SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Memory for restaurant orders

Change suggested by S.C. 3/5/85

5. TYPE OF REPORT & PERIOD COVERED
Technical Report

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
K. Anders Ericsson and Peter G. Polson

8. CONTRACT OR GRANT NUMBER(s)
N00014-84-k-0250

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Institute of Cognitive Science
University of Colorado, Campus Box 345
Boulder, CO 80309

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NR 667-536

11. CONTROLLING OFFICE NAME AND ADDRESS
Personnel & Training Research Programs,
Office of Naval Research (Code 458),
Arlington, VA 22217

12. REPORT DATE
March 1985

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Office of Naval Research (ONR), Program in
Personnel & Training Research, 800 N. Quincy St.
Arlington, VA 22217

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
To appear in M.T.T. Chi, R. Glaser, & M.J. Farr (Eds.), The nature of expertise.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Memory skill, exceptional memory, mnemonics, generalizability of skill, transfer, practice effects.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
A memory skill of a waiter is described and analyzed in the paper. The waiter (JC) can remember about 20 complete dinner orders without external aids, at the restaurant in which he worked. A laboratory analog of the dinner-order task was constructed and we found that JC's performance on this task was far superior to normal college students. An analysis of JC's memory skill, showed strong support for the three principles which Chase and Ericsson proposed for memory skills in their model of skilled

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) memory. First, from thinking aloud protocols we found clear evidence that JC employed sophisticated encoding processes to memorize the dinner orders (meaningful encoding). Second, from analyses of JC's order of recall and from his ability to recall a large number of different lists of dinner orders at the end of a study session (post-session recall), we found evidence that JC stores the dinner-orders in long-term memory and uses special retrieval cues for retrieval (retrieval structure). Two specially designed experiments provided converging support for the validity of these encoding processes and the retrieval structure.

Thirdly, we analyzed the study time used by JC throughout the two-year-long experiment and found a remarkable reduction of study time with further practice (speed-up). Two final experiments examined the degree to which JC's memory skill was specific to dinner orders or could transfer to other types of materials. JC showed considerable transfer to materials, where he could use his sophisticated encoding processes. Although JC's memory performance dramatically decreased for materials where he could not use his encoding processes, his performance was still better than normal students' memory performance for dinner orders. In the discussion we consider aspects of acquired memory skill, which could account for such generalizable performance.

INSTRUCTIONS FOR PREPARATION OF REPORT DOCUMENTATION PAGE

RESPONSIBILITY. The controlling DoD office will be responsible for completion of the Report Documentation Page, DD Form 1473, in all technical reports prepared by or for DoD organizations.

CLASSIFICATION. Since this Report Documentation Page, DD Form 1473, is used in preparing announcements, bibliographies, and data banks, it should be unclassified if possible. If a classification is required, identify the classified items on the page by the appropriate symbol.

COMPLETION GUIDE

General. Make Blocks 1, 4, 5, 6, 7, 11, 13, 15, and 16 agree with the corresponding information on the report cover. Leave Blocks 2 and 3 blank.

Block 1. Report Number. Enter the unique alphanumeric report number shown on the cover.

Block 2. Government Accession No. Leave Blank. This space is for use by the Defense Documentation Center.

Block 3. Recipient's Catalog Number. Leave blank. This space is for the use of the report recipient to assist in future retrieval of the document.

Block 4. Title and Subtitle. Enter the title in all capital letters exactly as it appears on the publication. Titles should be unclassified whenever possible. Write out the English equivalent for Greek letters and mathematical symbols in the title *(see "Abstracting Scientific and Technical Reports of Defense-sponsored RDT/E,"AD-667 000).* If the report has a subtitle, this subtitle should follow the main title, be separated by a comma or semicolon if appropriate, and be initially capitalized. If a publication has a title in a foreign language, translate the title into English and follow the English translation with the title in the original language. Make every effort to simplify the title before publication.

Block 5. Type of Report and Period Covered. Indicate here whether report is interim, final, etc., and, if applicable, inclusive dates of period covered, such as the life of a contract covered in a final contractor report.

Block 6. Performing Organization Report Number. Only numbers other than the official report number shown in Block 1, such as series numbers for in-house reports or a contractor/grantee number assigned by him, will be placed in this space. If no such numbers are used, leave this space blank.

Block 7. Author(s). Include corresponding information from the report cover. Give the name(s) of the author(s) in conventional order *(for example, John R. Doe or, if author prefers, J. Robert Doe).* In addition, list the affiliation of an author if it differs from that of the performing organization.

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Block 10. Program Element, Project, Task Area, and Work Unit Numbers. Enter here the number code from the applicable Department of Defense form, such as the DD Form 1498, "Research and Technology Work Unit Summary" or the DD Form 1634. "Research and Development Planning Summary," which identifies the program element, project, task area, and work unit or equivalent under which the work was authorized.

Block 11. Controlling Office Name and Address. Enter the full, official name and address, including office symbol, of the controlling office. *(Equates to funding/sponsoring agency. For definition see DoD Directive 5200.20, "Distribution Statements on Technical Documents.")*

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Block 13. Number of Pages. Enter the total number of pages.

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Blocks 15 & 15a. Security Classification of the Report: Declassification/Downgrading Schedule of the Report. Enter in 15 the highest classification of the report. If appropriate, enter in 15a the declassification/downgrading schedule of the report, using the abbreviations for declassification/downgrading schedules listed in paragraph 4-207 of DoD 5200.1-R.

Block 16. Distribution Statement of the Report. Insert here the applicable distribution statement of the report from DoD Directive 5200.20, "Distribution Statements on Technical Documents."

Block 17. Distribution Statement *(of the abstract entered in Block 20, if different from the distribution statement of the report).* Insert here the applicable distribution statement of the abstract from DoD Directive 5200.20, "Distribution Statements on Technical Documents."

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Block 19. Key Words. Select terms or short phrases that identify the principal subjects covered in the report, and are sufficiently specific and precise to be used as index entries for cataloging, conforming to standard terminology. The DoD "Thesaurus of Engineering and Scientific Terms" *(TEST),* AD-672 000, can be helpful.

Block 20. Abstract. The abstract should be a brief *(not to exceed 200 words)* factual summary of the most significant information contained in the report. If possible, the abstract of a classified report should be unclassified and the abstract to an unclassified report should consist of publicly- releasable information. If the report contains a significant bibliography or literature survey, mention it here. For information on preparing abstracts see "Abstracting Scientific and Technical Reports of Defense-Sponsored RDT&E," AD-667 000.

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION / 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS *(City, State, and ZIP Code)*	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING / SPONSORING ORGANIZATION / 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED FROM ____ TO ____	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE *(Include Area Code)* / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
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INSTRUCTIONS FOR PREPARATION OF REPORT DOCUMENTATION PAGE

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Only information appearing on or in the report, or applying specifically to the report in hand, should be reported. If there is any doubt, the block should be left blank.

Some of the information on the forms (e.g., title, abstract) will be machine indexed. The terminology used should describe the content of the report or identify it as precisely as possible for future identification and retrieval.

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In accordance with DoD 5200.1-R, Information Security Program Regulation, Chapter IV Section 2, paragraph 4-200, classification markings are to be stamped, printed, or written at the top and bottom of the form in capital letters that are larger than those used in the text of the document. See also DoD 5220.22-M, Industrial Security Manual for Safeguarding Classified Information, Section II, paragraph 11a(2). This form should be unclassified, if possible.

SPECIFIC BLOCKS

Block 1a. Report Security Classification: Designate the highest security classification of the report. (See DoD 5220.1-R, Chapters I, IV, VII, XI, Appendix A.)

Block 1b. Restricted Marking: Enter the restricted marking or warning notice of the report (e.g., CNWDI, RD, NATO).

Block 2a. Security Classification Authority: Enter the commonly used markings in accordance with DoD 5200.1-R, Chapter IV, Section 4, paragraph 4-400 and 4-402. Indicate classification authority.

Block 2b. Declassification / Downgrading Schedule: Indicate specific date or event for declassification or the notation, "Originating Agency Determination Required" or "OADR." Also insert (when applicable) downgrade to ________________ on ________________ (e.g., Downgrade to Confidential on 6 July 1983). (See also DoD 5220.22-M, Industrial Security Manual for Safeguarding Classified Information, Appendix II.)

NOTE: **Entry must be made in Blocks 2a and 2b except when the original report is unclassified and has never been upgraded.**

Block 3. Distribution/Availability Statement of Report: Insert the statement as it appears on the report. If a limited distribution statement is used, the reason must be one of those given by DoD Directive 5200.20, Distribution Statements on Technical Documents, as supplemented by the 18 OCT 1983 SECDEF Memo, "Control of Unclassified Technology with Military Application." The Distribution Statement should provide for the broadest distribution possible within limits of security and controlling office limitations.

Block 4. Performing Organization Report Number(s): Enter the unique alphanumeric report number(s) assigned by the organization originating or generating the report from its research and whose name appears in Block 6. These numbers should be in accordance with ANSI STD 239.23-74, "American National Standard Technical Report Number." If the Performing Organization is also the Monitoring Agency, enter the report number in Block 4.

Block 5. Monitoring Organization Report Number(s): Enter the unique alphanumeric report number(s) assigned by the Monitoring Agency. This should be a number assigned by a DoD or other government agency and should be in accordance with ANSI STD 239.23-74. If the Monitoring Agency is the same as the Performing Organization, enter the report number in Block 4 and leave Block 5 blank.

Block 6a. Name of Performing Organization: For in-house reports, enter the name of the performing activity. For reports prepared under contract or grant, enter the contractor or the grantee who generated the report and identify the appropriate corporate division, school, laboratory, etc., of the author.

Block 6b. Office Symbol: Enter the office symbol of the Performing Oganization.

Block 6c. Address: Enter the address of the Performing Organization. List city, state, and ZIP code.

Block 7a. Name of Monitoring Organization: This is the agency responsible for administering or monitoring a project, contract, or grant. If the monitor is also the Performing Organization, leave Block 7a. blank. In the case of joint sponsorship, the Monitoring Organization is determined by advance agreement. It can be either an office, a group, or a committee representing more than one activity, service, or agency.

Block 7b. Address: Enter the address of the Monitoring Organization. Include city, state, and ZIP code.

