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ASSESSMENTS OF PROGRESS
TOWARD EXPERT-LIKE BEHAVIOR
WHILE PERFORMING AUDIT TASKS IN THE FIELD

by

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ABSTRACT

This paper presents a model and methodology for examining the process by which individual auditors progress toward more expert-like task behavior. The model proposes that progress toward more expert-like task behavior can be assessed by measuring change in the automaticity with which knowledge to instantiate and perform task behaviors is accessed. Assuming that task behavior is knowledge driven, automatic access is modeled as a function of changes in three features of an auditor's knowledge base: organization, content, and knowledge availability. The model's application is illustrated by means of data obtained from observations of the behavior of four first-year auditors who performed audit-related tasks in simulated auditing environments. Findings reveal such diversity across subjects as to render "typical" measures of very limited value. Of the four auditors whose task behaviors were observed, one auditor showed neither any significant intra-task tendency toward more expert-like behavior nor any indication of knowledge base changes that would suggest progress toward eventual long term increases in expertise. At the other extreme, one auditor showed very significant improvement in overall task behavior, accounted for by significant gains in knowledge organization, content, and availability. Between these extremes, two auditors showed evidence of improvements in some knowledge base features which were either offset by contrary changes or hidden by random variation in others, resulting in no significant findings of gain in overall observed task expertise.

Findings reported in this paper show that by combining the observable and unobservable aspects of an auditor's task behavior, it becomes possible to explore new dimensions of the processes by which expertise develops. They also suggest several areas for further research. First, the pattern of findings suggests that expert-like behavior is initially affected by gains in knowledge organization and content and later by improved knowledge availability. While this pattern is consistent with model expectations, the data from this experiment do not permit making any strong statements on this point. Second, the great diversity in learning patterns observed across subjects invites further investigation along several lines of inquiry. For example, the model permits any auditor's task environment to evolve uniquely, reflecting that auditor's task strategy. Thus, one line of inquiry can address the extent to which the observed diversity in learning is attributable to differences in task strategy. Another line of inquiry would study the relationship between these findings and the past professional experience and post-experiment professional progress of each subject with a view toward use of the proposed model and methodology as a tool for evaluating training programs and personnel screening.

I. INTRODUCTION

All expert auditors were at one time novices. By what process does the transformation from novice to expert come about? There is a substantial body of research concerning what constitutes expertise in auditors and who are expert auditors. The literature is replete with studies of expert/novice differences, auditor knowledge from both a substantive and structural perspective, judgment, decision making, and performance, and the effect of experience on the foregoing (see Arnold & Sutton 1997 for a comprehensive review.) While the preceding research helps answer some questions about some parts of the transformation process, the literature is largely silent on a quantitative process model for studying and accounting for the observed effects of education and experience on the changes in task behaviors and performances of individual novices as they mature into expert auditors. Bouwman & Bradley (1997: 120), after a review of expertise research in auditing, conclude that there is a need to know more about the process of acquiring expertise and cite the acquisition of expertise as an attractive research opportunity. They particularly cite the need for longitudinal studies of individuals as they progress toward a recognizable level of expertise. This paper offers an approach to addressing these needs.

Proposed Approach

This paper furthers basic research concerning the development of expertise by examining, at a level of generality not previously addressed in behavioral auditing research, the *interactive process* by which individual auditors perform a task. If we believe that auditors behave rationally, then we are forced to acknowledge that their behaviors while performing professional tasks are knowledge-driven. Given that acknowledgment, we are also forced to acknowledge that learning is the ultimate source for changes in task behavior. This reasoning raises the two related research questions addressed in this paper. What kinds of changes in an auditor's knowledge base are associated with learning during performance of field tasks? How do these changes account for the perception of growing expertise? Answers to both questions can be expected to provide evidence of a novice auditor's progress toward a recognizable level of task expertise and to address the more general matter of whether learning, an essential prerequisite for growth in expertise, can take place, yet not be evident in the short run in terms of more expert-like task behavior.

Russo (1997a) has proposed a model and methodology for detecting learning by auditors during performance of tasks in the field. In that work, learning is defined as any experience-induced change in an auditor's knowledge base, and the methodology detects learning by isolating changes in knowledge base content and knowledge availability. This paper furthers that research by proposing an augmented model and methodology in which the progress of individual auditors toward more expert-like task behavior[1] is examined in terms of changes in three features of an auditor's knowledge base: organization, accessible content, and knowledge availability. Quantitative measures of the contributions to more expert-like behavior made by changes in each of these features are specified, thereby permitting precise study of the primary determinant of developing expertise.

The model's application is illustrated by means of data obtained from observations of the behavior of four first-year auditors who performed audit-related tasks in simulated auditing environments. Findings reported in this paper show that by broadening the focus of auditing expertise research beyond the currently dominant judgment/decision making purview to include (1) the observed behaviors of auditors during performance of tasks and (2) tasks and environments that are more representative of those encountered in the field, it becomes possible to explore new dimensions of the processes by which expertise develops.

