DOCUMENT RESUME

ED 107 246 IR 001 986

AUTHOR	Leshowitz, Barry; And Others
TITLE	Visual and Auditory Information Processing in Flying Skill Acquisition. Final Report for Period July 1973 through June 1974.
INSTITUTION	Arizona State Univ., Tempe. Dept. of Educational Psychology.
SPONS AGENCY	Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO	AFHRL-TR-74-103
PUB DATE	Dec 74
NOTE	22p.
EDRS PRICE	MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS	Armed Forces; Auditory Discrimination; Conceptual Schemes; *Flight Training; *Information Processing; *Information Seeking; Memory; Military Training; Models; *Performance Factors; *Research; Stress Variables; Visual Discrimination
IDENTIFIERS	Auditory Information; Visual Information

ABSTRACT

A series of experiments are described which were conducted to further refine experimental paradigms for the investigation of information processing skills relevant to pilot training. A series of tasks have been developed and studied which attempt to measure the individual's information processing capacity as well as his susceptibility to performance degradation resulting from the introduction of interfering stimuli. Data suggest performance on these tasks to be highly dependent on individual differences, therefore, making them good candidates for use as tools in the investigation of information processing skills in flying training. Implications for direct application to flying training research are discussed. (Author/DGC)

AFHRL-TR-74-103

AIR FORCE

HUMAN RESOURCES

VISUAL AND AUDITORY INFORMATION PROCESSING IN FLYING SKILL ACQUISITION

By

Barry Leshowitz
Stanley P. Parkinson
Arizona State University
Tempe, Arizona 85281

Wayne L. Waag

FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224

December 1974
Final Report for Period July 1973 – June 1974

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE,TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by Arizona State University, Department of Psychology, Tempe, Arizona 85281, under contract F41609-74-C-0002, project 1138, with Flying Training Division, Air Force Human Resources Laboratory (AFSC), Williams Air Force Base, Arizona 85224.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

WILLIAM V. HAGIN, Technical Director
Flying Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-74-103	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VISUAL AND AUDITORY INFORMATION PROCESSING IN FLYING SKILL ACQUISITION		5. TYPE OF REPORT & PERIOD COVERED Final* July 1973 – June 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Barry Leshowitz Stanley P. Parkinson Wayne L. Waag		8. CONTRACT OR GRANT NUMBER(s) F41609-74-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Psychology Arizona State University Tempe, Arizona 85281		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 11380102
11. CONTROLLING OFFICE NAME AND ADDRESS Hq Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78236		12. REPORT DATE December 1974
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Flying Training Division Air Force Human Resources Laboratory Williams Air Force Base, Arizona 85224		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

*Executive Summary

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

information processing
auditory processing
visual processing
flying skill

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

This document summarizes a series of experiments conducted to study further refinements in the development of experimental paradigms for the investigation of information processing skills relevant to pilot training. A series of tasks have been developed and studied which attempt to measure the individual's information processing capacity as well as his susceptibility to performance degradation resulting from the introduction of interfering stimuli. Data suggest performance on these tasks to be highly dependent upon individual differences, therefore, making them good candidates for use as tools in the investigation of information processing skills in flying training. Implications for direct application to flying training research are discussed.

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

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SUMMARY

Problem

The first year's effort of the present contract produced a conceptual model which emphasized the pilot's information seeking and information processing functions. A research program was generated in an attempt to isolate these skills and determine those conditions which led to a degradation of performance in tasks highly dependent upon these information processing functions. The objectives of the present effort were to further refine experimental paradigms found useful for the investigation of information processing skills relevant to pilot training and to gather baseline data using a male college population.

Approach

An attempt was made to refine existing experimental paradigms and develop new ones which were thought to be relevant to flying training and furthermore, sensitive to control and manipulation. Studies were designed to assess the extent to which these skills are affected by individual differences and the degree to which performance is degraded through the introduction of interfering and conflicting stimulus conditions. In this manner, a series of experimental tasks would be derived which could be used for the study of information processing skills within the pilot training environment.

Results

In a series of experiments, a number of basic information processing skills were investigated: array search, encoding latency, pattern processing, stimulus and response induced interference and processing capacity. Of importance was the finding that although digit span is a sensitive indicator of performance degradation resulting from the presence of interference stimuli, it does not appear to be related to processing capacity. Instead, it appears to measure the operation of a passive mnemonic system. In another series of studies, differences were reported among subjects in their ability to mentally rotate among figures lacking in verbal codability. Such findings have implications for the future study of spatial orientation necessary in flying.