Block 8a. Name of Funding/Sponsoring Organization: Enter the full official name of the organization under whose immediate funding the document was generated, whether the work was done in-house or by contract. If the Monitoring Organization is the same as the Funding Organization, leave 8a blank.

Block 8b. Office Symbol: Enter the office symbol of the Funding/Sponsoring Organization.

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Block 9. Procurement Instrument Identification Number: For a contractor grantee report, enter the complete contract or grant number(*s*) under which the work was accomplished. Leave this block blank for in-house reports.

Block 10. Source of Funding (Program Element, Project, Task Area, and Work Unit Number(s): These four data elements relate to the DoD budget structure and provide program and/or administrative identification of the source of support for the work being carried on. Enter the program element, project, task area, work unit accession number, or their equivalents which identify the principal source of funding for the work required. These codes may be obtained from the applicable DoD forms such as the DD Form 1498 (Research and Technology Work Unit Summary) or from the fund citation of the funding instrument. If this information is not available to the authoring activity, these blocks should be filled in by the responsible DoD Official designated in Block 22. If the report is funded from multiple sources, identify only the Program Element and the Project, Task Area, and Work Unit Numbers of the principal contributor.

Block 11. Title: Enter the title in Block 11 in initial capital letters exactly as it appears on the report. Titles on all classified reports, whether classified or unclassified, must be immediately followed by the security classification of the title enclosed in parentheses. A report with a classified title should be provided with an unclassified version if it is possible to do so without changing the meaning or obscuring the contents of the report. Use specific, meaningful words that describe the content of the report so that when the title is machine-indexed, the words will contribute useful retrieval terms.

If the report is in a foreign language and the title is given in both English and a foreign language, list the foreign language title first, followed by the English title enclosed in parentheses. If part of the text is in English, list the English title first followed by the foreign language title enclosed in parentheses. If the title is given in more than one foreign language, use a title that reflects the language of the text. If both the text and titles are in a foreign language, the title should be translated, if possible, unless the title is also the name of a foreign periodical. Transliterations of often used foreign alphabets (see Appendix A of MIL-STD-847B) are available from DTIC in document AD-A080 800.

Block 12. Personal Author(s): Give the complete name(s) of the author(s) in this order: last name, first name, and middle name. In addition, list the affiliation of the authors if it differs from that of the performing organization.

List all authors. If the document is a compilation of papers, it may be more useful to list the authors with the titles of their papers as a contents note in the abstract in Block 19. If appropriate, the names of editors and compilers may be entered in this block.

Block 13a. Type of Report: Indicate whether the report is summary, final, annual, progress, interim, etc.

Block 13b. Time Covered: Enter the inclusive dates (*year, month, day*) of the period covered, such as the life of a contract in a final contractor report.

Block 14. Date of Report: Enter the year, month, and day, or the year and the month the report was issued as shown on the cover.

Block 15. Page Count: Enter the total number of pages in the report that contain information, including cover, preface, table of contents, distribution lists, partial pages, etc. A chart in the body of the report is counted even if it is unnumbered.

Block 16. Supplementary Notation: Enter useful information about the report in hand, such as: "Prepared in cooperation with...," "Translation at (or by)...," "Symposium...," If there are report numbers for the report which are not noted elsewhere on the form (such as internal series numbers or participating organization report numbers) enter in this block.

Block 17. COSATI Codes: This block provides the subject coverage of the report for announcement and distribution purposes. The categories are to be taken from the "COSATI Subject Category List" (DoD Modified), Oct 65, AD-624 000. A copy is available on request to any organization generating reports for DoD. At least one entry is required as follows:

Field - to indicate subject coverage of report.

Group - to indicate greater subject specificity of information in the report.

Sub-Group - if specificity greater than that shown by Group is required, use further designation as the numbers after the period (.) in the Group breakdown. Use only the designation provided by AD-624 000.

Example: The subject "Solid Rocket Motors" is Field 21, Group 08, Subgroup 2 (page 32, AD-624 000).

Block 18. Subject Terms: These may be descriptors, keywords, posting terms, identifiers, open-ended terms, subject headings, acronyms, code words, or any words or phrases that identify the principal subjects covered in the report, and that conform to standard terminology and are exact enough to be used as subject index entries. Certain acronyms or "buzz words" may be used if they are recognized by specialists in the field and have a potential for becoming accepted terms. "Laser" and "Reverse Osmosis" were once such terms.

If possible, this set of terms should be selected so that the terms individually and as a group will remain UNCLASSIFIED without losing meaning. However, priority must be given to specifying proper subject terms rather than making the set of terms appear "UNCLASSIFIED." Each term on classified reports must be immediately followed by its security classification, enclosed in parentheses.

For reference on standard terminology the "DTIC Retrieval and Indexing Terminology" DRIT-1979, AD-A068 500, and the DoD "Thesaurus of Engineering and Scientific Terms (TEST) 1968, AD-672 000, may be useful.

Block 19. Abstract: The abstract should be a pithy, brief (preferably not to exceed 300 words), factual summary of the most significant information contained in the report. However, since the abstract may be machine-searched, all specific and meaningful words and phrases which express the subject content of the report should be included, even if the word limit is exceeded.

If possible, the abstract of a classified report should be unclassified and consist of publicly releasable information (Unlimited), but in no instance should the report content description be sacrificed for the security classification.

NOTE: **An unclassified abstract describing a classified document may appear separately from the document in an unclassified context e.g., in DTIC announcement or bibliographic products. This must be considered in the preparation and marking of unclassified abstracts.**

For further information on preparing abstracts, employing scientific symbols, verbalizing, etc., see paragraphs 2.1(n) and 2.3(b) in MIL-STD-847B.

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Block 22a,b,c. Name, Telephone and Office Symbol of Responsible Individual: Give name, telephone number, and office symbol of DoD person responsible for the accuracy of the completion of this form.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Institute of Cognitive Science 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Office of Naval Research
6c. ADDRESS (City, State, and ZIP Code) University of Colorado Campus Box 345 Boulder, CO 80309	7b. ADDRESS (City, State, and ZIP Code) Personnel & Training Research Programs 800 N. Quincy St. Arlington, VA 22217
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
	N00014-84-K-0250	NR667-536	

11. TITLE (Include Security Classification)
A Cognitive Analysis of Exceptional Memory for Restaurant Orders, unclassified

12. PERSONAL AUTHOR(S)
K. Anders Ericsson and Peter G. Polson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical Report	FROM ________ TO ________	85 April 25	50

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Memory skill, exceptional memory, mnemonics, generalizability of skill, transfer, practice effects.

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

A memory skill of a waiter is described and analyzed in the paper. The waiter (JC) can remember about 20 complete dinner orders without external aids, at the restaurant in which he worked. A laboratory analog of the dinner-order task was constructed and we found that JC's performance on this task was far superior to normal college students. An analysis of JC's memory skill, showed strong support for the three principles which Chase and Ericsson proposed for memory skills in their model of skilled memory. First, from thinking aloud protocols we found clear evidence that JC employed sophisticated encoding processes to memorize the dinner orders (meaningful encoding). Second, from analyses of JC's order of recall and from his ability to recall a large number of different lists of dinner orders at the end of a study session (post-session recall)

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Third, we analyzed the study time used by JC throughout the two-year-long experiment and found a remarkable reduction of study time with further practice (speed-up). Two final experiments examined the degree to which JC's memory skill was specific to dinner orders or could transfer to other types of materials. JC showed considerable transfer to materials, where he could use his sophisticated encoding processes. Although JC's memory performance dramatically decreased for materials where he could not use his encoding processes, his performance was still better than normal students' memory performance for dinner orders. In the discussion we consider aspects of acquired memory skill, which could account for such generalizable performance.

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The second dimension of the matrix (shown in Table 2) was by category. Furthermore, JC had special encoding schemes for each category of the menu. For example, salad dressings were encoded by their first letter such that bleu cheese was encoded as B, oil and vinegar as O, thousand island as T, and so on. If the first four dressings were bleu cheese, oil and vinegar, oil and vinegar, and thousand island, JC would recode them as B-O-O-T and if possible relate the sequence of four letters to an English word, in this case, BOOT. Temperatures were encoded as a spatial pattern in terms of how well the meat was cooked, exploiting the fact the temperatures are ordered. For example, rare, medium, medium-rare, rare, would have a spatial pattern similar to the one shown in Figure 1.

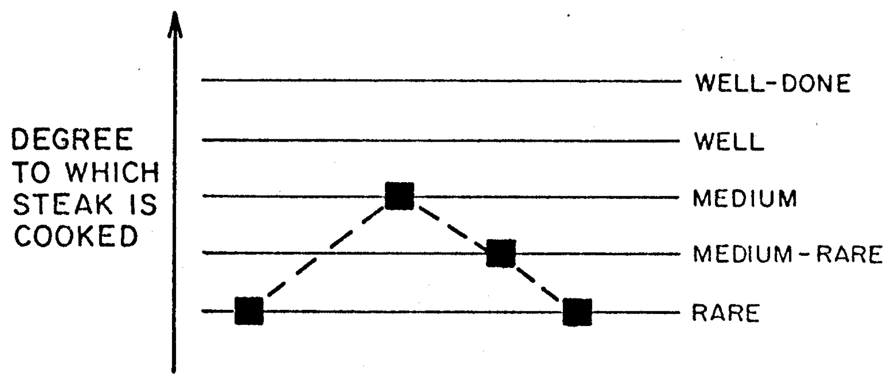

Figure 1

The spatial pattern corresponding to four temperatures of steaks in sequence: rare, medium, medium-rare, rare.

Starches were nearly always encoded as serial patterns, because with only three different starches, there was bound to be at least one repetition in a block of four orders. Entrees were the most variable, and JC reports relying on repetitions and also patterns emerging from a subdivision of the various meat orders into expensive and inexpensive steaks.

Generating within-category encodings requires considerable memory overhead. When a new order is presented, JC has to decide which category to encode, retrieve the earlier items from that category, encode the old items and the new item, and then use the same procedure for the remaining categories. Items in the current order have to be kept in a rehearsal buffer before they are successfully encoded with earlier items in their respective categories. Old and new items in a category must be in attention at the same time in order to permit the recognition of serial patterns in the items. The maximum capacity for attention, i.e., 4 or 5 items, is consistent with the largest within-category chunks used by JC while encoding dinner orders from one table. The assumptions of independent storage in a rehearsal buffer and size of units of encodings are remarkably consistent with the research on memory for digits (Chase & Ericsson, 1981, 1982).