The Route to Expertise

Given education and practice, most novice auditors eventually achieve a recognizable level of expertise. I am confident that this statement, at least in principle, will meet with universal agreement. However, taken at a level somewhat closer to implementation, it raises several issues of importance for those responsible for assuring continuity and growth in the competence of the profession's practitioners. The first issue concerns the nature of "education and practice," and the second concerns the meaning of "a recognizable level of expertise." While the distinction between education and practice is important to the understanding of what follows, I do not wish, nor is it necessary for present purposes, to delve into questions of curricula or substantive content. In this paper, the concern is only with the unobservable processes by which new knowledge required to perform a task is assimilated into an auditor's knowledge base and, that done, brought to bear in influencing subsequent task behavior.[2]

Experience vs. Education and Practice

Experience, in this research, is purposeful interaction by an auditor with a task environment. Both education and practice involve interaction with an environment and, therefore, represent different forms of experience. However, there is a distinction between them which rests with purpose. *Education* is interaction in which the purpose is primarily knowledge acquisition, with immediate application being of secondary importance, if at all. *Practice*, on the other hand, is interaction for the purpose of satisfying a present demand for professional performance (i.e., to complete a task) in the field. In practice, knowledge acquisition, when it takes place, is for the purpose of immediate application to the task at hand. In this paper, study is limited to the manifestations of learning from experience in the form of practice as thus defined.

Level of Expertise

Bouwman & Bradley (1997: 89-117) review and discuss the widely divergent views of what constitutes expertise in auditing and how the quality of expertise should be recognized and measured. This diversity most likely reflects the fact that different kinds of expertise exist, each more suited than the others to a specific purpose. In searching for an approach to studying the developing expertise of individual auditors observed during performance of a task and for a suitable conceptualization of a recognizable level of expertise, Russo (1997b), after a review of the relevant literature, argues strongly for adoption of neobehavioral principles from psychology in the study of auditor expertise.[3] He concludes that, under such principles,

> ...expertise is as much a perception formed by what one observes about the behavior of another as it is about what that observer expects of the other in a given task situation. That is, *expertise is a judgment made by people about the behaviors of others who are presented with a demand for expert performance.* Consequently, ... the study of expertise (is) the comparative study of problem solving behavior observed during performance of a specific task. (21)

Russo cites extensive research in the areas of consumer behavior, artificial intelligence, and auditing documenting widespread agreement that significant automaticity in performance of a task is a primary characteristic of expert behavior.[4] That is, as one acquires expertise in a task, one's task behaviors are carried on with diminishing effort and without conscious control. Consequently, in this paper, an auditor's level of expertise in performance of a task is taken as being reflected in the extent to which that auditor carries out task behaviors without cognitive mediation. In this approach to the study of expertise, the assumption that the task behaviors of experts are automatic functions as an ideal standard for analytical purposes rather than as a realizable standard of expert performance. Since task outcome is not considered, task behavior approaching this standard can only be said to have become more *expert-like*. In tasks such as those in auditing, for which definitive determinations of the quality of outcomes are relatively rare (e.g., an outcome from auditor litigation), a process oriented criterion can only indicate expert-like behavior.[5]

The remainder of this paper is organized as follows: Section II provides necessary background, related concepts, and terminology. Section III presents an operational definition of learning based on behavior observation methodology and a quantitative model for use in studying learning in terms of knowledge organization, accessible content, and availability. Section IV discusses the hypotheses. The behavior observation methodology and simulation experiments are discussed in Section V, and the experimental data are presented and findings discussed in Section VI. Finally, Section VII discusses some implications of the model and findings.

II. CONCEPTUAL BACKGROUND AND TERMINOLOGY

Iterative Model of Task Behavior

Russo's methodology, which forms the foundation for this paper, is based on an iterative model of behavior during performance of empirically intense tasks. Such tasks are characterized by significant information input from the task environment, application of a considerable body of domain and task knowledge, and solutions which require significant interaction with and transformation of the task environment. Tasks of this type are typical of those encountered in the field, especially during the first three years of professional auditing experience.[6]

Figure 1 presents a version of Russo's iterative model in which the purposeful interpretations of mental processing during performance of a task have been replaced with categorizations reflecting the presence of and access to knowledge in an auditor's memory.[7] During performance of empirically intense tasks, behavior proceeds according to a process in which information is acquired from the task environment (perception behaviors), processed in memory (cognitive and non-cognitive mental processing), and the environment transformed in accordance with the outcome of that processing (execution behaviors).[8] In thus transforming a task environment, environmental stimuli upon which the selection of behaviors in succeeding iterations is based are altered. Iterations continue until the auditor perceives that a solution state exists. By reason of this process, therefore, the task solution can be said to evolve out of the environment.

Model Terminology

During performance of a task, two types of behavior, perception and execution, can be observed. These behaviors follow one another, tracing out the auditor's chronological *solution sequence* in performing the task. A solution sequence can be divided into successive pairs of adjacent behaviors, each of which is referred to as a *couplet*. The first behavior of a couplet is the *initial behavior* and the second the *target behavior*. Except for the very first initial behavior, each observable behavior in a solution sequence is a member of two successive couplets, acting, alternately, as an initial behavior and a target.