Conclusions and Recommendations

The results have produced a refined set of paradigms and procedures which are useful for the study of basic information processing functions. It is recommended that this program of research be expanded and applied to the actual pilot training environment. The results of continued efforts could more clearly define the requirements and limitations of information processing skills in the training environment. Such data could produce more effective strategies for the training of these basic skills and thereby improve the current flying training program.

PREFACE

This report represents a portion of the research program of Project 1138, Perceptual Motor and Cognitive Components of the Flying Task, Dr. William V. Hagin, Project Scientist; Task 113801, Cognitive Components of the Flying Task, Dr. Edward E. Eddowes, Task Scientist, being carried out by the Air Force Human Resources Laboratory, Flying Training Division, Williams Air Force Base, Arizona. It represents the results of the second year's study of human information processing accomplished by the Department of Psychology, Arizona State University, Tempe, Arizona, under Contract F41609-74-C-0002 with the Air Force Human Resources Laboratory. Dr. Barry Leshowitz was the Principal Investigator for Arizona State University. Drs. Wayne L. Waag and Edward E. Eddowes were the Contract Monitors for the Air Force Human Resources Laboratory.

TABLE OF CONTENTS

VISUAL AND AUDITORY INFORMATION PROCESSING IN FLYING SKILL ACQUISITION

I. INTRODUCTION

Although considerable effort has been expended in various laboratories on the study of the general effects of stress on performance, little is known about the relationship between stress and flying performance. The older investigations were mainly concerned with demonstrating the deleterious consequences of stress and suggest that, in general, performance in a complicated task is adversely affected by continued exposure to stress-producing stimulation. However, this older research has not been directed at uncovering the specific effects of stress on the task. Therefore, one cannot rely on this older literature in designing an effective training program which seeks to teach reactions under emergency conditions.

Considerations of information processing provide a useful approach to the problem. Such an analysis of complex performance suggests that there exists three independent aspects of flying: alertness, selectivity, and processing capacity. The latter includes such processes as short-term memory, long-term memory, and encoding. It is reasonable to assume that stress may adversely affect one or another of these component processes, and that through experience, pilots learn processing skills which enable them to process information under emergency conditions. The aim of Phase II of the present contract has been to discern the effects of stress on these various aspects of processing, and to relate these findings to flying performance.

In order to more precisely define those processing demands crucial to flying, a series of auditory and visual information processing experiments have been conducted. The initial laboratory studies were devoted to defining the experimental task so that it would have face validity for experienced pilots and the capability of generating large amounts of useful data for eventual application to the flying training program. In Phase II, tasks shown to be realistic and heuristic were tested on a typical college age population. The direct output of this research program are instructional and diagnostic techniques for teaching information processing skills to a more homogeneous group, namely, incoming student pilots.

The advanced aircraft of today is highly sophisticated with numerous pilot aids, such as computerized automatic flight control systems. It is clear that the sheer ability to exercise motor control over the aircraft is of less importance than a pilot's ability to process information rapidly and accurately and to make correct decisions in real time. For example, the pilot must remember a great deal of information entering through the visual, auditory, and kinesthetic channels. This information is constantly being updated, and its criticality is subject to radical shifts at various points in the flight regime. For example, pilots must make visual judgements of distance, speed, position, and so forth, under conditions which are dynamically changing and therefore predisposing to error.

Basic research into flying skills conducted in the period between the Second World War and 1960 was devoted primarily to acquisition and retention of perceptual-motor skills. In today's aircraft, it is obvious that a great deal more is required of the pilot than mastering a repertoire of simple stimulus-response motor connections. Consequently, an information-processing framework seems to provide great utility in an analysis of the flying task. Unfortunately, while perceptual-motor abilities and their relationship to flying performance are reasonably well documented, a similar body of research devoted to information processing skills is not available at this time. Nevertheless, a great deal is known about human processing of information under normative conditions.

