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Designing Decision Aids to Promote the Development of Expertise

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ABSTRACT: We investigate whether the use of decision aids that integrate experts' knowledge structures into their designs can effectively promote the acquisition of expert-like knowledge and improve future judgments. Results of two laboratory experiments (one involving 115 senior accounting students and one involving 78 master of accounting students) indicate that: (1) novice users of a decision aid that has an expert knowledge structure embedded into its interface make complex fraud risk assessments that are more similar to experts' risk assessments than do users of aids without expert knowledge structures; (2) users of a decision aid that has an expert knowledge structure embedded into its interface develop knowledge structures that are more similar to the knowledge structures of experts than do users of aids without expert knowledge structures; (3) knowledge structures mediate the relationship between decision aid design and judgment performance; and (4) novices develop expertise through decision aid use even when they are not instructed to learn from the decision aid.

Keywords: decision aids; expertise; fraud risk assessment; knowledge structures.

I. INTRODUCTION

Theoretical models of expert judgment in accounting propose that judgment performance is directly affected by knowledge, and knowledge consists of both knowledge content and knowledge structure (Libby and Luft 1993; Libby 1995). Knowledge structures integrate

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both declarative knowledge (knowledge of facts) and procedural knowledge (knowledge of the steps needed to solve a problem or perform a task into meaningful patterns) (Anderson 1983). Substantial research indicates that knowledge structures are more representative of expertise than other measures of knowledge, and that knowledge structures are highly predictive of decision performance (e.g., Goldsmith and Davenport 1990; Schvaneveldt 1990; Kraiger et al. 1993; Day et al. 2001; Davis and Yi 2004; Rose et al. 2007). We propose that representations of experts' knowledge structures embedded in decision aids are valuable new tools for improving the development of expertise by novice accountants and auditors.

While accounting research has examined the role of knowledge structures in expert decision making and has recognized the importance of knowledge structures (e.g., Hammersley 2006; Vera-Muñoz et al. 2001; Bierstaker et al. 1999; Bedard and Biggs 1991; Bonner and Pennington 1991), sparse research has examined how to promote the development of expert-like knowledge structures, particularly through the use of decision aids. As Bonner and Walker (1994) and Earley (2001) indicate, it is essential to understand how expertise is acquired on the job, since accounting and audit practitioners achieve substantial expertise through professional experience. Our study addresses these issues by investigating the potential for decision aids to promote expert-like judgments that result from the development of expert-like knowledge structures.

Novices can recognize patterns of cues and relationships between cues, and they can structure their existing knowledge and newly acquired knowledge to mimic these patterns with little or no explanatory feedback (Kraiger and Cannon-Bowers 1995; Bonner et al. 1997; Yi and Davis 2003; Trumpower and Goldsmith 2004; Borthick et al. 2006; Davis and Yi 2004). The design of decision aid interfaces represents an opportunity to display cue patterns to users while they make professional judgments. Thus, we suggest that accounting professionals can be encouraged to develop more effective mental models simply by using decision aids that are organized to represent an expert's knowledge structure. While prior research finds that explicit training and prior knowledge influence judgment, this is the first study to demonstrate that simply displaying experts' mental models in decision aid interfaces improves judgment by promoting the development of these expert knowledge structures.

In a pair of controlled laboratory experiments, we embed a composite representation of experts' knowledge structures into a checklist decision aid designed to assist in the assessment of fraud risk. Our decision aid displays a representation of an expert knowledge structure in order to promote expertise development. This novel approach offers significant advantages, because organizing an aid's interface does not require the development of extensive explanation facilities, and pattern recognition can occur without extensive explanatory feedback or explicit training. Fraud risk assessment is an appropriate decision domain for our decision aid because fraud risk assessments are complex, they require professional judgment, and decision aids are currently employed to make fraud risk assessments in professional practice.

The results of the experiments indicate that novice users of a system that incorporates an expert knowledge structure make judgments that more closely resemble the judgments of experts than do users of an aid without embedded knowledge structures. Embedding expert knowledge structures into a decision aid interface allows users to develop knowledge structures that are similar to the knowledge structures of experts, and development of these structures leads to expert-like judgment. Further, and contrary to current beliefs about expertise development through decision aid use, we find that users of decision aids with embedded expert knowledge structures do not need to be instructed to learn from the decision aid in order to acquire expertise. The results suggest several changes to our theoretical assumptions about decision aid design and expertise development. Our results indicate that decision aids can effectively promote the development of expertise while still promoting decision effectiveness. The results are important to the design of decision aids for use in accounting/auditing practice and nearly all other decision domains (e.g., medical judgments, defense/military judgments, investment decisions). The potential value of knowledge structures for designing decision aids, developing expertise in novice accountants, and promoting high-quality judgment appears to be considerable.

II. LITERATURE REVIEW AND HYPOTHESES

Knowledge Structure Acquisition

Information gathered through experience is first encoded in long-term memory to create knowledge content, and knowledge content is then chunked into categories to form knowledge structures (Birnberg and Shields 1984). Sweller (1993) defines these knowledge structures as constructs that organize knowledge in the manner it will be used, and he states that knowledge structures relate directly to expert performance. Early evidence for the importance of knowledge structures in expert judgment and decision making came from studies of chess players. Chase and Simon (1973) discovered that expert chess players had better recall of realistic board configurations than did novices, but this difference was not found for improbable or impossible configurations. Their results indicated that experts have better recall of problem-relevant information than novices, but not better recall of all information. Similar studies in physics found that experts tend to categorize problems according to their solution mode, while novices categorize by surface features (Chi et al. 1982).

Individuals combine their knowledge structures with short-term information (such as cue patterns) to form a mental representation of a problem, and as decision makers accumulate more experience, their knowledge structures represent more total knowledge, more knowledge of relationships, and more abstract knowledge (Hammersley 2006; Christ 1993). Based on the mental representation formed, the individual then develops a strategy to solve a problem, formulate a decision, or make a judgment. Research has demonstrated that experts have high-quality problem representations and possess knowledge structures that allow them to recognize cue patterns to make higher quality, more complex judgments (e.g., Chi et al. 1982; Tarmizi and Sweller 1988; Hammersley 2006). That is, experts learn to combine cues into patterns ("chunks" that are organized in a single relational structure in memory), and when retrieved from memory, experts can recall more information, can perceive large meaningful patterns in their domain, have superior short- and long-term memory for domain-relevant information, and represent problems at a deeper level (Glaser and Chi 1988; Chase and Simon 1973).

Early accounting studies have provided evidence for the existence of accounting-related knowledge structures. For example, Weber (1980) demonstrated that accounting professionals possess valuable knowledge structures by asking auditors to freely recall information technology controls. Frederick (1991) offered further evidence for knowledge structure development by accounting experts when he found that experienced auditors had developed internal control knowledge structures that were organized by transaction flows, while students had not developed such organization of control knowledge. These studies indicate that experienced auditors possess acquired knowledge structures that are organized in a manner that is useful for judgment and decision making.

More recent studies have found that novices can be trained to organize their knowledge into meaningful structures that are similar to experts' structures (Rose et al. 2007; Borthick et al. 2006; Kopp and O'Donnell 2005). Based on Rose and Wolfe's (2000) study that estimated the complexity of knowledge structures through a series of problem complexity manipulations and analyses of the error patterns of their participants, Rose et al. (2007) provided the first direct and palpable measure of knowledge structure development by accounting professionals. These authors found that Pathfinder Network Scaling (Schvaneveldt 1990) techniques provide accurate and reliable measurements of knowledge structures, and that novice and expert knowledge structures can be directly compared. Taken as a whole, these accounting studies support the development of knowledge structures by expert practitioners, and they find that contemporary measures exist to capture these knowledge structures.

Thus, extant research provides compelling evidence that experts possess complex knowledge structures that allow them to make professional judgments, and knowledge structures are highly related to decision and judgment performance. However, existing research into the effects of training and decision aid use on expertise development by accounting professionals has relied almost exclusively on pretest and posttest differences in declarative and procedural knowledge to measure the knowledge gap of novices and experts (Earley 2001; Rose and Wolfe 2000; Bonner and Walker 1994). Differences in the content and quantity of knowledge, however, are only loosely related to knowledge structure (Trigwell and Sleet 1990), and knowledge structure is much more closely related to decision performance than measures of knowledge quantity (e.g., Sumfleth 1988; Kraiger and Cannon-Bowers 1995). Recent research finds that knowledge structures can fully mediate the relationship between training and performance (Davis and Yi 2004; Rose et al. 2007). In general, learning studies from the cognitive psychology literature find that the amount of procedural or declarative knowledge is not as important to performance or training outcomes as the organization of that knowledge (Johnson-Laird 1983; Rouse and Morris 1986; Kraiger et al. 1993). The present study examines the ability of decision aids to improve judgment performance by imparting expert-like knowledge structures to novice accounting practitioners.

