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THE USE OF RULE-BASED EXPERT SYSTEMS TO INVESTIGATE THE EFFECTS OF EXPERIENCE ON AUDIT JUDGMENTS

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ABSTRACT

Rule-based expert systems (RBES) are currently the focus of a great deal of research interest. Most of that work, however, has concentrated on the development of such systems. There has not been much analysis of the resulting RBES. This paper examines two RBESs designed to make audit judgments. The knowledge bases of the initial prototype versions of each system contain the rules used by novice auditors. Each system was refined by having experienced auditors use the system to make the audit judgments for actual clients. The rules contained in the refined versions of each RBES thus represent the knowledge used by an experienced auditor to make a particular audit judgment. The effects of experience are then examined by comparing the rules in the initial prototype knowledge base to those contained in the refined version of each system. Experience appears to provide the capability to deal with exceptions to general rules and expectations.

INTRODUCTION

Rule-based expert systems (RBES) are currently the focus of a great deal of research interest. Most of that work has concentrated on the development of such systems; that is, the construction of the RBES is the *goal* of the research. The construction of an RBES, however, can also serve as the *means* for conducting descriptive empirical research on decision-making behavior. The potential benefits of building an RBES for conducting descriptive research have been recognized by some researchers in the field of artificial intelligence:

> "The aim here (in building an RBES) is thus not simply to build a program that exhibits a certain specified behavior, but to use the program construction process itself as a way of explicating knowledge in the field, and to use the program text as a medium of expression of the many forms of knowledge about the task and its solution," (Davis and Lenat, 1982, p.471).

There are two reasons why the construction of an RBES is useful for conducting descriptive research. First, the RBES is developed by being used in the natural setting in which the judgments under study are normally made. Research on decision making and judgment behavior indicates that seemingly minor changes in either the content or the setting of the judgment task can significantly affect the behavior being studied (Adelman, 1981; Cox and Griggs, 1982; Ebbesen and Konecni, 1980; Einhorn and Hogarth, 1982; Hayes and Simon, 1977; Hoch

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and Tschirgi, 1983; Kahneman and Tversky, 1979). Second, the rules used by the RBES specify not only which factors influence a given judgment, but also specify the situation in which the rules apply. Thus, the set of rules, taken together, provides a model of the judgment process that explicitly includes the effect of the task environment.

Work on expert systems suggests that expert performance requires a large amount of domain-specific knowledge, the most important of which consists of heuristic rules-of-thumb for dealing with specific situations (Brachman, *et al.*, 1983; Feigenbaum, 1979; Hayes-Roth, *et al.*, 1983; Stefik, *et al.*, 1983). This heuristic knowledge is acquired through experience (Abelson, 1981; Einhorn and Hogarth, 1982; Hogarth, 1981; Kahneman and Tversky, 1982; Tversky and Kahneman, 1981). Previous auditing research has focused on the effects of experience on general metrics of decision-making behavior such as consensus, stability, and self-insight (Ashton, 1974a, 1974b; Ashton and Brown, 1980; Ashton and Kramer, 1980; Hamilton and Wright, 1982; Messier, 1983). In contrast, this study examines how experience affects the audit judgment process by changing the store of domain- specific knowledge used to make a particular judgment.

The remainder of this paper consists of three sections. The first section provides some background information about the two audit judgment tasks that were studied and describes the research method used in building the RBESs. Section two examines the knowledge bases of the refined versions of each RBES and discusses how they differ from their initial prototype versions. The final section summarizes our findings and explores implications for future research.

RESEARCH METHOD

Audit Judgment Tasks

This study examines the effect of experience on two audit judgment tasks: (1) the evaluation of the quality of a client's internal controls and (2) the determination of materiality in the planning stage of the audit process. Each of these tasks is described in more detail below.

Evaluation of internal controls

A company's business activity consists of a number of economic transactions that affect its resources. Business organizations create and implement a set of procedures called internal controls to ensure that transactions are executed in accordance with management's intentions and are accurately recorded in the firm's information system. The specific internal controls implemented by a company result from management's assessment of the types of risks likely to affect normal transactions. For example, one of the risks related to credit sales transactions includes the possibility that the revenue will not be collected. Formal policies for granting credit represent one of the internal controls that can be used to minimize that risk.

As part of an audit engagement, the auditor assesses the quality of a client's set of internal controls. This assessment has two aspects. First, the auditor evaluates the efficacy of the client's internal controls for controlling the risks likely to be faced by the client. Second, the auditor evaluates how well those controls are actually functioning by performing tests of employee compliance with the stated controls.

