Navy

1 Robert Ahlers
Code N711
Human Factors Laboratory
NAVTRAEQUIPCEN
Orlando, FL 32813

1 Dr. Meryl S. Baker
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Alvah Bittner
Naval Biodynamics Laboratory
New Orleans, LA 70189

1 Dr. Nick Bond
Office of Naval Research
Liaison Office, Far East
APO San Francisco, CA 96503

1 Lt. Alexander Bory
Applied Psychology
Measurement Division
NAMRL
NAS Pensacola, FL 32508

1 Dr. Robert Breaux
NAVTRAEQUIPCEN
Code N-095R
Orlando, FL 32813

1 Dr. Robert Carroll
NAVOP 115
Washington , DC 20370

1 Dr. Susan Chipman
Code 442PT
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 Dr. Stanley Collyer
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217

1 CDR Mike Curran
Office of Naval Research
800 N. Quincy St.
Code 270
Arlington, VA 22217

Navy

1 Dr. Charles E. Davis
Personnel and Training Research
Office of Naval Research (Code 442PT)
800 North Quincy Street
Arlington, VA 22217

1 Dr. Marshall J. Farr
2520 North Vernon Street
Arlington, VA 22207

1 DR. PAT FEDERICO
Code P13
NPRDC
San Diego, CA 92152

1 Dr. Jim Hollan
Code 51
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Ed Hutchins
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Norman J. Kerr
Chief of Naval Education and Training
Code 00A2
Naval Air Station
Pensacola, FL 32508

1 Dr. William L. Maloy (02)
Chief of Naval Education and Training
Naval Air Station
Pensacola, FL 32508

1 Dr. James McBride
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr William Montague
NPRDC Code 13
San Diego, CA 92152

1 Office of the Chief of Naval Operations
Research Development & Studies Branch
OP 115
Washington, DC 20350

1 LT Frank C. Petho, MSC, USN (Ph.D)
CNET (N-432)
NAS
Pensacola, FL 32508

Navy

1 Dr. Bernard Rimland
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Carl Ross
CNET-PDCD
Building 90
Great Lakes NTC, IL 60088

1 Dr. Alfred F. Smode
Senior Scientist
Code 7B
Naval Training Equipment Center
Orlando, FL 32813

1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Martin A. Tolcott
Leader, Psychological Sciences Division
Office of Naval Research
800 N. Quincy St.
Arlinsgon, VA 22217

1 Dr. James Tweeddale
Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Douglas Wetzel
Code 12
Navy Personnel R&D Center
San Diego, CA 92152

1 DR. MARTIN F. WISKOFF
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

1 Mr John H. Wolfe
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Donald Woodward
Office of Naval Research (Code 441)
800 North Quincy Street
Arlington, VA 22217

1 Dr. Steven Zornetzer
Associate Director for Life Sciences
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

Marine Corps

1 Major Frank Yohannan, USMC
Headquarters, Marine Corps
(Code MPI-20)
Washington, DC 20380

Army

1 Dr. Harold F. O'Neil, Jr.
Director, Training Research Lab
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Commander, U.S. Army Research Institute
for the Behavioral & Social Sciences
ATTN: PERI-BR (Dr. Judith Orasanu)
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Ray Perez
5001 Eisenhower Avenue
PERI-II
Alexandria, VA 22333

1 Joseph Psotka, Ph.D.
ATTN: PERI-1C
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Joyce Shields
Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Zita M. Simutis
Chief, Instructional Technology
Systems Area
ARI
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Hilda Wing
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

Air Force

1 Dr. William E. Alley
AFHRL/MOT
Brooks AFB
, TX 78235

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235

1 Mr. Raymond E. Christal
AFHRL/MOE
Brooks AFB, TX 78235

1 Dr. Alfred R. Fregly
AFOSR/NL
Bolling AFB, DC 20332

3 Dr. Sherrie Gott
AFHRL/MODJ
Brooks AFB
, TX 78235

1 Dr. Patrick Kyllonen
AFHRL/MOE

Brooks AFB, TX 78235

1 Dr. Roger Pennell
Air Force Human Resources Laboratory
Lowry AFB, CO 80230

1 Dr. Malcolm Ree
AFHRL/MP
Brooks AFB, TX 78235

1 Dr. Lawrence E. Reed
Research Psychologist
AFHRL/LRG
Wright-
Patterson AFB
, OH 45433

1 Dr. Joseph Yasatuke
AFHRL/LRT
Lowry AFB, CO 80230

Department of Defense

1 Dr. Craig I. Fields
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

1 Dr. Jerry Lehnus
OASD (M&RA)
Washington , DC 20301

1 Dr. W. Steve Sellman
Office of the Assistant Secretary
of Defense (MRA & L)
2B269 The Pentagon
Washington, DC 20301

1 Major Jack Thorpe
DARPA
1400 Wilson Blvd.
Arlington, VA 22209

1 Dr. Robert A. Wisher
U.S. Army Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria , VA 22333

Civilian Agencies

1 Dr. Helen J. Christup
Office of Personnel R&D
1900 E St., NW
Office of Personnel Management
Washington, DC 20015

1 Dr. Arthur Melmed
724 Brown
U. S. Dept. of Education
Washington, DC 20208

1 Dr. Andrew R. Molnar
Office of Scientific and Engineering
Personnel and Education
National Science Foundation
Washington, DC 20550

1 Dr. David Pearl
Room 10-C-09
5600 Fishers Lane
Rockville, MD 20857

1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Private Sector

1 Dr. John R. Anderson
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. Isaac Bejar
Educational Testing Service
Princeton, NJ 08450

1 Dr. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. John B. Carroll
409 Elliott Rd.
Chapel Hill, NC 27514

1 Dr. Lynn A. Cooper
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. Emmanuel Donchin
Department of Psychology
University of Illinois
Champaign, IL 61820

1 Dr. Jeffrey Elman
University of California, San Diego
Department of Linguistics
La Jolla, CA 92093

1 Dr. Susan Embertson
PSYCHOLOGY DEPARTMENT
UNIVERSITY OF KANSAS
Lawrence, KS 66045

1 Dr. Anders Ericsson
Department of Psychology
University of Colorado
Boulder, CO 80309

1 Dr. Dexter Fletcher
University of Oregon
Department of Computer Science
Eugene, OR 97403

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

Private Sector

1 Dr. Don Gentner
Center for Human Information Processing
University of California, San Diego
La Jolla, CA 92093

1 Dr. Robert Glaser
Learning Research & Development Center
University of Pittsburgh
3939 O'Hara Street
PITTSBURGH, PA 15260

1 Dr. Daniel Gopher
Faculty of Industrial Engineering
& Management
TECHNION
Haifa 32000
ISRAEL

1 Dr. Henry M. Halff
Halff Resources
4918 33rd Road, North
Arlington, VA 22207

1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105

1 Dr. Marcel Just
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. Demetrios Karis
Department of Psychology
University of Illinois
603 E. Daniel Street
Champaign, IL 61820

1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403

1 Dr. Scott Kelso
Haskins Laboratories, Inc
270 Crown Street
New Haven, CT 06510

1 Dr. Stephen Kosslyn
1236 William James Hall
33 Kirkland St.
Cambridge, MA 02138

Private Sector

1 Dr. Marcy Lansman
The L. L. Thurstone Psychometric Laboratory
University of North Carolina
Davie Hall 013A
Chapel Hill, NC 27514

1 Dr. Michael Levine
Department of Educational Psychology
210 Education Bldg.
University of Illinois
Champaign, IL 61801

1 Dr. Don Lyon
P. O. Box 44
Higley , AZ 85236

1 Dr. Jay McClelland
Department of Psychology
MIT
Cambridge, MA 02139

1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277

1 Dr. Donald A Norman
Cognitive Science, C-015
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. James W. Pellegrino
University of California,
Santa Barbara
Dept. of Psychology
Santa Barabara , CA 93106

1 Dr. Martha Polson
Department of Psychology
Campus Box 346
University of Colorado
Boulder, CO 80309

1 Dr. Mike Posner
Department of Psychology
University of Oregon
Eugene, OR 97403

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

Private Sector

1 Dr. David Rumelhart
Center for Human Information Processing
Univ. of California, San Diego
La Jolla, CA 92093

1 PROF. FUMIKO SAMEJIMA
DEPT. OF PSYCHOLOGY
UNIVERSITY OF TENNESSEE
KNOXVILLE, TN 37916

1 Dr. Arthur Samuel
Yale University
Department of Psychology
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Walter Schneider
Psychology Department
603 E. Daniel
Champaign, IL 61820

1 Dr. David Shucard
Brain Sciences Laboratories
Department of Pediatrics
National Jewish Hospital & Research Ctr
3800 E. Colfax Ave.
Denver, CO 80206

1 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

1 Dr. Kathryn T. Spoehr
Psychology Department
Brown University
Providence, RI 02912

1 James J. Staszewski
Research Associate
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

Private Sector

1 Dr. Perry W. Thorndyke
FMC Corporation
Central Engineering Labs
1185 Coleman Avenue, Box 580
Santa Clara, CA 95052

1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
1845 S. Elena Ave.
Redondo Beach, CA 90277

1 Dr. Keith T. Wescourt
FMC Corporation
Central Engineering Labs
1185 Coleman Ave., Box 580
Santa Clara, CA 95052

1 Dr. Christopher Wickens
Department of Psychology
University of Illinois
Champaign, IL 61820

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.

