FINAL REPORT

ON

Grant AF - AFOSR - 1008 - 65

from

Air Force Office of Scientific Research

to

University of Louisville

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Principal Investigator

February 1, 1968

I. Transformational processes and remembering

Introduction

Our studies of coding processes in verbal learning have centered around a detailed analysis of performance on a task devised by Underwood and Keppel (1963). These investigators attempted to make the concepts of "encoding" and "decoding" more explicit by creating a task where each of these processes could be operationally defined and where hypotheses about the effects of coding could be formulated and evaluated. They selected 10 trigrams each of which would, by rearrangement of the letters, produce two common three-letter words (e.g. UBT, BUT, TUB). In this way encoding could be understood as the process of performing letter-order transformations on the several trigrams. Furthermore, if the task was presented to S as one in which, even though such encoding were possible and permissable, he must learn to reproduce the trigrams, then decoding could be construed as the processes involved in reconstructing the trigram letter-order from the solution-word letter-order. In this way Underwood and Keppel arrived at the hypothesis that the effects of coding would largely depend upon the difficulty of decoding. That is, they supposed that if Ss encoded the trigrams into words, learning would progress more rapidly when they were permitted to reproduce the words than when they were required to reproduce the trigrams. This hypothesis was clearly supported by the results of their experiment.

We have retained the basic Underwood and Keppel paradigm in our experiments, but have modified the procedures in ways which permitted us to study coding processes of a more systematic character, viz., the learning and use of rules for encoding and decoding. A rule, in this context, is simply a statement of a letter-order transformation which applies to some subset of trigrams in a list. For example, the trigram FXO can be encoded to FOX and the rule could be expressed either as 1-3-2, or as "interchange the second and third letters."

Inasmuch as the research conducted during the tenure of this grant has already been reported in the request for continued support (Robinson, 1966c) in technical reports (Robinson, 1966a and 1966b) and in forthcoming publications (Robinson 1967a, 1967b) this report will simply and briefly summarize the most substantial research completed with the support of AF-AFOSR-1008-66.

A. Atlas of codeable trigrams

The legitimate inference of letter-order rule learning, rule use and rule interference requires carefully controlled stimulus materials, i.e. the coding operations must be specificable by the experimenter. Single-solution trigrams satisfy these requirements. An atlas of single-solution codeable trigrams was compiled as a preliminary to our research on coding processes. It contains over 300 trigrams with diagram frequencies, letter-association values, and meaningfulness ratings for each of the letter-order permutations of each trigram as well as the Thorndike-Lorge counts for the respective solution-words. These data have been punched onto IBM cards so that lists of trigrams can be prepared by simply sorting the deck in appropriate ways.

B. Rule learning and rule interference in trigram encoding

The discovery and use of transformational rules as well as subsequent interference among such rules was investigated. 24 single-solution trigrams were permuted from their respective solution-words by a uniform letter-order rule (LOR) and assigned to one of 2 lists. LORs were either the same for both lists or different. Ss encoded the lists under one of four conditions: (a) where the LORs of List I and List II were identical; (b) where the LOR for List II was different from that of List I. (c) a control condition where no prior rule-learning experience had been provided; (d) a no-rule condition. Ss were simply asked to discover and say aloud the solution-words. There was no suggestion that encoding rules could be formulated. Comparisons among conditions using mean median solution times for successive blocks of list-items indicated that (a) practice has no effect on solution time with nonrule materials; (b) encoding rule learning does occur as evidenced by significant changes in solution time for successive trigrams, and (c) when rules are changed (List I to List II) solution time increases significantly, i.e. encoding rule-interference results. This experiment has been discussed in greater detail in Robinson (1967a).

C. Effects of intralist rule order (IRO) on learning codeable trigrams

The Underwood and Keppel (1963) coding task was analyzed into three components: encoding, solution-word recall, and decoding. It was argued that Ss could be expected to formulate and use letter-order rules to mediate coding. The principle concern, however, was with the effects of intralist rule order (IRO) on the learning of a two-rule list of codeable trigrams. IRO was varied by presenting rule-associated trigrams in successive blocks (BLK), or in successive alternations (ALT). Four experiments were conducted. The general procedure consisted of encoding a ten-item training list followed by several presentations of a test list for which either solution-word or trigram recall was required.

In Experiment I Ss practiced the test lists for five trials. The results indicated that a BLK list was significantly easier to learn.

In Experiment II the effects of IRO on encoding were investigated. Ss were asked to encode either BLK or ALT list. Solution time was recorded for each trigram. The results indicated that IRO determines the point of maximum encoding-rule interference this being in the second rule set for a BLK list and in the first few rule alternations for the ALT list.