The analysis of performance with and without thinking-aloud and automatic irrelevant verbalization support the conclusion that no additional cognitive processing during the think-aloud trials (except vocalization) is involved, hence the verbalized information is information otherwise heeded. In addition, retrospective reports from silent and "think-aloud" trials contained very similar information on a process with the same structure.

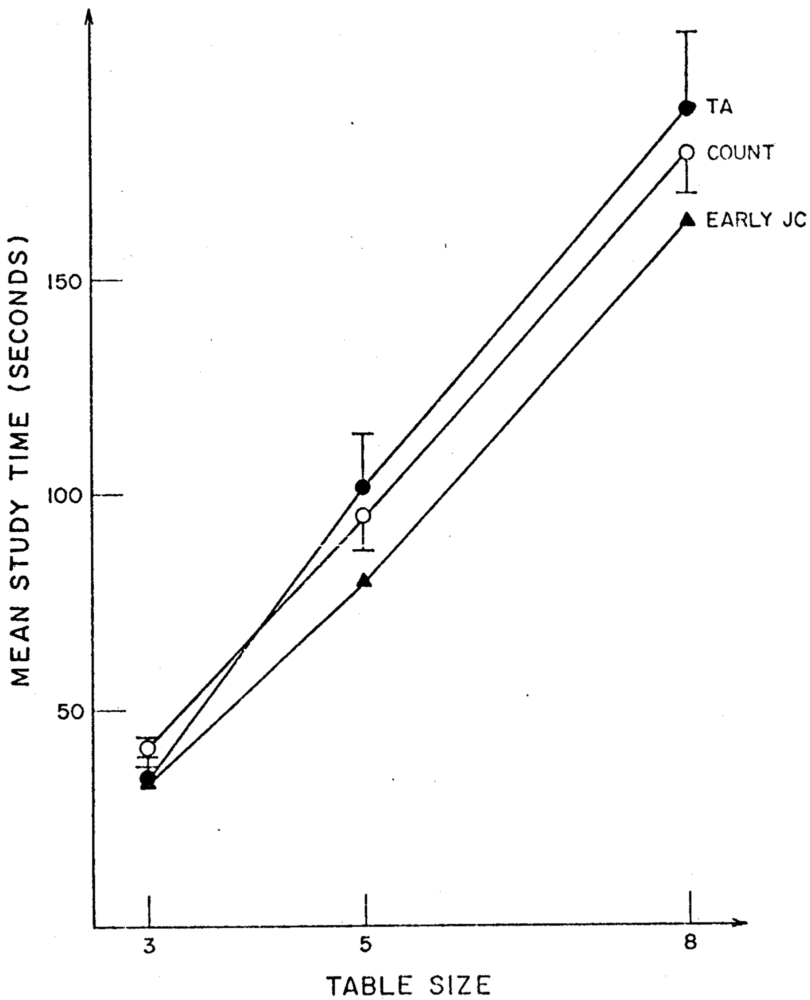

Figure 2

Study-time as a function of table size for Think-aloud (TA) condition, counting from 1 to 10 (COUNT) and silent control trials from the first experiment.

Protocol Data Supporting the Model of JC's Memory Skill

Table 3 presents a complete verbatim transcription of JC's think-aloud protocol for a 5-top (table with 5 people). The underlined portions are evidence relevant to the model; the remainder of the protocol is requests for presentations and simple repetitions of the just-presented order.

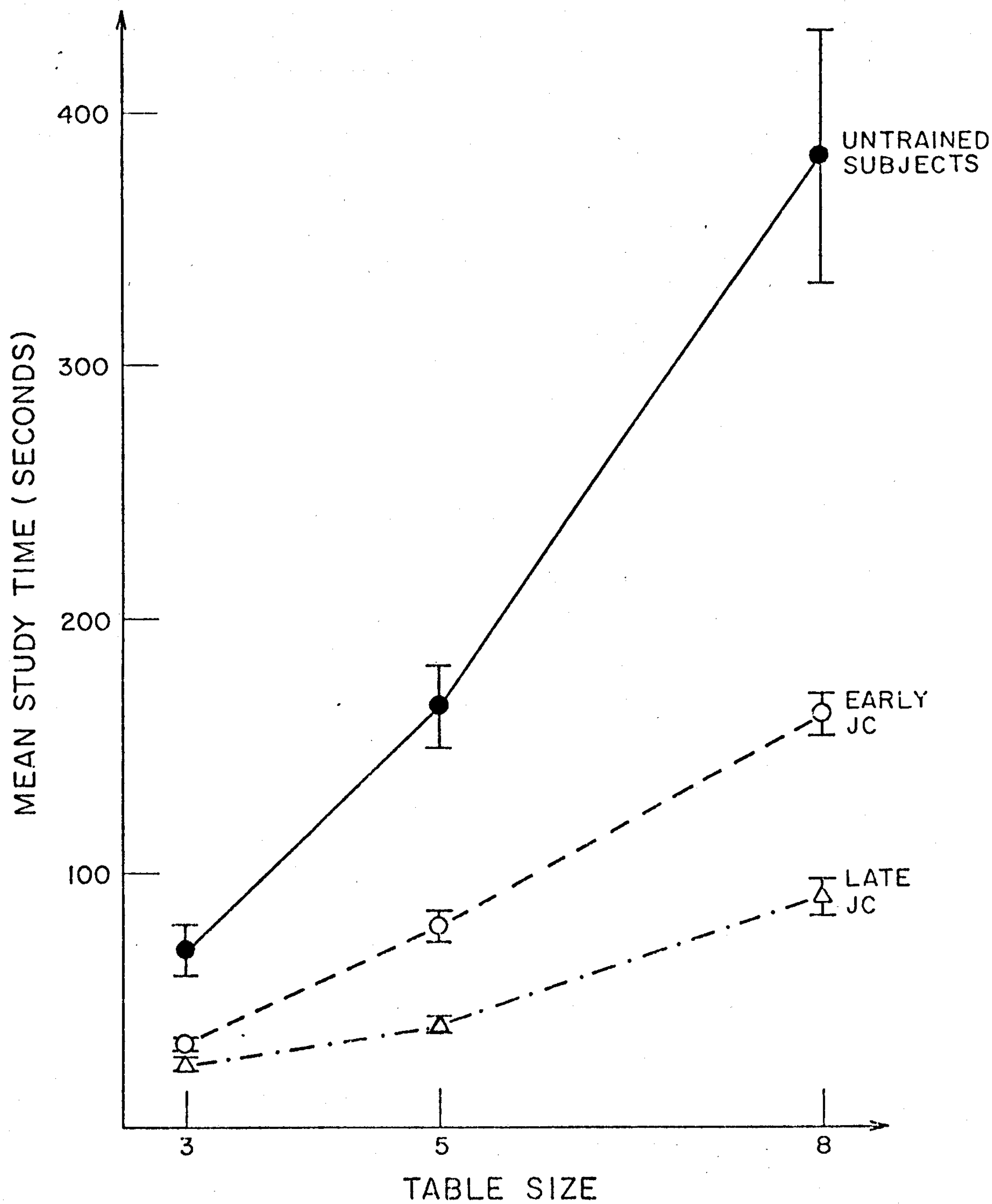

Figure 3

Study-time as a function of table size for untrained subjects and the memory expert (JC) early and late in the experimental investigation.

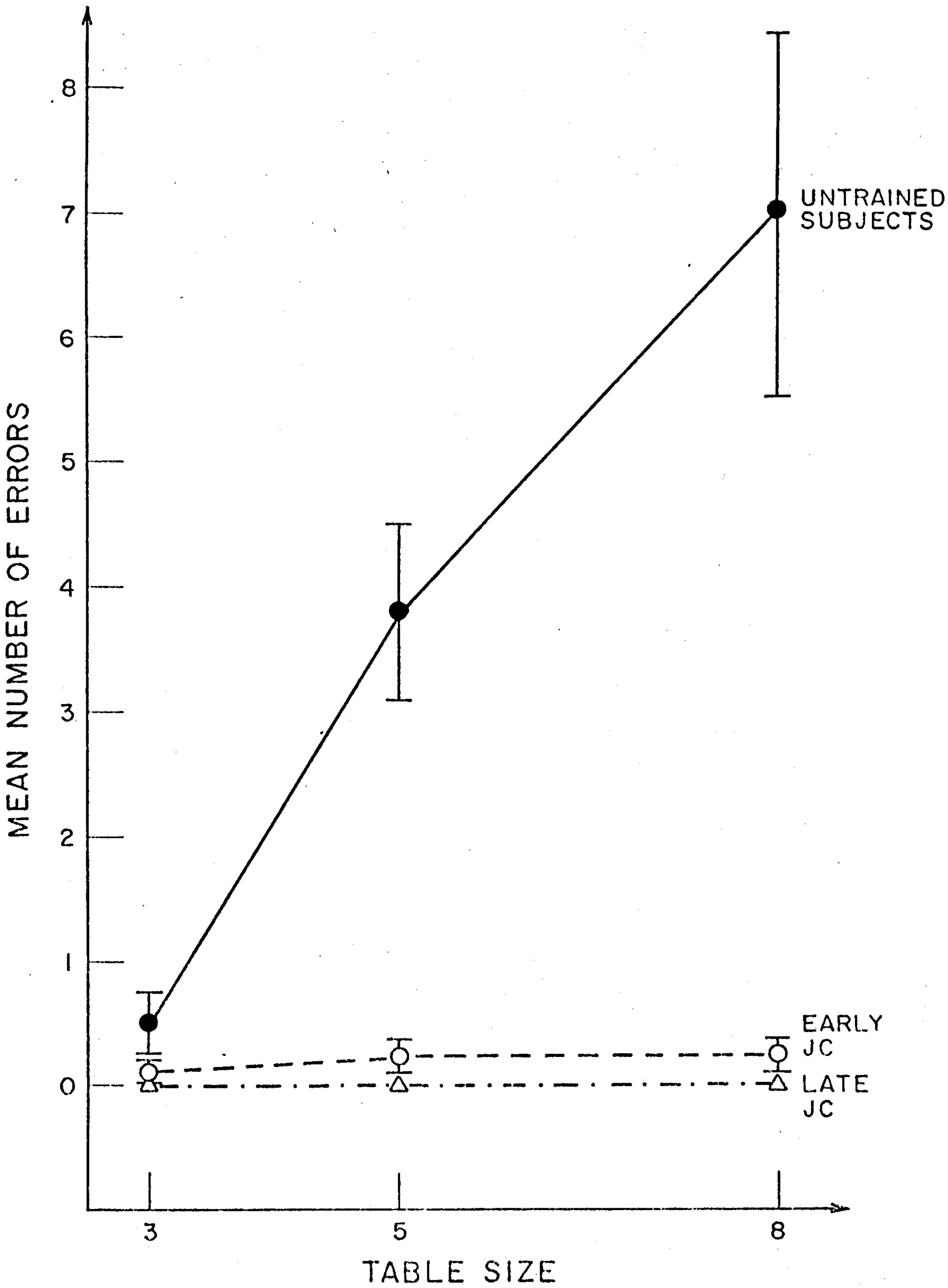

Figure 4

Mean number of errors as a function of table size for untrained subjects and the memory expert (JC) early and late in the experimental investigation.