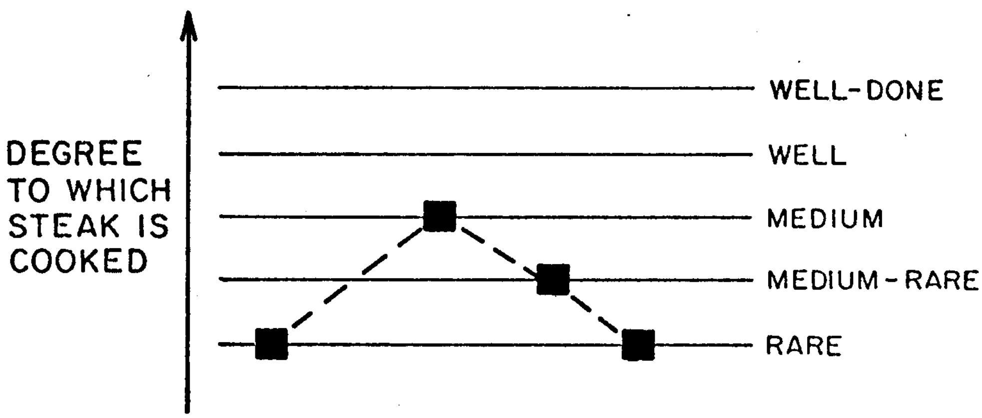

Figure 1

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.

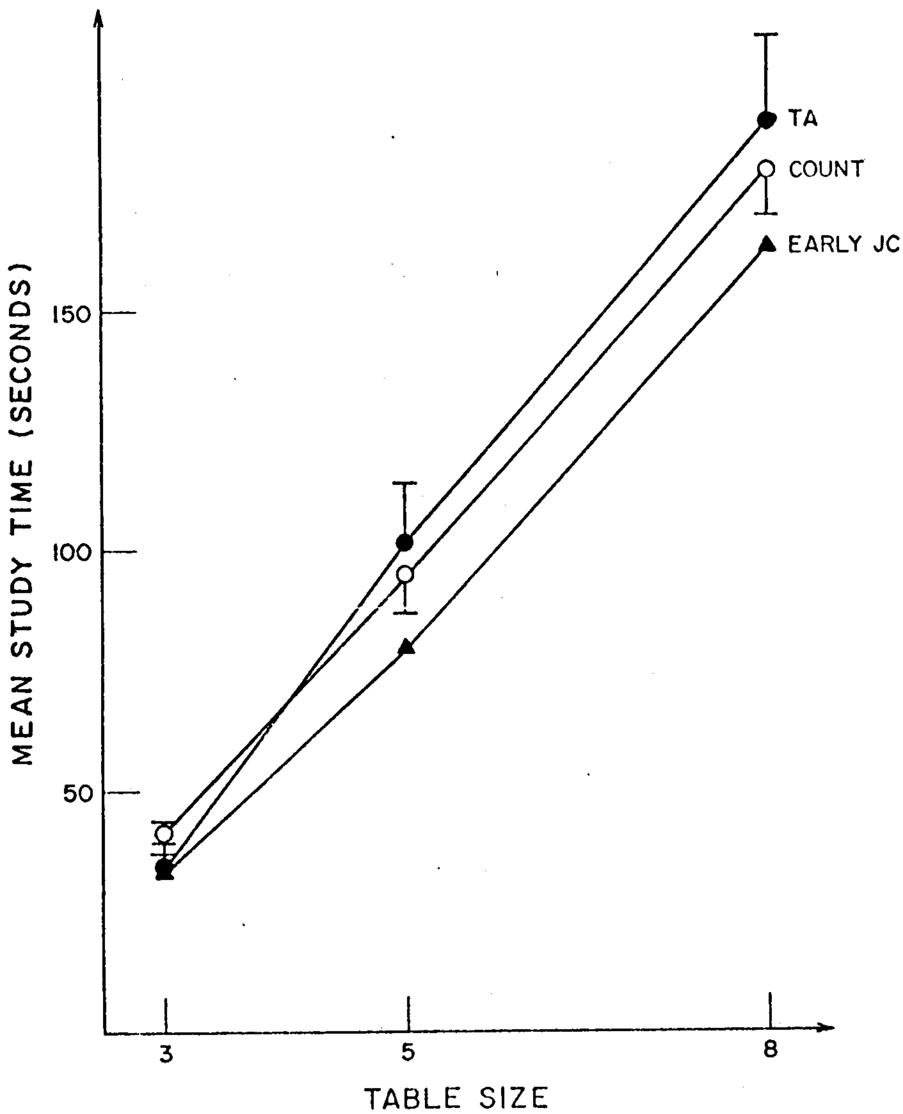

Figure 2

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.

<u>Protocol Data Supporting the Model of JC's Memory Skill</u>

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.

