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Expert and Novice Problem-Solving Behavior in Audit Planning: An Experimental Study

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(Comments and suggestions are welcome)

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Expert and Novice Problem-Solving Behavior in Audit Planning: An Experimental Study
This study compares the decision-making processes of 52 expert and novice auditors in an audit planning task. A process tracing method is used to monitor auditors’ information search behavior. Three dimensions of information search behavior are examined using a new method of analysis: information search strategy, information acquisition behavior and search duration.

In general, experts and novices exhibited different information search behavior. Experts exhibited a more global search pattern guided by an overall planning strategy. They also acquired significantly less information on internal control but attached more importance to these controls, indicating that they might acquire information more efficiently. Finally, experts were more efficient than novices in terms of information search time and required significantly less time to perform the task.

**Key Words:** Auditing, Expertise, Information Search, Audit Planning
This study compares the decision-making processes of 52 expert and novice auditors in the context of an audit planning task. Using a new method to analyze information search behavior, some propositions regarding the comparative decision-making processes of experts and novices are tested.

The study of expert decision-making processes in auditing is important for two principal reasons. First, expertise is the essence of the accounting profession. Second, auditors face an environment characterized by increasingly voluminous and complex professional standards, rapid technological change, and greater sophistication in the business environment. To cope with this environment, auditing firms allocate considerable resources to train auditors and to develop decision aids and expert systems that will help transfer experts' knowledge to novices. To assure that these resources are well spent, it is essential to know what differentiates expert from novice decision making.

Although expertise and its role in decision making has been the subject of several recent studies (see, for example, Biggs et al. 1985, 1989; Bouwman 1982; Gibbins 1984, 1988; Gibbins and Larocque 1989; Waller and Felix 1984a,b; and Wright 1988), knowledge in this area is still limited. The studies referred to are mostly exploratory. They provide interesting hypotheses about the nature of expertise and its impact on decision making processes, but given their descriptive orientation and small sample sizes, generalization to the population is somewhat risky. Thus, the propositions of interest could clearly benefit from formal tests of hypotheses based on larger sample sizes.

Such formal tests of hypotheses based on larger samples are essential parts of this study. In addition, an attempt has been made to obtain improved operational measures of expertise, to match indicators of expertise with task requirements, and to improve the measurement of the information search processes.

Fifty-two experts and novices were compared through a detailed analysis of their decision-making behavior. The study employs and extends a process tracing methodology that has been used in psychology and marketing research. The focus is on the comparative information search behavior of each group. Three dimensions of information search behavior are examined: information search strategy, information acquisition behavior and information search duration.

EXPERTISE AND INFORMATION SEARCH BEHAVIOR

Information search is a key element in the decision-making process which is often partitioned (e.g., Hogart, 1980) into three elements: (1) information search, (2) information processing and (3) output. Information may be retrieved from memory or acquired from other external sources. The decision to acquire information depends on the salience of the information which depends on memory, the task environment (e.g., nature of the task and quality of the information system), and their interactions.
Whether information search is considered a secondary decision (White 1975) or part of the primary decision process, it plays an important role in decision processes. Biggs and Mock found that information acquisition represented between 31 percent and 49 percent of the total operators used to describe auditors’ decision-making processes. Information search behavior has also been linked to decision accuracy. For example, Simmet and Trotman (1989) and Abdel- Kalik and El-Sheshai (1980), in experiments on corporate failure prediction, found that information choice was a limiting factor in performance.

Problem solving is done in the context of the knowledge available for a given problem. That knowledge constrains and guides the decision-making process and hence the nature and sequence of information acquisition. For example, research in medical problem solving indicates that a small set of prototypes representative of the initial data is first retrieved from long-term memory. These prototypes are then used to further guide the search for information (Elstein et al. 1978).

The literature on expertise indicates that experts can be differentiated from novices in terms of the content and organization of their domain knowledge and in terms of mechanisms for matching problems with this knowledge. Experts appear to have more knowledge than novices (Johnson et al. 1981) and better organization of that knowledge in terms of structure, grouping and cross-referencing (Chase and Simon 1973; McKeithen et al. 1981; Gibbins 1987).

Because of these knowledge differences between experts and novices, the judgment processes and hence the nature and sequence of information acquisition of the two groups are expected to be different. The objective of this research is to explore the appropriateness of this expectation.

Research hypotheses

In this section, the research hypotheses regarding the comparative information search behavior of experts and novices are derived. Hypotheses are presented for three dimensions of information search behavior.

Search Strategy

One dimension of information search that may be affected by experts’ and novices’ knowledge is their search strategy. For example, Bouwman (1982, 1984) compared expert and novice financial analysts’ problem solving behavior in a financial analysis task. He found that novices used an undirected, sequential strategy where information was examined in the order of presentation. The experts, on the other hand, appeared to base their search on a schema based on a standard list of questions, i.e., an experience-based mental model that guided their information search.

Through study and experience, the auditor gains knowledge that is organized in the brain in the form of cognitive structures called “schemata.” A schema is composed of a category and associated knowledge (Chi et al. 1981). Auditing research on expertise indicates that compared to novices, expert auditors have more knowledge (Frederick and Libby 1986) and have a higher clustering of knowledge (Weber 1980; Libby 1985; Choo and
Trotman 1989). As noted above, Bouwman (1982) found that search strategy was related to expertise. Based on these research studies, it is hypothesized that:

H1: Novice auditors are more likely to use a sequential search strategy than expert auditors.

In an experimental setting, sequential search will be evidenced by a search pattern similar to the order of presentation of audit evidence. Further, expert's experience-based mental model may guide their information search at both the general information search level and the detailed internal control evaluation level. At the general level, their schemata may be similar to the model proposed by the AICPA (1977) where general computer controls are first reviewed and application controls are then reviewed. If such a model has been internalized by expert auditors, they will tend to seek out EDP general control evidence before reviewing application controls.

For other audit details, expert auditors may also have developed a schema which guides their information search. At this stage, little is known about the precise nature of such a schema or on how it will impact the expert's information search. What Hypothesis 1 suggests, however, is that the experts' detailed search strategy will less closely resemble the order of evidence presentation than the novices' detailed search strategy.

Information Acquisition Behavior

Expert-novice differences in the judgment process may also arise from the expert's greater task familiarity and expected attention to efficiency and effectiveness (Gibbins and Larocque 1990). Experts, having more complete problem solving knowledge, are better able to recognize relevant cues. Thus they are more likely to use only the necessary and sufficient information needed to solve a task (Gibbins and Larocque 1990).

Novices should have some, but not all, of the requisite knowledge to perform a task. Thus they may tend to expend resources which are not needed, waste resources on irrelevant details (Gibbins and Shaver 1989) and take into account irrelevant information (Gibbins and Larocque 1990).