Transitions between the behaviors forming a couplet are mediated by episodes of unobservable mental activity. During these episodes, the ability of an auditor's knowledge base[9] to supply all the knowledge required to instantiate and perform target behaviors determines the kind of mental activity that takes place. How a knowledge base responds to a specific demand for knowledge is reported as the episode's *response vector* ($\vec{r}$).[10] A response vector consists of three elements (r_k) reporting whether sought knowledge was, respectively, highly available ($k=1$), present in the knowledge base but not highly available ($k=2$), or not present in the knowledge base ($k=3$), i.e., a state in which the knowledge base failed to supply required knowledge. The sum of the response vectors for a solution sequence or subset thereof is called the *knowledge state vector* ($\vec{R}$) and describes the state of the knowledge base for that sequence or subset.[11]

Contexts and Knowledge States

In this paper, it is proposed that what knowledge is expressed during performance of a task is a function of context (e.g., see Russo 1997b; Tulving 1992; Godden & Baddeley 1975). A context is a set of subconscious cues whose presence makes certain responses to subsequent cues more probable than others. Knowledge evoked from an auditor's memory is filtered through the context induced by the perceived environmental and internally generated cues[12] active at the moment of retrieval. The behavior observed or cognition expressed during performance of a task is that response which has survived the filtering process.

The process of filtering knowledge through a context can result in three possible outcomes. The first is a completely automatic evocation of an observable behavior. This form of response is evidence that, at the moment an observed behavior takes place, all the knowledge required to instantiate and carry out that behavior is present, highly available, and consistent with the context as then perceived. The second form of response is cognitive. A cognition can be considered as an internally generated cue which can potentially evoke a new context or modify an existing context, either of which, in turn, alters the permissible range and selectivity of subsequent knowledge base responses. Given a thusly altered context, knowledge which previously was not accessible may now become available, leading to observable behavior. Cognitions which produce this result (referred to hereafter as "analysis and planning cognitions") signal the presence of knowledge in the knowledge base which is accessible at a lower level of availability than that which can be accessed directly and automatically solely from cues received from the external environment. Knowledge that is present in the knowledge base but, in a given context, accessed by means of analysis and planning cognitions will be referred to as "unavailable." Both available and unavailable knowledge constitute the "accessible content" of a knowledge base.[13] Finally, knowledge evoked by both internal and external cues may be consistent with some aspects of a context but not with others, may be inconsistent within itself, or may otherwise cause a complete failure of the knowledge base, which then responds only with cognitions indicative of uncertainty, confusion, and the like. Such cognitions evidence the absence of knowledge from the knowledge base, and lead to processes whose intent is to acquire the missing knowledge or find means of doing without it.[14]

The relationships just described are summarized in Table 1. These relationships make it possible to ascertain the state of an auditor's knowledge base by examining the response vectors of mediating episodes in that auditor's solution sequence.

TABLE 1			
KNOWLEDGE STATES AND ASSOCIATED KNOWLEDGE RESPONSES			
Knowledge State	Form of Knowledge Base Response	Response vector element	Description
Available knowledge	Non-cognitive	r_1	Required knowledge is present in the knowledge base and is highly available, e.g., is evoked automatically.
	Cognitive:		Internally generated cues that alter context, thereby affecting knowledge accessability.
Unavailable knowledge	Analysis, Planning	r_2	Required knowledge is present in the knowledge base but must be located by "searching."
Absent knowledge	Uncertainty	r_3	Required knowledge is not in the knowledge base, is inconsistent, incomplete, etc.

Mediating Episodes and Their Properties

Types of Mediating Episodes

Episodes of mental activity mediating the transitions between observable behaviors are of two kinds, cognitive and non-cognitive, depending upon whether the episode includes thought. A thought, also referred to as a "cognition," is any normally unobservable mental activity which, under suitable conditions, can be verbally and concurrently reported.[15] Cognitive episodes are composed of at least one cognition, while non-cognitive episodes are characterized by a complete absence of cognition. That is, in non-cognitive episodes, all mental activity affecting the transition from one observable behavior to the next is carried out subconsciously, making the transition completely automatic.[16]

Episode Complexity

For any episode, the sum of the elements of its response vector is the measure of that episode's complexity, s. In principle, each kind of episode can be either simple ($s = 1$) or complex ($s > 1$). Simple cognitive episodes are composed of only one cognition; complex episodes of more than one. Because subconscious mental activity is inexpressible, and because at some level, all behavior involves some amount of subconscious processing, in the model to be presented in Section III, treatment of non-cognitive episodes as complex is neither possible nor meaningful. Further, for the same reasons and from an operational standpoint, recognition of the non-cognitive mental activity always present in cognitive episodes is omitted from the response vectors of those episodes.

Cognitive Complexity

Since internally generated cues are themselves important determinants of context, it is possible for a sequence of cognitions to mediate the transition from one observable behavior to the next. This sequence is generated by an internal cyclical process of cue evocation and context modification (see upper portion of Figure 1) which continues until an observable behavior is evoked. The mediating cognitive episode that results from such a process, which may be very loosely described as a "search of memory," is experienced as a "stream of consciousness" and expressed as a "chain of cognitions" leading to the behavior ultimately observed.

As mentioned earlier, the number of different knowledge base responses making up a mediating episode is referred to as its "complexity."[17] It was also pointed out that automatic knowledge accesses are not recognized in the response vectors of cognitive episodes. Therefore, only cognitive episodes can be complex. The complexity of a cognitive episode is negatively related to the degree to which there is a strong association or link between the environmental cues initiating the episode and the ultimately observed behavior.[18] Strong associations are evidenced by a minimum of searching, that is, by episodes of low complexity mediating transitions between observable behaviors. The stronger the association between an externally-delimited context and an observed behavior, the less likely it will be that internally evoked cues will be required to make a connection to that behavior.