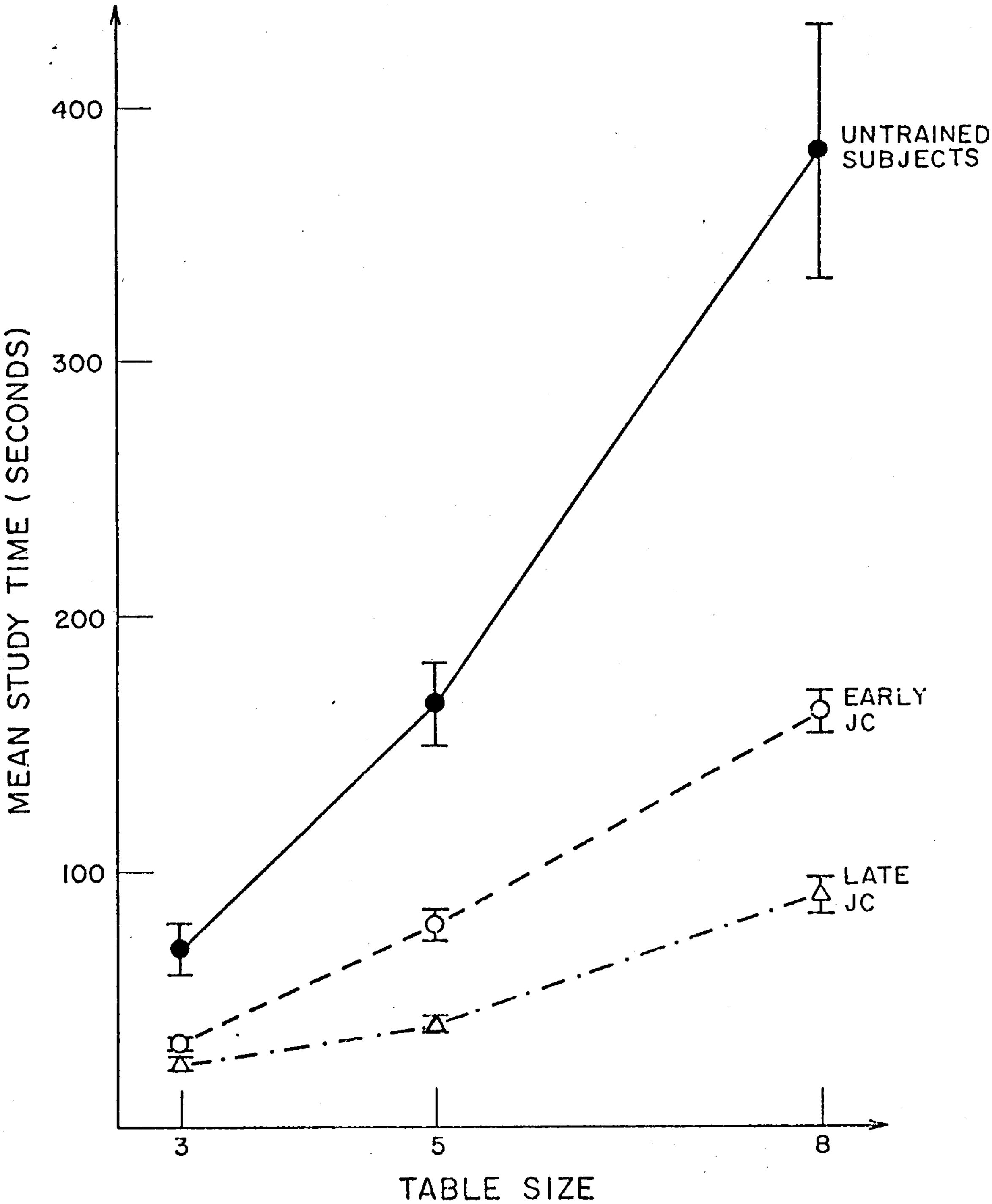

Figure 3

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

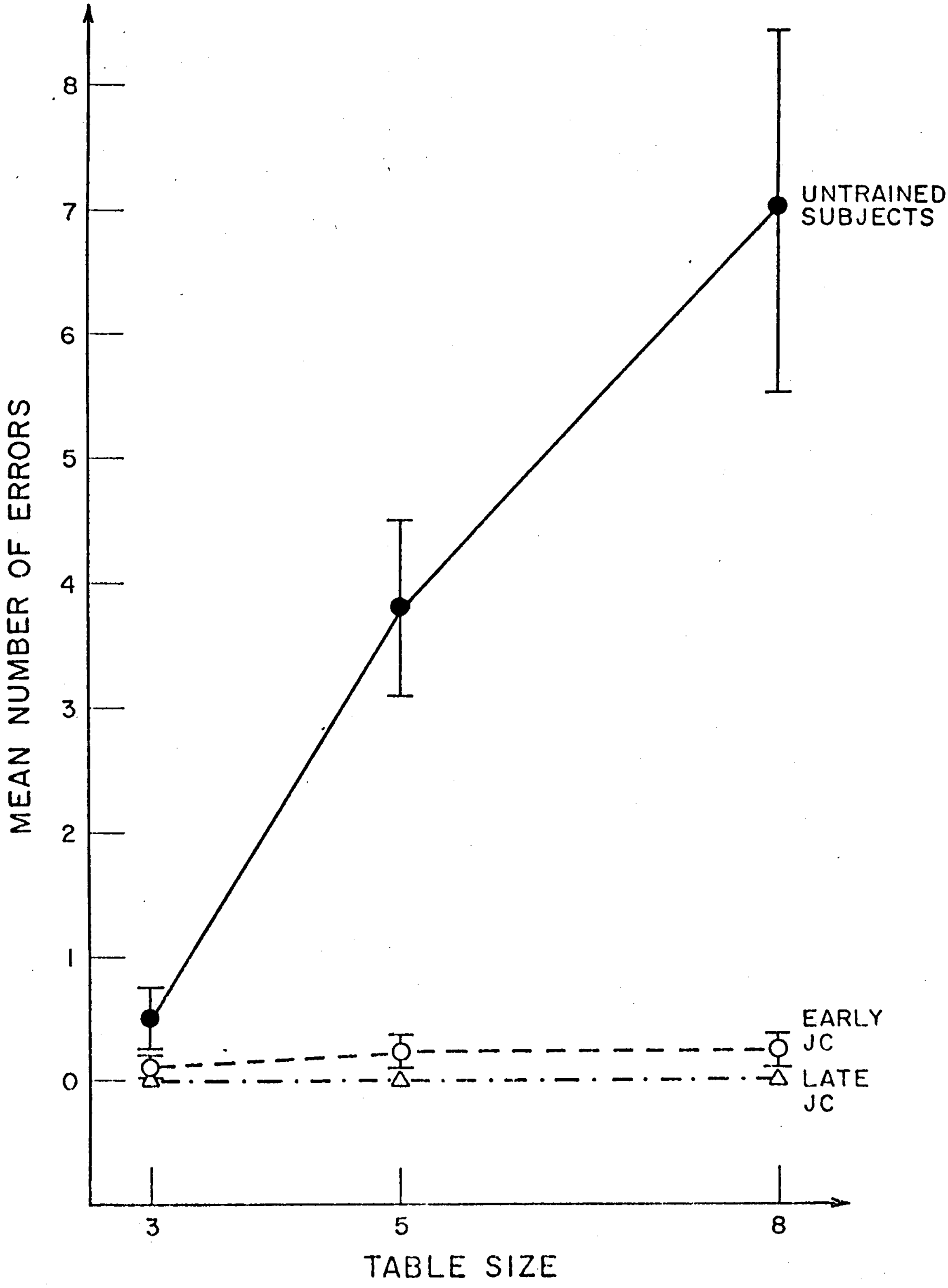

Figure 4

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.

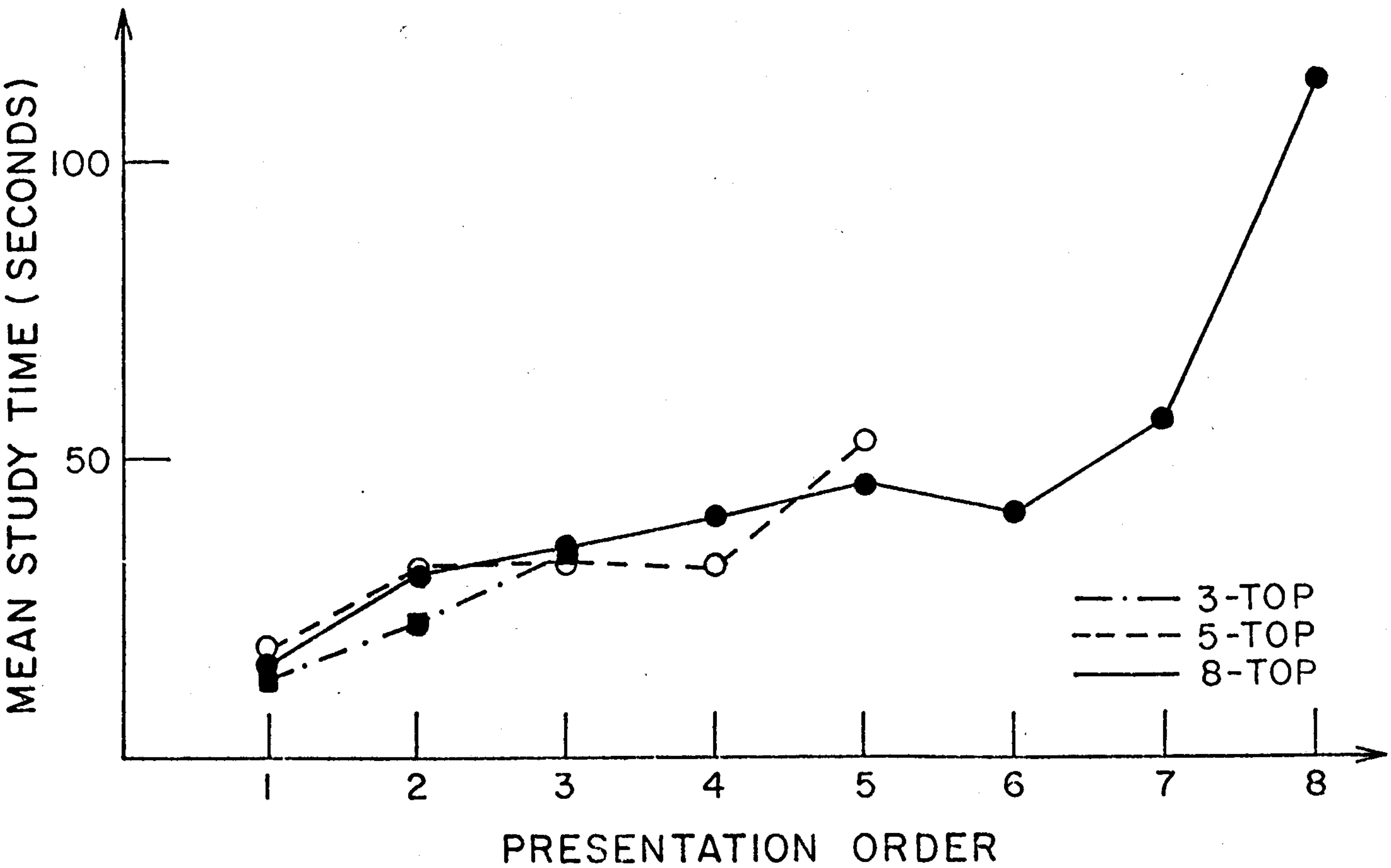

Figure 5

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.

