can explain the lack of interference in verbal laboratory studies from prior verbal experience outside the laboratory which is gained under wide distribution of practice. Repeating some of the first list responses in the second list greatly reduces the advantage of such distributed practice.

Postman (1962) examined the effects of different response relations in producing negative transfer. Subjects were tested on an A-B, A-D procedure and their performance compared with that found on an A-B, A-Br procedure. In the latter procedure, the same responses are used on both lists but are rearranged with different stimulus terms on the second list. This procedure involves a more difficult differentiation situation. As measured against an A-B, C-D control group, negative transfer was demonstrated in both conditions but was higher in the A-B, A-Br condition. In the A-B, A-Br procedure, greater negative transfer was a function of increasing practice on the first list.

It should be noted that item specific PI has been found as well as interference between lists (e.g., Russ-Eft, 1979). It is unclear whether item-specific and list-specific PI are the result of different processes or are the same differentiation problem at different levels of organization.

The relation between LD and PI has also been investigated in short-term retention studies. Perhaps best known are the release from PI studies conducted by Wickens and his associates (e.g., Wickens, 1972; Gardiner et al., 1972; Wickens et al., 1981). For example, in the Gardiner et al. (1972) study, subjects were given a number of Brown-Peterson trials with items from one of several categories. It was consistently found that PI built up rapidly when items were all from the same category. However, a shift between different categories provided a reduction in PI (e.g., garden flowers versus wild flowers). Bird (1977) showed that a shift from semantic to structural processing or vice versa produced more release from PI than did shifting from one semantic task to another. Similarly, no release from PI was obtained with two related structural tasks (Bird and Roberts, 1980).

The concept of LD as an important determinant of PI may provide insight into the lack of interference effects in motor transfer. As we noted at the outset, the study of perceptual-motor responding has long found important differences in retention and forgetting of such responses when compared with verbal-symbolic material. For example, Jahnke and Duncan (1956) showed no evidence of a retention loss over a four-week retention interval. Barch and Lewis (1954) showed that it was extremely difficult to produce in perceptual-motor performance the kinds of RI and PI found in verbal learning (cf. Bilodeau, Jones & Levy, 1964).

One possible explanation for these differences between motor and verbal responses may be in the relative distinctiveness of each. The quantity and similarity of much verbal-symbolic material can be seen to place a tremendous burden on the memory system. Humans try to remember an enormous amount of very detailed information which is often quite similar in character, use, or form to other information. This is not true to nearly the same extent with motor learning (cf. Adams, 1954). There are only a limited number of general action classes that are called upon in the course of a job and within a general response class or schema the individual response exemplars are usually quite distinct from each other. To the extent that motor responses can be easily differentiated from each other then PI should be reduced.

Encoding Deficits

Although LD seems to be an important factor in producing PI, it is doubtful that it is the sole basis for the phenomenon. As Postman (1976) notes, PI continues to be observed in situations in which interference from response competition or differentiation should be minimized such as the MMFR test (e.g., Ceraso and Henderson, 1966; Houston, 1967). The possibility that encoding deficits related to Task 2 acqusition may also play a role in PI has been suggested by experiments which showed that PI did not increase over time for either recognition or cued recall tests (e.g., Postman, Stark, & Burns, 1974).

The absence of progressive increases in PI over time suggests that the subject may not be learning the later list as well as the first, and thus, inevitably shows poorer retention compared to subjects who did not have specific prior learning. This is an interesting possibility because it has parallels with the encoding deficits for certain materials that were noted with organizational processing and automated performance. If experience with particular stimuli or responses affects the nature of the encoding operations, then subjects may not be encoding such material the same way at the end of training or on the transfer task that they were initially.

Hasher and Johnson (1975) examined the idea that in procedures such as the A-B, A-D paradigm in which the same stimulus is used twice, the subject employs the most effective mediators in establishing the A-B association. Thus, they would have employed less useful mediators for A-D learning. Hasher and Johnson showed that mediators used by subjects in learning the A-D list produced more forgetting in other subjects who had to use them in learning a single list (A-B).

More generally, Lockhart, Craik, & Jacoby (1976) argued that increased practice with list learning results in changes in the ease with which subjects acquire the new associations. For example, fewer trials to criterion are needed by subjects on lists presented later in a session compared to the number required at the start. The authors suggest that such learning set behavior is the result of a reduction of processing operations or effort needed to successfully encode the items, i.e., the subject encodes just those attributes needed to identify the stimulus, but not redundant or less correlated attributes which might also contribute to retention to some extent. Therefore, the amount of learning cannot be equated between successive lists by conventional methods such as equal training on both lists (cf. Underwood 1964). Warr (1964) equated the amount of study time to the list and found a large decline in the amount of PI observed in such conditions.

Postman and Keppel (1977) have shown, however, that the acquisition of successive lists (A-B, C-D, E-F) is a sufficient condition for the appearance of cumulative PI. In addition, at a given stage of practice, the amount of PI was independent of the level of retention for the prior lists. This finding would suggest that LD is a greater determinant of PI than an encoding deficit in the conventional P-A procedure. The buildup of PI was observed in both uncategorized and categorized lists and the rates of interference were comparable in both. Little evidence of PI was found in recognition performance on verbal discrimination tests. The small decline that was observed appeared to be similar in nature to that found by Underwood, Broder, & Zimmerman (1973), i.e., a slight but non-progressive decline in retention of the lists following the first.

The authors suggested that these findings made implausible the notion that PI is caused by learning decrements especially in light of the findings by Underwood and Ekstrand (1967) that showed heavy PI even when the rate of learning failed to increase over successive cycles. There can be little doubt that LD plays a key role in the development of PI, however, this fact does not preclude the influence of other processes on PI. It should be remembered that PI is observed in the MMFR test which is designed to minimize problems of LD. It seems more likely that LD and encoding deficits (and perhaps other processes) all can result in retention decrements in later learning. The extent to which each factor will determine the amount of PI in a given situation would presumably be dependent on the contingent factors existing in those circumstances.