Knowledge Organization and Episode Complexity

"Organization" is a term that can be applied to knowledge in two very different senses: logical structure and physical structure. In the sense of logical structure, the term is applied to an observer's perceptions of the shared characteristics and relationships among elements of knowledge. Hierarchies, taxonomic categorizations, cognitive heuristics, and schemata (collectively referred to hereafter as "schemata") of all kinds are knowledge organizations of this type. The distinguishing characteristic of logical organizations is that they are conditional upon the observer and the purpose for which the organization is constructed. Knowledge of the same object, for example, may belong simultaneously to any number of different logical organizations of knowledge. Much of the research on knowledge organization in auditing is carried out in terms of knowledge organized as logical structure. For example, Bouwman & Bradley (1997: 109ff) review studies of auditors' use of such knowledge organization schemata as transaction cycles, audit objectives, "financial templates," and the like. A concept of knowledge organization as schemata is useful only when cognition is involved, where it serves as a knowledge search and accessibility strategy. As knowledge related to a particular context becomes assimilated and, therefore, more automatically available, the cognitive indicia of such schemata become less recognizable. Knowledge organization in the sense of schema for search and accessability is a moot and largely irrelevant concept where behavior mediation occurs automatically because sub-conscious processes are neither observable nor reportable.

In the sense of a physical structure, the term "organization" is used to describe the manner in which members of a structure are physically connected or linked. When used in this sense, the logical relationships among the linked elements are secondary to their physical associations. Elements making up such an organization cannot be accessed except by means of the links that exist among them. The physical links among biological elements making up the seat of knowledge (neurons, dendrites, etc. of the brain and nervous system) are observable to a fair degree (e.g., see Senjowski & Churchland 1989: 322-342; Gregory 1987: 534-539.) However, at the current state of technology, their knowledge correlates (the specific microfeatures of knowledge they represent) are not. In spite of this difficulty, an isomorph of the linkages among these elements of knowledge may be inferred from indirect evidence gathered from such perceptions as the "strength" of the association between cues and evoked knowledge, the "difficulty" of access to knowledge in memory, and other well studied psychological and physiological phenomena.[19]

The preceding distinctions notwithstanding, the two concepts of knowledge organization complement each other in this research in that the repeated use of logical organizations to retrieve knowledge eventually alters the physical linkages among certain physical correlates of their knowledge microfeatures so that the associations among those elements become stronger.[20] That is, logical structures can serve as a form of scaffolding for building physical structure. As the physical linkage becomes sufficiently cured, the scaffolding upon which it was built gradually becomes superfluous; while it may still continue to exist, it is no longer actively employed to locate knowledge.[21] This transition is evidenced by a growing absence of cognition in responding to the demands of a task for knowledge. It is in this sense that the concept of a change in knowledge organization is used in this paper. Consequently, I investigate the effects of changes in knowledge organization without specifying what that organization is or how an auditor uses it to retrieve required knowledge.

To summarize, then, the less organized (linked) is the knowledge in memory, the more searching will be required to effect the transition to a target behavior, and the more complex will be the episode mediating that transition. The complexity of a mediating episode, therefore, is a surrogate for the extent to which the information within an auditor's knowledge base is organized.[22]

III. THE MODEL

Knowledge-Driven Behavior

In this research, it is assumed that all observable behavior is knowledge-driven. If auditors are held to be rational human beings, then knowledge-driven behavior is behavior which is (1) purposeful, meaning that auditors perform those behaviors they believe are appropriate to their objectives, and (2) intentional, meaning that the behaviors of auditors reflect their beliefs regarding the task and task environment.[23] These implications of knowledge-driven behavior, along with the previously discussed assumption that the problem solving behavior of task experts is automatic, imply that all the knowledge required to instantiate and execute each behavior is present within an auditor's knowledge base and is available at the moment each behavior is performed.

The Learning Ratio

Psychologists define learning as a permanent change in behavior that results from experience (Reber 1985).[24] Since behavior is assumed to be knowledge-driven, then learning can also be considered as a relatively permanent change in the state of an auditor's knowledge base. The manifestations of learning which are the foci of this paper are those which are indicative of progress toward more expert-like task behavior and which are also consistent with the assertion made in Section I that expertise during performance of a task is reflected in the degree to which task behaviors are automated. Thus, learning during performance of a task can be quantified by noting the improvement in observed automaticity of task behaviors with experience over the course of performing a task.

Any operational definition is necessarily linked to methodology. So it is with an operational definition of learning. The methodology for detecting learning (Russo 1997a) requires, for each kind of target behavior, separating the response vectors associated with all occurrences of that behavior in a solution sequence into two groups of equal frequency. The first group, termed the "naive sample," consists of instances of the behavior performed before any extensive experience in the task has accumulated. The second group, termed the "experienced sample," consists of all remaining instances, and, therefore, of those behaviors performed after the accumulated experience of the naive sample. The response of the knowledge base in terms of the accessability and availability of knowledge is then ascertained for each sample. In the present context, since all behavior is assumed to be knowledge driven, changes in the knowledge state vector resulting from experience is observable evidence of learning.

Based on this methodology, and focusing on automatically mediated behavior, the overall task learning ratio is defined as

$$l \equiv \frac{\sum^{j} n_{ej}^{X}}{\sum^{j} n_{ej}^{N}} \qquad [1]$$

where the superscripts indicate naive (N) and experienced (X) occurrences of target behavior (j), and n_{ej} is the number of available knowledge base responses for all episodes mediating transitions to the target behavior. Summations are taken over all target behaviors.