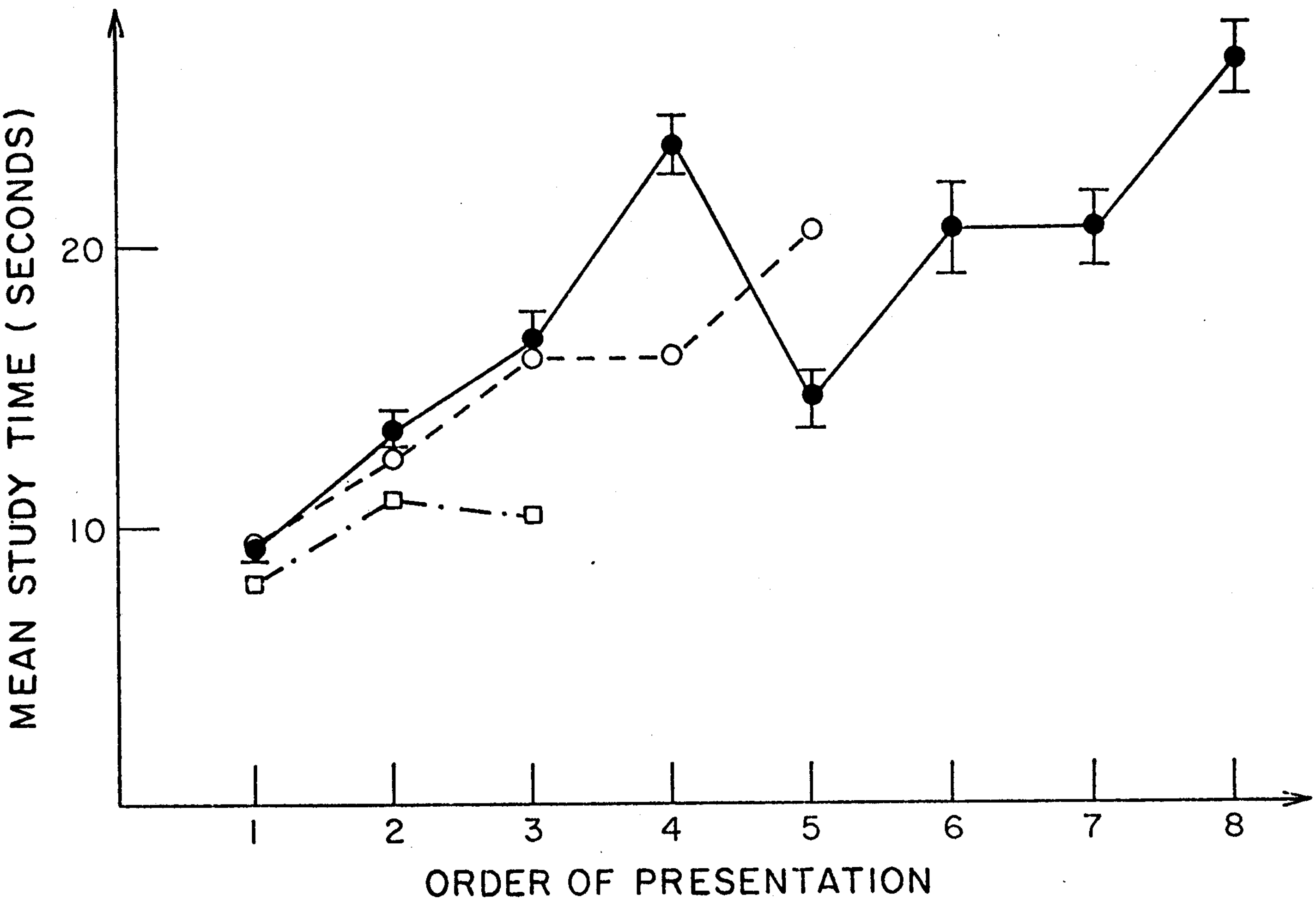

Figure 6

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.

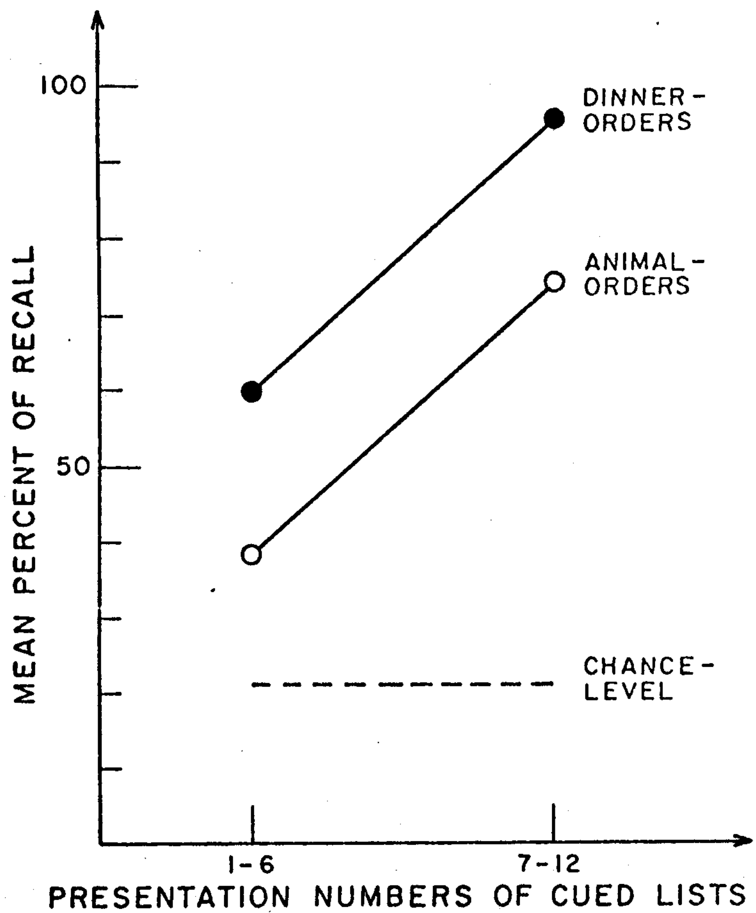

Figure 7

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.

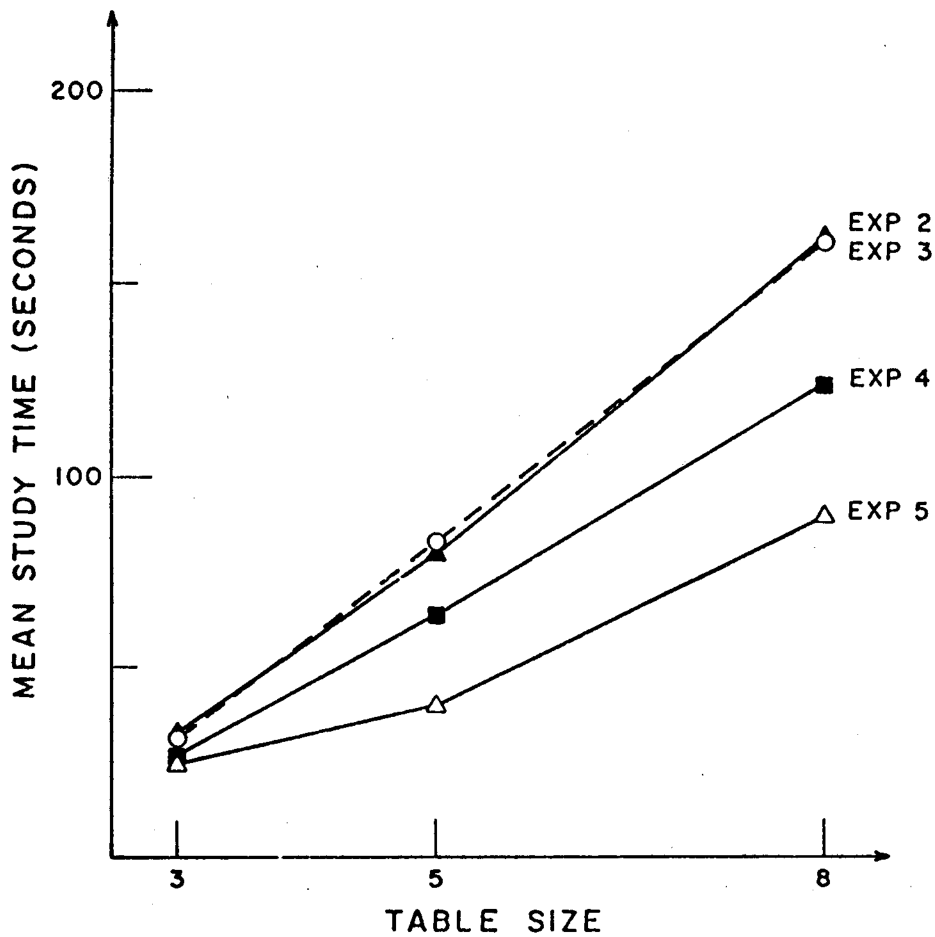

Figure 8

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.