Summary

Prior learning can proactively interfere with the acquisition and retention of later learning. Failures of list discrimination and reductions in the amount of information encoded about later tasks were shown to be two important factors in the development of PI, providing an information processing interpretation of some PI phenomena. Manipulations which increased the differentiation of material between Task 1 and Task 2 often significantly decreased the amount of observed PI. It was shown that perceptual-motor responding exhibits little PI in transfer, in contrast to verbal material, possibly because of the greater distinctiveness of motoric responses compared with verbal responses. In addition, subjects seem to encode TBR material on Task 2 more efficiently but also less completely than Task 1 material. This may serve as the basis for the small, non-progressive decline frequently observed for Task 2 retention.

Summary

Current information processing and memorial constructs are shown to have relevance for the interpretation of transfer of training effects. The five major factors examined in the present paper were: (1) the relation of the retrieval information present in the transfer task to the material encoded in Task 1; (2) the study-phase retrieval of information from Task 1 in the course of Task 2 learning which permits the integration and abstraction of both sets of information; (3) organizational strategies and schemata which enhance stimulus processing and performance; and (4) the automatizaon of performance with consistent stimulus training. All of these factors were examined for their applicability in the interpretation of transfer of training phenomena using both basic and applied research whenever possible. A wide range of research was reviewed to show the utility of these factors in the explanation of transfer of training effects. These factors were shown to provide a process-based account of transfer studies conducted in an S-R framework (e.g., simulation studies, PI), thereby unifying this literature with transfer studies conducted in the information processing area. In addition, these factors were shown to be relevant in many cases to both verbal-symbolic and motoric responses.

References

Adams, J. A. Psychomotor response acquisition and transfer as a function of control-indicator relationships. Journal of Experimental Psychology, 1954, 47, 411-417.

Adams, J. A. Human tracking behavior. Psychological Bulletin, 1961, 58, 55-79.

Adams, J. A. A closed loop theory of motor learning. Journal of Motor Behavior, 1971, 3, 111-149.

Adams, J. A. On the evolution of training devices F. V. Taylor Memorial Address. APA Convention, Toronto, Canada, 1978.

Adams, J. A. & Djikstra, S. Short-term memory for motor responses. Journal of Experimental Psychology, 1966, 71, 314-318.

Adams, J. A., Gopher, D., & Lintern, G. Effects of visual and proprioceptive feedback on motor learning. Journal of Motor Behavior, 1977, 9, 11-22.

Alexander, L., Frankiewicz, R. G. & Williams R. E. Facilitation of learning and retention of oral instruction using advance and post organizers. Journal of Educational Psychology, 1979, 71, 701-707.

Anderson, J. R., Kline, P. J., & Beasley, C. M. A general learning theory and its application to schema abstraction. In G. H. Bower (Ed.) The psychology of learning and motivation (vol. 13), N.Y.: Academic Press, 1979.

Annett, J. Learning a pressure under conditions of immediate and delayed knowledge of results. Quarterly Journal of Experimental Psychology, 1959, 11, 3-15.

Arnoult, M. D. Stimulus predifferentiation: Some generalizations and hypotheses. Psychological Bulletin, 1957, 54, 339-350.

Ausubel, D. P. The facilitation of meaningful verbal learning in the classroom. Educational Psychology, 1977, 12, 162-178.

Ausubel, D. P. & Fitzgerald, D. Organizer, general background and antecedent learning variables in sequential verbal learning. Journal of Educational Psychology, 1962, 53, 243-249.

Baker, L., Santa, J. L., & Gentry, J. M. Consequences of rigid and flexible learning. Bulletin of the Psychonomic Society, 1977, 9, 58-60.

Baker, R. A., Cook, J. G., Warnick, W. L., & Robinson, J. P. Development and evaluation of systems for the conduct of tactical training at the tank platoon level. Alex., Va.: HumRRO (Tech. Report 64-88), 1964.

Barch, A. M. & Lewis, D. The effect of task difficulty and amount of practice on proactive transfer. Journal of Experimental Psychology, 1954, 48, 134-142.

Barclay, J. R., Bransford, J. D., Franks, J. J., McCarrell, N. S., & Nitsch, K. Comprehension and semantic flexibility. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 471-481.

Battig, W. F. The flexibility of human memory. In L. S. Cermak & F. I. M. Craik (eds.) Levels of processing and human memory, Hillsdale, N.J.: Erlbaum, 1978.

Belleza, F. S. & Schirmann, N. J. Response dependence in simultaneously learned A-B, A-C lists. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 89-94.

Belleza, F. S., Winkler, H. B., & Andrasik, F. Encoding processes and the spacing effect. Memory and cognition, 1975, 3, 451-457.

Bernstein, B. R. & Gonzalez, B. K. Learning retention and transfer. (Tech. Report 68-C-0215-1, Vol. 1) Orlando, Fla.: Naval Training Device Center.

Bevan, W., Dukes, W. F., & Avant, L. L. The effect of variation in specific stimuli on memory for their superordinates. American Journal of Psychology, 1966, 79, 250-270.

Bilodeau, E. A. Some effects of various degrees of supplemental information given at two levels of practice upon the acquisition of a complex motor skill. (Tech. Report 52-15) Lackland AFB: USAF Human Resources Research Center, 1952.

Bilodeau, I. M. & Bilodeau, E. A. Transfer of training and physical restriction of responses. Perceptual and Motor Skills, 1958, 8, 71-78.