INTERNAL-CONTROL-ANALYZER (Gal, 1985) is designed to perform the former analysis for sales and cash receipts transactions. That is, it evaluates the overall efficacy of the controls designed by management, but does not test actual compliance with them. Figure 1 illustrates the evaluation process used by INTERNAL-CONTROL- ANALYZER. The figure indicates that the overall evaluation of the controls for the sales and cash receipts transaction cycle is the result of combining evaluations about three types of controls applied to those transactions: (1) population controls, (2) separation of duties, and (3) accuracy controls.

Population controls relate to the validity of the transactions, and can be broken down into controls designed to ensure that all valid transactions are recorded (completeness controls) and controls designed to ensure that all recorded transactions are indeed valid (authorization controls).

Separation of duties is based on the notion that no one person should be responsible for all phases of an economic transaction: having custody of a resource, possessing the ability to authorize transactions involving that resource, and

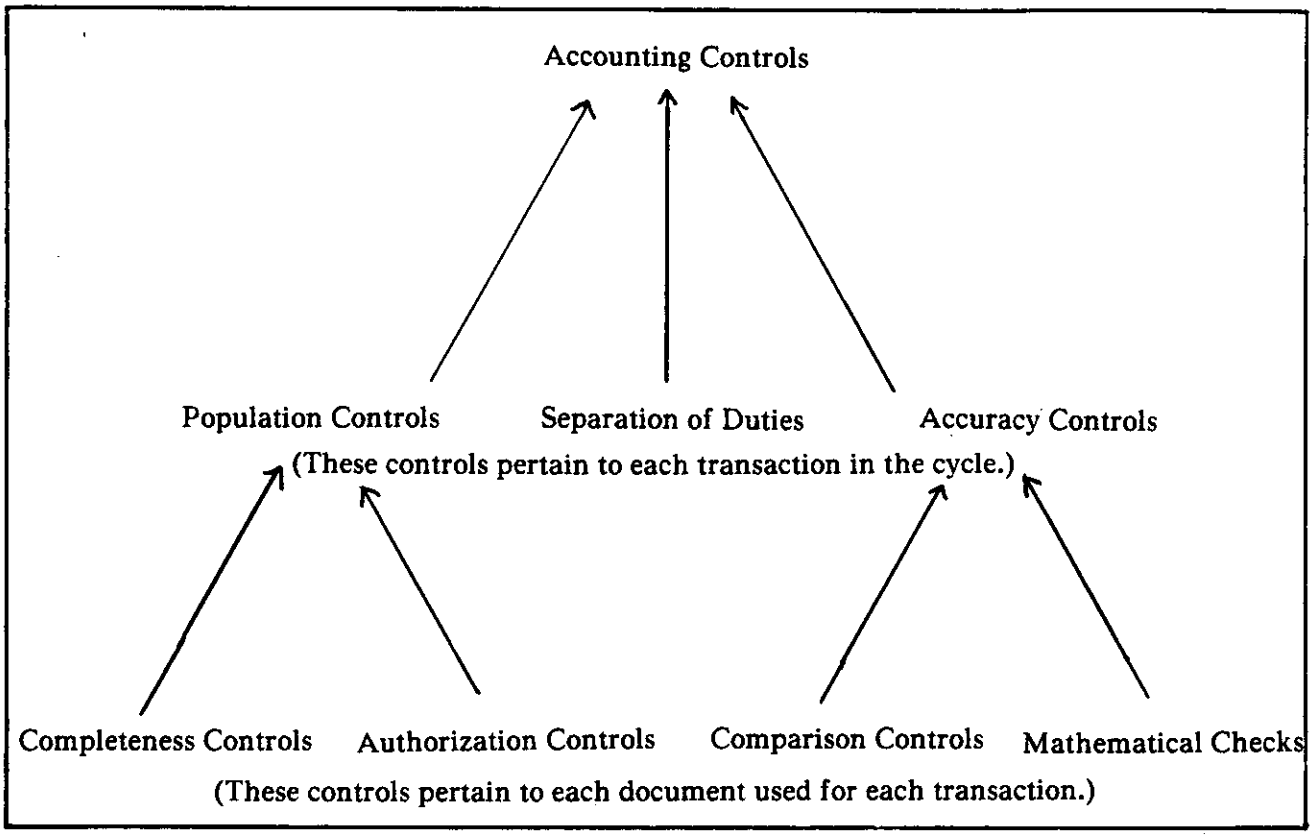

Figure 1: Types of Controls Examined in the Overall Evaluation.

being responsible for recording information about that resource.