Results of research in various areas supports the above analysis. For example, Chi et al. (1981) found that expert physicists tended to identify fewer cues as being relevant to their judgments. Patel et al. (1989) also found that expert doctors were more efficient in the use of information. Kleinmuntz (1968) found that expert neurologists searched for the most important cues in a diagnostic task. When comparing experienced and less experienced physicians, Muzzin et al. (1982) found that they differed in the cues used to judge whether a disease applied to the case in question. Bonner (1990) found that, for one of the two firms she studied, experts had a higher accuracy score when asked to select relevant information cues. That result was limited, however, to a task where experts had more complete knowledge.

These types of differences are investigated in this research by looking at auditors' utilization of internal control evidence. The experts (computer audit specialists or CASs) used in this study should have much more knowledge about EDP controls than novice auditors. Such experts should know which controls are important for the task. As in the studies reported above, CASs should be more efficient in their use of information cues and consequently, they are expected to acquire fewer cues.
In an internal control evaluation task, not only are the experts expected to know which controls are important, but if their prototypical sets of accounting controls are better cross-referenced than novices' sets are, CASs are more likely to search for compensatory controls only when a control in their prototypical set of controls is missing. In contrast, novice auditors will be less efficient in their use of cues and consequently, they will acquire more information. This inefficiency may come from their lower knowledge about EDP general controls or from weaker cross-referencing between controls. This leads to the second hypothesis concerning search behavior:

H2: Expert auditors will acquire fewer control cues than novice auditors.

Cue Importance

Bédard (1989) notes that out of five lens model studies which examined expertise, only two found even a small relationship between experience and cue importance. Ashton and Kramer (1980) found a low positive correlation between cue weights and experience while Hamilton and Wright (1982) found small differences between the cue weights of experienced and inexperienced auditors.

In this study, however, which utilizes a much larger number of available cues (156 cues as compared to 5 or 6 in lens model studies) and which operationalizes expertise in terms of domain specific knowledge, cue importance is expected to be different for expert and novice auditors.

The CASs (experts) in this study should have more domain specific knowledge about general controls in computerized accounting systems than novices. Given such knowledge, CASs may attach more importance to general EDP controls in making their planning decisions. Stated differently, less experienced auditors, who know less about these controls and their implications for audit planning, may be expected to attach less importance to EDP general controls:

H3: In audit planning, expert auditors will attach more importance to general computer controls than novice auditors.

Task Duration

According to Glaser and Chi (1988), research in cognitive psychology has shown that one of the key characteristics of experts' performance is rapidity in performing in their domain. A possible explanation for this speed is that experts reach solutions without conducting as extensive information search. De Groot (1965), for example, found that master chess players recognize relationships more quickly than non-experts. Given their greater task knowledge and attention to efficiency and effectiveness, expert auditors are expected to perform the task faster than novice auditors.

H4: Expert auditors will take less time to perform the task than novice auditors.
RESEARCH METHODOLOGY

Experimental task

A comprehensive audit case with a computerized accounting system was developed to study the information search behavior of experts and novices. The case materials were made complex in order to engage the experts' greater knowledge and reveal their superior way of performing the task. The accounting system therefore includes computerized controls, computerized calculations, data entry at multiple locations, and telecommunications technology. These are factors that increase complexity in a computerized environment (Touche Ross 1981).

The case focuses on the revenue cycle of a hardware distributor and contains the following information:
1. Instructions, study objectives and description of the judgment task.
2. Background client information including data about the general economic situation, the client's business, accounts receivable, the computer system, the timing of the audit, and materiality.
3. General computer controls description including controls over (1) organization and operation of the computer system, (2) development and maintenance of application systems, (3) system software and hardware, (4) access to equipment and data files, (5) data and procedures, and (6) the internal audit function. The strengths and weaknesses of these controls were presented in a 64-question internal control questionnaire.
4. Application controls, including the internal control strengths and weaknesses within the sales/receivable system, were described using a comprehensive internal control questionnaire (92 questions). The questionnaire included both computer application controls and user accounting controls.¹
5. Five decision sheets, one for reliance on the sales/accounts receivable internal controls and one for each of four sample size decisions.

The two categories of controls - general computer controls and application controls - were manipulated to produce two levels of control quality (strong and weak), resulting in four different case versions. The experimental design was as follow:

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer General Controls</td>
<td>Strong</td>
<td>Strong</td>
<td>Weak</td>
</tr>
<tr>
<td>Application Controls</td>
<td>Strong</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weak</td>
</tr>
</tbody>
</table>

For general computer controls at the weak level, there were weaknesses in controls over changes to existing computer programs. For application controls at the weak level, there were weaknesses in controls ensuring that goods are shipped only to good credit risks and in controls over past due accounts. These controls were present at the strong level. The subjects were assigned to the four cases at random.
Although the four case versions are not replications of the same task, the treatments are not expected to significantly affect the research hypotheses. These hypotheses state that there will be differences in the information search behavior of expert and novice auditors. The control treatments should not significantly affect the search differences between experts and novices. Although no significant impact was expected, the analysis was performed for each of the hypotheses with the treatments as independent variable along with other explanatory factors.

Subjects were asked to make two groups of planning judgments regarding the accounts receivable balance. They first made a decision about the planned degree of reliance on the sales/accounts receivable internal control system. They then determined the number of items to be selected for four substantive procedures: accounts receivable confirmations, review of delinquent accounts, follow-up of subsequent payments, and tests of transaction processing accuracy. The subjects were given a description of each of the procedures.

The audit case was pilot tested to check for errors, completeness, and accuracy. The pilot test involved one auditing professor, one audit partner, and one computer audit specialist. The two auditors were practicing at the Los Angeles office of the participating firm.

Process-Tracing Methods

A process-tracing method was used to study the information search behavior of the auditors. A primary attribute of this method is a focus on understanding the decision-making process used in acquiring and evaluating data (Payne et al. 1978). A computer-controlled information retrieval system (CIRS) was selected from the various process tracing methods. Payne and Braunstein (1977) used this method which involves monitoring subjects' information search behavior with a computer. A menu-driven CIRS running on a microcomputer was developed. Each screen contained a list and description of available options, making the program easy for subjects with little computer experience to use.

The system divides the audit case information into five categories as provided in the case. Each category is subdivided into individual information items that a subject can examine at will. For both the general computer and application controls, a list of unanswered questions appears on the screen. The subject must request an answer to see it. It is thus possible to keep track of each control question accessed.

To make the task more realistic, access to a control answer involves an attached cost. As in real audits where it takes time to discover whether a control procedure is present, it takes some time-less than five seconds-for the system to respond to a request. The CIRS keeps track of the individual information items accessed, the order in which information is accessed, the search duration, and the subjects' decisions.

To test for the possible impact of an expert's schema on information search, the order of presentation of the general and application controls in the main CIRS menu was reversed. This menu consisted of five elements ordered as follow:
Given the reversed order, an auditor who acquires cues sequentially would acquire the application controls before the general controls. If an auditor selects the general controls first, it is an indication that he is guided by a schema or some other cognitive process which is non-sequential.