Bilodeau, E. A. & Bilodeau, I. M. Motor skills learning. Annual Review of Psychology, 1961, 12, 243-280.

Bilodeau, E. A., Jones, J. B., & Levy, C. M. Long-term memory as a function of retention time and repeated recalling. Journal of Experimental Psychology, 1964, 67, 303-309.

Bird, C. P. Proactive inhibition as a function of orienting task characteristics. Memory & Cognition, 1977, 5, 27-31.

Bird, C. P. & Roberts, R. An examination of orienting task relationships in a proactive interference paradigm. Memory & Cognition, 1980, 8, 468-475.

Birnbaum, I. S. Organization of numbers in free recall. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 393-399.

Bobrow, D. G. & Norman, D. A. Some principles of memory schemata. In D. G. Bobrow & A. M. Collins (Eds.) Representation and understanding: Studies in cognitive science, N.Y.: Academic Press, 1975.

Boswell, J. J. & Irion, A. L. Transfer of training as a function of target speed in pursuit rotor performance: Practice and retroactive effects. Journal of Motor Behavior, 1975, 7, 105-111.

Bousfield, W. A. The occurrence of clustering in the recall of randomly arranged associates. Journal of General Psychology, 1953, 49, 229-240.

Bower, G. H. Stimulus sampling theory of encoding variability. In A.W. Melton & E. Martin (Eds.) Coding processes in human memory. Washington, D.C.: Winston, 1972.

Bower, G. H. & Lesgold, A. M. Organization as a determinant of part-to-whole transfer in free recall. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 501-506.

Briggs, G. E. Transfer of training. In E. A. Bilodeau (Ed.). Principles of skill acquisition, N.Y.: Academic Press, 1969.

Briggs, G. E. & Waters, L. K. Training and transfer as a function of component interaction. Journal of Experimental Psychology, 1958, 56, 492-500.

Burton, J. K., Lemke, E. A., & Williams, J. R. Transfer effects as a function of variety of method and ability level in elementary mathematics. Journal for Research in Mathematics in Education, 1975, 6, 228-231.

Buschke, H. & Schaier, A. H. Memory units, ideas and propositions in semantic remembering. Journal of Verbal Learning and Verbal Behavior, 1979, 18, 549-563.

Butter, E. J. Visual and haptic training and cross-modal transfer of reflectivity. Journal of Educational Psychology, 1979, 71, 212-219.

Campione, J. C. & Brown, A. L. Transfer of training: Effects of successive pretraining of components in a dimension abstracted oddity task. Journal of Experimental Child Psychology, 1974, 18, 398-411.

Caro, P. W. Aircraft simulators and flight training. Human Factors, 1973, 17, 533-541.

Caro, P. W. The relationship between flight simulator motion and training requirements. Human Factors, 1979, 21, 493-501.

Carpenter, P. A. & Just, M. A. Integrative processes in comprehension in D. La Berge & S. J. Samuels (Eds.). Perception and comprehension. Hillsdale, N.J.: Erlbaum, 1977.

Ceraso, J. & Henderson, A. Unavailability and associative loss in RI and PI: Second try. Journal of Experimental Psychology, 1966, 72, 314-316.

Chase, W. G. & Simon, H. A. Perception in chess. Cognitive Psychology, 1973, 4, 55-81.

Chiesi, H. L., Spilich, G. J., & Voss, J. F. Acquisition of domain related information in relation to high and low domain knowledge. Journal of Verbal Learning and Verbal Behavior, 1979, 18, 257-273.

Christina, R. W. & Anson, J. G. The learning of programmed and feedback based processes controlling the production of a positioning response in two dimensions. Journal of Motor Behavior, 1981, 13, 48-64.

Clark, H. Inferences in comprehension. In D. La Berge & S. Samuels (Eds.). Basic processes in reading, perception, and comprehension, Hillsdale, N.J.: Erlbaum, 1978.

Cohen, B. H. Recall of categorized word lists. Journal of Experimental Psychology, 1963, 66, 227-234.

Colle, H. A. & De Maio, J. Measurement of attentional capacity load using dual task performance operating curves (AFHRL-TR-78-5). Brooks AFB, Texas: Human Resources Lab, April, 1978.

Cote, J. J. & Schaefer, E. G. Perceptual processing strategies in cross-modal transfer of form discrimination: A development study. Journal of Experimental Psychology Human Perception and Performance, 1981, 7, 1340-1348.

Damos, D. L. The development and transfer of time sharing skills. Proceedings of the 21st Annual Meeting of the Human Factors Society, 1977.

Dee-Lucas, D. & DiVesta, F. J. Learner generated organizational aids: Effect on learning from text. Journal of Educational Psychology, 1980, 72, 304-311.

Deese, J. & Hulse, S. W. The psychology of learning. N.Y.: McGraw-Hill, 1967.

Deese, J. & Marder, V. J. The pattern of errors in delayed recall of serial learning after interpolation. American Journal of Psychology, 1957, 60, 594-599.

Diewart, G. L. & Stelmach, G. E. Intramodal and intermodal transfer of movement information. Acta Psychologia, 1977, 41, 119-128.

Duncan, J. The locus of interference in the perception of simultaneous stimuli. Psychological Review, 1980, 87, 272-300.

Dunham, P. Effect of practice order on the efficiency of bilateral skill acquisition. Research Quarterly, 1977, 48, 274-87.

Eberts, R. & Schneider, W. Compter assisted displays enabling intenualization and reduction of operator worload in higher order systems or pushing the barrier of human control beyond second order systems. Proceedings of the Human Factors Society, 1980, 59-62.

Egeth, H. Attention and preattention. In G. H. Bower (Ed.). The psychology of learning and motivation, (Vol. 11), N.Y.: Academic Press, 1977.