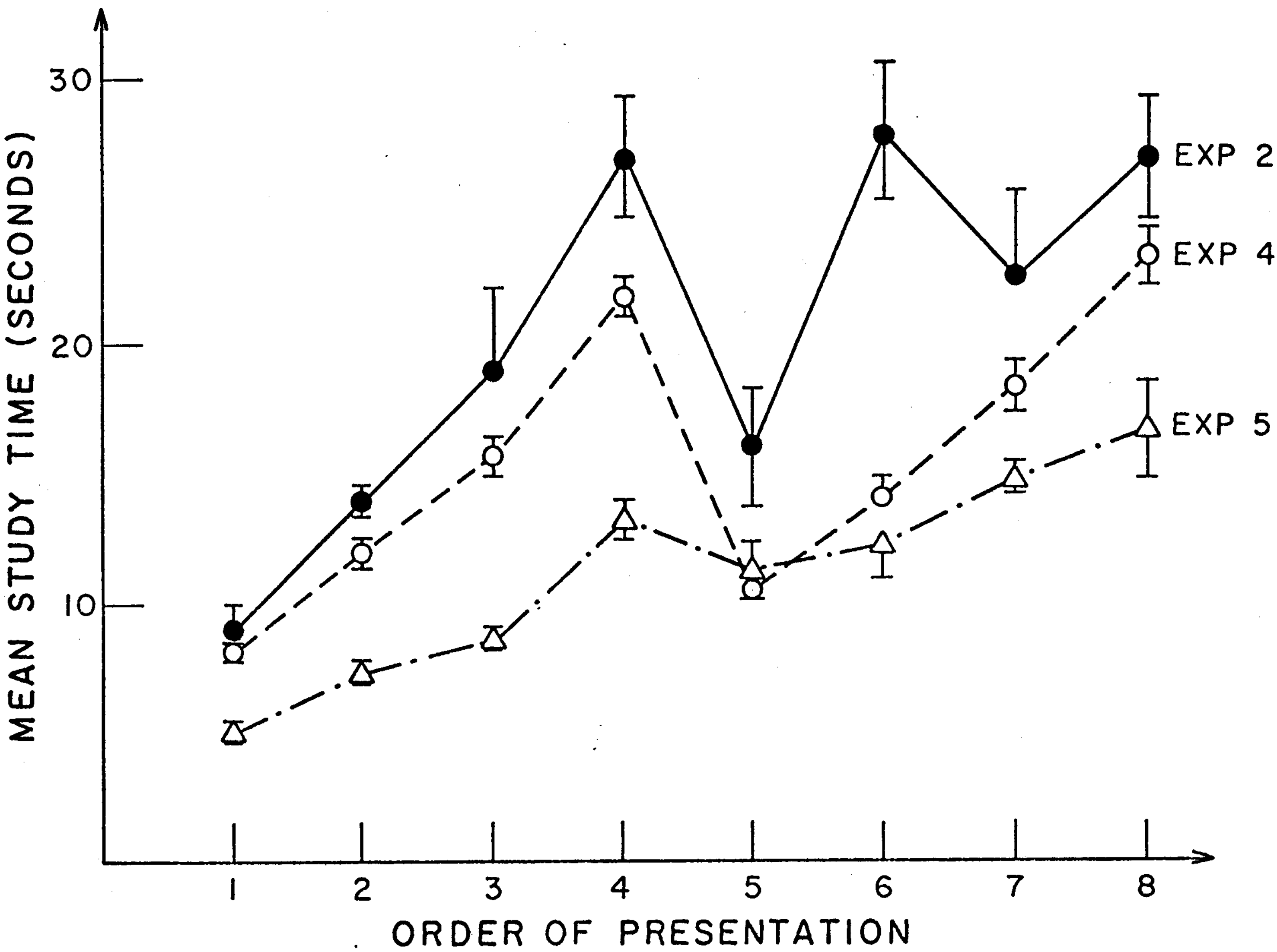

Figure 9

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.

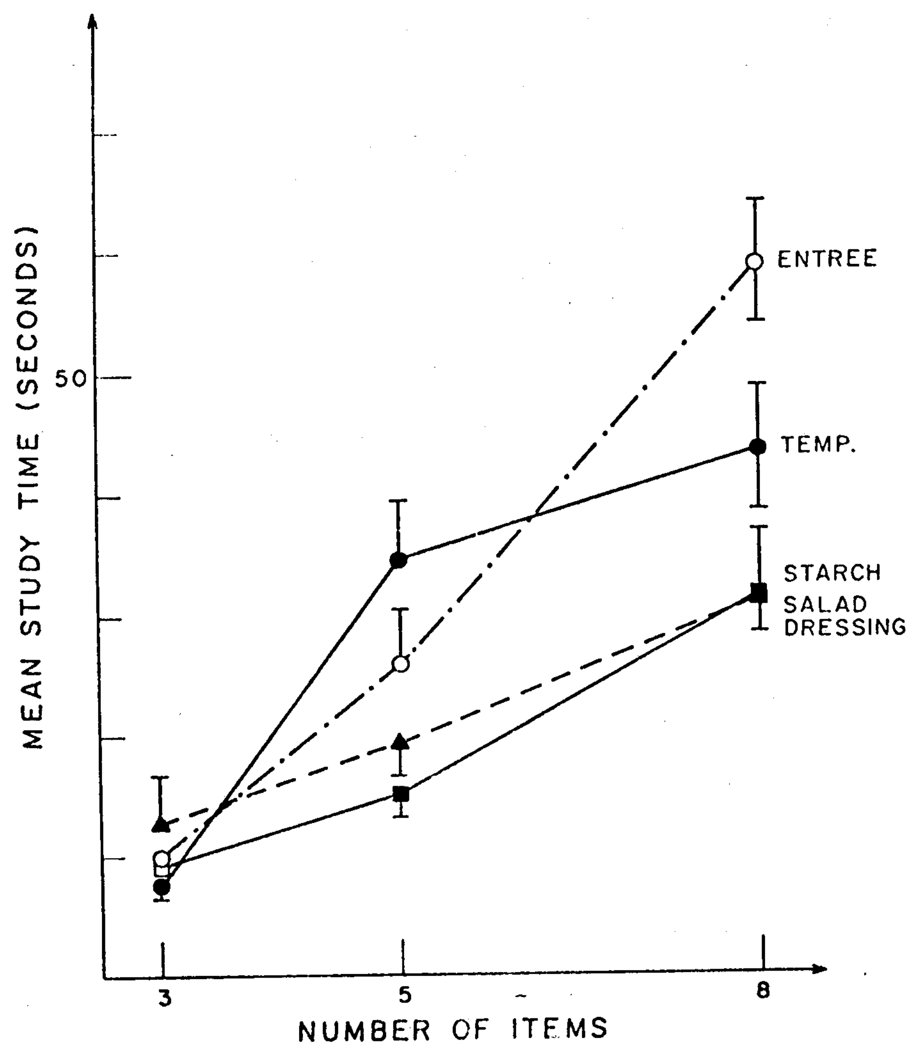

Figure 10

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.