The human processor can be described in terms of a system. Information from the environment enters the system as undifferentiated and unprocessed events. The input is accepted into sensory or iconic memory. The raw information is then processed in a short-term-memory buffer. The buffer may be either auditory or visual, depending on the sense modality receiving the original material. In short-term memory, sometimes called active memory, the material is rehearsed for more permanent storage in the long-term memory-buffer. Communication to the outside world is accomplished via the short-term-memory system.

In the high-information-load situation characterizing flying, great amounts of information enter iconic memory and pass through the short-term system. In a real sense, the sensory and short-term memory buffers are at the heart of the processing system. It is for this reason that considerable effort has been devoted to developing efficient diagnostic techniques for enhancing operation of the initial acceptance and filtering of information and subsequent processing of the short-term memory system.

In choosing particular experimental approaches to the problem, it was necessary to extend a rather broad net. To this end, the experiments reported here investigated several processing stages and employed several dependent and independent variables. In addition, the sensory modality through which the information entered was examined together with the interaction between various sensory modalities. This research program is divided (Part

1 and Part 2) into work completed by each of the two principle investigators.

II. PART 1 - RESEARCH PROGRAM

An overview of the Part 1 research program is presented in Table 1 with summaries of all experiments.

Table 1. Summary of Experiments

Experiment	Modality	Dependent Variable	Codability	Processing Stage
1. Array Search	Visual	Recognition	High	Iconic Memory
2. Processing Time	Visual	Recognition	Low	Short-Term Memory
3. Processing of Information Patterns	Auditory	Discrimination	Low	Iconic Memory Short-Term Memory
4. Encoding Latency	Visual	Reaction Time	High	Short-Term Memory, Long-Term Memory

Experiment I: Array Search

Investigations conducted in the course of the research program demonstrated that observers process arrays of visual information according to some well-defined principles. Moreover, it appears that there exist optimal strategies potentially available for reduction, synthesis, and retention of these complex arrays. For example, when an observer is asked to remember a 4 X 3 array of letters, all observers scan the information in a similar fashion, namely, from left to right, and from the center to the periphery. It was noted that additional time devoted to scanning enhances subsequent recognition of the array. Also, a subsequently presented interfering stimulus diminishes retention of the original array.

A partial-report recognition memory procedure was employed to assess the importance of response-induced interference in recognition of briefly-presented arrays of letters. An experimental trial consisted of presentation of a 3 X 4 visual array followed by four sequentially presented test letters from the indicated row. In contrast to data obtained using standard recall procedures, memory strength did not vary with position in the test list. The failure to obtain appreciable response-induced interference is taken as evidence indicating that fundamentally different mechanisms underlie retrieval and/or coding in recognition and recall.

Not enough quantitative data exist to define how pilots scan instrument panels or how efficient scanning strategies are learned in the course of flight training. Suppose a pilot is asked to scan an array of instruments and retain the information contained in the display. Retention of this information is then probed using a memory-recognition paradigm, wherein the subject is asked to recognize whether a subsequently-presented instrument reading (called a test stimulus) had occurred in the original stimulus array. It is anticipated that skilled instructor pilots will display highly effective scanning strategies which are quite different from those of the novice pilot.

Future research should focus on a longitudinal investigation of the development of scanning strategies over time for student pilots enrolled in the flying training program. With appropriate manipulation of the parameters of the stimulus array, it is anticipated that optimal strategies could be taught to student pilots. Actual instructional techniques for optimizing scanning behavior would be the output of this work (Leshowitz, Hanzi, and Zurek, 1975).

Experiment II: Visual Processing Time

In Phase I, a large effort was devoted to mapping the time-course of processing information in auditory memory. In Phase II, in order to measure the time required to process information in the visual store, a simple memory recognition paradigm was employed. Subjects were first presented a test stimulus, a visual pattern, and subsequent to presentation of the first stimulus, an interfering or retroactive masking stimulus was presented. When the retroactive masking stimulus closely followed the test stimulus, there was a large loss in retention of the test stimulus. With increases in temporal separation between test and retroactive stimuli, performance improved markedly. From these results, it was determined that approximately 250 milliseconds is required for processing an item of visual information.