Decomposition of the Learning Ratio

Changes in a knowledge base, and hence, learning, is manifest in various ways, depending on how knowledge organization, accessible content, and knowledge availability are affected by repeated accesses to knowledge required for performance of a particular behavior in a task environment. To capture these manifestations in a way that permits a direct relationship to the measure of learning defined in [1], three additional learning ratios are now defined:

Knowledge organization ratio (l_s): measures the relative complexity of mediating episodes after experience using each target behavior in a task compared with complexity before experience.

Accessible knowledge ratio (l_c): measures the relative proportion of knowledge responses indicating accessible knowledge content (see Figure 1) after experience using each target behavior in a task compared with the proportion before experience.

Available knowledge ratio (l_e): measures the relative proportion of accessible knowledge base responses which were automatic after experience using each target behavior in a task compared with the proportion before experience.

Symbolically, these definitions are presented respectively as [2a], [2b], and [2c].

$$l_s \equiv \frac{\sum^{j} n_{sj}^{X}}{\sum^{j} n_{sj}^{N}} \quad [2a] \qquad l_c \equiv \frac{\sum^{j} n_{cj}^{X} \sum^{j} n_{sj}^{N}}{\sum^{j} n_{cj}^{N} \sum^{j} n_{sj}^{X}} \quad [2b] \qquad l_e \equiv \frac{\sum^{j} n_{ej}^{X} \sum^{j} n_{cj}^{N}}{\sum^{j} n_{ej}^{N} \sum^{j} n_{cj}^{X}} \quad [2c]$$

where the subscripts qualify the variables as follows: s indicates all responses, cognitive and non-cognitive, c indicates accessible knowledge base responses, and e indicates only available responses. The relationship of the components of [2] to the overall task learning ratio is given by [3].

$$l = l_s l_c l_e \qquad [3]$$

Learning Ratio Indications

Any change in the state of a knowledge base will result in a task learning ratio (see [1]) that differs from unity. If there is to be progress toward long term development of more expert-like task behavior (i.e., increasingly automatic performance of task behaviors), the task learning ratio must be greater than one. However, it should be evident from [3], that the task learning ratio, even if less than unity, can hide learning taking place in the form of greater knowledge organization, and/or increasing accessible knowledge content, and/or increasing knowledge availability. In fact, one may speculate that increasing task expertise proceeds in the three step sequence represented in very basic terms in Figure 2. On the initial exposure to cues which fail to elicit a consistent knowledge base response, new knowledge may be acquired. However, evidence of the presence of that knowledge requires that there be a subsequent occasion for it to be accessed. Should such an occasion arise, (second stage occurrence in Figure 2) it is evidenced by one or more analysis and planning cognitions. Further, with additional utilization in the task, that knowledge is gradually assimilated into the knowledge base, becoming more available (third stage occurrence in Figure 2.)[25] This process is, of course, subject to variation. For example, it is possible that considerable well-organized knowledge may already exist in memory, but given the context active at the moment, lack accessability. In such cases, a single cognitive episode, evoked by a single cue received from the task environment, may be sufficient to immediately bring that knowledge to an available state, bypassing the intermediate state in which it is accessible but unavailable (e.g., omitting either the sequence labeled "Initial occurrence" or "Second stage occurrence" in Figure 2, going immediately to the third stage.)[26] By accumulating sequences of the prototypical responses shown in Figure 2 under various hypothesized experiential scenarios, one can form patterns useful for interpreting any set of observed learning ratio values. Table 2 summarizes some particularly useful interpretations which may be made of the learning ratios based on such a process.

TABLE 2		
LEARNING RATIO INDICATIONS		
Ratio	Description	Indications
Task learning (l)	Changing automaticity in use of task behaviors as a result of assimilation of knowledge into the knowledge base.	Long run progress toward more expert-like task behavior is indicated by a ratio > 1. In the short run learning may be occurring in aspects of the knowledge base, manifestations of which are not immediately evident from observations of automatic transitions between behaviors.
Knowledge organization (l_s) ("Episode complexity")	The extent to which memory must be "searched" before locating knowledge required to carry out an observable behavior.	Progress toward more expert-like task behavior, which depends on increasing assimilation of knowledge into a strongly organized knowledge structure, is indicated by a ratio < 1. Ratios > 1 can be due to (1) greater awareness of lack of knowledge, (2) disruption of previously existing relationships among accessible knowledge, and (3) growth in unavailable knowledge base content.
Accessible knowledge content (l_c)	Change in the proportion of accessible knowledge base responses (responses indicating that required knowledge is present in the knowledge base.)	In general, long term progress toward expert-like behavior is indicated by a ratio > 1. However, the direction of this ratio in the short run depends on the relationship between the rate at which there is exposure to previously unknown cues (negatively related to l_c), the rate of new knowledge acquisition and growth in access to knowledge present in the knowledge base but not available (positively related to l_c).
Available knowledge (l_e)	Change in the proportion of accessible knowledge base responses that are made automatically.	Long term progress toward more expert-like task behavior indicated by a ratio > 1. This ratio has the most direct effect on observable expert-like task behavior. Knowledge assimilation into an available form increases l_e.

IV. HYPOTHESES

Two questions are of primary concern in this paper. The first question addresses the kinds of changes in an auditor's knowledge base that are associated with learning during performance of field tasks. The second question, in asking how these changes account for the perception of growing expertise, addresses the more general matter of whether learning can take place during performance of a task, yet not be evident in the short run in terms of more expert-like task behavior. The following directional hypotheses, based on indications discussed previously and summarized in Table 2, provide the information needed to answer these questions.