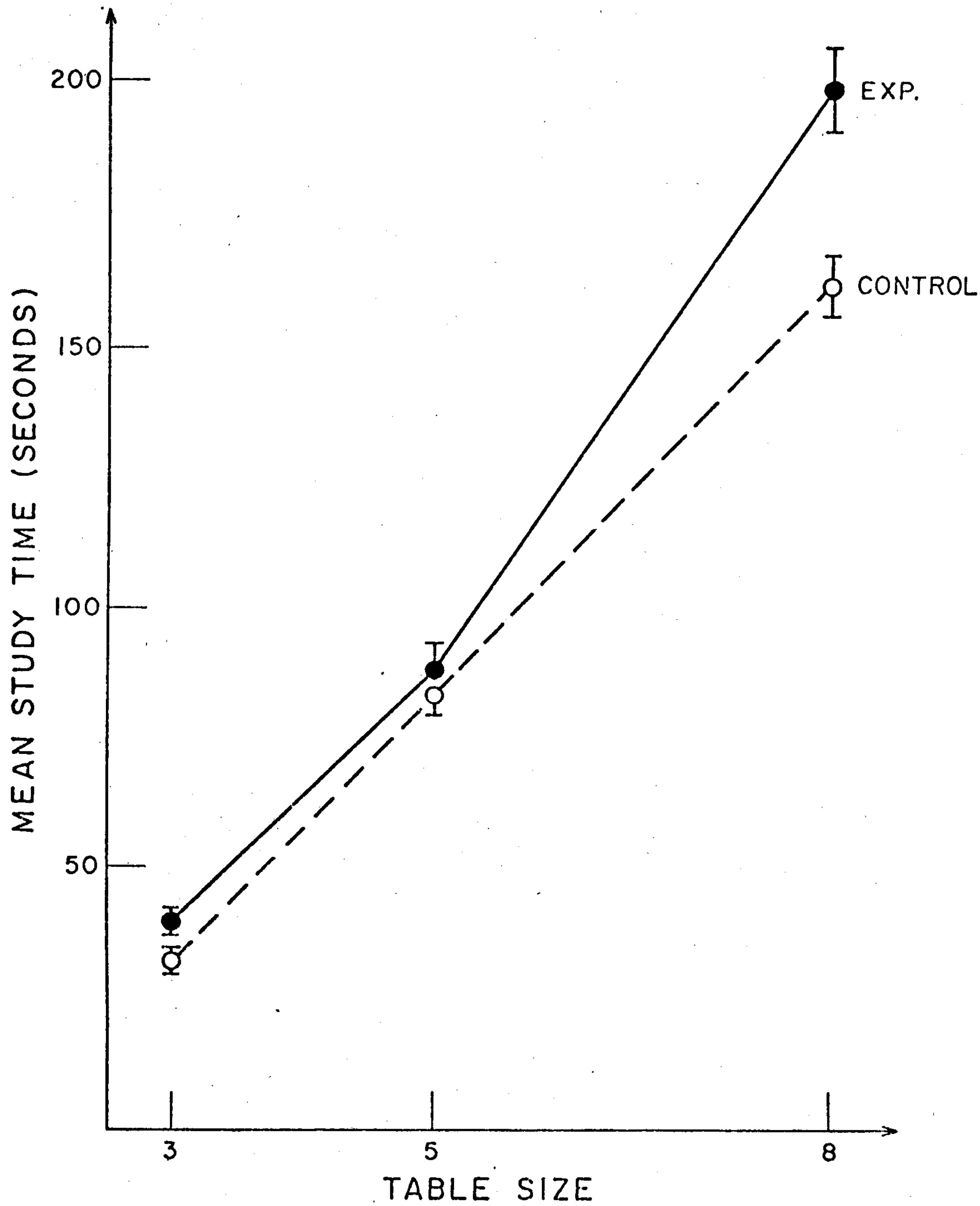

Figure 11

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

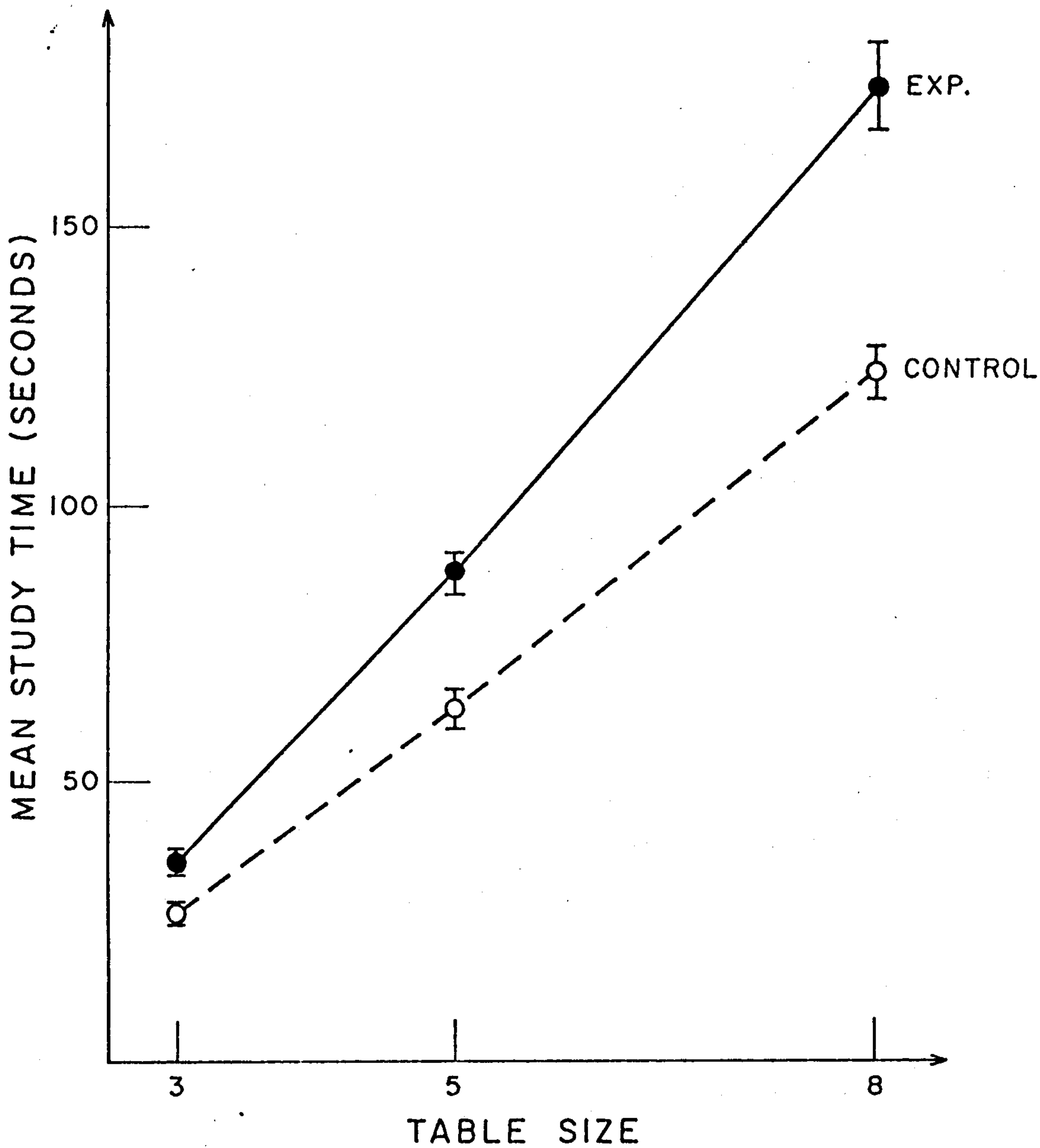

Figure 12

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

