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<th>5. TYPE OF REPORT &amp; PERIOD COVERED</th>
<th>6. PERFORMING ORG. REPORT NUMBER</th>
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<td>Memory for restaurant orders</td>
<td>Technical Report</td>
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<tr>
<td>K. Anders Ericsson and Peter G. Polson</td>
<td>N00014-84-K-0250</td>
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<td>Institute of Cognitive Science</td>
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<td>University of Colorado, Campus Box 345</td>
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<td>Personnel &amp; Training Research Programs,</td>
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<td>Office of Naval Research (Code 458),</td>
<td></td>
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<td>Office of Naval Research (ONR), Program in Personnel &amp; Training Research, 800 N. Quincy St. Arlington, VA 22217</td>
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| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) |

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<th>18. SUPPLEMENTARY NOTES</th>
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<td>Memory skill, exceptional memory, mnemonics, generalizability of skill, transfer, practice effects.</td>
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<td>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</td>
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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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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.

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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.
A Cognitive Analysis of Exceptional Memory for Restaurant Orders, unclassified

K. Anders Ericsson and Peter G. Polson

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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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.

![Diagram of temperature codes](https://example.com/diagram.png)

**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.

![Graph showing mean study time (seconds) 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.](image)

**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.
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.

![Diagram](image)

**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.

![Graph showing mean percent of recall as a function of presentation number for dinner orders and animal orders.]

**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.

![Graph showing mean study time as a function of table size for memory expert (JC) in the four consecutive experiments.]

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.

![Graph showing mean study time (seconds) vs. number of items for different categories.](image)

**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), temperatures (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.
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.
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.