Hypotheses 1 - Long Term

Three directional hypotheses, stated here in positive form, relate to the first research question. Long term progress toward more expert-like task behavior is evidenced by $l_s < 1$ (indicating greater knowledge organization), $l_c > 1$ (indicating growing accessible knowledge content), and $l_e > 1$ (indicating increasing availability of knowledge). Overall, there should be increasing automaticity in task behavior (i.e., $l > 1$).

Conditional Hypotheses 2 - Short Term

Three conditional directional hypotheses relate to the second research question. Since learning is operationalized as any change in the state of an auditor's knowledge base resulting from experience, then rejection of the null form of any of the preceding long term hypotheses is, *ipso facto,* evidence of learning with respect to the ratios which are the subject of the rejected hypotheses. Clearly, then, any significant finding regarding hypothesis 1 is simultaneously a significant finding of learning for purposes of hypothesis 2. However, learning does not proceed smoothly toward greater automaticity in task behavior (see preceding discussion regarding indications of learning ratios.) Consequently, if hypothesis 1 is not supported for any ratio, a separate test for learning may be performed for that ratio but with the sense of the inequality running in the opposite direction. A finding of support for any of the three long term or conditional short term hypotheses is evidence that significant learning has occurred, even if, overall, there is no observable progress toward more expert-like task behavior.

V. EXPERIMENT AND BEHAVIOR OBSERVATION METHODOLOGY

The details of the experiment performed and behavior observation methodology employed to obtain data on auditor behavior during empirically intense tasks are too lengthy and complex to be covered here. The following paragraphs present only a brief summary. For a more complete discussion, see Russo (1994, 1995).

Subjects, Task, and Procedure

Both the inexperienced auditor-subjects and a non-financial-audit related task were chosen for this experiment in order to assure observation of a novice problem solving process and to increase the likelihood of capturing a learning process. The subjects were four first-year auditors from the professional staff of a Big Six auditing firm. All subjects were volunteers who had sat for and passed some, but not all, parts of the CPA examination and all had no prior exposure to the subject matter of the task.

The task in this experiment was a review of the Statement of Operating Expenses of a new office building in which the client is a tenant, rendered pursuant to the rent escalation provisions of the client's lease. To acquaint them with the terminology, administrative, and computational procedures associated with operating expense rent escalations, on the day before the experiment, each subject was given background material and two samples of completed review reports to study. However, none of this material provided any information on examination or reporting procedures, the landlord's procedures, or the existence and nature of any documents used in the preparation of the statement rendered to the client. Therefore, such a task, to the extent that it differs from that of financial audit, would be unfamiliar to the subjects who participated in this experiment.

Each subject performed the task on a different day. The task was performed in a simulated business office in which each auditor-subject was presented with the equipment and supplies normally available in audit environments and the ability to communicate (via intercom) with and receive documents (via a mail slot) from other parties present in the task environment (e.g., client personnel, the audit partner, etc.). During performance of the task, each subject was free to contact any party in the task environment and to request any documents or explanations required. Although the researcher played the roles of others in the task environment, no face-to-face or verbal contact took place between subject and experimenter.

Behavior Observation Methodology

Synchronized video-taped and think-aloud verbal protocols were used to capture both the observable behaviors and cognitions of the auditor-subjects during their performance of the task. The experimental protocols were independently coded in terms of the behaviors and cognitions described in the Appendix A by the researcher and a first year doctoral student trained by the researcher. Kappa (Cohen 1960), a widely used measure of the agreement between independent coders, ranged from .78 to .72 over a total of approximately 8 hours of behavior observation. These levels of Kappa are significant at $p < .0000$.

Operationalization of the State of a Knowledge Base

The state of an auditor's knowledge base can be approximated by examining the composition of episodes mediating each observable behavior during performance of a task. The analysis is performed by subject, and within subjects, by behavior. Each behavior type (see Appendix A for definitions) is treated as a target. Each target behavior is sequenced chronologically then separated at the median occurrence into the N (below median) and X (above median) groups. Behaviors in each group are assigned a sequence number beginning with 1 and ending with n_j, the numeral assigned to the last behavior in a group. Each group, therefore, has an equal number of behavior occurrences.[27] The mediating episodes associated with each group are then analyzed in terms of the knowledge base response vector elements (i.e., available, unavailable, and absent). Uncertainty cognitions[28] preceding target behaviors are sufficient evidence that knowledge is absent from a knowledge base. Analysis and planning cognitions mediating transitions to behaviors are sufficient evidence of virtual access to knowledge, and hence of accessible, but unavailable knowledge. Finally, sequences in which a target behavior is preceded by another observable behavior is necessary and sufficient evidence of automatic access to all the knowledge demanded by that behavior transition. Table 3 summarizes these assignments in terms of the definitions in Appendix A.

TABLE 3

COMPONENTS OF MEDIATING EPISODES USED TO EVALUATE KNOWLEDGE BASE STATE

Knowledge State	Response Vector Element	Components of Mediating Episodes
Absent	r_3	Uncertainty cognitions
Accessible content:		
Unavailable	r_2	Analysis and planning cognitions
Available	r_1	Non-cognitively mediated transitions

Notes: See Appendix A for definitions of cognitive components.