Accuracy controls are designed, as their name implies, to ensure that transactions are recorded correctly. There are two types of accuracy controls: (1) checks on the consistency of information throughout the execution of the transaction (comparison controls) and (2) checks on the mathematical accuracy with which the transaction was recorded (mathematical controls). In summary, INTERNAL-CONTROL-ANALYZER combines judgments about all of these controls to evaluate the overall quality of the entire set.

Planning stage materiality judgment

Planning stage materiality is basically a judgment about the "importance" of any misstatements that might be present in a company's financial statements. Importance is defined in terms of potential impact on the users of the financial statements. Auditors do not examine every single transaction that occurred during a year; rather, they apply detailed audit procedures to a selected subset of those transactions. Materiality judgments made during the planning stage help determine the size of that subset. The auditor designs the audit program to be reasonably certain that any errors or misstatements that would be likely, either singly or in aggregate, to significantly affect the judgments of financial statements will be detected by the audit procedures that are used. AUDIT-PLANNER (Steinbart, 1985) is designed to determine the materiality level that should be used in planning the nature, timing, and extent of audit procedures.

Figure 2 shows the judgment model followed by AUDITPLANNER. The determination of planning stage materiality involves two sub- decisions: (1) the choice of a base for calculating materiality, and (2) the choice of a percentage rate to multiply by that base. The choice of a materiality base involves an assessment of what aspects of the client's financial statements users are most interested in. That decision is based on information about the client's (1) plans for future financing, (2) ownership structure (public