Large individual differences in ability to process information in sensory memory were obtained. For some individuals, it appears that a retroactive stimulus produces large deleterious effects on performance. For other observers, these interfering effects are minimal. It appears then that observers have different capacities for processing information. Future efforts should investigate auditory and visual processing of sensory information in the pilot environment. Suppose an observer is asked to monitor a single instrument, following which the observer is required to process information emanating from a second instrument. Temporal separation between presentation of the first reading and presentation of the second reading will serve as the major experimental variable. Undoubtedly, the requirement of monitoring the second instrument will interfere with retention of the original instrument reading. Now, suppose we also ask the subject to process not only the original test stimulus, but also the retroactive stimulus. In a second experiment, observers (pilots) would be required to retain both the first and second instrument readings. In this way, we could compare the interfering effects of the second stimulus both when it is used as a blanking stimulus (no processing required) and when it demands processing itself (both test and retroactive stimuli retained). In a third experiment, we would assess the pilot's ability to carry on a task in the face of disruption by his own interfering effects. Specifically, we would determine whether the second tested stimulus is more poorly retained than the first, irrespective of the item's original position as a test or interfering stimulus (Leshowitz and Baalman, 1975a).

Experiment III: Processing of Patterns of Auditory Information

Previous research has shown that brief sounds can be discriminated on the basis of differences in the spectral content of the waveform. The aim of the present work was to assess the importance of spectral processing in the perception of temporal order. In an effort to prevent spectral information from serving as the basis for perception of temporal order, sequences of four tones were presented dichotically in a repeated tape loop. Component tones in the sequence were administered to the left or right ear according to a predetermined random order. On each trial, two sequences of tones were presented, and the task of the observer was to determine whether the order of presentation was the same or different for the two sequences. The duration of component sounds required for reliable discrimination was 90 msec. The duration threshold for a dichotic presentation was 10 msec. A second study investigated the perception of temporal order for high and low tone bursts presented in a nonrepeated sequence consisting of the two tones, a noise, and a buzz. Here the task was to determine whether the order of the high and low tones in the two sequences was the same or different. The location and temporal order of the buzz and noise in the two sequences were randomized and irrelevant to the discrimination. Temporal order could be perceived when the duration of each component sound was 20 msec.

The results suggest that central processing of auditory patterns can be accomplished when duration of an item is about 100 msec. Thus, the time constant for processing information actually is considerably greater than that governing integration of information at the sensory register. The latter is about 10 msec. Whether individuals differ with respect to these integration times, and whether training can improve these capacities, are topics for future research (Leshowitz and Hanzi, 1974).

Experiment IV: Rotation of Nonlinguistic Mental Images

The ability to process abstract information was assessed in a number of investigations on rotation of mental images. This ability is especially important under flying conditions when decisions must be made accurately under time pressure. The present work represents a laboratory analog of this decision problem.

In Phase II, an extensive investigation of encoding visual information which was nonlinguistic in nature was carried out. The subject was first shown a visual figure to be retained for later recognition. After some inter-stimulus interval, a second stimulus was presented. The subject's task was to classify the second stimulus as the "same" or "different" as rapidly as possible, while maintaining a low error rate. The second figure could be rotated about its vertical axis, and, the subject had to classify the figure, irrespective of its rotation.

Some responses show a difference of 60 msec between nonrotated and rotated 45° at 0 ISI. This difference is 125 msec for 90°. At two seconds ISI, however, these differences are 0 for 45° and 20 msec for 90°. The 45° rotation remains flat over ISI while nonrotated increases by 55 msec over ISI. The data suggest that the subject views the first stimulus and then rotates it mentally to generate the alternative match. This mental rotation cannot be accomplished within the 0 ISI and therefore RT for the rotated figures is increased. By two sec the mental rotation has been accomplished and the match can be made more quickly, thus the reduction in rotated RT at two sec ISI. The nonrotated RT increases because the subject must now decide between the two "same" cases, rotated and nonrotated.

For the case of letters of the alphabet, a number of studies in the literature have shown that when the two stimuli to be compared are presented with no temporal interval separating them, reaction time to the physically same stimulus is much faster than when upper and lower case stimuli are compared. The comparison of different case symbols requires additional processing time and, therefore, gives rise to higher reaction times. When the separation between the two letters is appreciable (say a few seconds), subjects respond equally rapidly to physical and name matches. We have now demonstrated that a similar result characterizes processing noncodable, nonlinguistic visual stimuli. Apparently, visual stimuli can be processed without language serving as a mediator. That subjects can mentally rotate figures, and that this rotation is not language bound has important implications for interpretations of processing visual information in the cockpit.