Study-Times for Individual Orders

The study-times for individual orders are measured from the beginning of the presentation of the order until the presentation of the "next" order. This time includes requests for previously presented items of complete dinner-orders. The analyses of the naive subjects' recall coding and data suggests a sequential memorization of complete dinner-orders. Such memorization would lead to a linear increase of the time required for committing each new order.

Figure 5 presents the study-times for individual orders for the normal subjects. The data strongly supports the sequential hypothesis as the study-times for the first five orders are approximately equal regardless of table-size. The study-times roughly increase in a linear fashion with the number of earlier presented orders, except for the first order (no previous orders) and the eighth order, which contains a large number of requests of re-presentations of earlier orders. Naive subjects memorized the dinner-orders as they were a list of dinner-orders (units of 4 ordered items) with their cognitive process being independent of the length of the list to be presented. It was only at the end of the longer lists (tables of 5 and 8) that they use differential amount of effort to commit the entire list to memory.

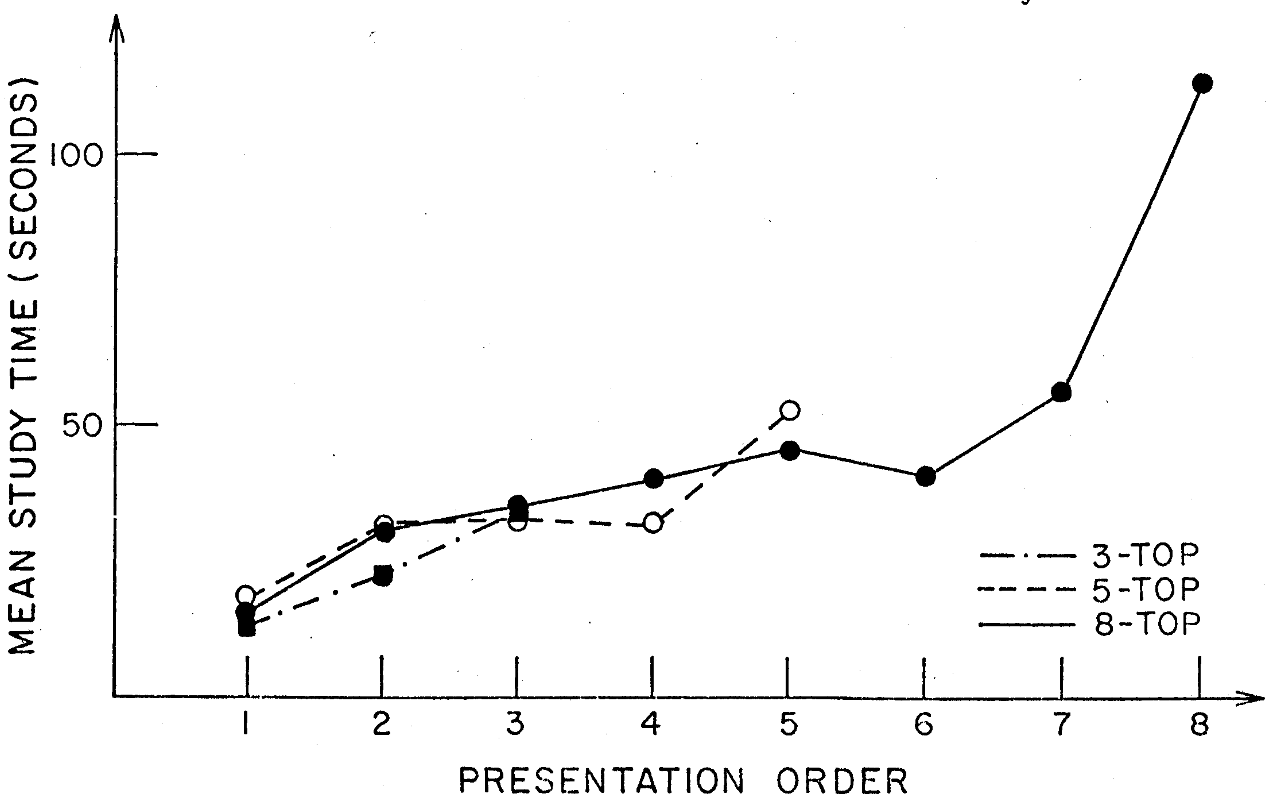

Figure 5

Average study-times for individual dinner orders as a function of presentation order for untrained subjects studying orders from tables 3, 5 and 8 people.

Figure 6 shows the average study times for each dinner order where each line corresponds to a given table size for JC's data. Comparison of Figures 5 and 6 shows that the naive subjects and JC show strikingly different patterns of study times. This is especially apparent for tables of 8. Study time increases linearly across the first four orders and then there is a sharp drop in study time between orders four and five. The study time again increases for orders five through eight and the first and last half of the serial position curves are strikingly similar. This pattern of study times is exactly what would be predicted from the model of JC's memory skills described in an earlier section. Recall that the model assumes that JC encodes items by category and in groups of four. Study times are predicted to progressively increase within a group of four because of larger processing demands for the later orders within each group. With the exception of the first order within a group, storage of items in subsequent orders requires that JC first retrieve earlier presented items of the same category, to allow extracting of patterns involving all items within the group of items of that category.

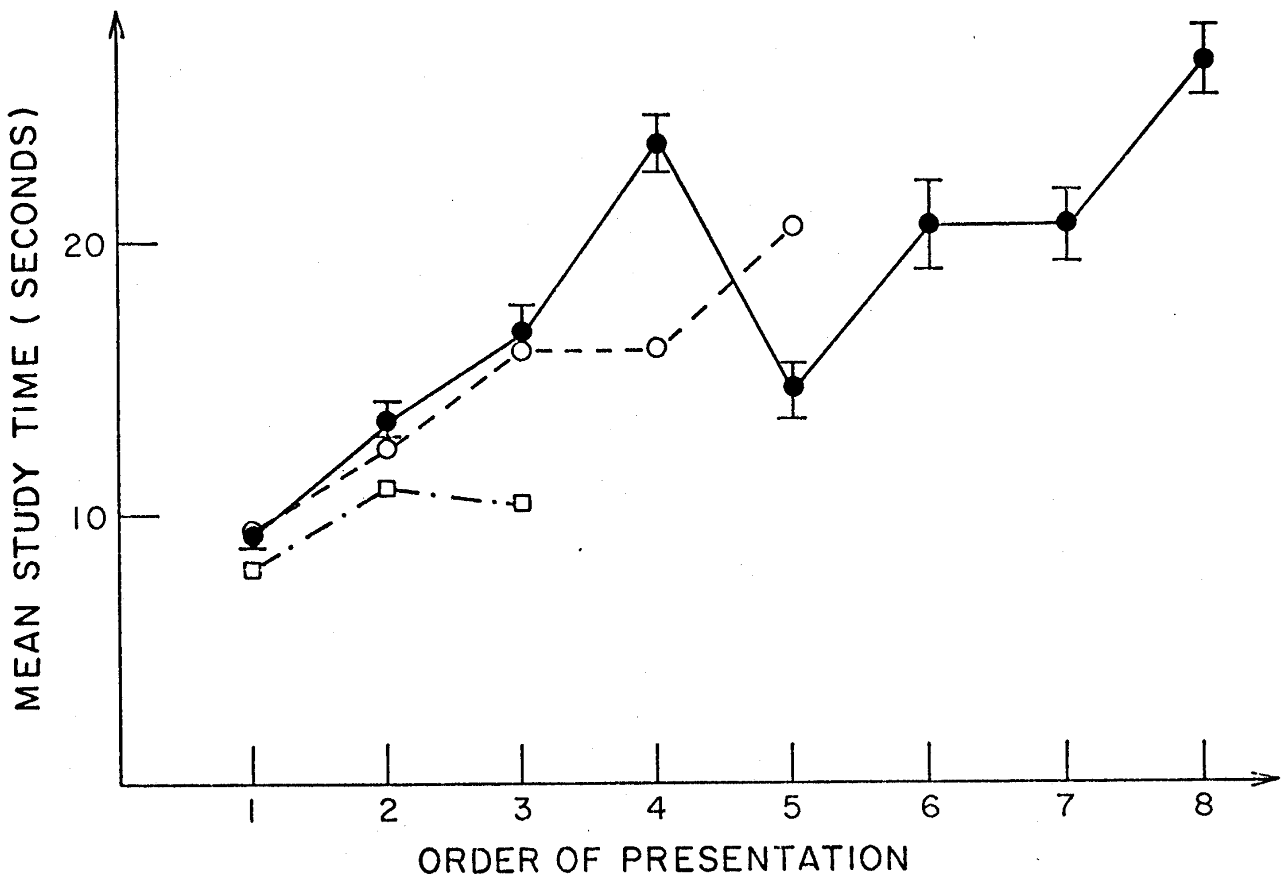

Figure 6

Average study-times for individual dinner orders as a function of presentation order for memory expert (JC) studying orders from 3, 5 and 8 people.

to tables 1 through 6 to serve as cues in the post-session recall, and during the other two sessions, the pictures corresponding to table 7 through 12 were presented. His accuracy of cued recall is given for both dinner orders and category lists (Animal orders") in Figure 7.