Ellis, H. C. Stimulus encoding processes in human learning. In G. H. Bower (Ed.). The psychology of learning and motivation, (Vol. 7), N.Y.: Academic Press, 1973.

Ellis, H. C. & Muller, D. G. Transfer in perceptual learning following stimulus predifferentiation. Journal of Experimental Psychology, 1964, 68, 388-395.

Ellis, H. C. & Shaffer, R. W. Stimulus encoding and the transfer of stimulus differentiation. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 393-400.

Ellis, H. C., Parente, F. J., & Walker, C. W. Coding and varied input versus repetition in human memory. Journal of Experimental Psychology, 1974, 102, 284-290.

Elmes, D. G., Greener, W. I., & Wilkinson, W. C. Free recall of items presented after massed and distributed practice items. American Journal of Psychology, 1972, 85, 237-240.

Eriksen, B. A. & Eriksen, C. W. Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception and Psychophysics, 1974, 16, 143-149.

Eriksen, C. W. & Schultz, D. W. Information processing in visual search: A continuous flow conception and experimental results. Perception and Psycholophysics, 1979, 25, 249-263.

Eriksen, C. W. & Spencer, T. Rate of information processing in visual perception: Some results and methodological considerations. Journal of Experimental Psychology Monographs, 1969, 79, No. 2.

Eysenck, M. W. Depth, elaboration, and distinctiveness. In L. Cermak & F.I.M. Craik (Eds.). Levels of processing in human memory, Hillsdale, N.J.: Erlbaum, 1979.

Fisk, A. W. & Schneider, W. Control and automatic processing during tasks requiring sustained attention: A new approach to vigelance. Human Factors, 1981, 23, 737-750.

Fleishman, E. A. The prediction of total task performance from prior practice on task components. Human Factors, 1965, 7, 18-27.

Fleishman, E. A. & Rich, S. Role of kinesthetic and spatial-visual abilities in perceptual motor learning. Journal of Experimental Psychology, 1963, 66, 6-12.

Flexser, A. J. & Tulving, E. Retrieval independence in recognition and recall. Psychological Review, 1978, 85, 153-171.

Frase, L. T. & Kreitzberg, V. S. Effect of topical and indirect learning directions on prose recall. Journal of Educational Psychology, 1975, 67, 320-324.

Freedle, D. O., Zavala, A., & Fleishman, E. A. Studies of component total task relations: Order of components, total task practice and total task predictability. Human Factors, 1968, 10, 283-296.

Friedman, A. Framing pictures: The role of knowledge in automatic encoding and memory for gist. Journal of Experimental Psychology General, 1978, 108, 316-355.

Fumato, N. Asymmetric transfer in a pursuit tracking task related to a change of strategy. Journal of Motor Behavior, 1981, 13, 197-206.

Gabriel, R. F. & Burrows, A. A. Improving time sharing performance of pilots through training. Human Factors, 1977, 19, 583-593.

Gardiner, J. M., Craik, F. I. M., & Birtwistle, J. Retireval cues and release from proactive inhibition. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 778-783.

Gerathewohl, S. J. Fidelity of simulation and transfer of training: A review of the problem (AM 69-24). Office of Aviation Medecine Federal Aeronautics Administration: Wash. D.C., 1969.

Gilbert, N., Spring, C., & Sassenrath, J. Effects of overlearning and similarity on transfer in word recognition. Perceptual and Motor Skills, 1977, 44, 591-598.

Goldstein, D. A. & King, W. J. Transfer retention for verbal and motor tasks (Tech. Report AD 255684). Wash. D.C.: Office of Naval Research, 1961.

Gopher, D. & North, R. A. The measurement of capacity limitation through single and dual task performance with individual adjustment of difficulty. Proceedings of the 18th Annual Meeting of the Human Factors Society, 1974, 480-485.

Gopher, D. & North, R. A. Manipulating the conditions of training in time sharing performance. Human Factors, 1977, 19, 583-593.

Graber, R. A., Means, R. S., & Johnston, T. D. The effect of subsuming concepts on student achievement of unfamiliar science learning material. Journal of Research in Science Teaching, 1972, 9, 277-279.

Graboi, D. Searching for targets: The effects of specific practice. Perception and Psychophysics, 1971, 10, 300-304.

Grimsley, D. L. Acquisition, retention, and retraining: Training category IV personnel with low fidelity devices (Tech. Report 69-12), Alex. Va., HumRRO, 1969.

Hirst, W., Spelke, E. S., Reaves, C. C., Charack, G., & Neisser, V. Dividing attention without alternation or automaticity. Journal of Experimental Psychology. General, 1980, 109, 98-117.

Holding, D. H. Guidance in pursuit tracking. Journal of Experimental Psychology, 1959, 57, 362-366.

Holding, D. H. Principles of training. London: Pergamon, 1965.

Holding, D. H. An approximate transfer surface. Journal of Motor Behavior, 1976, 8, 1-9.

Holding, D. H. & MacRae, A. W. Rate and force of guidance in perceptual-motor tasks with reversed or random spatial correspondence. Ergonomics, 1966, 9, 289-296.

Homa, D. Abstraction of ill-defined form. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 407-416.

Horowitz, L. M. & Manelis, C. Toward a theory of redintegrative memory: Adjective-noun phrases. In G. H. Bower (Ed.) The psychology of learning and motivation. (Vol. 6) N.Y.: Academic Press, 1972.

Houston, J. P. Proactive inhibition and competition at recall. Journal of Experimental Psychology, 1967, 75, 118-121.

Hull, C. L. Quantitative aspects of the evolution of concepts: An experimental study. Psychological Monographs, 1921, 28, No. 123.

Hunt, R. R. & Mitchell, D. B. Specificity in nonsemantic orienting tasks and distinctive memory traces. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 136-145.