The flexibility inherent in coding nonlinguistic visual stimuli and the ability to rotate visual images represents, we feel, an important cognitive capacity related to proficiently flying aircraft. In flying an aircraft, any number of stimulus conditions, although physically dissimilar, are conceptually equivalent. Experienced pilots undoubtedly learn these equivalences. Future investigations of conceptual equivalences could be incorporated in an experiment on processing complex stimuli. Suppose that a pilot is presented a complex array of information (instrument readings) which correspond to some aspect of a maneuver. Now suppose the subject is presented an equivalent, but nonidentical ensemble of instrument readings. The subject's task is to categorize the two stimulus arrays as the same or different. In other words, the "same" response would be required if either the two instrument readings were physically identical or conceptually equivalent. The experimental variable of major interest would be the temporal separation (encoding time) between the first and second stimuli. It is assumed that the experienced pilot would be able to respond rapidly and accurately, whereas a student pilot would have great difficulties determining functional equivalences under such time pressures. Thus, in the initial experiment, instructor pilots would be used to define the conceptual equivalences and then would be employed in actual research. The development of this encoding ability could be investigated in a second longitudinal investigation involving student pilots (Leshowitz and Baalman, 1975b).

III. PART 2 - RESEARCH PROGRAM

In so-called "multichannel" experimentation, individuals are confronted with the task of processing information received by two or more "channels" at the same time. The two "channels" might be within the same sensory modality (e.g., two different messages, one to the left ear and one to the right ear, as in dichotic listening) or they might be between two sensory modalities (e.g., one message spoken and one message pictorially displayed).

A pilot is always in the position of being required to process complex arrays of information which in many cases are presented over several channels simultaneously. For example, while listening for landing instructions from a control tower, a pilot must also maintain visual contact with his instrument panel, and in addition, commence a rather complicated series of movements (involving tactile and kinesthetic modalities) in preparation for landing. It would appear, therefore, that multichannel experiments offer a reasonable avenue for research directed toward analyzing information processing skills relevant to pilot training.

Phase I on the contract investigated the effects of multiple auditory channels on perception and memory. On each trial, subjects received two lists of digits simultaneously, one to each ear, with instructions to reproduce as many of the digits as possible immediately following stimulus presentation. It was found that subjects reported all of the digits received by one ear and then from the other ear rather than crossing between ears and reporting together pairs of items presented simultaneously.

The reliability of these report patterns suggested that subjects differentially processed the two lists of digits received on each trial. Subjects apparently attend to one message and report it first during recall. The second message is held in storage until processing of the first message has been completed, at which time it is given access to the processing mechanism.

Evidence for differential processing was also revealed by studies of interference. Subjects were instructed to attend to one ear and to report it first (attended-unattended report) or second (unattended-attended report) during recall. A binaural stimulus suffix UH was placed at the end of one-half of the lists. The effect of the binaural stimulus suffix was restricted to the terminal serial positions of the unattended ear message, regardless of whether that message was reported first or second.

Wide individual differences were obtained with the dichotic tasks employed during Phase I. It was found that these differences could be accounted for in large part by the subject's digit span. That is, by grouping subject's according to digit span, we accounted for approximately 80% of the variance in the dichotic task. Phase II of the contract was devoted to an expansion of these efforts. A brief summary of the scope of the second year's (Part 2) effort is presented in Table 2.

Table 2. Summary of Multichannel Experimentation

Experiment		Modality	Dependent Variable	Coda-bility	Processing Stage
1.	Interference in dichotic memory	Auditory	Recall	High	Echoic Memory Short-Term Memory
2.	Sequential Presentation	Auditory	Recall	High	Echoic Memory Short-Term Memory
3.	Stimulus Category	Auditory	Recall	High	Echoic Memory Short-Term Memory
4.	Binaural Auditory Memory	Auditory	Recall	High	Echoic Memory Short-Term Memory
5.	Processing Capacity	Visual and Auditory	Reaction-Time Recall	High	Echoic Memory Short-Term Memory

Experiment I: Stimulus Suffix Effects in Dichotic Memory

The first experiment was conducted to determine if digit spans were related to the amount of interference produced by a stimulus suffix in dichotic tasks. Thirty-two subjects (8 with digit spans of 6, 7, 8, and 9) were run with dichotic lists consisting of four digits per ear. Baseline performance for each subject was based on one-hundred trials. Each subject was instructed to attend to one ear (balanced right and left within each digit span group) and to report it first during recall. During the second one-hundred trials, a binaural stimulus suffix was recorded at the end of each dichotic list.