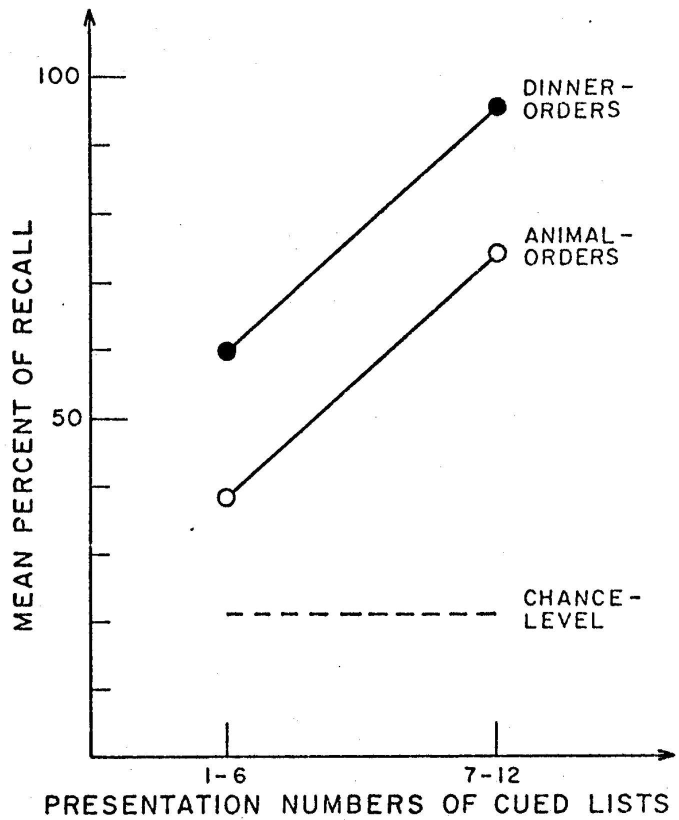

Figure 7

Mean percent correct recall of lists as a function of presentation number, when JC was given a post-session cued recall for either the first or last half of studied lists.

His recall of information about dinner orders is virtually perfect for the second block; 122 of 128 presented items, and reliably less for the first block. The recall of the analogous category lists have the same pattern, but the level of accuracy is lower. For these lists we noticed a couple of very obvious intrusions from Block 1 onto cued recall of Block 2. On both occasions with cued recall of Block 2, JC recalled one entire sub-list of items for a 5-top from Block 1. (The probability of one such event occurring by chance is less than one in 3000.)

Given that recall for dinner orders was virtually perfect for block 2, we examined the recall of dinner-orders from block 1 for differences in the amount recalled from each category, e.g., salad dressings. If systematic differences were found it might suggest that the better recalled category was more closely associated with the pictures of faces. When corrections for incorrect guesses were made, starches were recalled best (72%), entrees and salad dressings second (58% and 50% respectively) and temperatures worst (38%). Hence these results lend no support to the earlier suggestion that entrees are more directly associated to faces.

In sum, the evidence for post-session memory for the studied information is clear and in accordance with the characteristics of skilled memory (Chase & Ericsson, 1982). Furthermore, we observed clear interference from previously studied lists of the same structure and with the same type of information. Passage of time and other kinds of lists appeared to have smaller, if any, effect. Hence, only for lists of the same structure and content the massive inference effects observed in normal laboratory studies were obtained (Underwood, 1957).

Improvement in Performance During the Year-Long Experiment

During the year-long experiment JC showed a remarkable improvement. After the initial couple of sessions, his recall accuracy was virtually perfect for all the table-sizes. His improvement was also exhibited in a steady decrease in the study-times. In Figure 8 the average study-times for three different sessions are given.

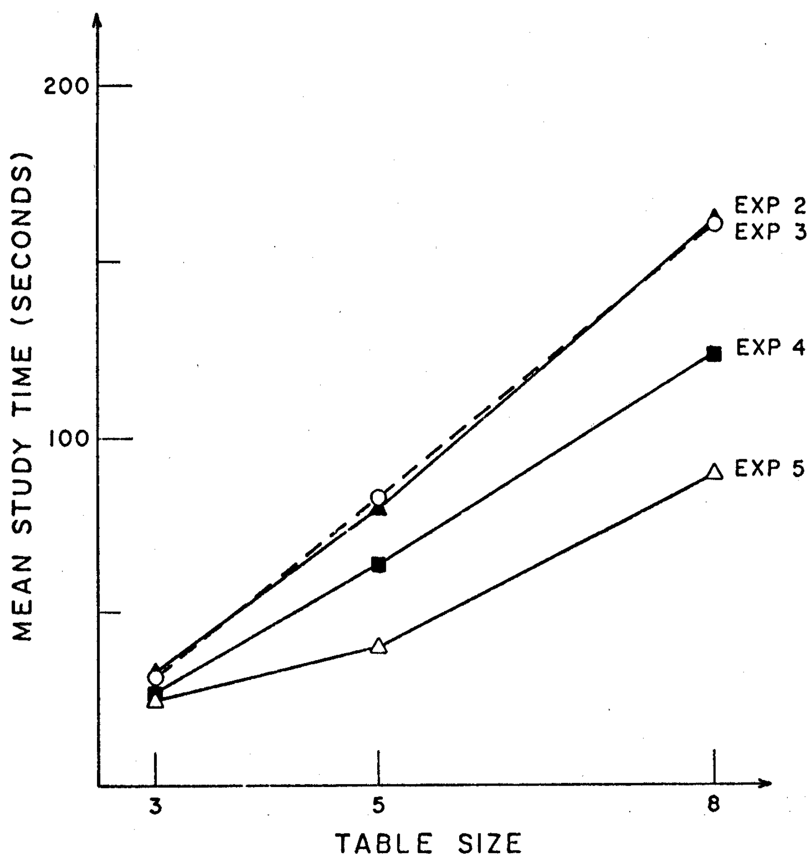

Figure 8

Mean total study-time as a function of table size for memory expert (JC) in the four consecutive experiments.

The most striking result is steady decrease in study-time, along with the lack of any sign of reaching a stable final performance-level. One should also notice that the improvement appears to be proportional over table-sizes and at each level of practice the study-times can be described as a linear function of table-size. Before turning to a discussion of this practice effect, let us compare the study-times for individual orders at different levels of practice, which are given in Figure 9. The rather clear increase in latency associated with grouping items into groups of four or five appears to have almost vanished with further practice. However, the reduction of study-times, as shown in the previous figure, is essentially unchanged.

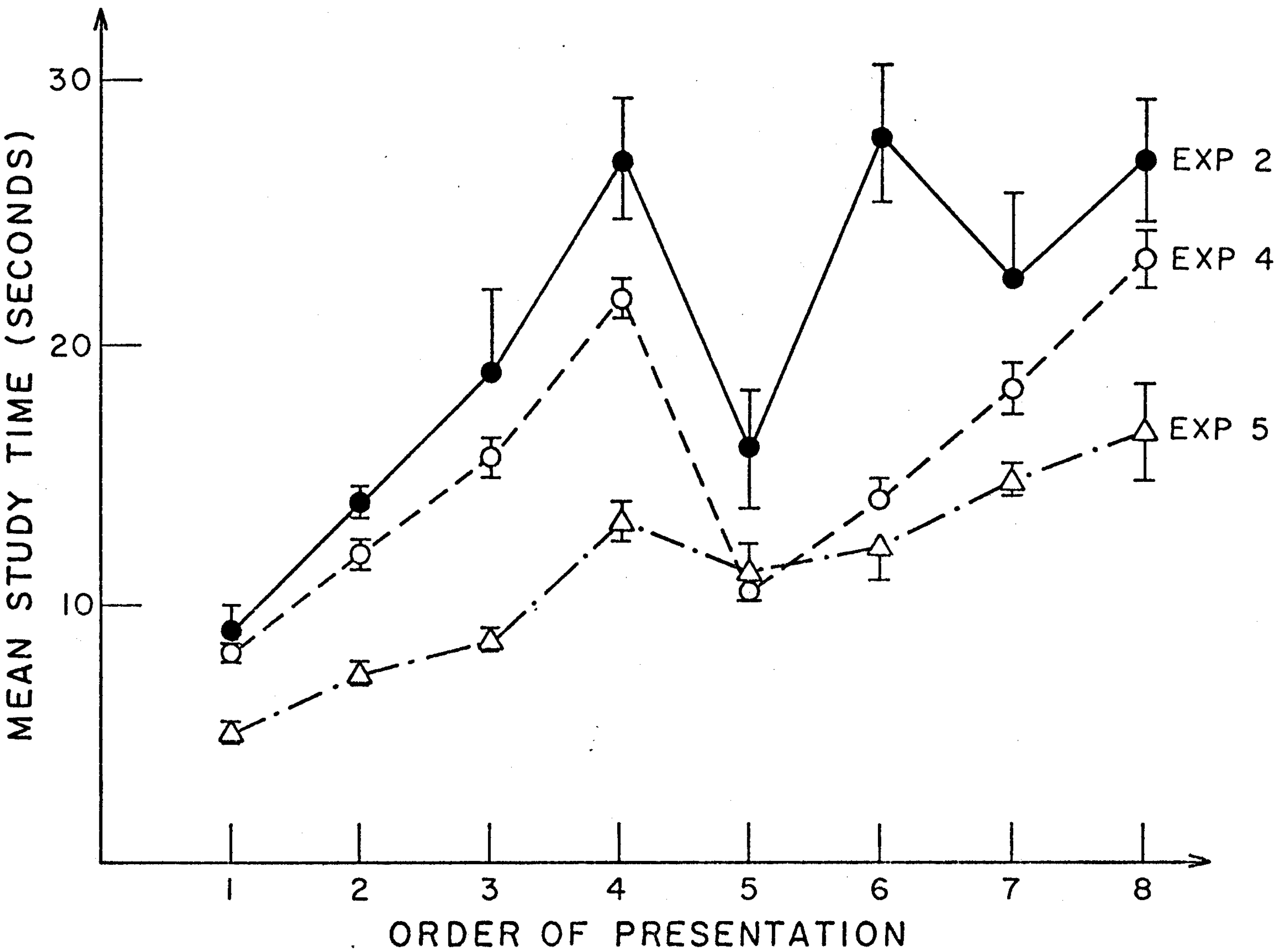

Figure 9

Study-time for individual dinner orders as a function of presentation order for memory expert (JC) in three different experiments.