Hunt, R. R., Parente, P. J., & Ellis, H. C. Transfer of coding strategies in free recall with constant and varied input. Journal of Experimental Psychology, 1974, 103, 619-624.

Husek, W. S. & Reeve, T. G. Novel response production as a function of variability and amount of practice. Research Quarterly, 1979, 50, 215-221.

Jacobs, R. S. & Roscoe, S. N. Simulator cockpit motion and the transfer of initial flight training. Proceedings of the Human Factors Society 19th Annual Meeting, Santa Monica, Calif.: Human Factors Society, 1975.

Jacoby, L. L. The role of mental contiguity in memory: Registration and retrieval effects. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 483-496.

Jahnke, J. C. & Duncan, C. P. Reminiscence and forgetting in motor learning after extended rest intervals. Journal of Experimental Psychology, 1956, 52, 273-282.

Jarvella, R. J. Coreference and short term memory for discourse. Journal of Experimental Psychology, 1973, 98, 426-428.

Jennings, A. E. & Chiles, W. D. An investigation of time-sharing ability as a factor in complex performance. Human Factors, 1977, 19, 535-547.

Johnson, S. L. Effect of training device on retention and transfer of procedural task. Human Factors, 1981, 23, 257-272.

Johnson, W. A. & Uhl, C. N. The contributions of encoding effort and variability to the spacing effect on free recall. Journal of Experimental Psychology: Human Learning and Motivation, 1976, 2, 153-160.

Kahneman, D. Attention and effort. Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Katz, R. A. & Zigler, E. Effects of labels on perceptual transfer, stimulus and development factors. Journal of Experimental Psychology, 1969, 80, 73-77.

Kelso, J. A. S. & Norman, P. E. Motor schema formation in children. Developmental Psychology, 1978, 14, 153-156.

Kessel, C. J. & Wickens, C. D. The transfer of failure detection skills between monitoring and controlling dynamic systems. Human Factors, 1982, 24, 49-60.

Kolers, P. Memorial consequences of automatized encoding. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 689-701.

Koonce, J. M. Effects of ground based aircraft simulator motion conditions upon prediction of pilot proficiency. Unpublished doctoral dissertation. University of Illinois at Urbana-Champaign, 1979.

Kristofferson, M. W. Effects of practice on Character classification performance. Canadian Journal of Psychology, 1972, 26, 54-60.

Kristofferson, M. W. The effects of practice with one positive set in a memory scanning task can be completely transferred to a different positive set. Memory and Cognition, 1977, 5, 177-186.

Lee, T. D. & Hirota, T. T. Encoding specificity principle in motor short-term memory for movement extent. Journal of Motor Behavior, 1980, 12, 63-67.

Leonard, S., Kormes, E. W., Oxendine, J., & Hesson, J. Effects of task difficulty on transfer performance on rotary pursuit. Perceptual and motor skills, 1970, 30, 731-736.

Lintern G. Transfer of landing skill after training with supplementary visual cues. Human Factors, 1980, 22, 81-88.

Livesey, J. P. & Laszlo, J. I. Effect of task similarity on transfer performance. Journal of Motor Behavior, 1979, 11, 11-21.

Lockhart, R. S., Craik, F. I. M., & Jacoby, L. Depth of processing, recognition and recall. In J. Brown (Ed.). Recall and recognition, N.Y.: Wiley, 1976.

Logan, G. D. On the use of a concurrent memory load to measure attention and automaticity. Journal of Experimental Psychology: Human Perception and Performance, 1979, 5, 189-207.

Logan, G. D. Attention and automaticity in Stroop and priming tasks: Theory and data. Cognitive Psychology, 1980, 12, 523-553.

Lovaas, O. I. & Simmons, J. Manipulation of self destruction in three retarded children. Journal of Applied Behavioral Analysis, 1969, 2, 143-157.

MacRae, A. W. & Holding, D. H. Method and task in motor guidance. Ergonomics, 1965, 8, 315-320.

MacRae, A. W. & Holding, D. H. Transfer of training after guidance or practice. Quarterly Journal of Experimental Psychology, 1966, 18, 327-333.

Madigan, S. A. Intraserial repetition and coding processes in free recall. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 828-835.

Mandler, G. Organization and memory. In K. W. Spence & J. T. Spence (Eds.). The psychology of learning and motivation (vol. 1), N.Y.: Academic Press, 1967.

Martin, E. Stimulus-encoding in learning and transfer. In A. W. Melton & E. Martin (Eds.) Coding processes in human memory. Wash. D.C.: Winston, 1972.

Mayer, R. E. & Bromage, B. K. Different recall protocols for technical texts due to advance organizers. Journal of Educational Psychology, 1980, 72, 209-225.

McCormack, P. D. Negative transfer in motor performance following a critical amount of verbal pretraining. Perceptual and Motor Skills, 1958, 8, 27-31.

McCracken, H. D. & Stelmach, G. E. A test of the schema theory of discrete motor learning. Journal of Motor Behavior, 1977, 9, 193-201.

McGeoch, J. A. The psychology of human learning, N.Y.: Longmans Green, 1942.

McGuigan, F. J. & McCaslin, E. F. Whole and part methods in learning a perceptual motor skill. American Journal of Psychology, 1955, 68, 658-661.

McKoon, G. & Ratcliff, R. Priming in item recognition: The organization of propositions in memory for text. Journal of Verbal Learning and Verbal Behavior, 1980, 19, 369-386.

Michelli, G. Augmenting feedback and transfer of training (Tech. Report IH-41), Port Washington, N.Y.: Naval Training Device Center, 1966.

Miller, E. E. Military psychology. In R. N. Singer (Ed.) The psychomotor domain, Philadelphia, Pa.: Lea & Febiger, 1972.