The results indicated that performance varied as a function of digit span with high digit span subjects (8 or 9) recalling with greater accuracy than low digit span subjects (6 or 7). Furthermore, the interference produced by a stimulus suffix was an inverse function of digit span. Considering only the difference between baseline and suffix performance on the terminal serial position of the unattended ear, the following decrements were observed: 6 digit span = 33%; 7 digit span = 32%; 8 digit span = 23% and 9 digit span = 18% (Parkinson and Hubbard, 1974).

Experiment II: Stimulus Suffix Effects with Sequentially Presented Auditory-Verbal Stimuli

This experiment was essentially a replication of Experiment I with the exception that instead of presenting eight digits dichotically, four digits per ear, digits were presented sequentially in a single auditory channel. This was done to determine if the relation between digit span and interference were unique to dichotic tasks.

Forty subjects (8 each with digit spans of 6, 7, 8 and 9; 4 each with digit spans of 5 and 10) were given two-hundred trials consisting of seven sequentially presented digits. One-hundred of the trials included a stimulus suffix at the end of each list. Control and suffix trials were presented in ABBA order in two one-hour sessions.

The results were again clear; i.e., subjects with higher digit spans achieved higher performance and their recall accuracy was less vulnerable to interference produced by a stimulus suffix (Parkinson and Perey, in press).

Experiment III: The Influence of Stimulus Category in Dichotic Tasks

In the dichotic studies conducted previously, stimuli consisted entirely of digits. In the present experiment, subjects received dichotic lists comprised of word/digit pairs with instructions to recall either by spatial location (right ear, left ear) or by stimulus category (words, digits).

The digits were selected randomly from the set 1-6, 8, and 9 while the words were selected from the following set: book, cat, clock, day, girl, hill, leg, and moon. No digit or word appeared twice on a given trial.

There were three kinds of lists used, based on the number of times subjects had to switch between categories to report by ear or between ears to report by category. With 1-crossing lists, subjects were required to switch once from one ear to the other in order to report by category and from one category to the other to report by ear; with 2-crossing lists, subjects had to switch twice; and 3-crossings lists, three switches were needed. An example of a 3-crossings list would be "girl-5-clock-1" presented to the right ear and "3-road-6-hill" presented to the left ear.

The results of this experiment indicated that accuracy of performance was an inverse function of the number of times subjects had to switch between channels, either between categories for ear reports or between ears for category reports.

Reporting by stimulus category was superior to reporting by ear. A binaural stimulus suffix was included in a second phase of this experiment. Greater interference was found with ear reports than with category reports.

The results of this experiment show that when subjects receive two "channels" of information, those channels are not used with equal effectiveness in determining memory persistence. Organizing reports by stimulus category resulted in more persistent traces which were less susceptible to interference than comparable ear reports (Knight and Parkinson, 1974).

Experiment IV: Memory for Binaurally Presented Stimuli

In the variants of the dichotic task employed, subjects have received sequences of digit or word/digit pairs with instructions to reproduce as many of the items as possible. Both spatial location and stimulus category have been shown to be effective channels by which subjects organize stimuli for recall. If both members of each digit pair are presented binaurally (thus removing the cue of spatial location) but are made to differ along dimensions of pitch or loudness, subjects organize their reports along those dimensions.

In the present experiment, an attempt was made to remove all cues (other than temporal) by which subjects might order reports. Subjects received sequences of either two, three, or four digit pairs. Both members of each pair were recorded by the same male voice and both were presented binaurally, thus removing the cue of spatial location

Pulse-coded speech stimuli were used to insure greater control over cues of: (a) onset and offset asynchrony between members of each digit pair, and (b) total energy.

Two important results have emerged from the binaural experiments. First, accuracy of performance in this task was lower than is generally found in dichotic tasks. This indicates the importance of cues of spatial location, loudness, and pitch in the perception and retention of auditory-verbal information. Second, report patterns in these experiments were not random. Subjects' structured their reports according to temporal sequence; i.e., they reported one member from the first digit pair, then one from the second pair followed by one member from the third pair. This set of digits was followed by the remaining numbers of the first, second, and third pairs respectively.