Results. The detailed method of analysis as well as the actual analysis is presented elsewhere (Ericsson & Polson, in preparation) and hence only the major findings are discussed here. No effects were found for the experimental condition (normal vs. category presentation) or its interaction with table-size. The effect of table-size was large and accounted for nearly 90% of the variance.

An analysis of the average study time for both conditions showed no difference between conditions even for the first session. The absence of practice effects suggests that JC did not have to adapt to the category presentation, and thus this method of presentation is compatible with his usual encoding processes.

In the category presentation condition we have recorded the time taken to memorize three, four or five items of a given category. An initial analysis showed that the time taken to memorize such a group of items appeared the same regardless of when it was presented in the sequence. This contrasts markedly with the linear increases of study times observed for individual dinner orders as function of presentation order discussed earlier. Hence there is good evidence that storage of within-category groups is direct and non-cumulative.

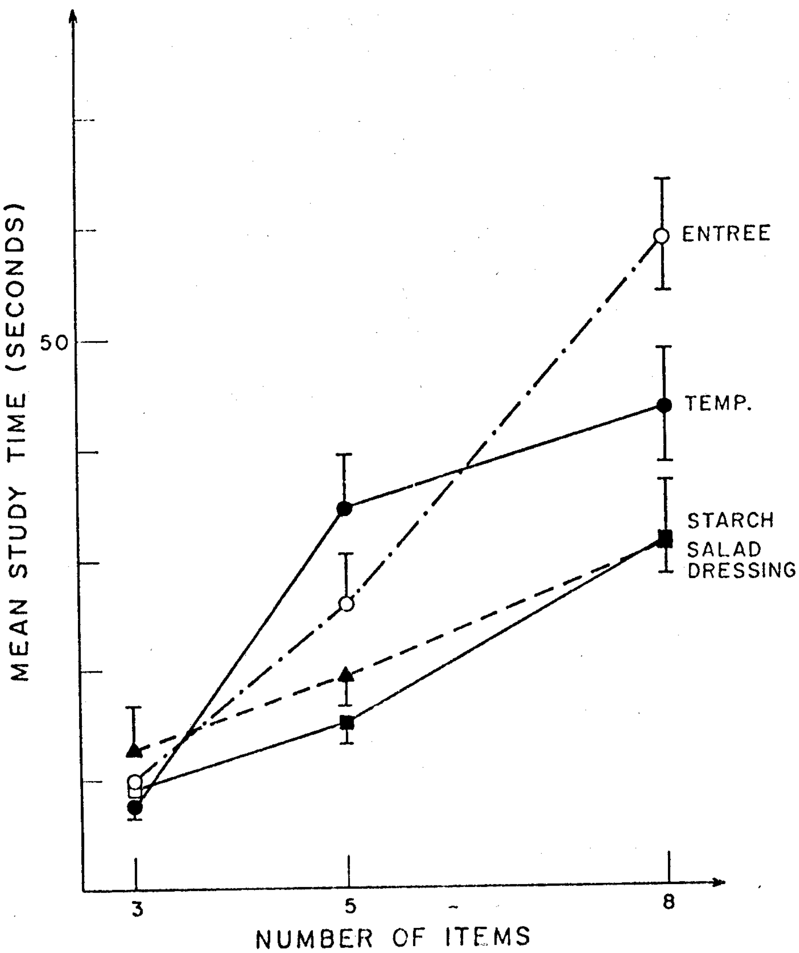

Figure 10

Average study-time with standard error bars for groups of 3, 5, and 8 items from different categories i.e., salad dressings (filled circles), starches (unfilled circles), tempreatures (filled squares) and entrees (unfilled squares).

of course, highly significant, and all the effects reported below were at least significant at 1%-level. The main effect of condition (normal vs. varied presentation) was significant as well as its interaction with table-size.

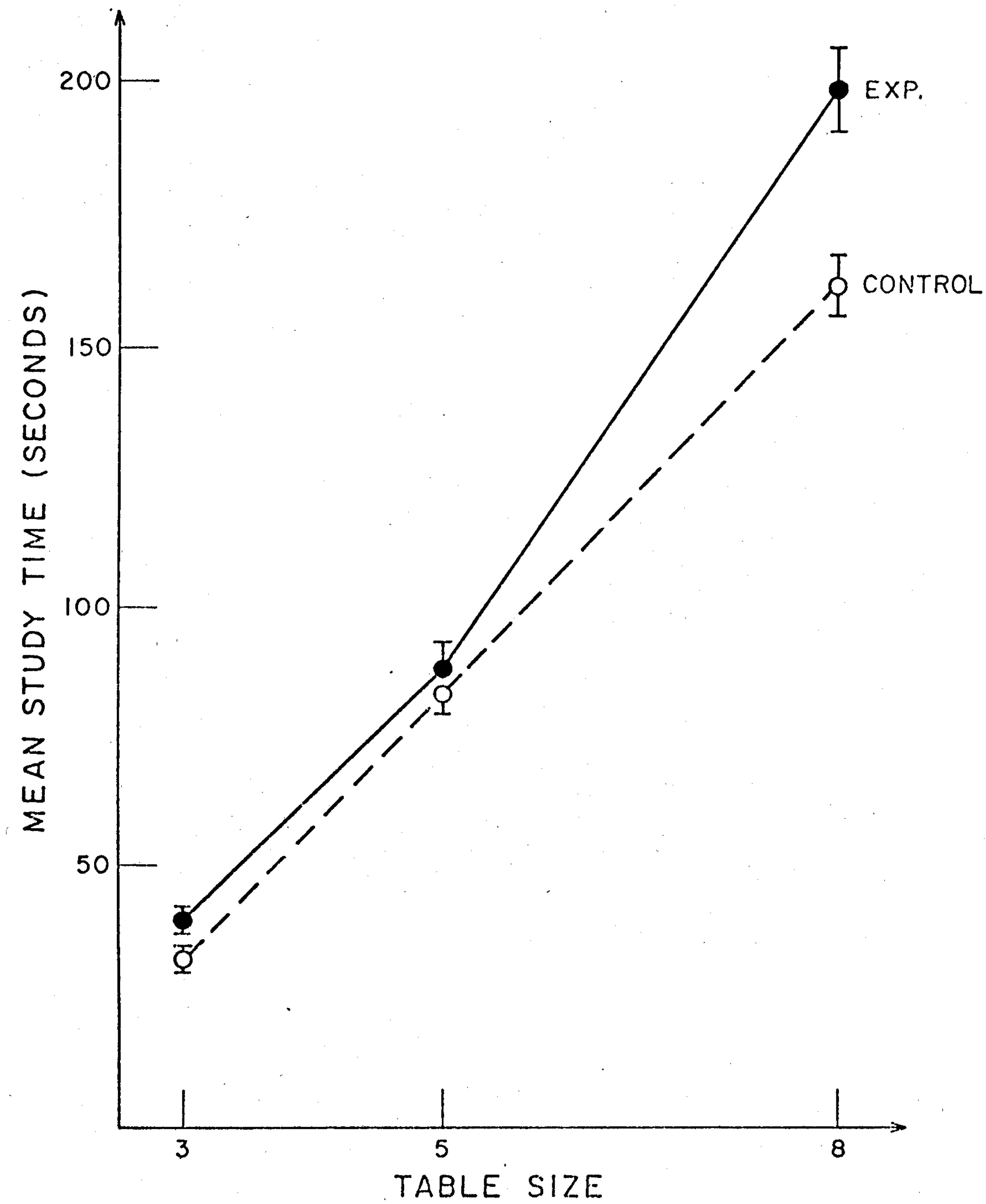

Figure 11

Mean total study-times as a function of table size for control and experimental condition in Varied Presentation Experiment.

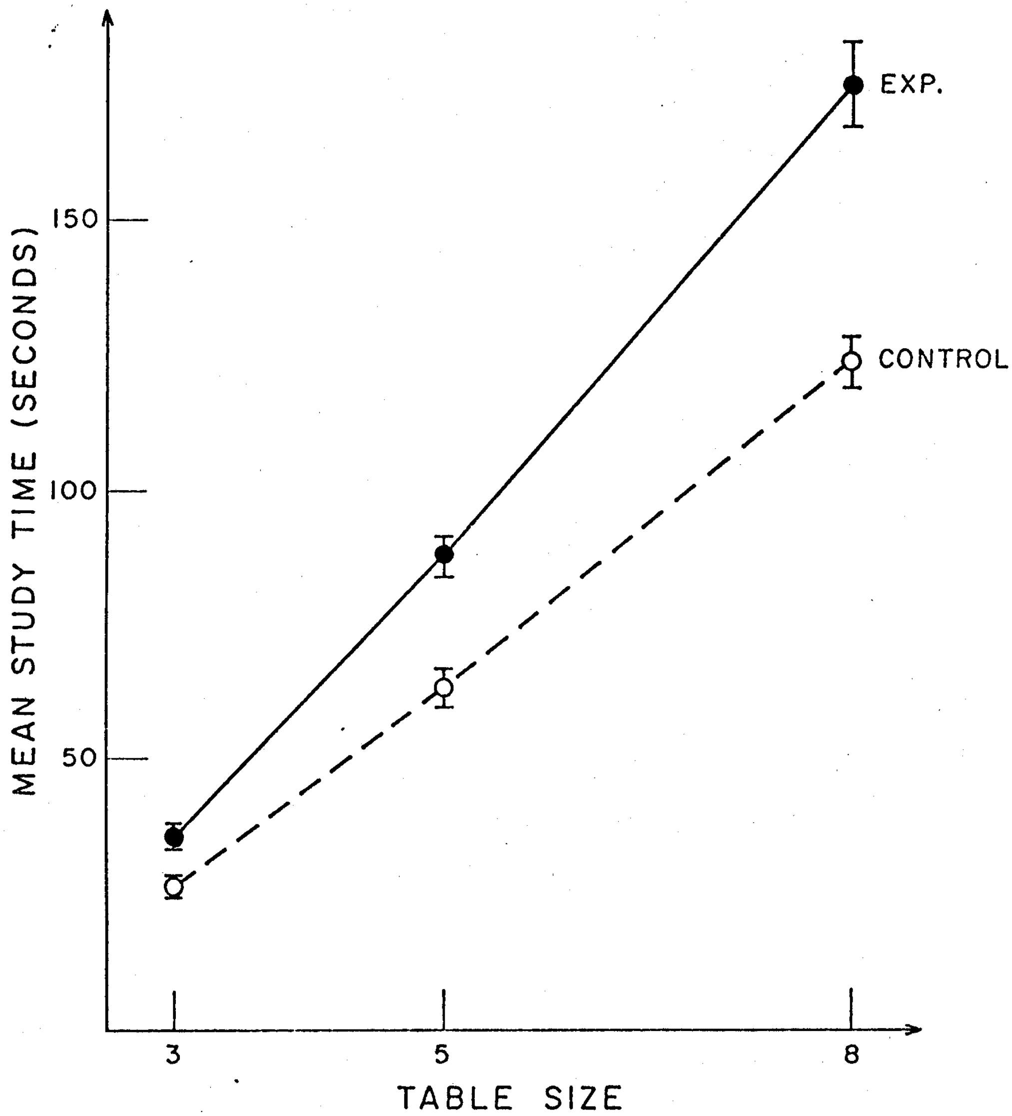

Figure 12

Mean total study-times as a function of "table size" for control and experimental condition in Category Materials Experiment.