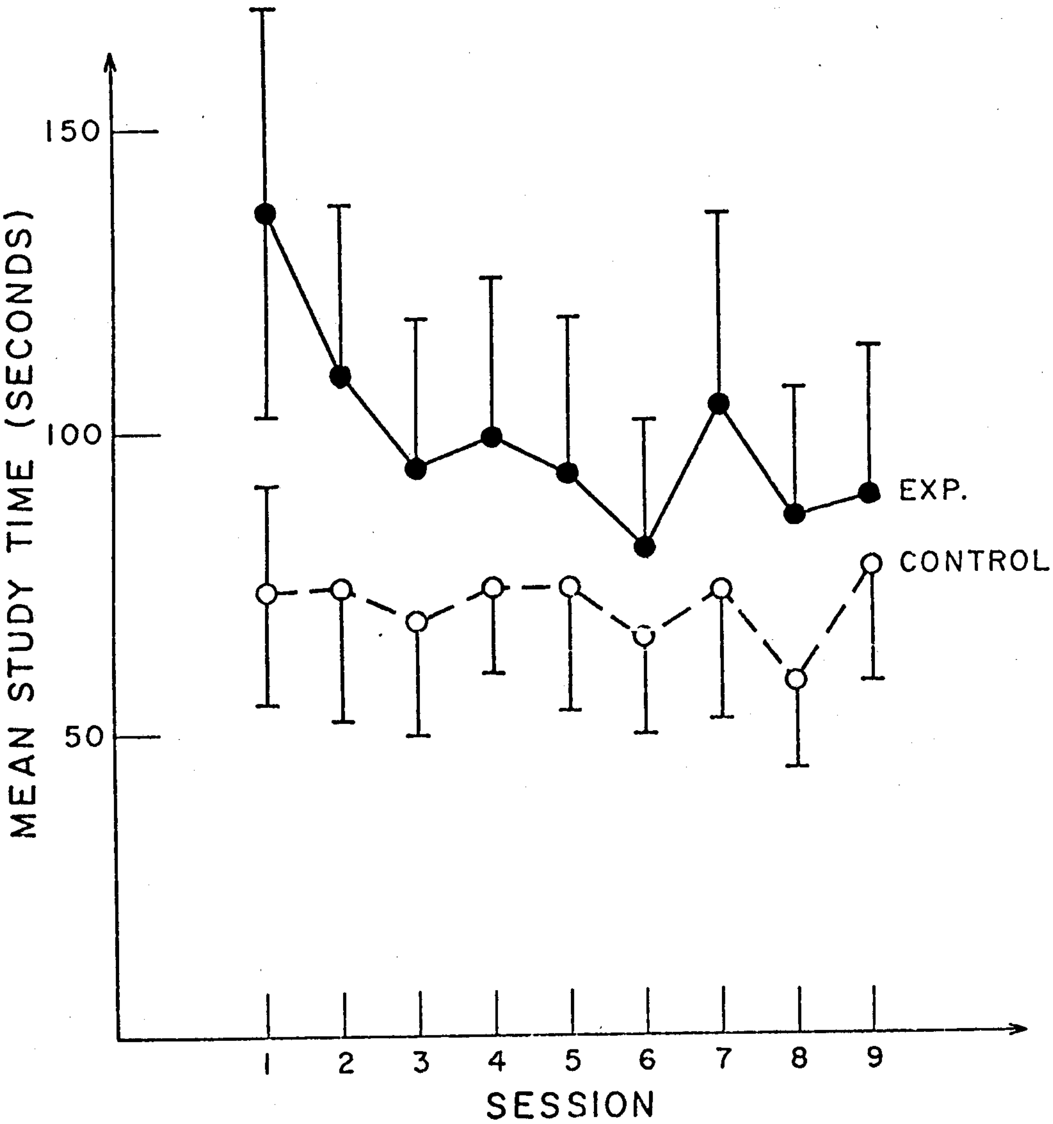

Figure 13

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.

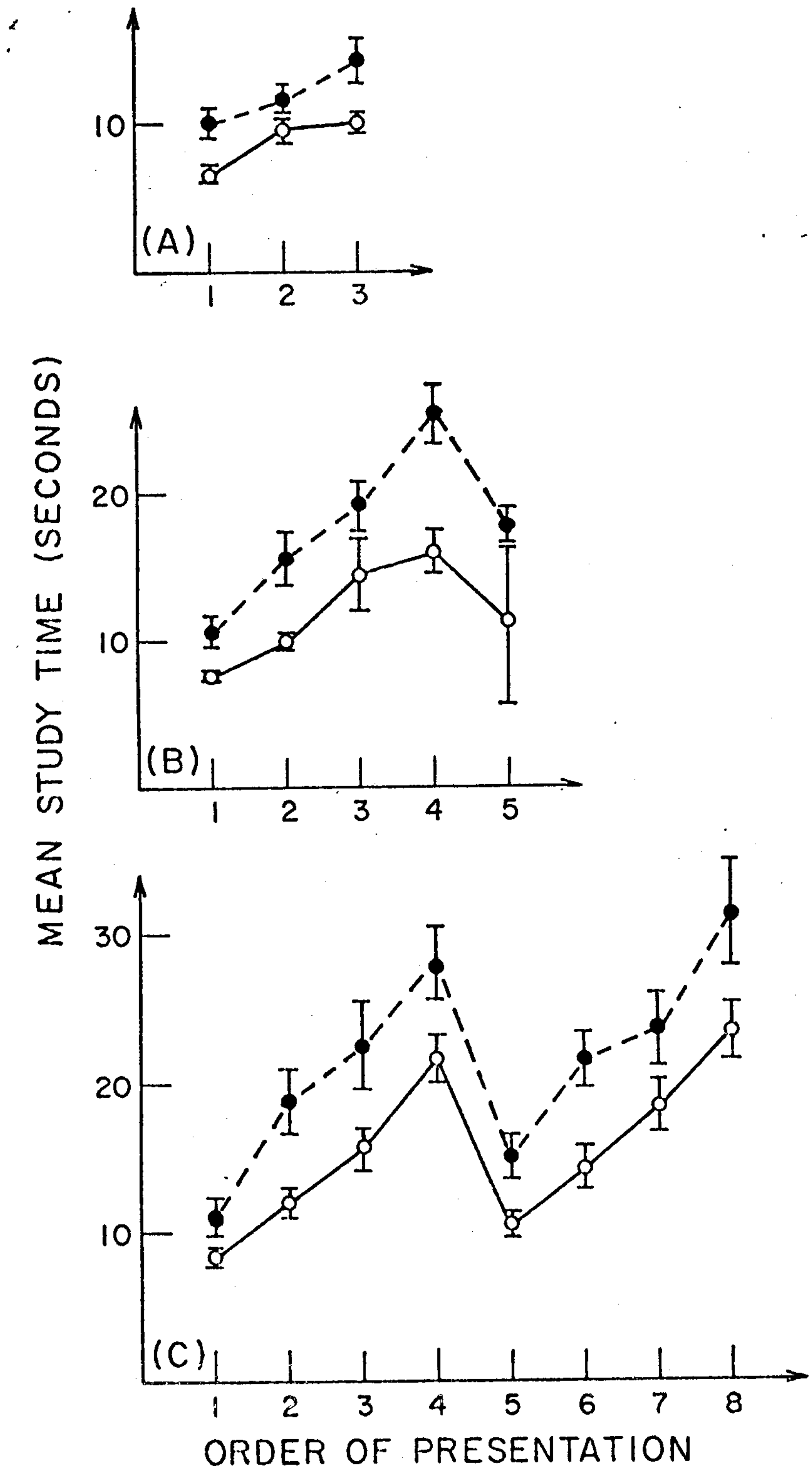

Figure 14

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.