The results from studies of interference have implications for transmitting auditory-verbal information. The capacity of the human perceiver for receiving information is sharply limited. For effective transmission of information, it is suggested that the messages be kept short. The suffix experiments indicate that if two messages are to be received in rapid succession, more efficiency would be achieved if the second message were spoken in a different voice or at a different intensity than the first message. This would enable the pilot to rapidly shift attention to the second message and it would preclude loss of first message information resulting from the presentation of the second message (Parkinson, Knight, DeMaio, and Connors, 1974).

Experiment V: Processing Capacity

One concept which has been mentioned repeatedly in this research is that of "central processing capacity." In terms of the way this concept is used, it refers to the attention or energy demands of a task. It is assumed that the perceptual system is a limited capacity central processor which receives inputs and transforms them to generate output. The input messages and the functions which transform them take up capacity or energy which is common to both.

Previous attempts to define processing capacity have emphasized either the informational content of messages or stimulus-response compatibility. However, neither of these approaches has been adequate. If the perceptual system is actually a limited capacity central processor, then we might ask whether differences in performance between subjects (i.e., in dichotic tasks or in visual search tasks) can be attributed to differences in amount of central processing capacity.

In Experiment 5, subjects with digit spans of 5, 6, 7, 8, and 9 were tested in a task-load problem. Previous experiments directed toward measuring processing capacity have employed a Probe-Reaction-Time Procedure. This consists of a Primary Task, the processing capacity of which is to be measured. Occasionally, while the subject is performing the Primary Task, a stimulus is presented to which he must respond as rapidly as possible (Secondary Task). The difference between an individual's reaction time (RT) on a Secondary Task and on a baseline task (RT as only task) is used as an index of the processing requirement of the Primary Task.

In the present experiment, digit recall was the primary task. Each subject received sequences of seven to-be-remembered digits. A visual probe was presented once during each list. Subjects were instructed to respond to the probe as rapidly as possible and to reproduce the digit sequence in the correct order. The difference in reaction time to the probe during baseline and when it was superimposed on digit recall was used as the measure of processing capacity.

Wide individual differences in processing capacity were obtained but they were not a function of digit span. Rather than measuring central processing capacity, digit span appears to measure the operation of a passive mnemonic system.

The secondary task or task-load procedure outlined above has been employed extensively in information processing literature. It also provides a potential vehicle for monitoring processing demands of piloting.

Future research should employ a variety of relevant primary tasks such as dial searching, detecting a signal in noise, memory tasks, etc., on which a battery of secondary tasks can be superimposed. Mapping of secondary task interference could aid in measuring the processing demands of components of the flight task which would, in turn, suggest a more efficient program for simulator research (DeMaio and Parkinson, 1974).

REFERENCES

DeMaio, J., & Parkinson, S. R. Auditory-verbal information processing: Storage and processing capacity. Journal of Experimental Psychology: Perception and Human Performance, 1974.

Knight, M., & Parkinson, S. R. Stimulus set and response set: The influence of instructions on stimulus suffix effects in dichotic memory. Journal of Experimental Psychology: Verbal Learning, in press, 1974.

Leshowitz, B., & Baalman, J. Processing time for visual patterns, unpublished manuscript, 1975a.

Leshowitz, B., & Baalman, J. Rotation of nonlinguistic mental images, unpublished manuscript, 1975b.

Leshowitz, B., & Hanzi, R. Discrimination of auditory sequences, unpublished manuscript, 1974.

Leshowitz, B., Hanzi, R., & Zurek, P. M. Response-induced interference in recognition memory for briefly exposed visual arrays, unpublished manuscript, 1975.

Parkinson, S. R. Effects of motivation and practice on report patterns in dichotic memory, unpublished manuscript, 1975.

Parkinson, S. R., & Hubbard, L. The effects of digit span on stimulus suffix effect magnitude in dichotic memory, Journal of Experimental Psychology, 1974, Vol. 102, 266-276.

Parkinson, S. R., Knight, M., DeMaio, J., & Connors, J. Channels and order of report in dichotic memory. Perception and Psychophysics, 1974, Vol. 16, 235-241.

Parkinson, S. R. and Perey, A. Stimulus suffix effects: A study of individual differences, unpublished manuscript, 1975.