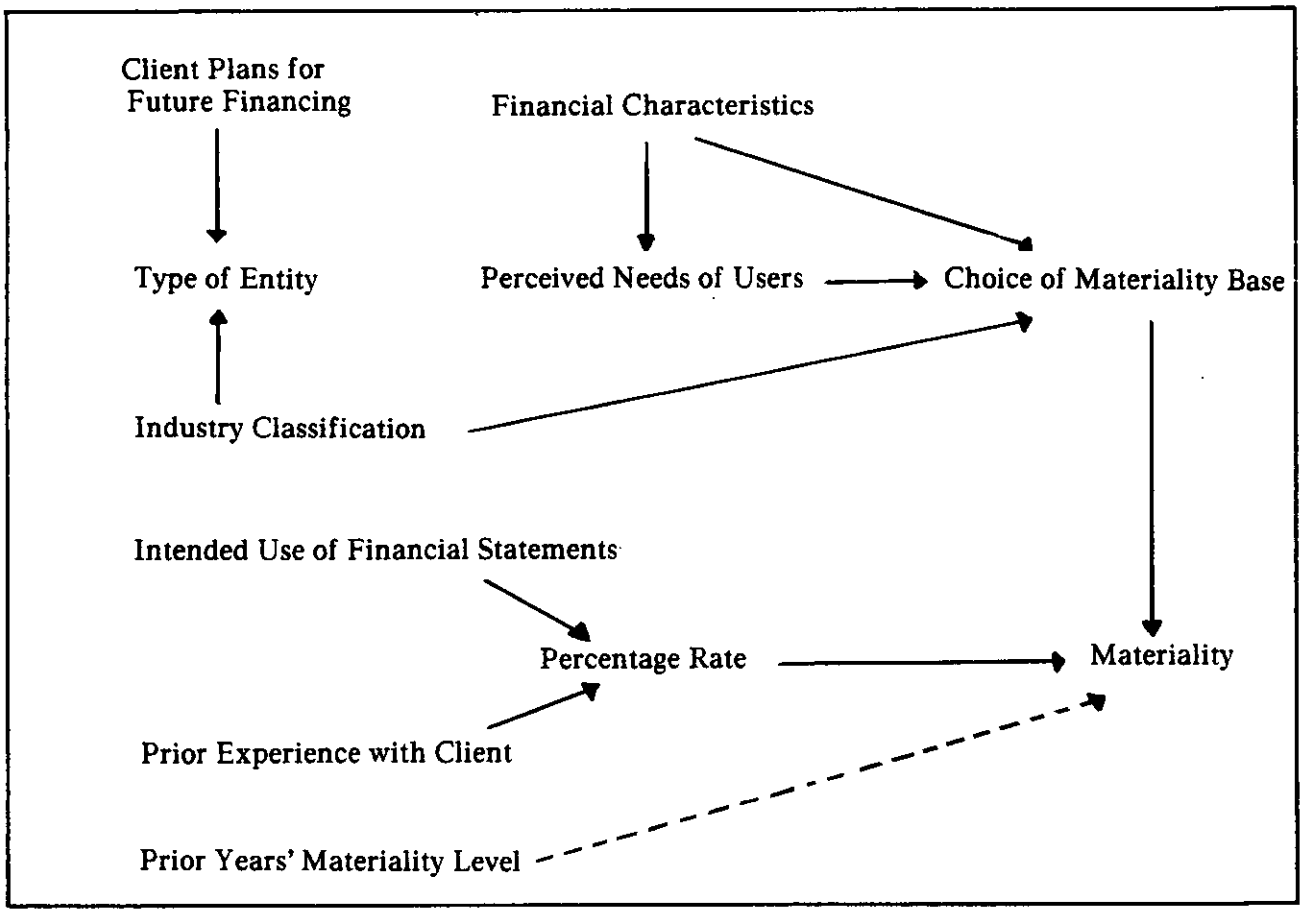

Figure 2: AUDITPLANNER's Judgment Model

or privately-owned), (3) the industry classification, and (4) financial characteristics. The choice of a percentage rate involves the auditor's assessment of any situations that would represent a greater than normal level of risk associated with the audit. That assessment is based on information about the intended uses of the financial statements and the auditor's prior experiences with the client.

Construction of the RBESs

The objective of this study is to examine the effect of experience on the audit judgment process. The method chosen to accomplish that objective involved a comparison of the knowledge base of an RBES that represents the judgment model used by a novice auditor with the knowledge base of an RBES that represents the judgment model used by an experienced auditor. The construction of each knowledge base is described below.

Development of novice RBES

Novice auditors can be characterized as possessing a fair amount of "book knowledge," but very little practical experience. They usually begin their careers in public accounting by attending a series of courses designed to teach them that firm's audit methodology. Thus, the training manuals used in those courses contain most of the novice auditor's knowledge about how to make different audit judgments.

The initial knowledge bases of both INTERNAL-CONTROL- ANALYZER and AUDITPLANNER consisted only of rules gleaned from the training manuals of two public accounting firms. The rules were first developed by reading the training materials. Then the proposed rules were discussed with an experienced auditor in each firm to ensure that the researchers had correctly interpreted the materials. The accuracy of the rules was then further verified by testing both RBESs on sample problems contained in the training materials. Both

AUDITPLANNER and INTERNAL-CONTROL-ANALYZER reached the conclusions suggested in the training materials.

Development of experienced RBES

The initial prototype RBESs were refined by having an experienced auditor use them to make audit judgments for actual clients. Each RBES was built using the shell EMYCIN. EMYCIN's question and answering capabilities were used to facilitate the refinement process. Whenever the auditor disagreed with the RBES, EMYCIN's question and answering program was used to identify the rules that were the cause of the disagreement. The auditor was then asked to explain what was wrong with the rules and to recommend how the system could be improved. Those suggestions were written down and implemented before the next interactive session. At that time, the revised RBES was tested to determine whether or not the correction had solved the problem. The revised RBES was also rerun on clients for which it had previously made correct decisions, to ensure that there were no unintended side effects from the revisions. Iterations of this interactive refinement process continued until the experienced auditors indicated that the systems were performing acceptably. Each RBES was then tested on a set of additional clients that had not been used to develop the system, and was found to make those judgments reasonably and acceptably. The contents of the knowledge bases of each RBES was then examined to investigate the effects of experience. The next section presents the results of that investigation.

ANALYSIS

The knowledge bases of the refined versions of both AUDITPLANNER and INTERNAL-CONTROL-ANALYZER differ from those of the initial prototype versions of each system. Those changes resulted from the use of each system by an experienced auditor, and were necessary to enable the RBES to reach the same conclusions as had the experienced auditor. Consequently, the changes in the knowledge base of each RBES can be taken to represent the effects of experience on making particular audit judgments.

One obvious difference between the initial and refined knowledge bases is the number of rules contained in each. The refined versions contained several times the number of rules in the initial prototypes. This merely tells us, however, that experienced auditors have larger knowledge bases than novice auditors. Of more interest is the nature of new rules and the types of changes made to rules in the initial prototype knowledge bases. The remainder of this section provides examples of rules in the knowledge bases of both AUDITPLANNER and INTERNAL- CONTROL-ANALYZER to illustrate how experience affects the audit judgment process.

New Rules

Most of the rules included in the initial knowledge bases of both INTERNAL-CONTROL-ANALYZER and AUDITPLANNER were very general, and applied to a wide variety of "average" clients. Many of the new rules added during the refinement of each system were designed to deal with situations representing exceptions to those general conditions. For example, AUDITPLANNER initially contained several rules that could be used to classify the type of entity that a client is:

IF - the client has publicly-traded debt or equity securities, *or*

- the client has restrictive debt covenants that are measured by or depend on periodic financial statement amounts or ratios that involve the results of operations

THEN the client is a public entity.