VI. EXPERIMENTAL DATA AND FINDINGS

Table 4 presents a summary of the task behaviors and knowledge base responses for each subject during performance of the experimental task. In order to compute the learning ratios specified by definitions [1] and [2], it is most convenient to first summarize the frequency data. The following relationships are required:

$$n^P_{ej} = \sum^i r^P_{1ij} \quad [4a] \qquad n^P_{cj} = \sum^i (r^P_{1ij} + r^P_{2ij}) \quad [4b] \qquad n^P_{sj} = \sum^i (r^P_{1ij} + r^P_{2ij} + r^P_{3ij}) \quad [4c]$$

where r^P_{kij} refers to the *k*th element of the *i*th response vector of behavior *j* in group *P*. Summations are taken over the range of all *i* vectors of the group. The summarized frequencies are presented as Table 5 and the computed learning ratios are found in Table 6.

TABLE 4A

GROUP ASSIGNMENTS AND OBSERVED RESPONSES

Subject	Naive (N) Group				Experienced (X) Group			
	n^N	$\sum^j\sum^i r^N_{1ij}$	$\sum^j\sum^i r^N_{2ij}$	$\sum^j\sum^i r^N_{3ij}$	n^X	$\sum^j\sum^i r^X_{1ij}$	$\sum^j\sum^i r^X_{2ij}$	$\sum^j\sum^i r^X_{3ij}$
1	92	35	51	44	92	31	53	52
2	108	47	55	31	108	56	48	32
3	115	44	66	51	115	49	55	32
4	73	20	98	34	73	35	44	14

TABLE 4B								
OBSERVED DISTRIBUTIONS OF EPISODE COMPLEXITIES#								
	Subject 1		Subject 2		Subject 3		Subject 4	
Complexity/ Response	1	>1	1	>1	1	>1	1	>1
r_1	67	0	105	0	95	0	56	0
r_2	36	70	55	48	57	64	40	102
r_3	41	56	29	34	42	41	10	39
Responses*	144	126	189	82	194	105	106	141
Episodes	144	44	189	29	194	38	106	42
Total episodes	188		218		232		148	

Notes: r_1 reports instances of available knowledge, r_2 reports instances of unavailable knowledge, r_3 reports instances of absent knowledge, n is the count of episodes mediating transitions to observable target behaviors. # Cells report the sum of the indicated element of all response vectors (i) over all behaviors (j) in each group. * In the case of episodes of complexity = 1, the number of episodes is equal to the number of responses. Some totals derived from Table 4A are slightly less than those shown in Table 4B because of the omission of median episodes in assigning episodes to N and X groups (see text.)

TABLE 5

FREQUENCY DATA FOR COMPUTING LEARNING RATIOS

Subject	N Group			X Group		
	$\sum^{j} n^{N}_{ej}$	$\sum^{j} n^{N}_{cj}$	$\sum^{j} n^{N}_{sj}$	$\sum^{j} n^{X}_{ej}$	$\sum^{j} n^{X}_{cj}$	$\sum^{j} n^{X}_{sj}$
1	35	86	130	31	84	136
2	47	102	133	56	104	136
3	44	110	161	49	104	136
4	20	118	152	35	79	93

Note: n_e = count of non-cognitively mediated behavior transitions (response vector element r_1), n_c = count of non-cognitively mediated transitions and analysis and planning cognitions (response vector elements r_1 and r_2), n_s = count of all cognitive and non-cognitive knowledge base responses (vector elements $r_1 + r_2 + r_3$). Summations are taken over all behavior types.

TABLE 6				
LEARNING RATIOS				
Subject	l_s	l_c	l_e	l
1	1.046	0.934	0.907	0.886
2	1.023	0.997	1.169	1.192¤
3	0.845*	1.119*	1.178	1.114
4	0.612*	1.094*	2.614*	1.750*
Hypotheses:				
H_0	$l_s \geq 1$	$l_c \leq 1$	$l_e \leq 1$	$l \leq 1$
H_{1a}	$l_s < 1$	$l_c > 1$	$l_e > 1$	$l > 1$
H_{2a}	$l_s > 1$	$l_c < 1$	$l_e < 1$	$l < 1$

Note: * H_0 rejected at $p \leq .10$ in favor of H_{1a}.
¤ H_0 rejected at $p \leq .11$ in favor of H_{1a}.
H_0 rejected at $p \leq .10$ in favor of H_{2a}.

See Table 2 for descriptions of l_s, l_c, l_e, and l. H1a present the long term positive indications of progress toward increasing expert-like task behavior. H_{2a}, on the other hand, are conditional hypotheses which support the presence of learning when there is no significant finding of current progress toward greater long term task expertise. None of the subjects participating in this experiment and showing an absence of long term progress toward increased expert behavior in any knowledge base feature showed evidence of learning.

Sources of Error and Tests of Significance

The sources of error of concern in tests of significance, given the experimental data such as it is, are (1) non-systematic (i.e., random) coding error and (2) non-systematic over/under recognition of the cognitive and automatic components of mediating episodes. The methodology for detecting learning and the model's functional relationships do not lend themselves to description by any of the commonly used probability distributions. Consequently, in order to test the learning ratios for significance, the probability distributions associated with each of the ratios in Table 6 were generated by simulating each subject's task behavior and knowledge base response, as summarized in Table 4, 10,000 times. After each iteration, each response vector, subtotal, and learning ratio, as described above, was computed and the probability distributions updated.[29 30] The probability tables generated by this means are extensive. Selected critical values of the learning ratios are found in Appendix B.