In Experiment III the effects of IRO on decoding were investigated. The results indicated that decoding (trigram recall) was significantly easier with a BLK list, and that the association of decoding rules with appropriate solution-words was the major focus of difficulty. Further evidence of the effects of IRO on encoding were demonstrated by deficient solution-word recall when Ss were given an ALT list with a brief presentation interval. Finally, word recall itself was found to be significantly affected by IRO. Presumably, this latter result reflects the organizational influence of rule-order.

Experiment IV was an extension of Experiment III and further substantiated the debilitating effects on learning associated with an ALT list.

The general conclusion drawn from these experiments was that IRO significantly affects each task component though the basis of these effects varied among the three components.

These experiments have been discussed in greater detail in Robinson (1967b).

II. Organizational processes in multitrial free recall

Following the definition by Miller, Galanter and Pribram (1960) of a Plan as "any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed" (p. 16) we have attempted to describe the anatomy of the Plans controlling the retrieval of categorizeable word lists in free recall. These materials were chosen because it was possible to distinguish levels of potential Plans, e.g. category recall and word (intracategory) recall. We supposed that any demonstration of the tendency for organization of elements to occur at these two levels of the material would provide evidence of the formulation and operation of retrieval Plans. Organization, in this case, reflects a growing redundancy in the order of recall. Success in accounting for this aspect of performance is tantamount to a demonstration of the reality of Plans. Furthermore, if it can be shown that performance covaries with organization, e.g. that amount of organization is highly correlated with amount recalled, then we may conclude that remembering is, in some sense, productive rather than being simply reproductive.

The procedure followed in these experiments is quite simple: a 30-word list representing 10 different categories is presented to Ss in random order five times. A two-minute recall period follows each list-presentation. Analyses of the data, however, became rather complex. The main property of interest is the order in which the categories are recalled and the order in which words within categories are recalled. We have designated the former as Level I and the latter as Level II of the hypothetical retrieval Plan.

Degree of organization at Level I was determined by coding the sequence of words recalled into sequences of category-transitions. These, in turn, are entered in a matrix and the frequency with which each category followed (and preceded) every other category is tabulated. We arbitrarily decided that only those pairs of categories (CP) which recurred contiguously two or more times would be included in further analyses. These recurrent CPs were considered to be the components of the Plan at Level I. In order to further characterize the structure of Level I we utilized some concepts from graph theory (cf. Flament, 1963). A graph is a series of nodes (or points) and paths (or lines) The pattern of nodes and their path-mediated connections is a portrait of the structure latent in the data.

If we regard each category as a potential node and the recurrent contiguity of categories in recall as evidence that a path exists between, or connects them, then it is possible to (a) evaluate the degree of organization reflected in the graph and, (b) trace the evolution of the components of the graph. The metrics of graph theory provide two measures of amount of organization: node degree - the number of paths converging on a node, and connectedness - the extent to which it is possible to get from one node to any other node by traversing

existing paths. Utilizing techniques introduced by Rapoport et.al. (1965) we demonstrated that both node degree and connectedness for Level I was significantly greater than would be expected on the basis of chance.

The "evolution" of Level I of the Plan was studied by marking each path in terms of the trial on which it first occured. In this way we could demonstrate that Level I Planning proceeds by the integration of sub-graphs and that increments in category recall on successive trials covaries with increments in graph or sub-graph organization.

The real test of whether a Plan exists and is operable lies in the demonstration that the order of recall is consistent with the relations specified in the Plan. One of the remarkable aspects of these data is that Plans are completed midway in the experimental session. Subsequent trials are, then, tests of our descriptions, for the sequences of category-transition on trials subsequent to the completion of Plans should be predictable from the internode connections in the graphs constructed for each S. Brief consideration suggests, however, that a second process must be included, a recency principle, in order to account for the initiation of recall. When both of these processes are taken into account - recency and Plan - specified transitions - we were able to account for, on the average, 85% of the order of category recall. Consequently, we have concluded that Ss were engaged in Planning and that recall has been shown to be under the control of such processes.

Level II organization - intracategory clustering - was evaluated by a modification of the ratio of repetition (Bousfield, 1953) which takes account of the maximum number of intracategory repetitions possible given the particular list being used. This index was computed for every subject and every trial. The mean value of this index increased in a regular way with each trial and was linearly related to increases in total word recall. By referring to an equation developed by Bousfield & Bousfield (1963) it was possible to show that the amount of Level II organization was significantly greater than chance on every trial.

The results of this investigation seem to fully warrant the conclusion that remembering - in the sense of retrieving familiar information upon demand - requires the development of some reliable "addressing system" which we have called a Plan. A number of other implications for present theory will be included in the detailed statement now being prepared for publication.