Seminal knowledge acquisition research finds that accounting professionals learn through combinations of instruction and experience, and that experience should include practice and explanatory feedback for knowledge acquisition and expertise development to occur (e.g., Libby 1995; Bonner and Pennington 1991; Bonner and Walker 1994). Many existing theories and experimental results are, however, based upon the acquisition of declarative and procedural knowledge, rather than the development of knowledge structures. This focus on quantity of knowledge and the lack of validated measures for expertise in less structured decision environments has hindered the ability of researchers and practitioners to assess the capacity of decision aids to effectively impart expert-like knowledge to novice decision makers. We suggest that decision aids can efficiently promote the organization of knowledge into expert-like knowledge structures and that expertise development can be promoted during professional practice without the theoretical prerequisites of instruction and explanatory feedback. We propose that there are routes to knowledge structure development that deviate from those described by existing theory, and understanding these routes is essential to robust theory development and improvements in practice.

Decision Aids and Fraud Risk Assessment

While external auditors are increasingly expected to prevent and detect fraud, they tend to lack fraud-related experience (Zimbelman 1997; Knapp and Knapp 2001), and they tend to see more examples of non-fraudulent reporting than fraudulent reporting (Loebbecke et al. 1989; Solomon et al. 1999). Even simple, linear combinations of fraud cues have been shown to have higher predictive accuracy than experienced auditors (Bell and Carcello 2000). Given the complexity of fraud risk assessments, auditors' lack of fraud-related experience, and auditors' impoverished capability for assessing fraud relative to deterministic models, auditors commonly employ fraud risk assessment decision aids in practice (e.g., Allen et al. 2006; Shelton et al. 2001). The appendix of Statement on Auditing Standard (SAS) No. 99, *Consideration of Fraud in a Financial Statement Audit*, provides a checklist decision aid for use in practice (AICPA 2003).

Decision aids are designed to increase accuracy, expedite the decision-making process, increase decision quality, decrease the effort required for effective performance, free cognitive resources, and train novice users to make judgments like experts (e.g., Kachelmeier and Messier 1990; Messier 1995; Johnson and Kaplan 1996; Rose 2002; Barrick and Spilker 2003; Arnold et al. 2004). Public accounting firms rely on decision aids to help novices acquire expert-like knowledge (Messier 1995; Rose and Wolfe 2000; Rose 2002; Dowling and Leech 2006). Given that it is not practical or cost effective to provide formal instruction and explanatory feedback for all tasks (Bonner and Walker 1994; Earley 2001), decision aids represent tools for promoting expertise development on the job. However, standard checklists have been found to hinder the effectiveness of auditors' judgments (Pincus 1989; Asare and Wright 2004), which suggests that the design of a decision aid is essential.

Prior research finds that the design of decision aid interfaces and explanations is a critical determinant of the ability of users to acquire knowledge through decision aid use (see, e.g., Eining and Dorr 1991; Pei et al. 1994; Steinbart and Accola 1994; Pei and Reneau 1990; Odom and Dorr 1995; Rose and Wolfe 2000). Explanation facilities (i.e., explanations of the underlying processes of the decision aid that aid users can access during aid use) have often failed to promote knowledge acquisition. For example, Murphy (1990) demonstrated that users of a decision aid with explanation facilities did not acquire more procedural knowledge than did users of aids without explanation facilities. Similarly, Eining and Dorr (1991) found that explanations in an expert system used to evaluate internal controls failed to promote the acquisition of knowledge. Steinbart and Accola (1994) extended these earlier studies by examining the potential for more elaborate explanations to produce positive learning effects. Once again, the results did not support the hypothesis that explanations result in knowledge acquisition.

Other design approaches have, however, resulted in the acquisition of knowledge by aid users. Requiring users to reflect upon problems they have solved and explanations of their performance on these problems can facilitate the acquisition of procedural knowledge (Hornik and Ruf 1997). A study by Mascha (2001) also finds that aid users can acquire procedural knowledge from procedural explanations. More recently, Smedley and Sutton (2007) verified that explanations of procedures designed to promote goal structuring can impart procedural knowledge to aid users. Overall, there is evidence that explanations in decision aids can both hinder and promote the acquisition of knowledge, and the effects of explanations vary widely with their design.

Rose and Wolfe (2000) studied knowledge acquisition from a different perspective and examined the acquisition of knowledge structures, rather than the acquisition of declarative or procedural knowledge. They demonstrate that accounting firms have the opportunity to achieve significant training efficiency gains by designing aids that promote the acquisition of knowledge structures. Knowledge structures are critical to expert performance, and aids that promote the development of expert-like knowledge structures by novice users have the capacity to significantly influence accounting practice during and after aid use. Psychology research finds that decision makers can begin to develop knowledge structures through studying worked examples of problems (Sweller and Cooper 1985; Zhu and Simon 1987; Chi et al. 1989). Decision makers are able to recognize cue patterns and other features of examples, and use their knowledge of problem features when attempting to solve future problems. Training that emphasizes knowledge structure can promote the development of expert-like knowledge structures (e.g., Day et al. 2001; Kozlowski et al. 2001; Trumpower and Goldsmith 2004; Kopp and O'Donnell 2005; Borthick et al. 2006). Further, training novices to learn a graphical representation of experts' knowledge structures can result in novice acquisition of the expert-like knowledge structures (Trumpower and Goldsmith 2004).

Given that novices can recognize cue patterns and problem features in worked examples and develop knowledge structures that represent patterns and features, we propose that decision aid users can recognize cue patterns inherent in the layout of a decision aid, and decision aid users will develop knowledge structures that are representative of these patterns.

H1: Novice users of a fraud checklist decision aid with an embedded expert knowledge structure will develop more expert-like knowledge structures than will novice users of a decision aid that does not have an embedded expert knowledge structure.

Research has specifically addressed the relationships between knowledge structure and judgment quality. There is substantial evidence that the development of expert-like knowledge structures leads to superior judgment and decision performance (e.g., Goldsmith and Davenport 1990; Schvaneveldt 1990; Kraiger et al. 1993; Kraiger and Cannon-Bowers 1995; Day et al. 2001; Davis and Yi 2004; Rose et al. 2007). Research in accounting, education, and psychology consistently finds that the development of more expert-like knowledge structures results in more expert-like judgments and decisions.

H2: Novice users of a fraud checklist decision aid with an embedded expert knowledge structure will make judgments more similar to experts' judgments than will novice users of a decision aid that does not have an embedded expert knowledge structure.

Knowledge structure is highly related to decision performance (e.g., Sumfleth 1988; Kraiger and Cannon-Bowers 1995), and recent research finds that knowledge structures mediate the relationship between training and performance (Davis and Yi 2004; Rose et al. 2007). We posit that improvements in decision performance associated with the organization of a decision aid result from a user's acquisition of expert-like knowledge structures.

H3: The similarity of novices' knowledge structures to the knowledge structures of experts will mediate the relationship between decision aid organization and judgment performance.

Instructions to Learn While Using a Decision Aid

Studies by Cummins (1992) and Bernardo (1994) demonstrated that individuals acquire significantly more expertise during task completion when they are told that learning is a task goal. Rose and Wolfe (2000) indicate that it is important to require decision aid users to learn from the decision aid because expertise development will not occur unless decision aid users intentionally direct effort toward expertise acquisition. Decision makers view energy conservation as an important goal when completing tasks with a decision aid (Todd and Benbasat 1992, 1994). That is, decision aid users take advantage of these systems to conserve effort and redirect cognitive resources to other tasks. As such, when users are not instructed that learning is an important task goal, mental resources are not devoted to acquiring decision aid-related knowledge that is embedded in aids' explanatory feedback.

Unlike research related to learning from explanation facilities embedded in decision aids, prior studies related to mental representations of information have found that pattern recognition and mental representation of data occur without instruction to learn (e.g., Hammersley 2006; Maletta and Kida 1993; Bierstaker et al. 1999). Pattern recognition does not require the same conscious consumption of working memory that is necessary to interpret complex explanations of aid steps and procedures. Thus, investigation of the effects of decision aid organization on aid users' structuring of knowledge is distinct from existing decision aid research. While prior decision aid research indicates that instruction to learn from the decision aid is necessary for learning to occur, we posit that instruction to learn is not compulsory for users of decision aids to develop mental models that are similar to the expert knowledge structure embedded in a decision aid's interface. This leads to the following hypothesis:

H4: Subsequent to decision aid use, the judgments of novice users of a fraud checklist decision aid with an embedded expert knowledge structure (both with and without instruction to learn from the decision aid) will make judgments more similar to experts' judgments than will novice users of a decision aid without an embedded expert structure.