Miller, G. A. The magic number seven plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Moeser, S. D. Inferential reasoning in episodic memory. Journal of Verbal Learning and Verbal Behavi... 1976, 15, 193-212.

Morrisett, L. & Hovland, C. I. A comparison of three varieties of training in human problem solving. Journal of Experimental Psychology, 1959, 58, 152-155.

Moxley, S. E. Schema: The variability of practice hypothesis. Journal of Motor Behavior, 1979, 11, 65-70.

Nagae, S. Nature of discriminating and categorizing functions of verbal labels on recognition memory for shape. Journal of Experimental Psychology: Human Learning and Memory, 1980, 6, 421-429.

Naylor, J. C. Parameters affecting the relative efficiency of part and whole practice methods: A review of the literature. (TDC TR 950-1) Port Washington, N.Y.: Naval Training Development Center, 1962.

Neisser, U., Novick, R., & Lazar, R. Searching for ten targets simultaneously. Perceptuai and Motor Skills, 1963, 17, 955-961.

Nelson, D. L. Remembering pictures and words: Appearance, significance, and name. In L. S. Cermak & F. I. M. Craik (Eds.) Levels of processing in human memory. Hillsdale, N.J.: Erlbaum, 1979.

Nelson, D. L. & Rowe, F. A. Information theory and stimulus encoding in paired-associated acquisition: Ordinal position of formal similarity. Journal of Experimental Psychology, 1969, 79, 342-346.

Newell, A. & Rosenbloom, P. S. Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.) Cognitive skills and their acquisition, Hillsdale, N.J.: Erlbaum, 1981.

Newell, J. M. & Shapiro, D. C. Variability of practice and transfer of training: Some evidence toward a schema view of motor learning. Journal of Motor Behavior, 1976, 8, 233-243.

Nitsch, K. E. Structuring decontextualized forms of knowledge. Unpublished doctoral dissertation, Vanderbilt University, 1977.

Novinski, L. S. A reexamination of the part/whole effect in free recall. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 229-233.

Nugent, G. C., Tipton, T. J., & Brooks, D. W. Use of introductory organizers in television instruction. Journal of Educational Psychology, 1980, 72, 445-451.

Ornstein, P. A. Role of prior-list organization in a free recall transfer task. Journal of Experimental Psychology, 1970, 86, 32-37.

Ornstein, G. N., Nichols, I. A., & Flexman, R. E. Evaluation of a contact flight simulator when used in an Air Force primary pilot training program: Part II, effectivness of training on component skills. (AD 62373) Air Force Personnel & Training Center, Lackland AFB, Texas, 1954.

Osgood, C. E. The similarity paradox in human learning: A resolution. Psychological Review, 1949, 56, 132-143.

Petrich, J. A. Organization of recall in the retroactive inhibition paradigm. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 294-301.

Pew, R. W. Human perceptual motor performance. In B. H. Kantowitz (Ed.) Human information processing: Tutorials in performance and cognition, N.Y.: Erlbaum, 1974.

Popp, R. & Voss, J. F. Acquisition-transfer and retention of S-R, and S-R_2: Assocations as a function of S-R_1, S-R_2 pattern. Journal of Experimental Psychology, 1965, 70, 304-308.

Posner, M. I. & Keele, S. W. On the genesis of abstract ideas. Journal of Experimental Psychology, 1968, 77, 353-363.

Posner, M. I. & Keele, S. W. Retention of abstract ideas. Journal of Experimental Psychology, 1970, 83, 304-308.

Posner, M. I. & Keele S. W. Skill learning. In R.M.W. Travers (Ed.) Second handbook of research on teaching. Chicago, Ill.: American Educational Research Association, 1973.

Postman, L. Transfer of training as a function of experimental paradigm and degree of first list learning. Journal of Verbal Learning and Verbal Behavior, 1962, 1, 109-118.

Postman, L. Interference theory revisited. In J. Brown (Ed.) Recall and Recognition, N.Y.: Wiley, 1976.

Postman, L. & Hasher, L. Conditions of proactive inhibition in free recall. Journal of Experimental Psychology, 1972, 92, 276-284.

Postman, L. & Keppel, G. Conditions of cumulative proactive inhibition. Journal of Experimental Psychology: General, 1977, 106, 376-403.

Postman, L. & Parker, J. F. Maintenance of first list associations during transfer. American Journal of Psychology, 1970, 83, 171-188.

Postman, L., Stark, K., & Burns, S. Sources of proactive inhibition on unpaced tests of retention. American Journal of Psychology, 1974, 87, 33-56.

Poulton, E. C. Measuring the order of difficulty of visual-motor tasks. Ergonomics, 1958, 1, 234-239.

Prather, D. C. Trial and error versus errorless learning: Training transfer and stress. American Journal of Psychology, 1971, 84, 377-386.

Prather, D. C. & Berry, G. A. Comparison of trial and error versus highly prompted learning of a perceptual skill. Proceedings of the 78th Annual Convention of the American Psychological Association, 1970, 5, 677-678.

Prather, D. C., Berry, G. A. & Bermudez, J. M. Effect of prompting and feedback on performance during learning, stress, and transfer of a perceptual skill. Proceedings of the 80th Annual Convention of the American Psychological Assocation, 1972, 7, 643-644.

Price, R. H. & Slive, A. B. Verbal processes in shape recognition. Journal of Experimental Psychology, 1970, 83, 373-379.

Prophet, W. W. & Boyd, H. A. Device task fidelity and transfer of training: Aircraft cockpit procedures training. Tech. Report 70-10, Alex., Va.: HumRRO, 1970.