The CIRS was submitted to two types of tests. First, the system was tested for processing accuracy and efficiency. Results from test data produced by the system were compared with results produced manually. Second, the system was pilot tested with two practicing auditors, one of whom was a computer audit specialist (CAS). Both participants found the system user friendly. The computer audit specialist suggested that his audit firm should use a similar system to document computer controls. All important participant comments were incorporated into the final version of the program.

Subjects

Expertise is defined by Hayes-Roth et al. (1983, 4) as "knowledge about a particular domain, understanding of domain problems, and skill about solving some of these problems." As this definition implies, expertise is domain-specific (Elstein et al. 1978; Eisenstadt and Kareev 1975; Gibbins and Shaver 1989; Wright 1988). Although knowledge and skills are acquired through education and experience, years of audit experience, as used in most previous studies, may not be an adequate surrogate for expertise. If expertise is domain-specific, experience must be related to the specific task being studied. To evaluate the match between the task and the person, Gibbins and Shaver [1989] suggest making a mechanical inventorying and comparison of what the task requires and what the person knows.

In this study, the task required the review of EDP general controls and application controls in order to evaluate the quality of controls over a complex computerized accounting system. Besides general accounting/auditing knowledge, this task requires knowledge about application controls and their evaluation, and specific knowledge about EDP general controls and their evaluation.

Consistent with the above definition of expertise, this study distinguishes between expert and novice auditors on the basis of domain-specific knowledge. Specifically, computer audit specialists were selected as experts because they presumably have more knowledge about the specialized domain of computer auditing than general auditors. This greater domain-specific knowledge is recognized by the Canadian accounting profession which has recommended that computer auditors be the first designated specialists in the profession (CICA 1982).

The subjects were 52 practicing auditors from three California offices of an international auditing firm. A single firm was selected to standardize the experimental material and control a variable, firm affiliation, that has been
found to be related to auditor judgment (Nanni 1984). The subjects were selected by each office on the basis of availability. Novices had to be at least at the senior level and experts had to be computer audit specialists.

Patel and Groen (in press) make a distinction between generic (e.g., medicine) and highly specific (e.g., cardiology) knowledge. As indicated in Table 1, in this study both novices and experts have generic auditing knowledge enabling them to perform the audit planning task. The experts, however, have more audit experience (74 months) than the novices (42 months) and are at a higher position in the firm. Both groups also have a minimum of specific knowledge in application control evaluation. Novices have a moderate level of specific experience in this area with an average of 17 evaluations and experts a high level with an average of 37 evaluations. 48 percent of the novices' evaluations, were for computerized accounting applications systems and 74 percent of the experts' evaluations.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>COMPARISON OF EXPERTS' AND NOVICES' KNOWLEDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOVICES (28 subjects)</td>
</tr>
<tr>
<td>GENERIC KNOWLEDGE</td>
<td></td>
</tr>
<tr>
<td>Accounting/auditing</td>
<td></td>
</tr>
<tr>
<td>• University degree</td>
<td>96%</td>
</tr>
<tr>
<td>• Audit experience</td>
<td>42 months</td>
</tr>
<tr>
<td>• Position</td>
<td></td>
</tr>
<tr>
<td>Partner</td>
<td>0</td>
</tr>
<tr>
<td>Senior Manager</td>
<td>3</td>
</tr>
<tr>
<td>Manager</td>
<td>7</td>
</tr>
<tr>
<td>Senior</td>
<td>18</td>
</tr>
<tr>
<td>Computer science</td>
<td></td>
</tr>
<tr>
<td>• University degree</td>
<td>0%</td>
</tr>
<tr>
<td>SPECIFIC KNOWLEDGE</td>
<td></td>
</tr>
<tr>
<td>Application controls</td>
<td></td>
</tr>
<tr>
<td>• Mean number of evaluations</td>
<td>17</td>
</tr>
<tr>
<td>• % for computerized systems</td>
<td>48%</td>
</tr>
<tr>
<td>EDP general controls</td>
<td></td>
</tr>
<tr>
<td>• University credits (mean)</td>
<td>2.8</td>
</tr>
<tr>
<td>• Firm training</td>
<td>0%</td>
</tr>
<tr>
<td>• Computer audit specialist</td>
<td>0%</td>
</tr>
<tr>
<td>• Experience</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Where the experts and novices differ most, is in the experts’ domain- specific expertise — EDP general controls. As indicated in Table 1, none of the novices had received firm training in that area while 21 of the experts had. Also, all the experts were computer audit specialists and had, on average, 43 months of experience as computer audit specialists. Novices' knowledge about general controls is not non-existent, as most of them had a university course in computer auditing.

12
From these knowledge profiles, it appears that both novices and experts have the necessary knowledge for the study of the application controls and the background information. Experts have more experience, but novices' knowledge is above a critical level. For the review of the general computer controls, both novices and experts had similar levels of university training. Experts, however, had more firm training and more experience in the assessment of EDP general controls and possess more complete knowledge of general control review. In summary, the novices in this study have generic knowledge but they have limited specialized knowledge of EDP general control review.

Experimental Procedures

Each experimental session was held in a small conference room under the supervision of a researcher. There were one to six participants per session. Because the objective was to elicit the auditors' personal decision processes, the subjects were instructed to perform the task individually without referring to firm manuals or forms. Participants were also instructed not to talk about the experiment with other members of the firm.

Before working with the CIRS, the subjects were given a brief oral explanation of the computer keyboard and the computerized information retrieval system. They were encouraged to ask questions at any time during the session if something was unclear. Finally, it was emphasized that they should not take notes but simply return to an individual item of information if necessary.

Debriefing

The subjects completed a debriefing questionnaire at the end of the experiment. As suggested by Hagerty and Aaker (1984), they were asked to rank the various information items by order of importance to help corroborate the measures of cue importance provided by the CIRS (information items accessed and time spent on each item). These rankings were obtained by asking the subjects to select the ten controls they considered most important in making their reliance decisions and to rank them (Green and Tull 1978).

When asked to rate the audit task on a scale of one to seven, one being uninteresting and seven interesting, the subjects rated the task as 5.1 on average, indicating that it was an interesting experience. On the same scale, with unrealistic (one) and realistic (seven) as anchors, the audit task was rated as five. Written and verbal comments suggest that many of the subjects found the task realistic and well adapted to the firm's procedures.

RESULTS

Search Strategy

Two dimensions of the search strategies of experts and novices are compared: strategy at the general level and strategy at the detailed level.

General level. As indicated earlier, in order to test the impact of expertise on information search at the general level, the order of presentation of the general and application controls was reversed. Subjects were classified
in two groups depending on which category of controls (EDP general or application) they acquired first. Overall, the results indicate that the order of acquisition of the categories of control was influenced by level of expertise (Pearson $r=9.18$, $p<.005$) with 17 percent of the experts acquiring the EDP general control first compared to 4 percent of the novices. As hypothesized, significantly more experts had a search strategy guided by an experience-based model similar to the model proposed by the AICPA.