III. OVERVIEW OF EXPERIMENTS

We conduct two laboratory experiments to test our hypotheses. In both experiments, we manipulate whether the decision aid contains an embedded expert knowledge structure in order to determine whether embedded expert knowledge structures allow aid users to develop more expert-like knowledge structures and make decisions more like experts. We also manipulate the presence/absence of instructions that tell users to study the aid processes such that we can investigate whether instruction to learn is needed for decision aid users to develop knowledge structures through aid use. The second experiment includes a delay between decision aid use and testing in order to determine whether the effects of aid use on knowledge structures and decision performance persist beyond short-term effects in the laboratory.

IV. EXPERIMENT 1

Participants

Participants are 115 senior-level accounting students. The student participants represent novices with no professional experience or training in fraud risk evaluation. Students completed the experiment at the beginning of their audit course, prior to covering SAS No. 99. The participants were informed that the "top 10 performers on the task would each receive $20." Student participants are the most appropriate for the experiment because these participants do not have well-developed knowledge structures for fraud risk assessment, which facilitates measurement of the effects of decision aid use on the organization of knowledge and future judgment performance.

Design

The experiment employs a 2 × 2 between-subjects design with manipulations of the way the fraud checklist was organized (*checklist organization)* and instructions to learn from the aid (*learning requirement*). *Checklist organization* represents the layout of the cues on a fraud cue checklist. Cues are organized: (1) according to the fraud triangle presented in Statement on Auditing Standards No. 99 (AICPA 2003), or (2) according to an aggregate expert knowledge structure. The requirement to learn (*learning requirement*) is either: (1) present or (2) absent.

Procedure

Participants were randomly assigned to one of four treatment conditions. The task was automated, completed in a controlled laboratory setting, and required 40 minutes to complete on average (a one-hour total time limit was set, and all participants included in the analyses completed the task within the time limit). Participants used the decision aid to assess the risk of financial statement fraud for three cases (case order was randomized across subjects). Extensive pilot testing indicated that three trials were sufficient for participants to develop knowledge structures that are representative of the expert structure. After each assessment, participants received outcome feedback (the average fraud risk assessment from experts) and were allowed to study their assessment. After completing three risk assessments with outcome feedback, the participants completed a concept pair rating task where they evaluated the relatedness of all combinations of the 15 red flags included in the decision aid. The relatedness evaluations were used in Pathfinder analysis to generate a knowledge structure. After the pair rating task, participants completed a test case where they evaluated the risk of financial fraud without the use of a decision aid.

Dependent Variables

We collected two dependent variables: decision performance and a measure of the degree to which participants' knowledge structures matched those of experts. Decision performance represents each participant's fraud risk assessment accuracy. Fraud risk assessment accuracy is computed by comparing each participant's fraud risk assessment from the test case to an aggregate of experts' fraud risk assessments of the identical test case. The absolute difference between a participant's fraud risk assessment on the test case and an aggregate of assessments by five experts can range from 0 to 6 (based on an aggregate expert score of 7 on a risk rating scale of 1 to 9). Higher scores represent worse performance.

We used Pathfinder Network Scaling analysis (Schvaneveldt 1990) to calculate C-scores, which represent how closely an individual's knowledge structure matches that of an expert aggregate knowledge structure (i.e., the C-score is an index of similarity). This measure has been shown to be a better representation of expertise than most other available measures (Goldsmith and Davenport 1990; Schvaneveldt 1990; Kraiger et al. 1993). The C-score can range from 0 to 1, with 0 indicating that the two knowledge structures are completely dissimilar and 1 indicating that the two knowledge structures are identical. C-scores typically do not approach 1 (or even the mid-point of the C-score) in complex judgment tasks (e.g., Schvaneveldt 1990; Goldsmith et al. 1991; Trumpower and Goldsmith 2004). Prior research finds that training programs that can produce C-scores between 0.20 to 0.28 are associated with significant and meaningful improvements in judgment performance that approximate experts' judgment performance (e.g., Goldsmith et al. 1991; Trumpower and Goldsmith 2004; Rose et al. 2007).

Development of the Decision Aid

The decision aid for our experiment was designed to mimic the fraud checklist aid that is included in the appendix of SAS No. 99 (AICPA 2003). The primary purpose of such list aids is to promote decision effectiveness and efficiency, and to free cognitive resources for other tasks. We argue that expertise can be acquired through the use of list aids (and other varieties of decision aids and expert systems) because users can assimilate the patterns of cues present in a decision aid to form knowledge structures. Thus, our decision aid is designed to serve multiple purposes: it is intended to promote the same levels of decision effectiveness promoted by aids in practice, while also enhancing expertise development.

Development of our decision aid was accomplished in several stages. First, we selected fraud cues from the SAS No. 99 (AICPA 2003) appendix. According to Cooke (1994), at least 12 cues are necessary to adequately define a decision domain for the purpose of knowledge structure measurement, and Rose et al. (2007) suggest that 15 cues allow for robust differentiation between individuals' knowledge structures. Increasing the number of cues beyond 15 rapidly increases the duration and complexity of the experimental task because participants must evaluate the relatedness of all possible combinations of cues. Thus, we elected to define our decision domain with 15 cues, most of which (13 of the 15 selected cues) replicate cues from Wilks and Zimbelman (2004), who validated these 13 cues as essential to risk assessment judgments. Two additional cues were added to the Wilks and Zimbelman (2004) cue list to represent all three sides of the fraud triangle.[1]

[1] Wilks and Zimbelman (2004) held management attitude constant in their study. As a result, no attitude cues were present in their experimental materials. We added two attitude cues to the list of 13 cues to better represent the fraud triangle and the risk assessment recommendations of SAS No. 99 (AICPA 2003).

Wording of the 15 cues was abbreviated to allow all cues to be presented on one screen. The abbreviated wording was reviewed by three researchers and an experienced practitioner until all reviewers agreed that the abbreviations captured the meaning of each cue.

After selecting 15 fraud cues to include in the checklist aid, we asked a group of fraud experts to complete a concept-pair rating task to elicit their knowledge structures. The fraud experts included a Certified Fraud Examiner (CFE) with 16 years of professional experience, a Chief Audit Executive with a CFE license, an auditing professor who teaches a course on fraud examination, a second Chief Audit Executive with fraud detection experience, and a national audit partner of an international audit firm. The experts rated the similarity of the 15 abbreviated fraud cues using the identical software employed to measure participants' ratings of similarity in the experiment (experts and participants evaluated the 105 randomly presented comparisons by clicking on a Likert scale; Appendix A provides a screen shot of the similarity rating task).