Rathert, G. A., Creer, B. Y. & Sadoff, M. The use of piloted flight simulators in general research. (Tech. Report 365), Paris, France. Advisory Group for Aeronastical Research and Development, NATO, 1961

Rieck, A. M., Ogden, G. D. & Anderson, N. S. An investigation of varying amounts of component task practice on dual task performance. Human Factors, 1980, 22, 373-384.

Ross, J. Extended practice within a single character classification task. Perception and Psychophysics, 1970, 8, 276-278.

Rothkopf, E. Z. & Koether, M. E. Instructional effects of discrepancies in content and organization between study goals and information sources. Journal of Educational Psychology, 1978, 70, 67-71.

Royer, J. M. & Cable, G. W. Facilitated learning in connected discourse. Journal of Educational Psychology, 1975, 67, 116-123.

Royer, J. M., Perkins, M. R., & Konald, C. E. Evidence for a selective storage mechanism in prose learning. Journal of Educational Psychology, 1978, 70, 457-462.

Rundus, D. Organization and part-whole transfer. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 91-101.

Runquist, N. N. & Runquist, P. A. Interference reduction with conceptually similar paired associates. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 370-381.

Russ-Eft, D. Proactive interference: Buildup and release for individual words. Journal of Experimental Psychology: Human Learning and Memory. 1979, 5, 422-434.

Russell, D. G. Spatial location cues and movement reproduction. In G.E. Stelmach (Ed.) Motor control: Issues and trends. N.Y.: Academic, 1976.

Ruocco, J. N., Vitale, P. A. & Benfari, R. C. Kinetic cueing in simulated carrier approaches. (AD 617689) Naval Training Device Center, Port Washington, N.Y., 1965.

Salthouse, T. A. & Somberg, B. L. Skilled performance: Effects of adult age and experience on elementary processes. Journal of Experimental Psychology: General, 1982, 111, 176-207.

Salvendy, G. & Piltsis, J. The development and validation of an analytical training program for medical suturing. Human Factors, 1980, 22, 753-70.

Schmidt, R. A. A schema theory of discrete motor skill learning. Psychological Review, 1975, 82, 225-260.

Schneider, W. Automatic/control processing concepts and their implications for the training of skills (HARL-ONR-8101) Arlington, Va.: Office of Naval Research, 1982.

Schneider, W. & Fisk, A. D. Degree of consistent training: Improvements in search performance and automatic process development. Perception and Psychophysics, 1982, 31, 160-168.

Schneider, W. & Fisk, A. D. Degree of consistent training and the development of automatic process. Perception and Psychophysics, in press.

Schneider, W. & Shiffrin, R. M. Controlled and automatic human information processing I. Detection, search, and attention. Psychological Review, 1977, 84, 1-66.

Schulze, N. & Gorfein, D. S. Subject strategies in part-whole transfer in free recall. Memory & Cognition, 1976, 4, 311-317.

Schwartz, R. M. & Humphreys, M. S. List differentiation in part-whole transfer in free recall. American Journal of Psychology, 1973, 86, 79-88.

Shaffer, L. H. Multiple attention in continuous verbal tasks. In P. M. A. Rabbit & S. Dornic (Eds.) Attention and performance V. N.Y.: Academic Press, 1975.

Shaffer, W. O. & LaBerge, D. Automatic semantic processing of unattended words. Journal of Verbal Learning and Verbal Behavior, 1979, 18, 413-426.

Shapiro, D. C. A preliminary attempt to determine the duration of a motor program. In D. M. Landers and R. W. Christina (Eds.) The psychology of sport and motor behaviors, I. Champaign, Ill.: Human Kinetics, 1976.

Shapiro, D. C., Zernicke, R. F., Gregor, R. J., & Dostel, J. D. Evidence for generalized motor programs using gait pattern analysis. Journal of Motor Behavior, 1981, 13, 33-47.

Shea, J. B. & Morgan, R. L. Contextual inference effects on the acquisition, retention, and transfer of a motor skill. Journal of Experimental Psychology: Human Learning and Memory, 1979, 5, 179-187.

Shiffrin, R. M. & Schneider, W. Controlled and automatic human information processing II. Perceptual learning, automatic attending and a general theory. Psychological Review, 1977, 84, 127-190.

Singer, R. N. To err or not to err: A question for the instruction of psychomotor skills. Review of Educational Research, 1977, 47, 479-498.

Singer, R. N. & Gaines, L. Effects of prompted and problem solving approaches on learning and transfer of motor skills. American Educational Research Journal, 1975, 12, 395-403.

Singer, R. N. & Pease, D. Effect of guided vs. discovery learning strategies on initial motor task learning, transfer, and retention. Research Quarterly, 1978, 49, 206-217.

Smith, E. E., Shoben, E. J., & Rips, L. J. Structure and process in semantic memory: A feature model for semantic decisions. Psychological Review, 1974, 81, 214-241.

Spelke, E. Hirst, W. & Neisser, U. Skills of divided attention. Cognition, 1976, 4, 215-230.

Sullin, R. A. & Dooling, D. J. Intrusions of a thematic idea in the retention of prose. Journal of Experimental Psychology, 1974, 103, 255-262. of Motor Behavior, 1975, 7, 229-241.

Sweller, J. The effect of task complexity and sequence on role learning and problem solving. British Journal of Psychology, 1976, 67, 553-358.

Sweller, J. & Gee, W. Einstellung, the sequence effect, and hypothesis theory. Journal of Experimental Psychology: Huma. Learning and Memory, 1978, 4, 513-526.

Terzuolo, C. A. & Viviani, P. The central representation of learned motor patterns. In R. E. Talbott & D. R. Humphrey (Eds.) Posture and movement, N.Y.: Raven Press, 1979.

Thomson, D. M. & Tulving, E. Associative encoding and retrieval: weak and strong cues. Journal of Experimental Psychology, 1970, 86, 255-262.