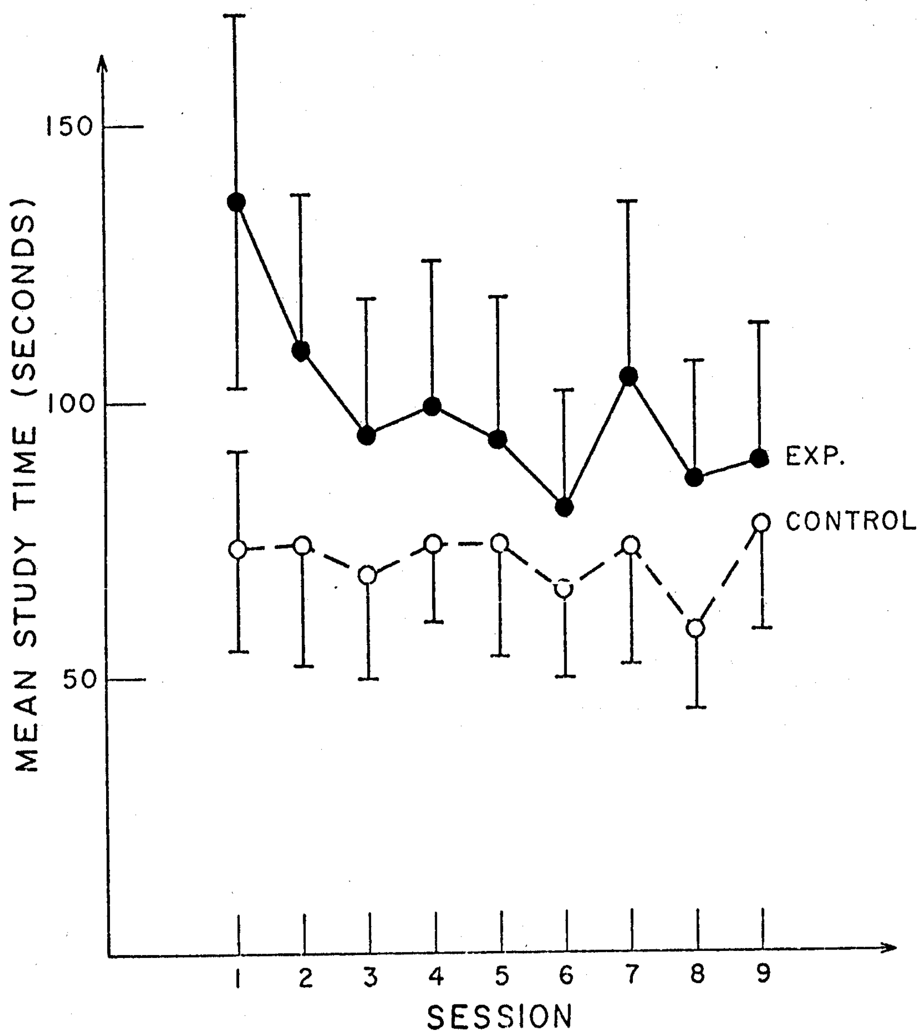

Figure 13

Average total study-times as a function of session number for control and experimental condition in Category Materials Experiment.

It appears clear that JC memorized the animal tables by category and we will now turn to an examination of the pattern of study-times for individual orders. Figure 14 shows the mean study-times for individual orders for control and animal-tables.

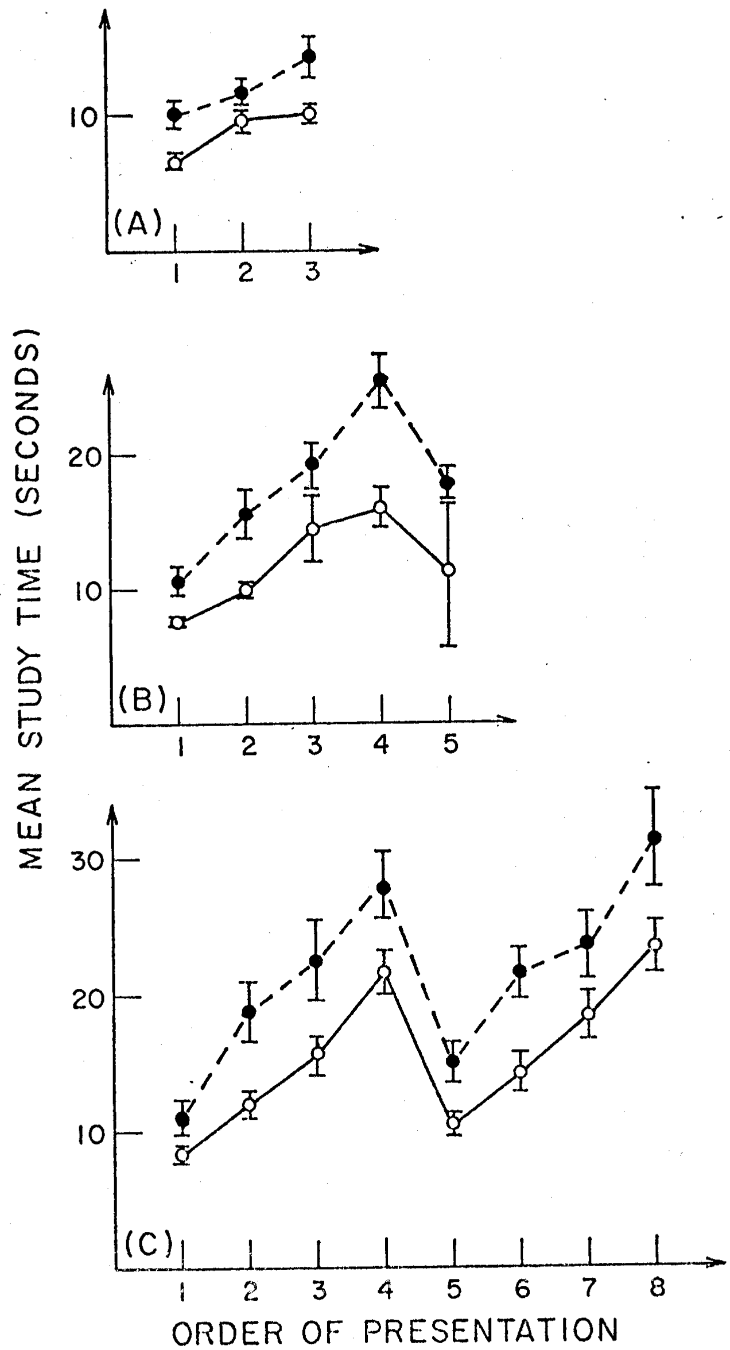

Figure 14

Study-times for individual "dinner-orders" as a function of order of presentation for control and experimental condition in Category Materials Experiment, for lists of 3 "orders" (upper panel), of 5 "orders" (middle panel) and of 8 "orders" (lower panel).

time than Type-B lists, because the Type-A lists are, on the average, more redundant. Finally, less improvement due to practice was expected because the categories from which items were sampled varied from trial to trial.