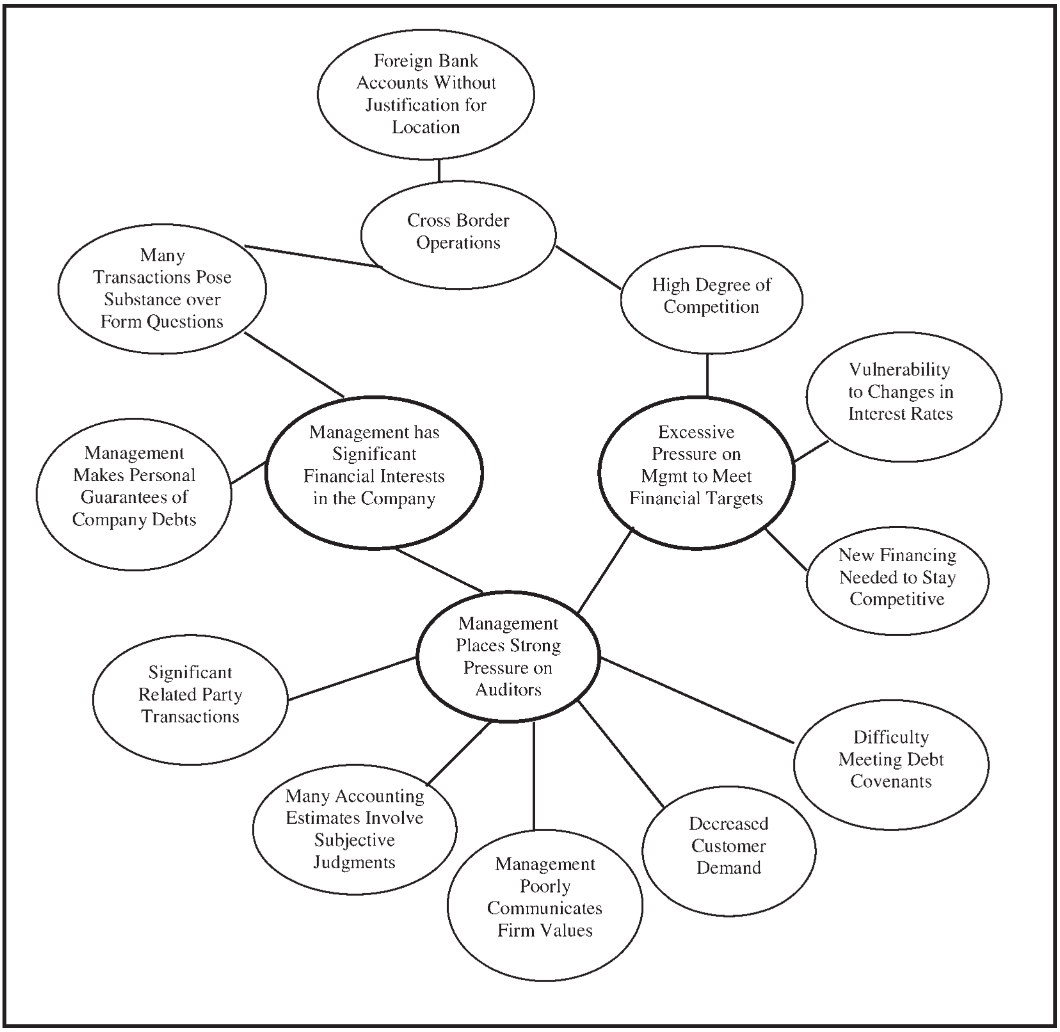
The relatedness judgments provided by the experts were analyzed using Pathfinder Network Scaling (PNS) to measure their knowledge structures. PNS is a technique that evaluates non-hierarchical interrelationships among concepts stored and organized in long-term memory (Choo and Curtis 2000). Measurements of these relationships reveal an individual's organization of concepts related to a particular decision domain (Kraiger et al. 1993; Kraiger and Cannon-Bowers 1995). In order to measure the relationships among concepts in memory, PNS utilizes individuals' evaluations of the relatedness of pairs of concepts to compare the knowledge structures of different individuals or groups of individuals (Schvaneveldt 1990). PNS provides a direct measure of a decision maker's knowledge structure, and Pathfinder-based measures of knowledge structures are predictive of performance, skill retention, and skill transfer (Goldsmith and Davenport 1990; Schvaneveldt 1990; Kraiger et al. 1993; Day et al. 2001). Pathfinder analyses allow for direct comparisons of novices' and experts' knowledge structures that are independent of the complexity of the decision domain, and these comparisons reveal the capability of novices to perform like experts.

PNS can be used to create a two-dimensional representation of an individual's knowledge structure (Taricani and Clariana 2006; Goldsmith et al. 1991). The result is a visual knowledge map based upon the series of paired comparisons. Day et al. (2001) find that mechanical aggregation of multiple experts' knowledge structures measures are much more correlated to decision performance than measures based on the consensus of a group of experts. Therefore, we aggregated the experts' knowledge structures to create a single expert knowledge map (see Figure 1).

We created two different versions of the decision aid, each organizing the checklist of cues in a different manner. One *checklist organization* reflected the way our panel of experts structured their knowledge (see Figure 2), while the other was based on the model developed in SAS No. 99. SAS No. 99 includes a checklist of risk factors organized into three categories that are commonly referred to as the fraud triangle: (1) incentive/pressure to perpetrate a fraud, (2) opportunity to carry out a fraud, and (3) attitude/ability to rationalize the fraudulent action. The system organized according to SAS No. 99 is presented in Figure 3, and screenshots of key elements of the experiment are presented in Appendix A.

A major strength of our experimental design involves the use of the aggregate of experts' knowledge structures as a benchmark for the measurement of the acquisition of expertise by aid users and as a basis for the aid design. By comparing the knowledge structures of aid users to the knowledge structure of the experts used to develop our aid, we are able to demonstrate that aid users can develop knowledge structures that are similar to experts. If our users begin to think like the experts, then we will have evidence that aids can be designed to represent knowledge structures, and users can develop the knowledge structures through aid use.

FIGURE 1
Expert Aggregate Knowledge Structure



V. RESULTS—EXPERIMENT 1

Pathfinder Network Scaling analysis is used to evaluate whether users of the decision aid where the checklist is organized to mimic an expert knowledge structure, acquired more expert-like knowledge structures than did users of the decision aid not organized to match the expert structure (H1). The mean C-score of users of the system organized according to experts' knowledge structures is 0.190, while the mean C-score of users of the SAS No. 99 organized aid is 0.146. We formally test H1 with an ANOVA model where the dependent variable is the participant's C-score, and independent variables represent the *checklist organization*, the presence or absence of instructions to learn the decision aid processes (*learning requirement*), and the interaction of

FIGURE 2
Decision Aid: Expert Checklist Organization

When management places pressure on the auditors, management faces excessive pressure to meet financial targets, or management has significant financial interests in the company, there may be a risk of fraud. Related red flags are grouped together.

	Management Places Strong Pressure on Auditors	Management may attempt to pressure the external auditor in order to achieve desired financial results.
	Management Poorly Communicates Firm Values	
	Significant Related Party Transactions	
	Many Accounting Estimates Involve Subjective Judgments	
	Difficulty Meeting Debt Requirements	
	Decreased Customer Demand	

	Excessive Pressure on Management to Meet Financial Targets	Management may face strong pressures to meet its financial targets.
	New Financing Needed to Stay Competitive	
	Vulnerability to Changes in Interest Rates	
	High Degree of Competition	
	Foreign Bank Accounts With No Justification for Location	
	Cross-Border Operations	

	Management has Significant Financial interests in the Company	Management may have significant financial interests in the company.
	Many Transactions Pose Substance Over Form Questions	
	Management Makes Personal Guarantees of Company Debts	

checklist organization and *learning requirement*. The results from the ANOVA model are presented in Panel B of Table 1, and associated means for the C-scores are presented in Panel A of Table 1. *Checklist organization* is statistically significant in the model ($F = 18.623$, $p < 0.001$).[2] Combined with the means in Panel A, the significant effect of *checklist organization* indicates that participants

[2] We evaluated the data to ensure that neither outliers nor unequal variances were driving the results.

FIGURE 3
Decision Aid: SAS No. 99 Checklist Organization

When management has certain incentives, opportunities, or attitudes, there may be a risk of fraud. Related red flags are grouped together.

	Incentives Incentives result from a perceived pressure on a person to commit fraud, and they create a motivation to commit fraud.
	High Degree of Competition
	Vulnerability to Changes in Interest Rates
	Decreased Customer Demand
	New Financing Needed to Stay Competitive
	Excessive Pressure on Management to Meet Financial Targets
	Difficulty Meeting Debt Requirements
	Management has Significant Financial interests in the Company
	Management Makes Personal Guarantees of Company Debts

	Opportunity Opportunities result from conditions of situations that would allow a person to commit fraud, such as weak internal controls.
	Many Accounting Estimates Involve Subjective judgments
	Many Transactions Pose Substance Over Form Questions
	Significant Related Party Transactions
	Cross-Border Operations
	Foreign Bank Accounts With No Justification for Location

	Attitude Attitudes allow a person to rationalize the act of fraud, and these attitudes result from the quality of the character of management.
	Management Poorly Communicates Firm Values
	Management Places Strong Pressure on Auditors

TABLE 1
Experiment 1
Knowledge Structure Acquisition (C-score)

Panel A: Descriptive Statistics (C-Score)

Mean (Standard Deviation) {Sample Size} Responses across Treatment Conditions

	Organization		
Instruct	**Expert**	**SAS No. 99**	**Main Effect: Instruct**
Present	0.188 (0.074) {29}	0.129 (0.040) {29}	0.159 (0.066) {58}
Not-Present	0.193 (0.055) {28}	0.163 (0.048) {29}	0.181 (0.058) {58}
Main Effect: Organization	0.190 (0.065) {57}	0.146 (0.047) {58}	0.168 (0.060) {115}

Panel B: ANOVA Model

Source	Sum of Squares	df	Mean Square	F	Sig.
Organization	0.057	1	0.057	18.623	<0.001
Instruct	0.010	1	0.010	3.406	0.068
Organization × Instruct	0.006	1	0.006	2.075	0.153
Error	0.342	111	0.003		