**Detailed level.** To verify hypothesis 1 at the detailed or information items level, the similarity between information search and the order of presentation must be measured. The detailed search strategy was based on the trace CIRS registered as the auditors searched for information. Various methods of measuring or classifying search strategy have been proposed in the literature. These methods do not attempt to measure search pattern directly. They are measures of similarity between the search sequences of two subjects. Three measures of similarity have been used: the path structure coefficient (RPSC) (Bettman 1971, 1974), the Spearman rank correlation coefficient (SRC) and the Kendall tau coefficient (TAU) rank-order correlation. They are explained and their reliability and validity is discussed in Appendix 1.

The subjects’ order of acquisition was compared with the order of presentation using these three measures of similarity. Table 2 gives summary statistics for these measures. For the correlation coefficients SRC and TAU, a score of one indicates that the subject reviewed each item of information in the presentation order. A value between zero and one indicates that the subject’s order of acquisition is somewhat similar to the order of presentation and a negative value indicates that the subject’s order of search is different from the order of presentation. For the RPSC, a value of one indicates that the subject acquired all the items of information in the order of presentation and a value of zero indicates that the subject did not acquire any of the available cues.

<table>
<thead>
<tr>
<th></th>
<th>Novices</th>
<th>Experts</th>
<th>All Auditors</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPSC</td>
<td>0.49</td>
<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td>Spearman Rank</td>
<td>0.45</td>
<td>0.38</td>
<td>0.42</td>
</tr>
<tr>
<td>Kendall tau</td>
<td>0.47</td>
<td>0.41</td>
<td>0.45</td>
</tr>
<tr>
<td>Similarity factor</td>
<td>0.07</td>
<td>-0.09</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Since these three measures of search pattern are relatively new in auditing research, an analysis of their validity, using common factor analysis, was performed (see Appendix 1). The analysis indicates that RPSC, SRC and TAU measure one common factor or concept of similarity in the order of acquisition and that the uniqueness in the three variables is negligible. This factor, hereinafter called the similarity factor, is used as the measure of the similarity between the subjects' order of acquisition and the order of presentation.

The summary statistics for the similarity factor are given in Table 2. The similarity factor is a standardized variable with a mean of zero, a variance of one and values between -1.62 and 1.40. Because the three similarity
measures have a positive bearing on the similarity factor, a positive value indicates greater similarity between the acquisition order and the presentation order, and a negative value less similarity.

The results from Table 2 indicate that experts’ detailed search (factor = -.09) was less similar to the order of presentation than novices’ detailed search (factor = .07). The difference in the similarity factor between experts and novices was tested with a regression model to control for the possible impact of the four control treatment conditions. The regression model is not significant \((F=.714, p=.66)\) with a R\(^2\) of .10. It then seems that, on average, both expert and novice auditors had a similar detailed search pattern. As indicated by the three similarity measures, this search pattern is somewhat similar to the order of presentation. An examination of the detailed search pattern indicates that acquisition at the individual information items was mostly sequential.

To control for the potential influence of the number of information items acquired and of the acquisition of EDP general controls first on the similarity factor, the latter was also regressed on the expertise level with these two other variables as covariates. The regression model is significant \((F(3,48) = 0.714, p = 0.66)\) and has a good fit with an R\(^2\) of 0.89. Almost all of the model variance, however, is explained by the covariates. The effect of expertise is not significant \((F(1,48) = 0.23, p = 0.63)\).

**Discussion.** At the general level, more expert auditors had a search strategy that is consistent with the overall model proposed by the professional standards. Although the percentage of experts acquiring the EDP general control first is not very high (17 percent), it is of interest since an auditor following this strategy might be more efficient and make better decisions because he will consider the effect of weaknesses in general controls when reviewing application controls. For example, if the general computer controls are very weak, the auditor should not rely on computer related application controls, but he might rely on user controls. Also, this percentage may be considered as a lower bound because experts needed a strong mental-based model in order to skip item three (application controls) in the main menu and select item four (general controls).

At a detailed level, both groups of auditors exhibited a sequential search for information similar to the order of presentation. Thus contrary to what has been found for expert financial analysts (Bouwman 1982), expert auditors’ information search may be more data-driven than schema-driven. This result is consistent with Gibbins and Embry’s (1986) point that professional judgment is more systematic and data-oriented than judgment in general and with Biggs et al. study (1989) where it was found that auditors’ information search was largely sequential.

An alternative explanation of this result is that the structure of the task was very similar to the experts’ standard list of questions. In this case, the experts’ search would be similar to the order of presentation. In order to test that alternative hypothesis, it would be necessary to present the information to the subjects in a random order.

**Acquisition Behavior - Information Acquired**

Information acquisition is measured by the amount of information requested which has been defined by Payne (1976) as the number of available items of information requested. On average, the experts sought fewer
information items than novices -138 versus 149 of a total of 201 possible items. For the instructions, background information and decision categories, the acquisition rate was 100 percent for both groups. The difference in number of information items acquired is entirely attributed to differences in the number of acquired general and application controls.

EDP General Controls. The experts acquired fewer controls for all categories of general computer controls other than application system controls (see Table 3). To determine whether these differences were statistically significant, a multivariate regression model was used. The six categories of general computer controls were regressed on expertise level, the two experimental treatments and the variables representing the interaction between these three variables. Information acquisition should not be affected by the two treatments nor should there be any interaction between expertise level and the experimental treatments; but to account for this possibility, these variables were included in the model.