Should neither premise clause be true, AUDITPLANNER concludes that the client is likely to be a private entity; the following rule is then applied to make this determination with certainty:

IF - the client is likely to be a private entity and

- the client is filing with a regulatory agency in preparation for the sale of its securities in a public market *or*

- the client intends to go public within the next two or three years

THEN the client is a public entity.

If this rule was not satisfied, AUDITPLANNER concluded that the client was a private entity. During the refinement process the experienced auditor indicated that the following rule needed to be added to the knowledge base:

IF the client is an insurance company

THEN the client is a public company.

In other words, even if the client met all of the conditions for being considered a private entity, if it could be classified as an insurance company, then it should be treated as a public entity. The rationale for this rule is that the regulators of insurance companies generally have the same needs and interests as do investors and creditors of public entities.

The refinement process added many rules of this type to the knowledge bases of both AUDITPLANNER and INTERNAL-CONTROL- ANALYZER. The common aspect of all such rules was that they described specific situations which were not explicitly mentioned in the accounting firms' training manuals (probably because it would not be practical to list every specific situation). They serve to highlight exceptions to more general situations, and also prescribe a method for dealing with those exceptions.

Modification of Existing Rules

The second type of change made to the knowledge bases of both INTERNAL-CONTROL-ANALYZER and AUDITPLANNER involved a modification of some of the clauses of rules in the initial version of the knowledge base. Changes of this type generally reflect the experienced auditor's belief that the rules in the initial knowledge base were too general, and that their scope of application needed to be limited. An example of this type of change is found in the way that INTERNAL-CONTROL-ANALYZER determines whether there are problems with a lack of separation of duties. The initial knowledge base contained the following rule:

IF the various functions responsible for the execution of sales transactions are not performed by different people

THEN there is a problem with incompatible functions.

Information about incompatible functions was then used as follows:

IF there is a problem with incompatible functions

THEN there is a problem with separation of duties.

The experienced auditor indicated that this rule was too general. In particular, he stated that there were several other conditions which could mitigate the problem of incompatible functions so that there would not be any problem with separation of duties. The refined knowledge base of INTERNAL-CONTROL-ANALYZER, therefore, contains the following modified version of the previous rule:

IF - there is a problem with incompatible functions *and*

- the number of employees performing these functions is small, *and*

- there is adequate supervision of those employees

THEN there is no problem with separation of duties.

There were numerous changes of this type for both AUDITPLANNER and INTERNAL-CONTROL-ANALYZER. In general, they serve to moderate some of the general rules in the audit manuals by taking into account mitigating circumstances which represent situations in which those rules should not be applied.

CONCLUSIONS AND IMPLICATIONS

The initial knowledge bases of both INTERNAL-CONTROL-ANALYZER and AUDITPLANNER contained only those rules

that represented the book knowledge possessed by a novice auditor. Experienced auditors were used to refine each system, and suggested changes and additions to the knowledge base that would enable each RBES to more closely match the auditor's actual judgments. The refined knowledge bases of each RBES were then compared with the initial knowledge bases to examine the effects of experience.

The changes made to the knowledge bases were analyzed and classified into two categories: (1) the addition of new rules to deal with special situations, and (2) the modification of existing rules to alter the scope of their application. Examples of each type of change were presented. Both types of change represent methods for dealing with exceptions to general rules. Thus it appears that a major effect of experience is the development of the ability to make and recognize exceptions to more general courses of action.

There are several areas for future research. This study used qualitative methods for comparing novice and experienced knowledge bases, drawing on examples to illustrate differences. Research is needed on the development of quantitative measures for making such comparisons. This is not an easy task. Obvious measures, such as the size of the knowledge base, are of dubious worth because the number of rules can be easily changed by decisions on whether or not to include multiple clauses in the premises and conclusions of rules.

Another avenue for future research concerns the comparison of knowledge bases developed by working with different auditors, both from the same and from different public accounting firms. Holstrum (1981) reviewed empirical research on a wide range of audit judgments and concluded that:

> "In general, the most crucial aspect of the auditor judgment research to date is the lack of consensus among auditors in typical judgments made in the audit process," (pp. 31-32).

The comparison of knowledge bases that reflect the judgment strategies of different auditors may provide some insight into the true causes of the observed lack of consensus.

Finally, this study illustrates that the construction of an RBES can help answer research questions about human decision making and judgment behavior, and need not be viewed simply as a means to automate those processes. Additional studies which use RBESs as a *means* for conducting research on aspects of human decision making and judgment behavior are needed.

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