Organization: The checklist aid was organized using either the SAS No. 99 organization or the expert knowledge structure organization.
Instruct: Participants were either instructed to learn how experts use fraud cues to make fraud risk assessments while using the decision aid, or they were not instructed to learn.
Dependent Variable:
C-Score = Measure (i.e., index of similarity) of the closeness of an individual's knowledge structure compared to that of an expert aggregate knowledge structure, using Pathfinder Network Scaling analysis.

who used the aid that was organized according to an aggregate of experts' knowledge structures acquired a knowledge structure that was more like the aggregate expert knowledge structure than did participants using the system organized according to the SAS No. 99 checklist.[3]

H2 proposes that participants using the financial statement fraud checklist that is organized according to an expert's knowledge structure will have better fraud risk assessment performance than participants using a system organized using the SAS No. 99 checklist (which represents aids currently employed in practice). We test H2 with an ANOVA model (see Table 2, Panel B) where the dependent variable is judgment performance (measured by absolute value of the difference

[3] We perform a similar set of tests to verify that users of the SAS No. 99 decision aid acquire knowledge structures that are more similar to the SAS No. 99 organization of fraud cues than do users of the expert-organized decision aid. Similar to the first analysis, users of the decision aid organized according to SAS No. 99 organize their knowledge more like the SAS No. 99 organization (C-score = 0.238) than do users of the expert-organized decision aid (C-score = 0.120). The difference between the two groups is again statistically significant ($p < 0.001$).

TABLE 2
Experiment 1
Judgment Performance

Panel A: Descriptive Statistics (Judgment Performance)

Mean (Standard Deviation) {Sample Size} Responses across Treatment Conditions

	Organization		
Instruct	**Expert**	**SAS No. 99**	**Main Effect: Instruct**
Present	0.76	2.10	1.43
	(0.689)	(1.543)	(1.365)
	{29}	{29}	{58}
Not-Present	0.75	1.31	1.03
	(0.645)	(0.930)	(0.837)
	{28}	{30}	{58}
Main Effect: Organization	0.75	1.71	1.23
	(0.662)	(1.325)	(1.150)
	{57}	{58}	{115}

Panel B: ANOVA Model—Judgment Performance

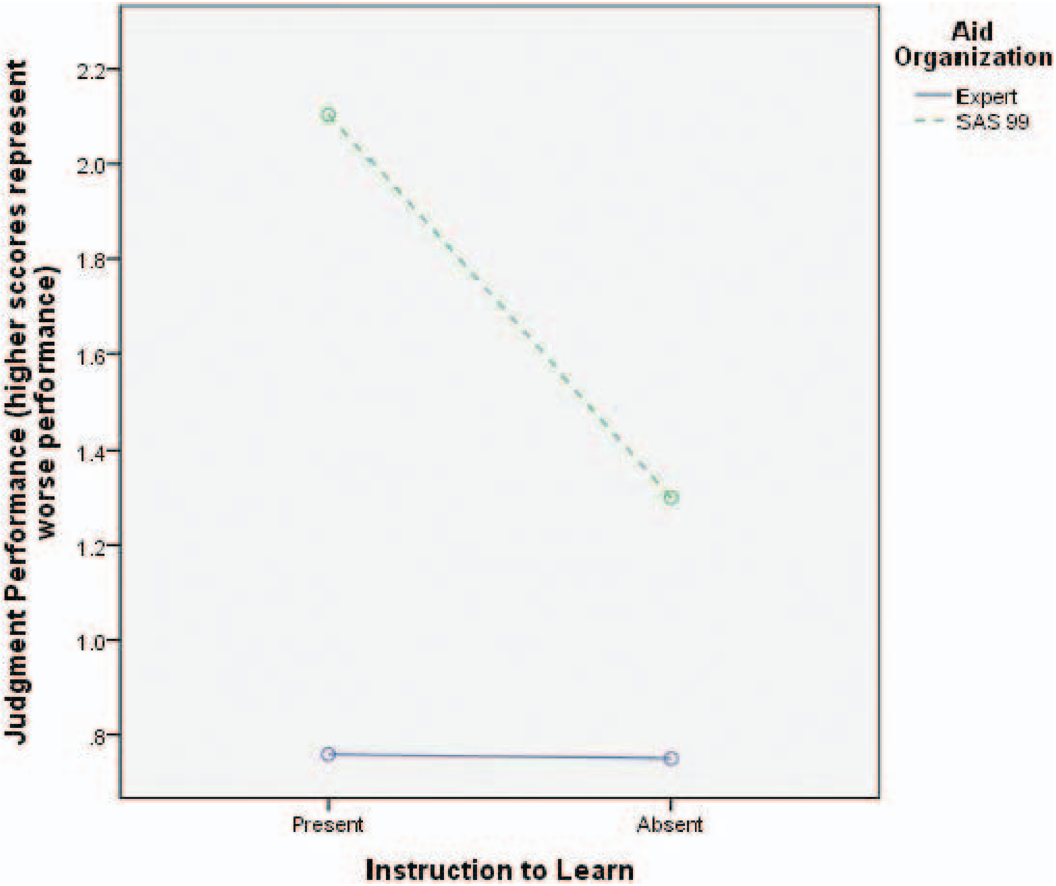
Source	Sum of Squares	df	Mean Square	F	Sig.
Organization	26.082	1	26.082	25.075	< 0.001
Instruct	4.619	1	4.619	4.440	0.037
Organization × Instruct	4.422	1	4.422	4.252	0.042
Error	115.457	111	1.040		

Organization: The checklist aid was organized using either the SAS No. 99 organization or the expert knowledge structure organization.
Instruct: Participants were either instructed to learn how experts use fraud cues to make fraud risk assessments while using the decision aid, or they were not instructed to learn.
Dependent Variable:
Judgment Performance = Judgment performance is the absolute value of the difference between experts' fraud risk assessments and participants' assessments. Higher scores represent worse performance.

between experts' fraud risk assessments and participants' assessments). The main effect of *checklist organization* is statistically significant ($p < 0.001$), and the pattern of means from Panel A of Table 2 indicates that the effect is in the expected direction. Users of the decision aid that is organized according to an expert's knowledge structure make fraud risk assessments that are significantly more similar to experts' assessments than do participants using a decision aid organized using the SAS No. 99 checklist. H2 is supported.

While not hypothesized, the results also indicate that there is an interactive effect of *checklist organization* and *learning requirement* ($F = 4.252$, $p = 0.042$). The interaction is displayed in Figure 4. The means in Panel A of Table 2 suggest that instruction to learn from the decision aid provides no benefit to users of the decision aid organized according to an expert knowledge structure, but harms the decision performance of participants who used a decision aid without the embedded knowledge structure. To test these observations, we conducted two simple effects tests. The first test compares judgment performance for users of the expert-organized decision aid who were instructed to learn (mean performance = 0.75) to the performance of users who were not

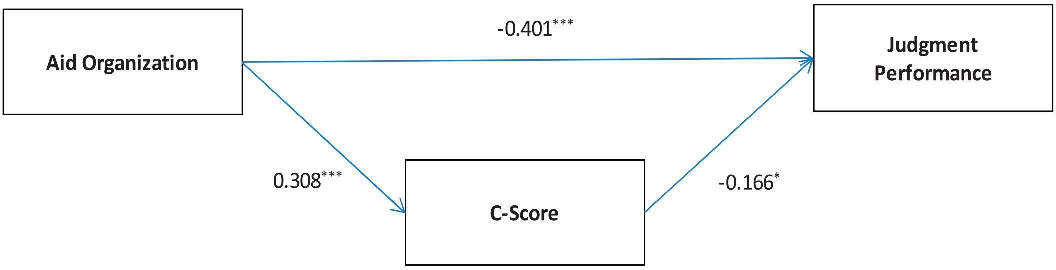
FIGURE 4
Interaction of Decision Aid Organization and Instruction to Learn



instructed to learn (mean = 0.76). There is no significant difference ($p > 0.90$). The second test compares judgment performance for users of the SAS No. 99 decision aid who were instructed to learn (mean = 2.10) to the performance of users who were not instructed to learn (mean = 1.31). Judgment performance is significantly diminished when users of the SAS No. 99 decision aid are instructed to learn ($p < 0.01$). It appears that instruction to learn from the aid caused the users of the SAS No. 99 aid to acquire an inappropriate mental model (i.e., a knowledge structure that differs from experts' knowledge structures).