**TABLE 3**

GENERAL COMPUTER CONTROL CUES ACQUIRED BY SUBCATEGORY

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Information Available</th>
<th>Information Acquired</th>
<th>Difference</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novices # (%)</td>
<td>Experts # (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORGANIZATION/OPERATION</td>
<td>25</td>
<td>16.3(65)</td>
<td>15.0 (60)</td>
<td>-1.3</td>
</tr>
<tr>
<td>EDP organization structure</td>
<td>1</td>
<td>0.7</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Separation between departments</td>
<td>5</td>
<td>3.6</td>
<td>3.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Segregation within EDP</td>
<td>6</td>
<td>4.1</td>
<td>3.9</td>
<td>-0.2</td>
</tr>
<tr>
<td>EDP personnel</td>
<td>6</td>
<td>3.6</td>
<td>3.5</td>
<td>-0.1</td>
</tr>
<tr>
<td>Procedures for continued</td>
<td>7</td>
<td>4.2</td>
<td>3.6</td>
<td>-0.6</td>
</tr>
<tr>
<td>APPLICATION SYSTEMS</td>
<td>14</td>
<td>8.8(63)</td>
<td>9.5 (68)</td>
<td>+0.7</td>
</tr>
<tr>
<td>Systems development</td>
<td>4</td>
<td>2.3</td>
<td>2.5</td>
<td>+0.2</td>
</tr>
<tr>
<td>Programs changes</td>
<td>5</td>
<td>3.2</td>
<td>3.7</td>
<td>+0.5</td>
</tr>
<tr>
<td>Documentation</td>
<td>5</td>
<td>3.3</td>
<td>3.3</td>
<td>0</td>
</tr>
<tr>
<td>SYSTEM SOFTWARE/HARDWARE</td>
<td>9</td>
<td>4.4(49)</td>
<td>4.3 (48)</td>
<td>-0.1</td>
</tr>
<tr>
<td>System software</td>
<td>6</td>
<td>2.5</td>
<td>2.4</td>
<td>-0.1</td>
</tr>
<tr>
<td>Hardware</td>
<td>3</td>
<td>1.9</td>
<td>1.9</td>
<td>0</td>
</tr>
<tr>
<td>ACCESS CONTROLS</td>
<td>13</td>
<td>8.2(63)</td>
<td>8.0 (61)</td>
<td>-0.2</td>
</tr>
<tr>
<td>Data files and programs</td>
<td>10</td>
<td>5.8</td>
<td>5.9</td>
<td>+0.1</td>
</tr>
<tr>
<td>Computer hardware</td>
<td>2</td>
<td>1.5</td>
<td>1.4</td>
<td>-0.2</td>
</tr>
<tr>
<td>Program documentation</td>
<td>1</td>
<td>0.8</td>
<td>0.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>DATA AND PROCEDURES</td>
<td>6</td>
<td>4.4(73)</td>
<td>4.0 (65)</td>
<td>-0.4</td>
</tr>
<tr>
<td>Control function</td>
<td>2</td>
<td>1.7</td>
<td>1.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>Documentation</td>
<td>3</td>
<td>2.0</td>
<td>1.9</td>
<td>-0.1</td>
</tr>
<tr>
<td>File retention</td>
<td>1</td>
<td>0.7</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>INTERNAL AUDIT</td>
<td>10</td>
<td>8.5(85)</td>
<td>6.4 (64)</td>
<td>-2.1</td>
</tr>
<tr>
<td>Organization</td>
<td>2</td>
<td>1.7</td>
<td>1.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>Competence</td>
<td>4</td>
<td>3.5</td>
<td>2.5</td>
<td>-1.0</td>
</tr>
<tr>
<td>Activities</td>
<td>4</td>
<td>3.3</td>
<td>2.5</td>
<td>-0.8</td>
</tr>
<tr>
<td>GENERAL COMPUTER</td>
<td>77</td>
<td>51(66%)</td>
<td>47(61%)</td>
<td>-4</td>
</tr>
</tbody>
</table>

* MANOVA for general computer control and ANOVA for the subcategories.
As expected, none of the interaction terms were significant. The effect of expertise was tested using the Pillai Trace (Johnson and Wichern 1982). Its effect on the six categories of general computer controls was statistically significant ($F(6,39) = 2.33$, $p = .05$). Expert auditors were more efficient in their information acquisition of controls in which they had more expertise, i.e., general computer controls.

An examination of Table 3 indicates that experts acquired fewer controls in all subcategories of EDP general controls except for application systems controls where they acquired more information. The results for the application systems controls indicate that experts find controls over system development and program changes more relevant than novices. Within these two subcategories, the experts' acquisition rate of each for the nine individual controls was higher than the novices' acquisition rate.

The largest negative differences are found for the organization/operation controls and internal audit controls. In the organization/operation controls subcategory, experts seem to consider the separation of functions between departments and the procedures for continued operations as less relevant for the task than novices do. For the internal audit subcategory, the novices acquired 85 percent of the control information compared to 64 percent for the experts. For this category, the experts' acquisition rate is close to their average acquisition rate for general computer controls (61 percent). Thus, the difference may be attributed to the novices, who acquired a larger proportion of internal audit controls - 85 percent compared to 66 percent on average for general computer controls.

For the novices, the percentage of internal audit cues acquired is the highest of the six subcategories. This difference may be caused by the novices' greater familiarity with the internal audit function compared to other EDP general controls. It may also indicate that novices attach more importance to the internal audit function. To check this interpretation, the number of times an internal audit control was mentioned as one of the ten most important controls in the debriefing questionnaire was compiled. At least one internal audit control was included 26 percent of the time in the 10 most important controls for the novices compared to 13 percent for the experts. It thus seems that novices considered the internal audit function more important than the experts did.

**Application controls.** Experts acquired fewer application controls for all subcategories of application controls (see Table 4). To determine whether these differences were significant, a multivariate regression model was used. The five categories of application controls were regressed on expertise level, experimental treatments and interaction terms. Consistent with the general control results, treatment effects and interaction terms were not statistically significant. The effect of expertise on the five categories of application controls was tested with the Pillai Trace. Although experts acquired fewer application controls than novices, this difference is not statistically significant ($F(5,40) = 0.93$, $p = 0.47$).
One of the possible explanations for experts' greater efficiency in information use is that, if their prototypical sets of accounting controls are better cross-referenced, they then search for compensatory controls only when a control is missing. To examine this possibility, 10 pairs of redundant computer controls were deliberately included in the application control questionnaire, i.e., for each of these 10 controls there was another control that was achieving the same objective than the first.

These redundant controls were present for the validation of the data entry for ordering, shipping, credit notes, and remittances. Two control procedures were always present: a programmed check for non-numeric data and a comparison to file information. For entry of the merchandise number for example, there was a programmed test for non-numeric input and a comparison to the inventory file for number validity.

On average, novices and experts acquired respectively 6 percent and 28 percent less of the ten redundant controls. A comparison of these two means with a t-test indicates that they are significantly different ($t=6.04$, $p=.0001$). Experts always acquired fewer of the weakest control, a programmed test for non-numeric input. For eight of the redundant controls, novices acquired fewer of the weakest controls. For the other redundant controls, their acquisition rate is about the same.

As expected, experts were more efficient in the area where they have better domain-specific knowledge — computer general controls. This result is consistent with Weber (1980), who found that EDP auditors have a better organization of general computer controls than novice auditors. For application controls, although both experts and novices knowledge is above a critical level, the results from the analysis of the acquisition of redundant application computer controls indicates that in this study experts may have more knowledge about these controls than novices. However, this better knowledge may be limited to computerized application controls because there are no statistically significant differences between experts’ and novices’ total acquisition rate for application controls.