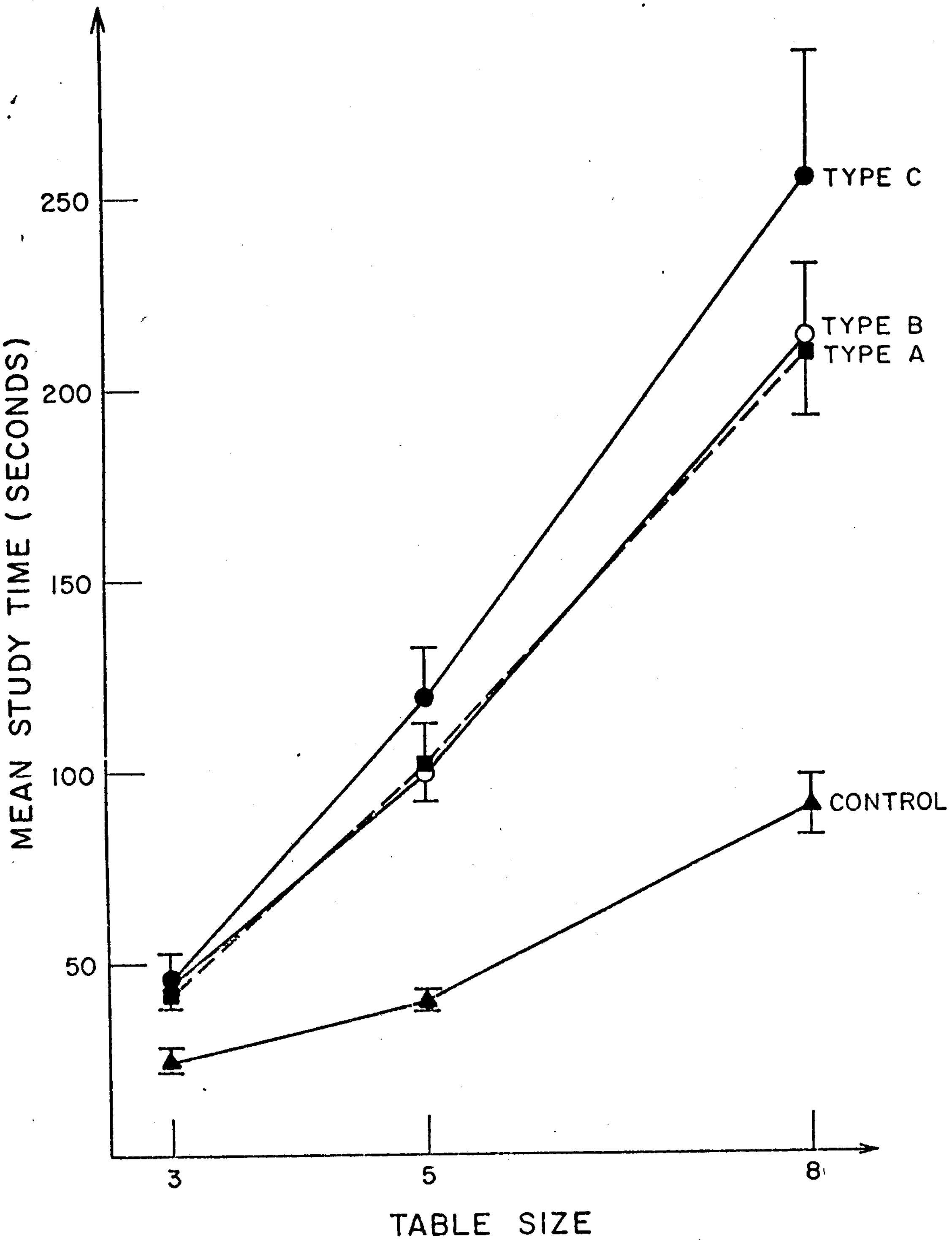

Figure 15

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

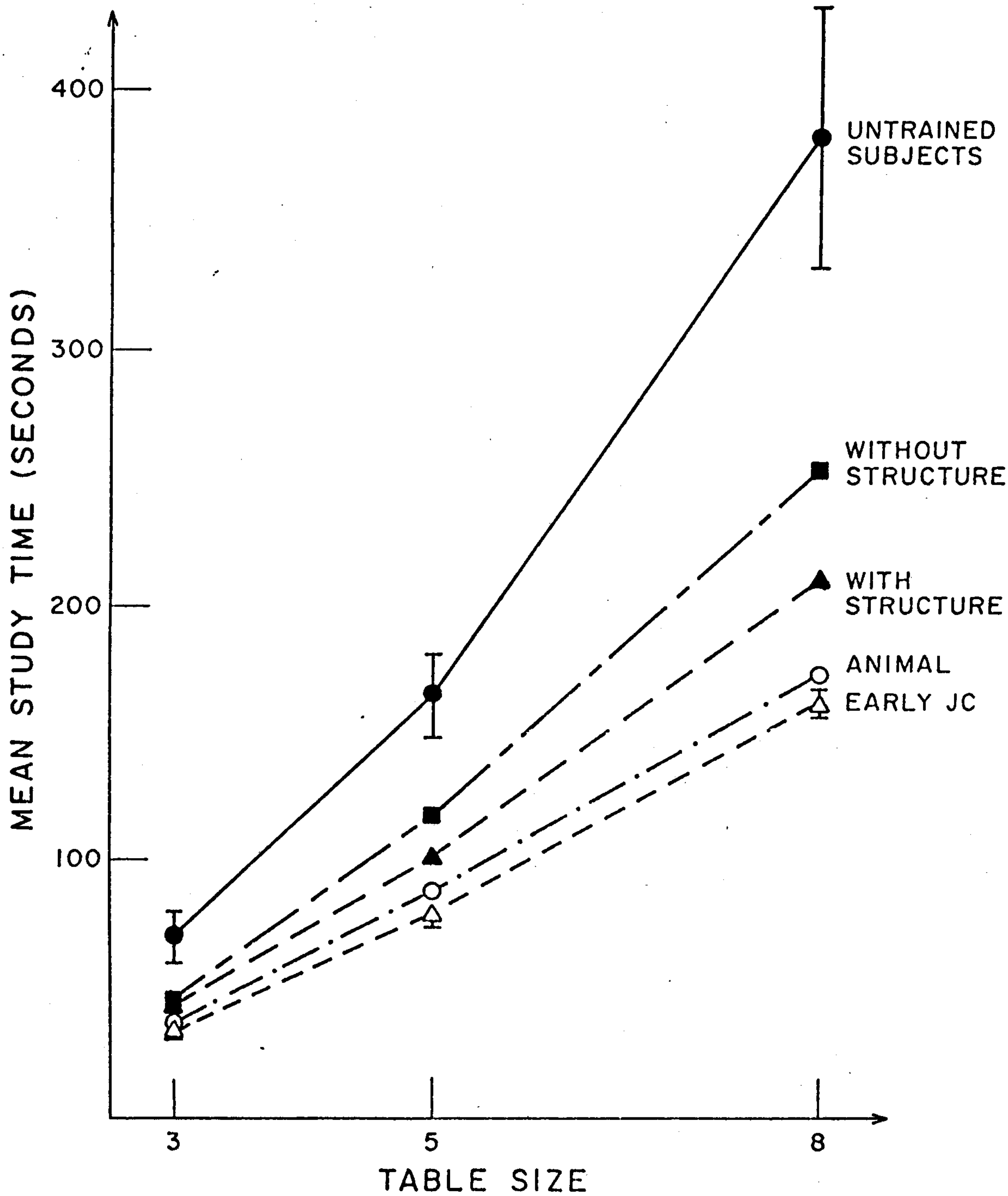

Figure 16

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.

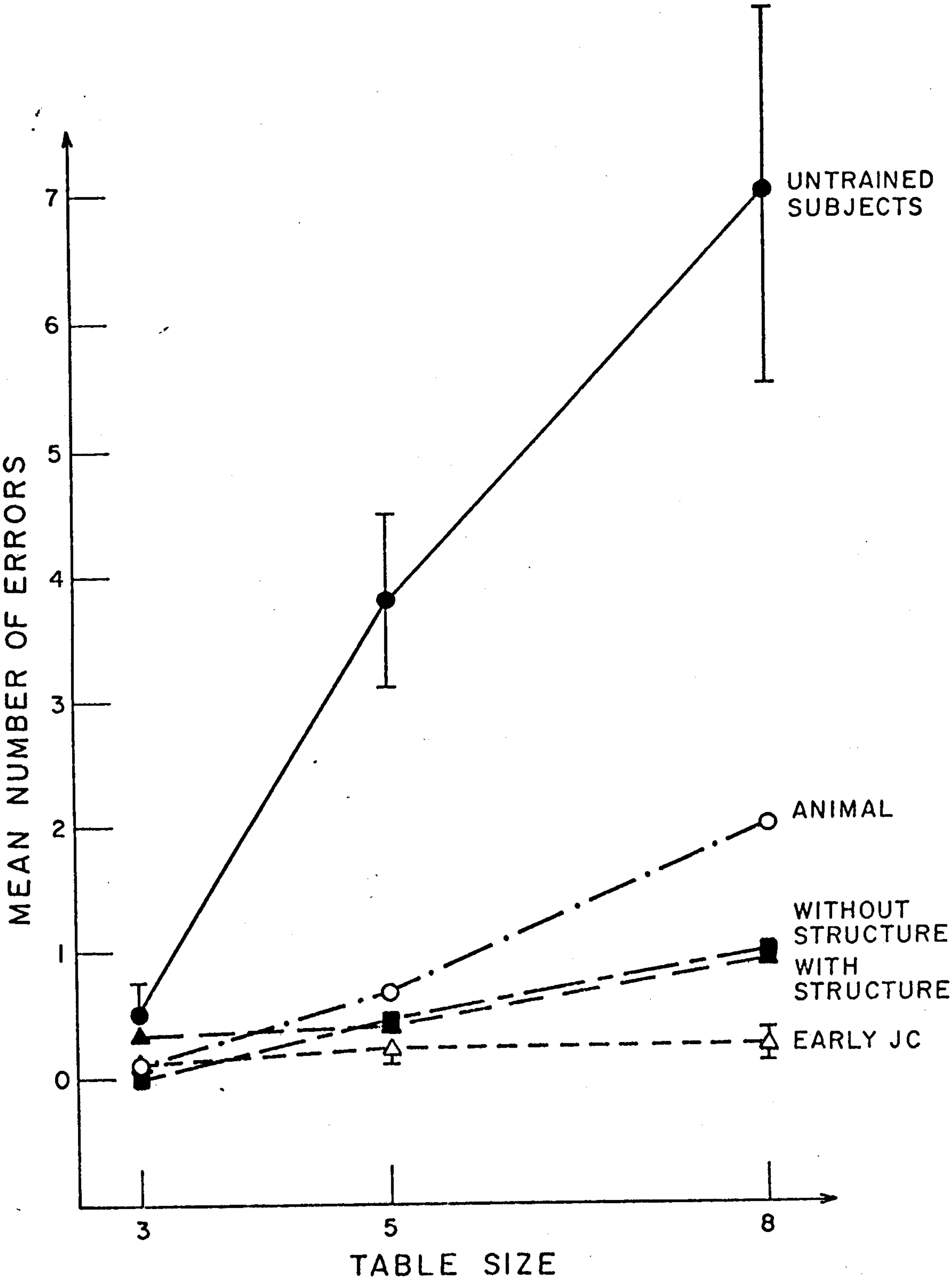

Figure 17

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.