In order to test H3, we conduct mediation analysis to determine whether the C-score mediates the relationship between the organization of the decision aid checklist and judgment performance (see Figure 5). Following the steps outlined by Baron and Kenny (1986), we test four mediation conditions using a series of regression models. The C-score qualifies as a mediator if: (1) variations in *checklist organization* significantly account for variations in judgment performance (beta = –0.401, t = –4.576, $p < 0.001$); (2) variations in *checklist organization* significantly account for variations in the C-score (beta = 0.308, t = 3.383, $p < 0.001$); (3) variations in the C-score significantly account for variations in judgment performance (beta = –0.166, t = –1.817, $p < 0.07$); and (4) the relationship between *checklist organization* and judgment is diminished when the

FIGURE 5
Mediation Testing



*, *** Significant at $p < 0.1$ and $p < 0.001$, respectively.
Path coefficients are standardized betas.
Aid Organization: The checklist aid was organized using either the SAS No. 99 organization or the expert knowledge structure organization (0 = SAS No. 99 and 1 = Expert).
C-Score: Measure (i.e., index of similarity) of the closeness of an individual's knowledge structure compared to that of an expert aggregate knowledge structure, using Pathfinder Network Scaling analysis.
Judgment Performance: Judgment performance is the absolute value of the difference between experts' fraud risk assessments and participants' assessments. Higher scores represent worse performance.

relationships between *checklist organization* and the C-score and between the C-score and judgment performance are controlled (significance is reduced from beta = –0.401, t = –4.576, $p < 0.001$ to beta = –0.250, t = –2.839, $p < 0.01$). All four conditions are met, but because *checklist organization* still has a significant effect on judgment performance, there is evidence of only partial mediation. Thus, the third hypothesis is partially supported.

The fourth hypothesis posits that users of the expert-organized decision aid (with or without instruction to learn) will make judgments more similar to experts' judgments than will novice users of a decision aid without an embedded expert structure. There is a main effect of *learning requirement* ($F = 4.440$, $p = 0.037$). However, we are primarily interested in whether instructing users to learn is a prerequisite for acquiring the mental representation of experts' knowledge that is embedded in a decision aid's interface. We test H4 with a series of planned contrasts. The first contrasts compare the judgment performance of users of the expert-organized aid with instructions to learn from the aid (0.76) to the judgment performance of users of the SAS No. 99 aid with instructions to learn from the aid (2.10, $p < 0.001$) and without instructions to learn from the aid (1.31, $p < 0.001$). A second set of contrasts compares the judgment performance of users of the expert-organized aid without instructions to learn from the aid (0.75) to the judgment performance of users of the SAS No. 99 aid with instructions to learn from the aid (2.10, $p < 0.001$) and without instructions to learn from the aid (1.31, $p < 0.001$). The results support H4 which suggest that decision aid organization can influence judgment independently from instruction to learn.

VI. EXPERIMENT 2

The second experiment employed the same 2×2 between-subjects design as experiment 1, with the same manipulations of the organization of the checklist in the decision aid (*checklist organization*) and instructions to learn how experts use red flags (*learning requirement*). The decision aid was also identical. Participants were 79 Master's-level accounting students who were in the first week of their graduate program. All of these participants had completed an undergraduate course in auditing and were aware of SAS No. 99.

The second experiment differed from the first experiment in two important ways. First, we collected pretest evaluations of knowledge structures. This allows us to more directly examine the influence of decision aid use by measuring changes in knowledge structure after use of the decision aid. The use of a pretest that controls for existing knowledge also allows us to use more advanced participants than in the first experiment, because we do not need to employ participants who lack existing knowledge of SAS No. 99 or fraud risk assessment. The other difference is that participants in the second experiment completed the post-experiment knowledge structure measurement task and the judgment performance task 48 hours after the pretest measurement of knowledge structure and after use of the decision aid. Thus, the second experiment allows us to verify that reorganizing a decision aid to represent experts' knowledge structures promotes the development of knowledge structures that are retained in long-term memory, and that reorganizing the aid leads to improvements in judgment that will be maintained over time.

VII. RESULTS—EXPERIMENT 2

Table 3, Panel A presents an ANOVA model where the dependent variable is the percentage change in C-score from before decision aid use to after aid use. The associated means for the percentage change in C-score are presented in Panel A. Similar to the first experiment, *checklist organization* is statistically significant in the model ($F = 46.738$, $p < 0.001$). Aid users refine their knowledge structures to be more like experts' knowledge structures when a decision aid has an embedded knowledge structure. Further, the results from the second experiment demonstrate that improvements in knowledge structure persist in long-term memory.

We reexamine H2 with an ANOVA model (see Table 4, Panel B) where the dependent variable is again judgment performance, but where judgment takes place 48 hours after decision aid use. The main effect of *checklist organization* is statistically significant ($F = 14.986$, $p < 0.001$), and the pattern of means from Panel A indicates that users of the expert-organized decision aid make fraud risk assessments that are significantly more similar to the expert assessment than do participants using a decision aid organized using the SAS No. 99 checklist.

Next, we perform mediation analysis for the second experiment. Similar to the first experiment, we find that: (1) variations in *checklist organization* significantly account for variations in judgment ($t = -3.844$, $p < 0.001$); (2) variations in *checklist organization* significantly account for variations in the C-score ($t = 10.030$, $p < 0.001$); (3) variations in the C-score significantly account for variations in judgment ($t = -5.558$, $p < 0.001$); and (4) the relationship between the *checklist organization* and judgment is diminished when the relationships between the *checklist organization* and the C-score and between the C-score and judgment are controlled (significance is reduced from $t = -3.844$, $p < 0.001$ to $t = 0.032$, $p = 0.974$). All four conditions are met, and the effect of *checklist organization* on performance is no longer significant when the C-score is included in the model. Thus, we find evidence that the C-score fully mediates the effects of *checklist organization* on judgment performance. Finally, the data provide no evidence for an effect of *learning requirement* on either C-scores or judgment performance when there is a two-day delay between aid use and measurement of knowledge structures and judgment.

VIII. DISCUSSION AND CONCLUSIONS

This study investigated the potential for experts' knowledge structures to be employed as design tools for organizing decision aids, as well as the effects of the organization of cues in a checklist decision aid on users' development of expertise and judgment performance. Our study is conducted within the context of risk assessment due to the significant effect this judgment has on the overall conduct of the audit (Taylor 2000), such as allocation of audit resources and costs associated with

TABLE 3
Experiment 2
Knowledge Structure Acquisition (Percentage Change in C-Score)

Panel A: Descriptive Statistics (Percentage Change in C-Score)

Mean (Standard Deviation) {Sample Size} Responses across Treatment Conditions

	Organization		
Instruct	**Expert**	**SAS No. 99**	**Main Effect: Instruct**
Present	0.914 (0.866) {20}	−0.084 (0.253) {19}	0.430 (0.813) {39}
Not-Present	0.695 (0.462) {20}	0.013 (0.358) {19}	0.363 (0.535) {39}
Main Effect: Organization	0.804 (0.694) {40}	−0.035 (0.310) {38}	0.395 (0.684) {78}

Panel B: ANOVA Model

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Organization	13.744	1	13.744	46.738	<0.001
Instruct	0.073	1	0.073	0.249	0.619
Organization × Instruct	0.485	1	0.485	1.649	0.203
Error	21.760	74	0.294		

Percentage Change in C-Score: Calculated as follows: [C-score measured after decision aid use] − [C-score measured before decision aid use]/[C-score measured before decision aid use].
Organization: The checklist aid was organized using either the SAS No. 99 organization or the expert knowledge structure organization.
Instruct: Participants were either instructed to learn how experts use fraud cues to make fraud risk assessments while using the decision aid, or they were not instructed to learn.

undetected fraud (Smith et al. 2000). Further, auditors are concerned about the potential for judgment errors in ill-structured audit tasks (Earley 2002), such as fraud risk assessments.

We demonstrate that measures of experts' knowledge structures based on Pathfinder Network Scaling analysis are valuable resources for designing a decision aid that promotes expert-like judgments by novice decision makers. Results of two laboratory experiments indicate that when checklist aids are organized to represent the knowledge structures of experts, novice decision makers develop knowledge structures that are more similar to the expert knowledge structure embedded in the aid, and they make decisions more similar to the experts whose knowledge structures are represented by the aid than do users of aids without representations of experts' mental models. These benefits are realized even in the absence of instructions to learn while using the decision aid, and the judgment improvements persist over time.