**Acquisition Behavior - Reacquisition Rate**

The more important an information cue, the more attention it should receive. Based on this rationale, Russo (1978) suggests using the number of reacquisitions as an indication of importance. Thus, a cue that is acquired

---

### Table 4

**Application Control Cues Acquired by Category**

<table>
<thead>
<tr>
<th>Category</th>
<th>Information Available</th>
<th>Information Acquired</th>
<th>Difference</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novices # %</td>
<td>Experts # %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Orders</td>
<td>28 22.4 80</td>
<td>18.7 66</td>
<td>2.40</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td>17 10.8 64</td>
<td>9.7 57</td>
<td>0.41</td>
<td>.53</td>
<td></td>
</tr>
<tr>
<td>Recording Sales</td>
<td>7 5.5 81</td>
<td>5.0 71</td>
<td>0.79</td>
<td>.38</td>
<td></td>
</tr>
<tr>
<td>Returns &amp; Allowance</td>
<td>16 10.7 70</td>
<td>9.4 57</td>
<td>0.79</td>
<td>.38</td>
<td></td>
</tr>
<tr>
<td>Maintaining A/R Records</td>
<td>24 16.8 70</td>
<td>16.2 67</td>
<td>0.15</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>Application Controls</td>
<td>77 66 72</td>
<td>59 64</td>
<td>0.93</td>
<td>.47</td>
<td></td>
</tr>
</tbody>
</table>
four times is deemed to be more important than a cue not acquired or acquired once. As noted in the literature review, this interpretation of acquisition rate has been validated by Russo and Rosen (1975). Abdel-Khalik and El-Sheshai (1980, 333) used this measure in an accounting experiment and found a “one-to-one correspondence between the relative frequency with which an information item was acquired and the perceived importance attached to it by the analysts”.

The relative frequency with which a cue is indicated as acquired may be lower than the real rate of acquisition because subjects may memorize information. This problem may occur when it is costly to obtain information. For example, Russo and Dosher (1975), monitoring eye fixations, reported that 75 percent of subjects’ acquisitions were reacquisitions, while Jacoby et al. (1976), with the same task but using information display boards, found that between 2 percent and 7 percent of subjects’ acquisitions were reacquisitions. In this study, the effect of memorization on acquisition rate was partially compensated by using a large number of cues which made it difficult for the subjects to remember all the required information.

The reacquisition rate for all cues was 16 percent. It seems that there was less memorization than in the Jacoby et al. study but there might still be some, since the rate obtained in this study is lower than the rate obtained by Russo and Dosher. The task in the latter study, however, is different and does not include as many items of information.

Expert auditors, because of their superior knowledge of controls in computerized systems, were expected to attach more importance to general computer controls than novice auditors. A regression of reacquisition rate for each of the five main categories of information indicates that expertise is significant only for the general computer controls (See Table 5). Using the reacquisition rate as a measure of importance, it appears that experts do attach more importance to general computer controls since they reacquired 9.6 percent of general controls compared to 4.3 percent for novices.

<table>
<thead>
<tr>
<th>Category/subcategory</th>
<th>Information Reacquired</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Novices</strong></td>
<td><strong>Experts</strong></td>
<td><strong>ANOVA</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
</tr>
<tr>
<td>ORGANIZATION/OPERATION</td>
<td>0.50</td>
<td>3.1%</td>
<td>0.63</td>
<td>4.2%</td>
</tr>
<tr>
<td>APPLICATION SYSTEMS</td>
<td>0.61</td>
<td>6.9%</td>
<td>1.38</td>
<td>14.5%</td>
</tr>
<tr>
<td>Systems development</td>
<td>0.07</td>
<td>3.0%</td>
<td>0.29</td>
<td>11.6%</td>
</tr>
<tr>
<td>Programs changes</td>
<td>0.36</td>
<td>11.2%</td>
<td>0.92</td>
<td>24.9%</td>
</tr>
<tr>
<td>Documentation</td>
<td>0.18</td>
<td>5.5%</td>
<td>0.17</td>
<td>5.2%</td>
</tr>
<tr>
<td>SYSTEM SOFTWARE/HARDWARE</td>
<td>0.64</td>
<td>14.5%</td>
<td>0.88</td>
<td>20.1%</td>
</tr>
<tr>
<td>ACCESS CONTROLS</td>
<td>0.18</td>
<td>2.2%</td>
<td>1.08</td>
<td>13.5%</td>
</tr>
<tr>
<td>Data files and programs</td>
<td>0.11</td>
<td>1.9%</td>
<td>0.79</td>
<td>13.4%</td>
</tr>
<tr>
<td>Computer hardware</td>
<td>0.04</td>
<td>2.5%</td>
<td>0.13</td>
<td>9.2%</td>
</tr>
<tr>
<td>Program documentation</td>
<td>0.04</td>
<td>5.0%</td>
<td>0.17</td>
<td>24.3%</td>
</tr>
<tr>
<td>DATA AND PROCEDURES</td>
<td>0.07</td>
<td>1.6%</td>
<td>0.21</td>
<td>5.3%</td>
</tr>
<tr>
<td>INTERNAL AUDIT</td>
<td>0.21</td>
<td>2.5%</td>
<td>0.38</td>
<td>5.9%</td>
</tr>
<tr>
<td>GENERAL COMPUTER</td>
<td>2.21</td>
<td>4.3%</td>
<td>4.54</td>
<td>5.90</td>
</tr>
</tbody>
</table>

* The difference between experts and novices is statistically significant only when general EDP controls are weak.
To validate this measure, the subjects' answers to the question on the ten most important controls were analyzed. The average number of general computer controls selected as one of the ten most important was 2.5 for the novices and 3.5 for the experts. As with the reacquisition rate measure, this measure indicates that the experts attached more importance to the general computer controls. The two measures of importance were tested simultaneously using a multivariate regression model (MVRM). The effect of expertise on the measures of importance is statistically significant \( F(2,40) = 4.61, p = 0.01 \). Expert auditors did attach significantly more importance to general computer controls.

Table 5 provides the reacquisition rate by category of general computer controls and, for those categories with significant differences, by subcategory. Although experts reacquired more information for all the categories of general controls, the largest differences are for application systems and access controls. For application system controls, experts reacquired more controls related to program changes and system development. The ANOVA results for the program change controls indicate that experts reacquired more information only when the computer general controls were weak. Since three of the five controls in that subcategory were manipulated, it appears that experts attach more importance to those controls when they are weak.

For access controls, experts reacquired more controls in all subcategories. The largest difference is for access controls to data files and programs. For that subcategory, experts reacquired 13.4 percent of the controls compared to 1.9 percent for the novices. These results are independent of the treatment levels.

**Task Duration**

The duration of the experimental task for each subject was measured by the CIRS. The total duration is defined as the total time elapsed from the beginning of the task to the moment when the subject has made all decisions. Duration was measured for each item of information and each CIRS menu. The summary of these data is presented in Table 6.