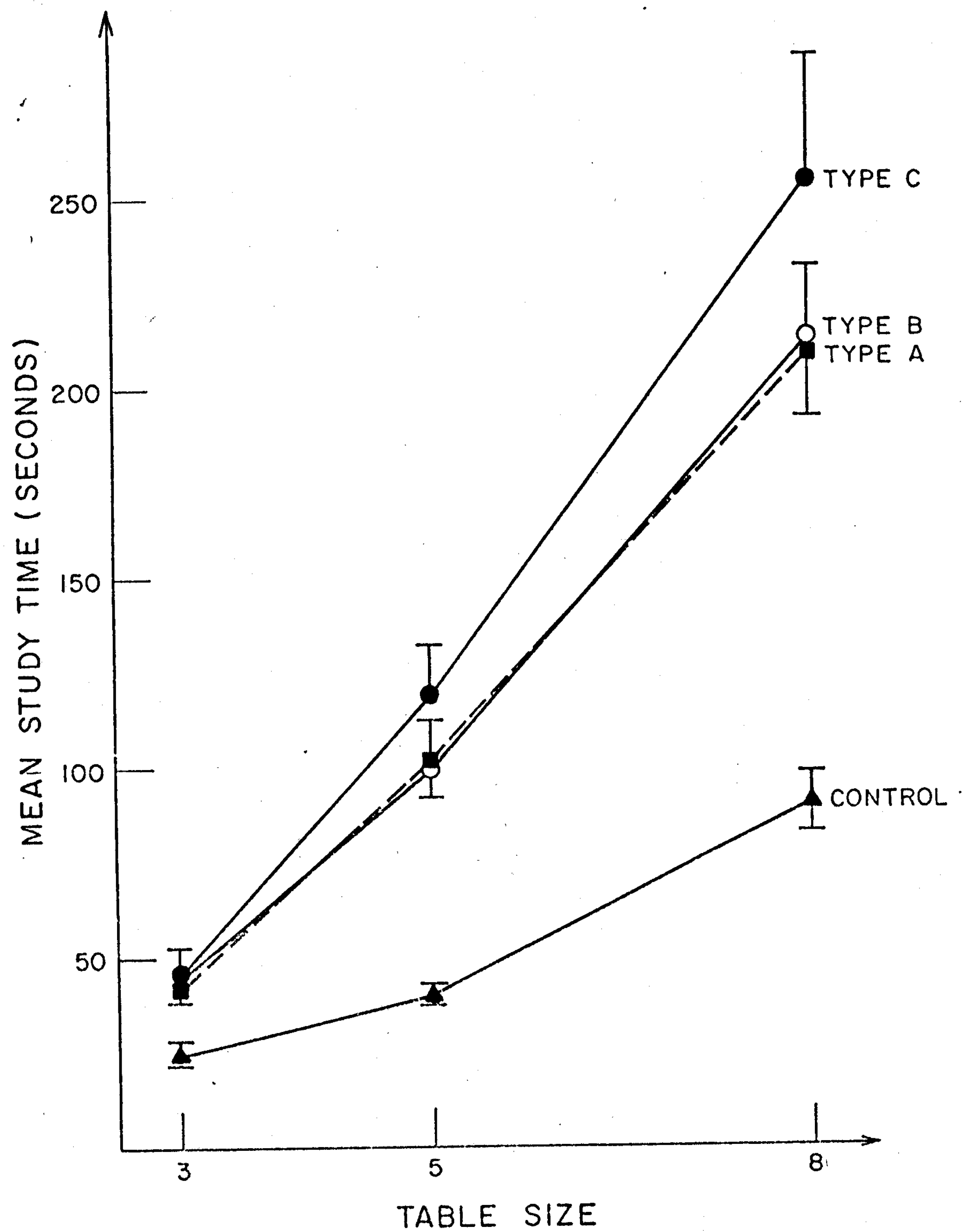

Figure 15

Mean total study-times as a function of "table-size" for the three types of lists in Generalizability of Skills Experiment.

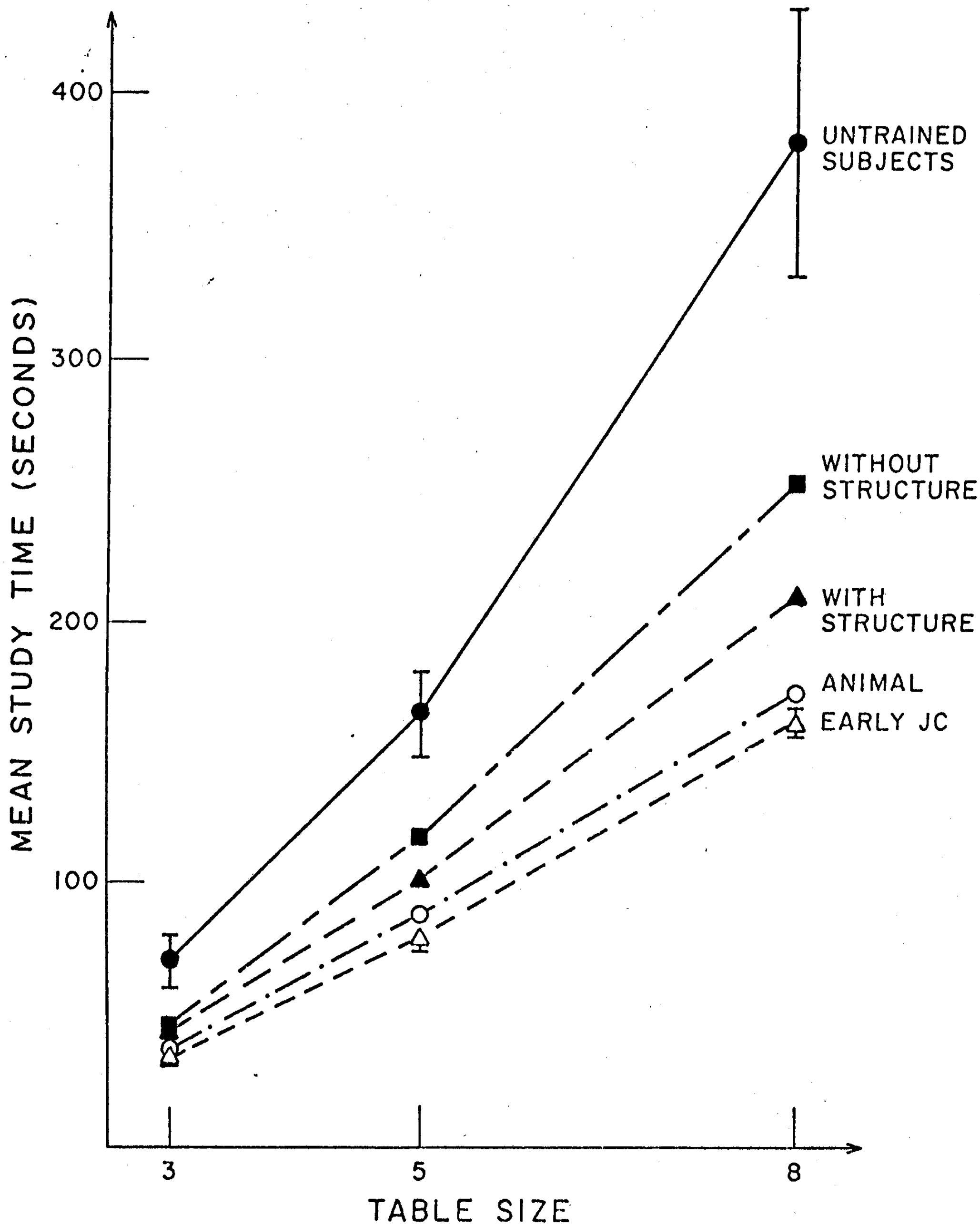

Figure 16

Mean total study-times as a function of "table-size" for memory expert (JC) for dinner orders in Category Presentation experiment (Early JC), for fixed category-lists in Category Materials Experiment (Animal), for category lists with and without structure from Generalizability of skill experiment and for untrained subjects.

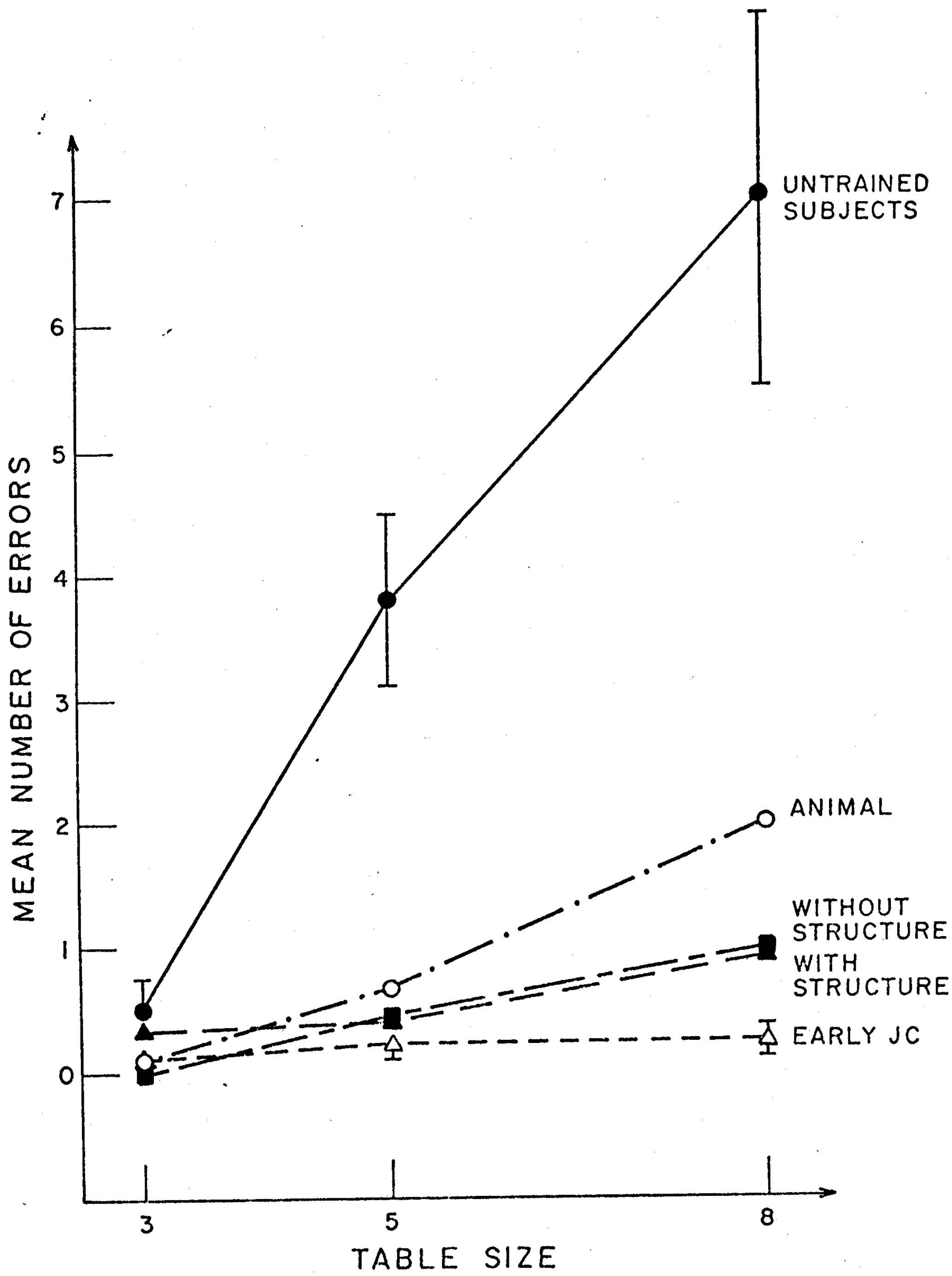

Figure 17

Mean number of errors as a function of "table-size" for memory expert (JC) for dinner orders in Category Presentation experiment (Early JC), for fixed category-lists in Category-list experiment (Animal), for category lists with and without structure from Generalizability of skill experiment and for untrained subjects.