Thorndike, E. L. The fundamentals of learning, N.Y.: Teachers College, 1932.

Thorndike, E. L. & Woodworth, R. S. The influence of improvement in one mental function upon the efficiency of other functions. Psychological Review, 1901, 8, 247-261.

Thorndyke, P. W. Cognitive structures in comprehension and memory of narrative discourse. Cognitive Psychology, 1977, 9, 77-110.

Trabasso, T. R. Stimulus emphasis and all-or-none learning in concept identification. Journal of Experimental Psychology, 1963, 65, 398-406.

Treisman, A. M. & Gelade, G. A feature-integration theory of attention. Cognitive Psychology, 1980, 12, 97-136.

Trumbo, D., Ulrich, L., & Noble, M. Verbal coding and display coding in the acquisition and retention of tracking skill. Journal of Applied Psychology, 1965, 49, 368-375.

Tulving, E. Subjective organization and the effects of repetition in multi-trial free recall learning. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 193-197.

Tulving, E. Ecphoric processes in recall and recognition. In J. Brown (Ed.) Recall and recognition, N.Y.: Wiley, 1976.

Tulving, E. & Donaldson, W. Organization of memory. N.Y.: Academic Press, 1972.

Tulving, E. & Pearlstone, Z. Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 381-391.

Turvey, M. T. Preliminaries to a theory of action with reference to vision. In R. Shaw & J. Bransford (Eds.) Perceiving, acting and knowing: Toward an ecological psychology, Hillsdale, N.J.: Erlbaum, 1977.

Underwood, B. J. Degree of learning and the measurement of forgetting. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 112-129.

Underwood, B. J. Attributes of memory. Psychological Review, 1969, 76, 559-573.

Underwood, B. J., Broder, P. K., & Zimmerman, J. Retention of verbal discrimination lists as a function of number of prior lists, word frequency, and type of list. Journal of Experimental Psychology, 1973, 100, 101-105.

Underwood, B. J. & Ekstrand, B. R. An analysis of some shortcomings in the interference theory of forgetting. Psychological Review, 1966, 73, 540-549.

Underwood, B. J. & Ekstrand, B. R. Studies of distributed practice: XXIV. Differentiation and proactive inhibition. Journal of Experimental Psychology, 1967, 74, 574-580.

Underwood, B. J. & Postman, L. Extra-experimental sources of interference in forgetting. Psychological Review, 1960, 67, 73-95.

Valverde, H. H. A review of flight simulator transfer of training studies. Human Factors, 1973, 15, 510-523.

Von Wright, J. Cross modal transfer and sensory equivalence: A review. Scandinavian Journal of Psychology, 1970, 11, 21-30.

Wallace, S. A. The coding of location: A test of the target hypothesis. Journal of Motor Behavior, 1977, 9, 157-169.

Warr, P. B. The relative importance of proactive inhibition and degree of learning in retention of paired-associate items. British Journal of Psychology, 1964, 55, 19-30.

Watkins, M. J. Engrams as cuegrams and forgetting as cue overload. In R. C. Puff (Ed.) Memory, organization and structure, N.Y.: Academic Press, 1979.

Wehman, P., Abramson, J., & Norman, C. Transfer of training in behavior modification programs: An evaluative review. Journal of Special Education, 1977, 11, 217-231.

Weisberg, R., DiCamillo, M., & Phillips, D. Transferring old associations to new situations: A nonautomatic process. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 219-228.

Welford, A. T. Fundamentals of skill. London: Methuen & Co., 1968.

Wickens, D. D. Characteristics of word encoding. In A. W. Melton & E. Martin (Eds.) Codoing processes in human memory, Wash., D.C.: Winston, 1972.

Wickens, D. D., Moody, M. J., & Dow, R. The nature and timing of the retrieval process and of interference effects. Journal of Experimental Psychology: General, 1981, 110, 1-20.

Wilcoxon, H. C., Davy, E., & Webster, J. C. Evaluation of the SNJ operational flight trainer. (AD 086988) Navy Special Devices Center, Port Washington, N.Y., 1954.

Williams, I. D. & Rodney, M. Intrinsic feedback interpolation and the closed loop theory. Journal of Motor Behavior, 1978, 10, 25-36.

Wolfgang, A. Errors and latency of response as a function of order of presentation of tactile visual stimuli in concept identification. Psychonomic Science, 1981, 22, 237-238.

Wood, M. E. & Gerlach V. S. Transfer from audiovisual pretraining to a continuous perceptual motor task. (AFHRL-TR-74-8) Brooks AFB, Texas: AF Human Resources Lab, 1974.

Wrisberg, C. A. & Ragsdale, M. R. Further tests of Schmidt's schema theory: Development task. Journal of Motor Behavior, 1979, 11, 159-166.

Yekovich, F. R. & Walker, C. H. Identifying and using referents in sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 1978, 17, 265-277.

Yekovich, F. R., Walker, C., & Blackman, H. S. The rule of presupposed and focal information in integrating sentences. Journal of Verbal Learning and Verbal Behavior, 1979, 18, 535-548.

Young, D. R. & Belleza, F. S. Encoding variability memory organization and the repetition effect. Journal of Experimental Psychology: Learning Memory & Cognition, 1982, 6, 545-559.

Zechmeister, E. B. Orthographic distinctiveness as a variable in word recognition. American Journal of Psychology, 1972, 85, 425-430.

Zelaznik, H. N., Shapiro, D. C. & Newell, K. M. On the structure of motor recognition memory. Journal of Motor Behavior, 1978, 10, 313-323.

Reference Note

1. Schneider, W. & Fisk, A. D. Developing automatic search to a category and its transfer to nontrained examples. Unpublished manuscript.