<table>
<thead>
<tr>
<th>Category</th>
<th>Novices</th>
<th>Novices %</th>
<th>Experts</th>
<th>Experts %</th>
<th>All Auditors</th>
<th>All Auditors %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions</td>
<td>4.1</td>
<td>6</td>
<td>2.9</td>
<td>5</td>
<td>3.8</td>
<td>6</td>
</tr>
<tr>
<td>Background Information</td>
<td>8.9</td>
<td>14</td>
<td>6.0</td>
<td>12</td>
<td>7.6</td>
<td>13</td>
</tr>
<tr>
<td>General Computer Controls</td>
<td>16.1</td>
<td>25</td>
<td>14.7</td>
<td>29</td>
<td>15.4</td>
<td>27</td>
</tr>
<tr>
<td>Application Controls</td>
<td>16.6</td>
<td>26</td>
<td>12.8</td>
<td>25</td>
<td>14.8</td>
<td>25</td>
</tr>
<tr>
<td>Decisions</td>
<td>18.7</td>
<td>29</td>
<td>15.0</td>
<td>29</td>
<td>17.0</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>64.4</td>
<td>100</td>
<td>51.4</td>
<td>100</td>
<td>58.3</td>
<td>100</td>
</tr>
</tbody>
</table>

Experts are expected to be more efficient and thus to take less time to perform the task. As hypothesized, experts utilized 21 percent less time to perform the task, with an average time of 51.4 minutes compared to 64.4 minutes for novices. As indicated in Table 6, this efficiency in performing the task is present for all five categories of information. Using a one-tailed \( t \) test, it was found that the experts used significantly less time to perform the task \( (t = 1.69, p = 0.04) \).
Experts' speed in solving problems rest on the notion that experts can often arrive at a solution without conducting extensive, external or internal, search (Glaser and Chi 1988). In this study various measures of external information search are available. It is then possible to explore the possible sources of the difference in the duration of the task. Duration was analyzed using the acquisition rate (ACQ), the reacquisition rate (REACQ), the search strategy similarity factor (FACTOR) and the expertise level (EXPE) as explanatory variables. The regression model is:

\[
DURATION = a + b_1 \text{EXPE} + b_2 \text{ACQ} + b_3 \text{REACQ} + b_4 \text{FACTOR} + e
\]

where \( e \) is the random disturbance term.

The regression model explained a relatively low (24 percent) but significant \((F(6,45) = 2.99, p=.015)\) portion of the variance in the task duration. The detailed results are given in Table 7, where the sum of squares is a sequential sum of squares (SSQ), i.e., the increment in the model SSQ as each variable is added to the model.

**TABLE 7**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SSQ</th>
<th>Percent</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>39073</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>30060</td>
<td>76%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>9013</td>
<td>24%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>4.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acquisition</td>
<td>0.35</td>
<td>6839</td>
<td>10.69</td>
<td>.002</td>
</tr>
<tr>
<td>Reacquisition</td>
<td>-0.08</td>
<td>18</td>
<td>0.03</td>
<td>.868</td>
</tr>
<tr>
<td>Similarity Factor</td>
<td>-7.90</td>
<td>748</td>
<td>1.17</td>
<td>.285</td>
</tr>
<tr>
<td>Expertise</td>
<td>-10.54</td>
<td>1408</td>
<td>2.20</td>
<td>.145</td>
</tr>
</tbody>
</table>

Notation: SSQ = Sum of Squares.

The most important variable is the acquisition rate \((F(1,47)= 10.69, p=.002)\) with 18 percent of the total variance explained. Controlling for acquisition behavior, the difference between experts and novices decreased from 13 minutes to 10 minutes, indicating that experts' efficiency is due not only to their more efficient external search but may also be caused by more efficient internal search. However, the marginal effect of expertise is weak \((F = 2.20, p=.145)\).

Compared to novices, experts spent proportionally more time on general computer controls than on application controls, even if they acquired fewer general computer controls. The proportion of the total time the experts used on these two types of controls is 29 and 25 percent respectively, compared to 25 and 26 percent for the novices. Thus experts attach more importance to computer general controls and also spend more time searching for and processing them.

**SUMMARY AND CONCLUSION**

This study has investigated several important components of auditor judgment. Experts and novices were differentiated in terms of task specific knowledge rather than in terms of years of auditing experience which has...
been the case in most previous studies. The research focused on components of judgment related to information search behavior. To monitor the subjects' information search behavior, a computer-controlled information retrieval system was employed. This process tracing method provided a detailed trace of search behavior and facilitated the use of a larger number of subjects than in previous auditing research. Three dimensions of the information search behavior were studied: information search strategy, information acquisition and search duration.

In general, the results indicate that experts and novices utilized different information search behaviors. For information search strategy, it was found that more experts than novices seem to use a global search strategy, similar to the framework proposed by professional standards. However, both experts' and novices' detailed search was mostly sequential. Experts auditors were more efficient and acquired significantly fewer information items than the novices in their specific area of expertise, computer general controls. Experts were also more efficient and acquired significantly fewer redundant controls than novices. Although they acquired fewer general computer controls, experts attached significantly more importance to those controls. Finally, experts required significantly less time to perform the task. This difference was in part related to their lower acquisition rate but also to what might be faster internal information retrieval or processing.

By addressing these issues, this study provides further understanding of the nature of expertise in auditing, particularly, the role of task specific knowledge on auditor information search behavior. It also demonstrate that a computer-controlled information retrieval system can be used to investigate complex tasks with a large number of information cues.

The results of this study are somewhat comforting. Expert auditors were more efficient than novice auditors. The results also indicate some area where novices decision behavior might need to be improved. For instance, the comparison of the two groups' information search behavior indicates that novices may look for superfluous information such as redundant controls. They may also, not attach enough importance to general computer controls.

The results reported in this study must be interpreted with several limitations in mind. First, since all of the subjects came from the same public accounting firm, the results may not apply to the entire auditing profession. Second, since the method used to monitor information search only traced retrieval of external (working paper) information, it is not clear what types of information from an auditor's stored memory were used nor do we have direct evidence to determine whether a subject actually used the information acquired.

This study reinforces the need to identify the memory structures of auditors and to examine what effects they may have on search behavior. An interesting direction for future research would be a free recall experiment designed to identify memory structures and then examine their effects on problem solving behavior.

Ashton et al. (1988) suggest that researchers should study the extent to which information search (or strategy) in auditing is schema-driven as opposed to data-driven. The results of this study indicate that an auditor's detailed search strategy may be more data-driven than schema-driven. To obtain more evidence on this issue,
A similar study could be performed using information presented in a more random order.

Appendix I

In this appendix, three measures of similarity are explained and their validity is discussed.

Path structure coefficient

Bettman (1971, 1974) suggests using a path structure coefficient (PSC) as a measure of similarity between the search sequences of two subjects. To illustrate this measure, Figure 1 gives a hypothetical example of the information search pattern of two subjects, A and B. The nodes (circles) represent the information items and the directed arcs the connection between two nodes. A path between two nodes is a collection of nodes and arcs. For example, the path between nodes 3 and 2 for subject A is composed of nodes 3, 6, 2 and arcs (3,6), (6,2). Finally, a node i is said to be reachable from node j if there is a path between them. Thus, node 2 is reachable from node 3 and the distance between them is 2 because there are two arcs.