A closely related problem, the nature and efficiency of different retrieval strategies, has been explored in a preliminary way and the results have been reported in Technical Report No. 2 (Robinson, 1966b) and in the request for continued support (Robinson, 1966c).

* * * * * *

In conclusion, we wish to point out that our investigations into the role of organization in multitrial free recall and on transformational processes in learning lists of codeable trigrams are both directed to the same end: to yield a fuller appreciation of basic psychological processes within the context of a dynamic information-processing approach to cognition.

Publications and Papers resulting from

Grant AF-AFOSR-1008-66

1. Category clustering and category recall. Paper read at meeting of Midwestern Psychological Association, Chicago, May, 1966.

2. Category clustering: A "Plan" for category retrieval in free recall. Technical Report No. 1 under AF-AFOSR-1008-66, 1966 (a).

3. Scanning and clustering: An exploratory investigation of retrieval strategies in free recall. Technical Report No. 2 under AF-AFOSR-1008-66, 1966 (b).

4. Transformational and organizational processes in memory: Request for continuation of support submitted to Air Force Office of Scientific Research, 1966, (c).

5. Rule learning and rule interference in trigram encoding. Psychological Reports, 1967 (a), 21, 921-927.

6. Effects of intralist rule order on learning codeable trigrams. Journal of Experimental Psychology, 1967 (b), (submitted).

7. Effects of intralist rule order and solution-word categorizability on learning codeable trigrams. Paper read at meeting of Kentucky Academy of Science, November, 1967.

8. Anatomy of a retrieval plan. (In preparation).

9. Two retrieval strategies in multitrial free recall. (In preparation).

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Rapoport, A., Rapoport, Amnon, Livant, W.P. & Boyd, J. A study of lexical graphs. Foundations of Language: International Journal of Language and Philosophy, 1966, 2, 338-376.

Underwood, B.J. & Keppel, G. Coding processes in verbal learning. Journal of Verbal Learning and Verbal Behavior, 1963, 1, 250-257.

1. ORIGINATING ACTIVITY: University of Louisville, Louisville, Kentucky

2. REPORT SECURITY CLASSIFICATION: None

3. REPORT TITLE: Final Report

5. AUTHOR(S): John A. Robinson

6. REPORT DATE: February 1, 1968

7 a. TOTAL NO. OF PAGES: 6

7 b. NO. OF REFS: 6

8 a. CONTRACT OR GRANT NO: AF-AFOSR-1008-66

10. AVAILABILITY/LIMITATION NOTICES: Available to qualified requestors from DDC

12. SPONSORING MILITARY ACTIVITY: Air Force Office of Scientific Research

13. ABSTRACT:

SYNOPSIS

Two types of problems have been investigated: (1) the role of encoding and decoding rule learning and rule interference in what is, ostensibly, a nonsense-anagram list learning experiment; (2) the nature and role of organizational processes in multitrial free recall. The materials used in these experiments were codeable trigrams (e.g. RJA; JAR) and categorizeable words (e.g. flute, trumpet; week, day, etc.)

The results of seven experiments on coding have produced the following conclusions:

(1) Subjects do learn and use both encoding and decoding rules.

(2) Intralist encoding or decoding rule interference is a significant determinant of performance.

(3) Sufficient structure can be built into these anagram materials to completely offset what have been assumed to be the detrimental effects of coding.

The results of the experiments in free recall document the occurrence of intercategory organization (CO) as well as the more familiar intracategory organization. Using techniques from graph theory it has been possible to show that the degree of CO observed is greater than chance, and that CO is highly correlated with category recall. One theoretical conclusion of special interest was that hierarchical models of retrieval are inadequate as an explanation of these data.

14. KEY WORDS: RULE LEARNING
RULE INTERFERENCE
CODING
ORGANIZATION
PLAN
RETRIEVAL

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY (Corporate author) University of Louisville Psychology Department Louisville, Kentucky	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

TRANSFORMATIONAL AND ORGANIZATIONAL PROCESSES IN MEMORY

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific Final

5. AUTHOR(S) (First name, middle initial, last name)

John A. Robinson

6. REPORT DATE February 1, 1968	7a. TOTAL NO. OF PAGES 6	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO. AF-AFOSR-1008-66 b. PROJECT NO. 9778-01 c. 6144501F d. 681313	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR-68-0528	

10. DISTRIBUTION STATEMENT

1. Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES TECH, OTHER	12. SPONSORING MILITARY ACTIVITY Air Force Office of Scientific Research 1400 Wilson Boulevard (SRLB) Arlington, Virginia 22209

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DD FORM 1473

Security Classification

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rule learning						
Rule interference						
Coding						
Organization						
Plan						
Retrieval						