The findings suggest substantial potential for improving the design and efficacy of decision aids. Specifically, if systems are designed to impart expert-like knowledge structures to users, then firms will be able to take advantage of the effectiveness gains that these systems provide, while also promoting expertise development during system use. Our experiments indicate that simple

TABLE 4
Experiment 2
Judgment Performance

Panel A: Descriptive Statistics (Judgment Performance)

Mean (Standard Deviation) {Sample Size} Responses across Treatment Conditions

	Organization		
Instruct	**Expert**	**SAS No. 99**	**Main Effect: Instruct**
Present	0.550	1.579	1.051
	(0.510)	(1.071)	(0.972)
	{20}	{19}	{39}
Not-Present	1.000	1.474	1.231
	(0.795)	(0.964)	(0.902)
	{20}	{19}	{39}
Main Effect: Organization	0.775	1.526	1.141
	(0.698)	(1.001)	(0.936)
	{40}	{38}	{78}

Panel B: ANOVA Model—Judgment Performance

Source	Sum of Squares	df	Mean Square	F	Sig.
Organization	11.000	1	11.000	14.986	<0.001
Instruct	0.579	1	0.579	0.789	0.377
Organization × Instruct	1.502	1	1.502	2.046	0.157
Error	54.318	74	0.734		

Organization: The checklist aid was organized using either the SAS No. 99 organization or the expert knowledge structure organization.
Instruct: Participants were either instructed to learn how experts use fraud cues to make fraud risk assessments while using the decision aid, or they were not instructed to learn.
Dependent Variable:
Judgment Performance = Judgment performance is the absolute value of the difference between experts' fraud risk assessments and participants' assessments. In experiment 2, performance was measured 48 hours after decision aid use. Higher scores represent worse performance.

adjustments to the organization of a checklist decision aid can have substantial effects on the development of expertise after only limited use of the aid. Our findings also indicate that existing theory related to the limitations of outcome feedback may be inappropriate for knowledge structure acquisition. Knowledge acquisition research finds that instruction and explanatory feedback are essential to the acquisition of declarative and procedural knowledge (e.g., Bonner and Walker 1994; Earley 2001), but we demonstrate that novice accounting practitioners can chunk and organize their knowledge into expert-like knowledge structures through experiences that do not involve either instruction or explanatory feedback.

Knowledge structures represent a different dimension of knowledge than knowledge content. Accounting researchers have long recognized the importance of these knowledge structures, and links between knowledge structures and decision performance have been validated. However, empirical studies of methods to promote the acquisition of expertise have focused upon knowledge content. Similarly, decision aid research has emphasized the role of explanation facilities for enhancing the acquisition of knowledge content, often finding that decision aids are ineffective for promoting expertise. The current study demonstrates that a simple list aid can promote expertise by revealing the knowledge structures of experts to novice users.

Our study is subject to several limitations. First, experts may possess multiple knowledge structures within a decision domain (such as fraud risk assessment), and we cannot claim that the structure we measured with our concept pair comparisons is the optimal structure for assessing fraud risk or the only structure employed by our experts when assessing fraud. Thus, it is possible that another group of experts could yield a different aggregate expert knowledge structure. However, the purpose of our study was not to identify the "best" knowledge structure for assessing fraud risk, but rather to determine whether an expert knowledge structure embedded in a decision aid could be acquired by users of the aid. Additional research could focus on methods for measuring the most effective knowledge structures for assessing fraud risk. Finally, our research examined the effects of embedded expert knowledge structures on novices, and we cannot speak to the effects of decision aids with embedded knowledge structures on experts.

Future research will be needed to determine how expert knowledge structures can be embedded in highly complex systems with large numbers of information cues, sophisticated graphical interfaces, and information split across many screens. In addition, the dissimilar results for the effects of instruction in the short run and long run, as well as the finding that instruction harmed the users of the aid without an expert knowledge structure in the short run, indicate avenues for additional research. Prior research related to instructions to learn from decision aids has only examined knowledge content, but has not considered knowledge structure acquisition. The findings from our two experiments suggest that knowledge structures are acquired and related judgments are improved in the long run without any need for instruction to learn. This suggests that users of decision aids can adopt the mental models inherent in decision aids without consciously devoting effort to the acquisition of these models. If mental models are indeed adopted with little conscious effort, organizing decision aids to represent experts' knowledge structures may prove to be highly efficient.

In conclusion, our findings suggest a new method for system design that can be employed in applications far beyond the narrow scope of fraud risk assessment. Knowledge structures can be readily assessed with Pathfinder analysis in any field that involves judgment (e.g., audit, law, medicine, military applications). Given that decision aids and expert systems are readily available and commonly used in many fields that require judgment, organization of practice aids to mimic experts' knowledge structures appears to hold considerable potential for training novices and less experienced professionals to think more like experts and make judgments more like experts.

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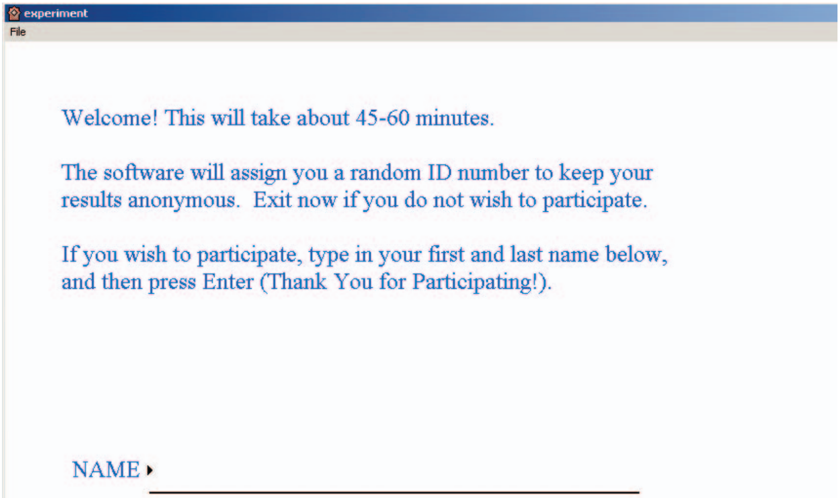
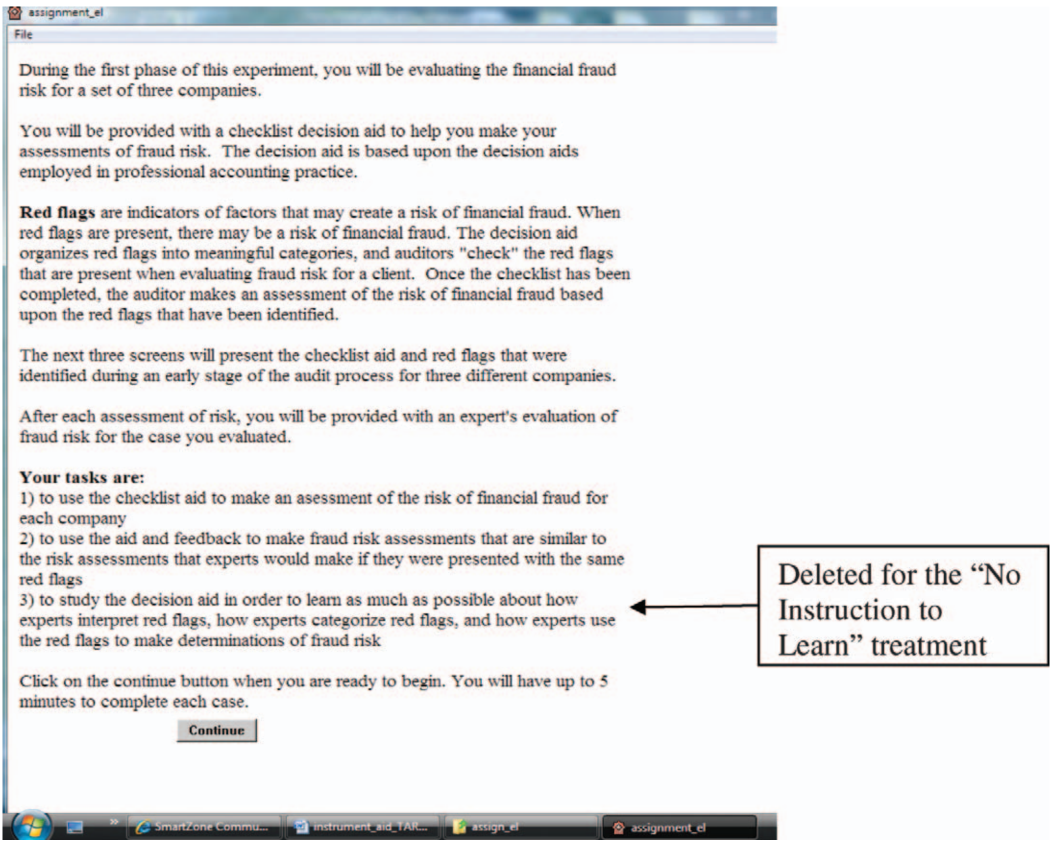
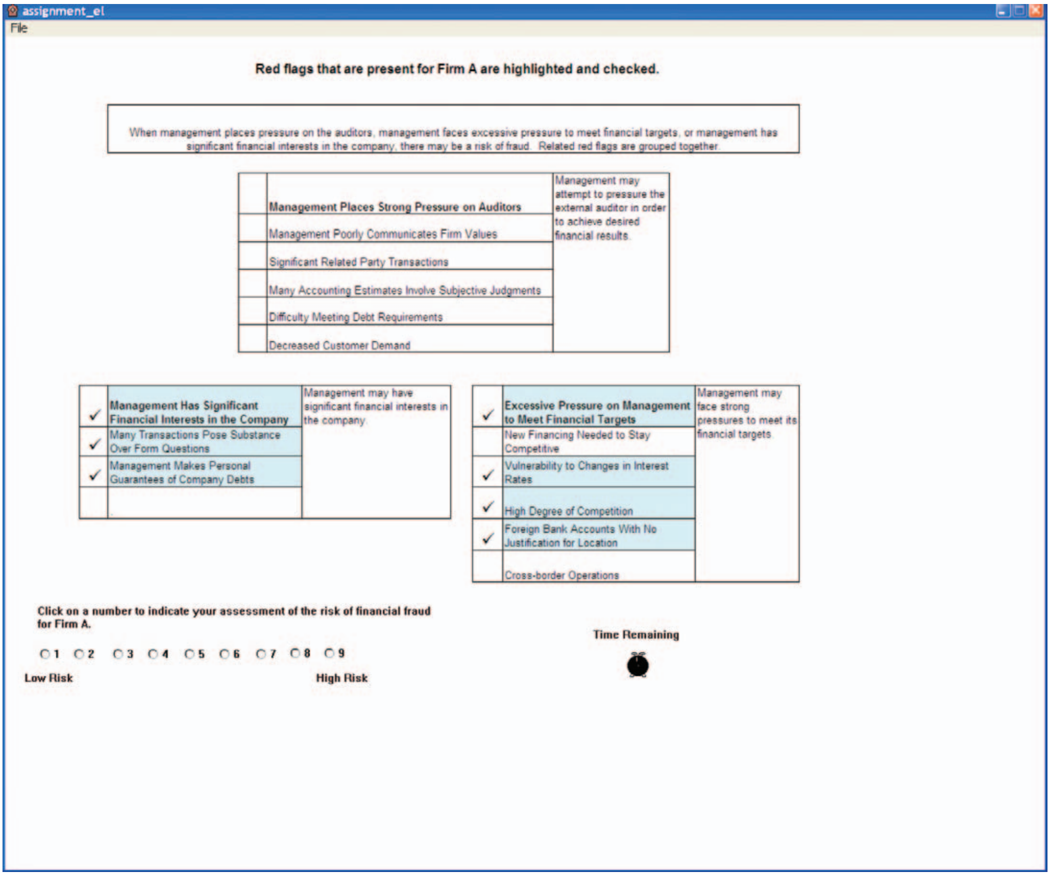
APPENDIX A