The PSC is based on the path and reachability measure; if two graphs have a path between node i and node j of length n or less, the similarity between the two graphs should be greater than if they do not have such a path. In the example given in Figure 1, the graphs of subjects A and B have a path between node 3 and node 6 of length one. This indicates more similarity between the two graphs than if subject A only had a path of length one. Bettman has developed the following formula for the PSC based on this model:

\[
PSC(G_1,G_2) = \sum_{i=0}^{\infty} \sum_{j=1}^{n} \sum_{s=1}^{l} (p_{ij}^e - p_{ij}^a)
\]

where:

- \(p_{ij}^e = 1\) if there is a path of length n between nodes i and j in graph G,
- \(p_{ij}^a = 0\) if node i or node j is not in graph G,
- \(l = maximum\) of: (a) length n between nodes i and j in G,
  (b) length n between nodes i and j in G,
- \(t = number\) of distinct cues in both graphs.

The PSC for subjects A and B is 0.341. It is unclear how one should interpret PSC in absolute terms, but it is possible to make relative comparisons. PSC is equal to 1 when the two graphs are identical and is equal to 0 when there are no nodes common to the two graphs. When the number of common nodes v(S) for the two graphs is between 0 and the total number of nodes, the lower and upper bounds are:

Lower: \([(l + 1) v(S)] / [t + l(t - 2v(I)) + v(I)]\)

Upper: \([v(S) + lv(S) - l(v(I)) + v(I)] / [t + lv(S) + l(v(I)) + v(I)]\)

where

- \(v(S) = the\) number of common information cues used by both subjects.
- \(v(I) = the\) number of idiosyncratic information cues used by subject k.
For the example in Figure 1, the lower and upper bounds are 0.103 and 0.861 respectively. Because the upper and lower bounds vary for each pair of subjects, it is meaningless to compare two PSC coefficients. To eliminate this problem, the PSC coefficient may be rescaled on the basis of its lower and upper bounds. The new scale varies between zero and one, zero being the lower bound and one the upper bound. The rescaled PSC (RPSC) is 0.315. Assuming that subjects A and C have an RPSC of 0.6, comparing the two coefficients indicates that A’s sequence of search is more similar to C’s sequence of search than to B’s.

Rank Order Correlation

Another measure of similarity between two search sequences is the rank-order correlation which shows the tendency of two rank orders to be similar. Depending on the definition of similarity, two correlation coefficients can be used (Hays 1981): (1) the Spearman rank correlation coefficient (SRC) and (2) the Kendall tau coefficient (TAU). The Spearman rank correlation considers that when two subjects’ rank orders are similar, the rank assigned by individuals should correlate positively, whereas dissimilarity should be reflected by negative correlation. In terms of search behavior, the rank assigned to individuals is the search sequence number (i.e., 1 + the number of information cues selected before). The Spearman rank correlation for the search sequence of subjects A and B is -0.31. The order of search of the two subjects is then dissimilar.

With the Kendall tau coefficient (TAU), the number of times subject A selects cue i before cue j and subject B selects cue j before cue i (i.e, inversion in order) is considered evidence of dissimilarity. Each inversion is weighted equally, with the tau coefficient, whereas with the SRC, the process of squaring the difference between the search sequence numbers places different weights on a particular inversion in order. The TAU is -0.20 for the search sequence of subjects A and B.

Validity analysis

The common factor analysis model (Gorsuch 1983) was used to analyze the validity of the three measures of search sequence similarity. The advantage of the common factor model is that it decomposes the variance in the observed variables into the variance that is common and the variance that is unique to each variable. The latter may represent error in the measurement process (random or systematic) and/or legitimate influences that are not measured by other variables. More formally, the model for the three measures of similarity is:

\[ x = Wf + u \]

where \( x \) is a vector of the three observed measures of similarity (RPSC, SRC, TAU), \( W \) is a matrix of weights (loadings) of the observed variables \( x \) on the unobserved factors \( f \) and \( u \) is a vector of unique factor scores for the observed measures. The model was estimated using the principal factor method (Gorsuch 1983).

The discussion of the results of this analysis is divided into two parts. In the first part, the number of factors which can adequately account for the common variance (commonalities) in the three similarity measures is determined, i.e., how many concepts of similarity do these three variables measure? In the second part, the uniqueness and reliability of the measures is examined.
The proportion of variance in the three similarity measures accounted by one, two and three factors are 97 percent, 3 percent and 0 percent respectively. With 97 percent of the common variance accounted by only one factor, it seems that RPSC, SRC and TAU measure only one common concept of similarity. In the common factor model, the variance which is unique to each observed variable is given by \( u \) (uniqueness). Assuming that there are no measurement errors in the three similarity measures, uniqueness indicates an influence that is measured by one variable only. For the similarity measures, the uniqueness is minimal (see Table II), with a uniqueness of almost zero for SRC and TAU and of 0.037 for the RPSC.

In summary, the results of the analysis indicate that RPSC, SRC and TAU measure one common concept of similarity in the order of acquisition.
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Footnotes

1 EDP application controls are controls maintained by EDP personnel or the computer itself on input, processing, and output, and user accounting controls are controls maintained by the user department (Watne and Tumey 1984).

2 The treatments are discussed in more detail in (Citation to be provided).

3 Very few questions were asked by the subjects. One subject asked if he could take notes and one or two others asked a question on the use of the computerized information retrieval system. In the experimental sessions where there was more than one subject, subjects raised their hands and one of the researchers approached them to hear the question and answer it. This was done quietly. Because of the kind of question the subjects were encouraged to ask, the low number of questions, and the way it was done, the performance of other participants in the session was not influenced.

4 To answer this question, the subjects were provided with a hard copy of the internal controls questionnaire.

5 On the basis of common factor analysis, it seems that the path structure coefficient developed by Bettman (1971) is a good approximation of the correlation coefficients and that it might not provide more information than traditional correlation coefficients.

6 In the regression model, the acquisition rate accounts for 74 percent of the total variance. The regression for the acquisition rate is positive, meaning that acquiring more items of information increases the subjects' score on the similarity factor. The portion of variance not explained (26 percent) by the acquisition rate is assumed to represent the similarity between the subject's acquisition sequence and the order of presentation. Of that portion of variance, 15 percent is explained by the fact that some subjects acquired the EDP general controls first.

7 For the instructions and decisions categories, the subjects were required to acquire all the information items.

8 MANOVA allows simultaneous testing of all variables and considers the various interrelations among them. Thus, although a series ANOVA uncovers no significant differences, an overall difference may be determined by MANOVA (Hair et al. 1979, 145).

9 Because of the large number of questions, there were other redundant or compensatory controls. That redundancy is not as clear as for the controls examined here.

10 The experimental treatments and interactions are not significant.