Instruction Screens



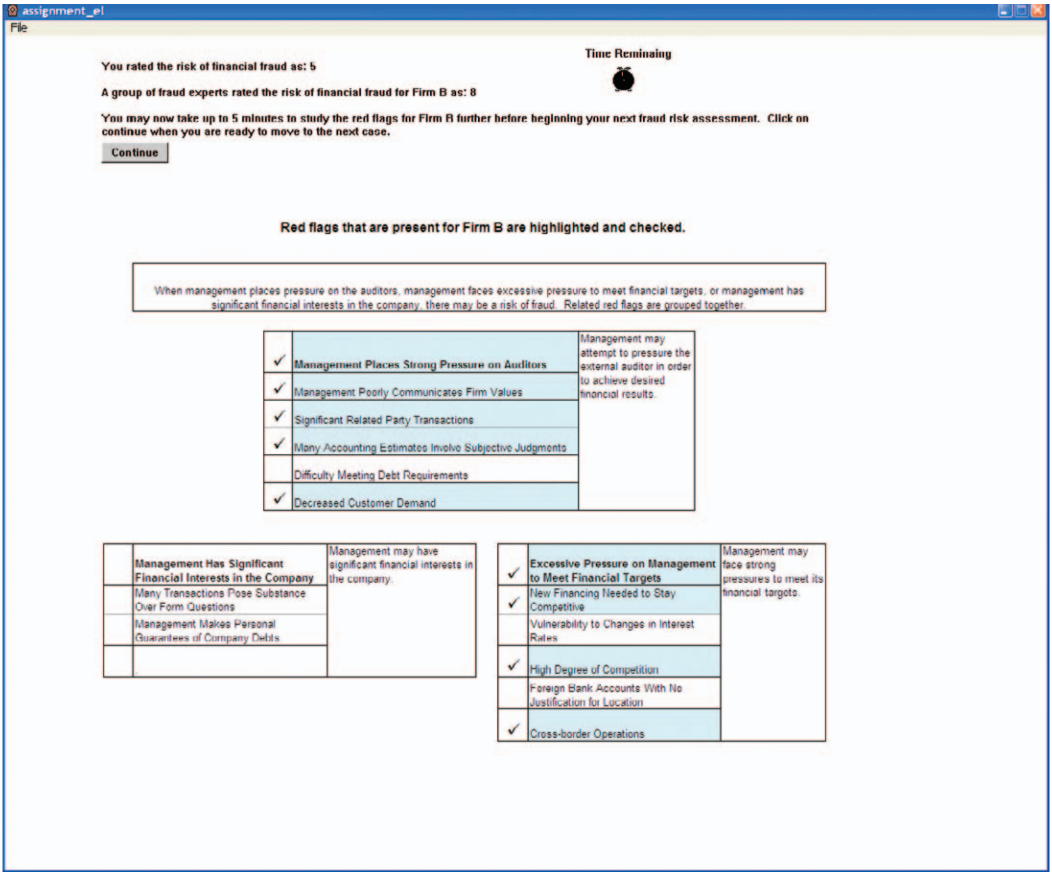


Expert Organization Decision Aid*



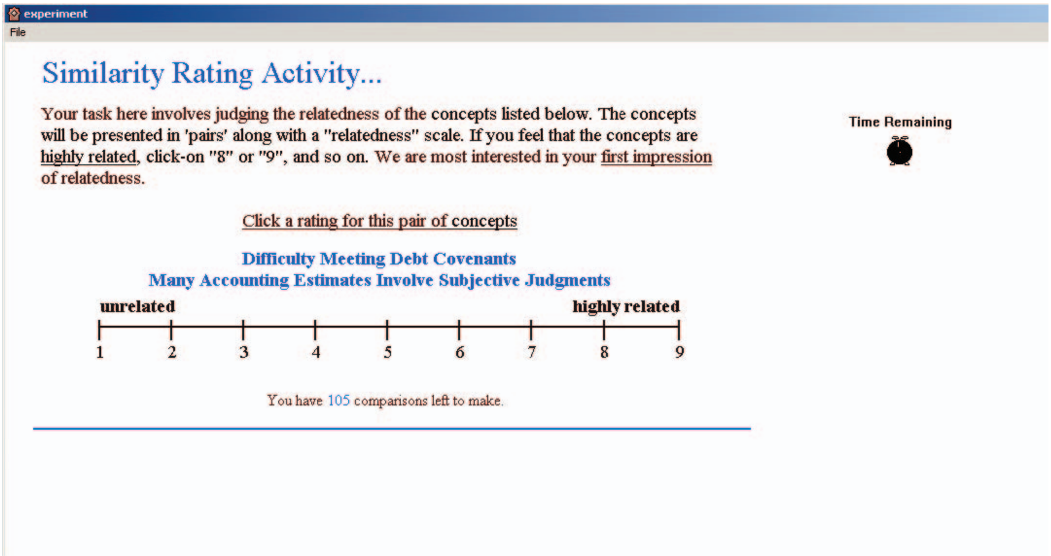
* A similar decision aid organized the red flags according to SAS No. 99. Participants used either the Expert Organization Aid or the SAS No. 99 Organization Aid three times during the experiment.

Feedback Screen*



* A similar feedback screen was provided to users of the SAS No. 99 Organization Aid. Participants received feedback after each of their three uses of the decision aid.

Similarity Rating Screen*



* Participants completed 105 pair ratings.

Test Screen Used to Measure Decision Performance