Findings

Overall Changes in Performance

Evidence for progress toward increasing expert-like performance is provided by an increasing automaticity of observed task behaviors (i.e., $l > 1$). Table 6 shows that overall task automaticity improved for Subjects 2, 3, and 4 while that of subject 1 declined. Of the auditors showing improved task automaticity, only Subject 4's overall learning ratio was significantly greater than unity ($p < .025$). The ratios for Subjects 2 and 3 are in the proper direction to suggest improved automaticity, but they are not sufficiently greater than unity so as to rule out random error as the cause of the results obtained ($p > .10$). In sharp contrast to the pattern of these auditors, subject 1's overall ratio of .886 suggests a *decrease* in task automaticity, but the data cannot rule out random error as the cause of this finding at conventional levels of significance.

Examination of Learning Processes

With respect to how learning contributes to more expert-like task performance, it must be kept in mind that learning processes may be present but be manifested in ways not immediately evidenced by an increase in overall task automaticity. These short run manifestations reflect learning in the form of changes in knowledge organization (long run favorable indication of $l_s < 1$) and accessible knowledge content (long run favorable indication of $l_c > 1$). In addition, although increasing knowledge availability ($l_e > 1$) most directly affects overall task automaticity, increases in this area may be offset by unfavorable changes in the other learning areas just mentioned.

With regard to the present data, the processes contributing to increased expert-like performance are most clearly evident in the results for Subject 4. The data show significant findings of increased knowledge organization ($l_s < 1$), accessible content ($l_c > 1$), and knowledge availability ($l_e > 1$). This pattern is evidence of strong progress toward long run expert development.

Moving on to subjects whose ratio outcomes are progressively less clear, Subject 3, who did not show a statistically significant increase in overall automaticity, nevertheless did show significant gains in knowledge organization ($l_s = .845$, $p < .05$) and accessible knowledge content ($l_c = 1.119$, $p < .075$). While knowledge availability moved in the proper direction for long term growth in expert-like behavior ($l_e > 1$), the data do not reject the null hypothesis that this result could be due to random error. Here, then, is a case in which progress in at least some aspects of expert development are hidden when making an overall assessment of progress.

Subject 2 shows a pattern that is unusual in that complexity increased and accessible content decreased, both reflecting an erosion in expert-like task behavior, while knowledge availability increased. The first decrease suggests deterioration in knowledge organization and the second growing uncertainty and confusion in the face of an absence of knowledge. Offsetting these unfavorable findings, there is the suggestion of increased knowledge availability, a long run indicator of developing expertise. While these results are not statistically significant, and in spite of their mixed indications, the overall learning ratio ($l = 1.192$) just marginally misses significance ($p < .11$). Here, then, is another case in which progress in one factor contributing to increased expert-like task behavior (availability of knowledge) may be hidden by the relative lack of development in others.

Finally, all the component learning ratios relative to Subject 1's performance are in a direction that is contraindicated for long term growth in expert-like task behavior and, in addition, there is no statistically significant evidence that any learning has taken place. While learning may have taken place, the data are insufficient to support a conclusion that this subject has benefitted in any way from experience in performing this task.

VII. DISCUSSION

This research is unique on several counts. First, rather than attempting to ascertain the substantive content of an auditor's knowledge base — what the auditor "knows about" — this research ascertains the extent to which an auditor possesses the required knowledge to perform a specific task at a specific time and how easily that knowledge is accessed. Second, this research focuses on aspects of an auditor's knowledge base that account for what that auditor does rather than focusing on the substantive reasons for why it is done or whether it is the correct thing to do. This shift in focus represents a more abstract and universal approach to dealing with a knowledge base and its functionality that allows researchers to study the relationships among knowledge presence, its accessibility, and observed task behaviors more directly and in terms that are comparable across a wide range of tasks and task environments. In these respects, the model and methodology proposed in this paper augment current judgment/decision making auditing research by addressing an additional significant component of the perception of expertise, *viz.*, the automaticity with which a task is performed. The perception of expertise in performing an empirically intense task is most directly based on an auditor's observable behaviors, what is done and how, as the task environment evolves toward a solution state, and only indirectly on what an auditor knows and how that auditor thinks. Finally, the model and methodology presented is focused on individuals as their expertise develops, thereby responding to Bouwman & Bradley's (1997: 120) call for research on the process by which expertise is acquired.

In answer to the research questions posed in the Introduction, the model and methodology presented herein identify the changes in an auditor's knowledge base responsible for changes in task behavior, and provide a simple quantitative means by which researchers may objectively assess the relationship between various knowledge base developments and measures of expert-like task behavior. In this experiment, two extremes of learning are noted. At one extreme, one auditor showed neither any significant intra-task tendency toward more expert-like behavior nor any indication of knowledge base changes which would suggest progress toward eventual long term increases in expertise. At the other extreme, one auditor showed very significant improvement in overall task behavior, accounted for by significant gains in knowledge organization, content, and availability. Between these extremes, two auditors showed evidence of improvements in some knowledge base features, but these were either offset by contrary changes or hidden by random variation in others, resulting in no significant findings of overall gain in observable task expertise.

The great diversity observed in this experiment in learning patterns across subjects invites further investigation along several lines of inquiry. First, whether such diversity exists in the general population of auditors, or any specific subgroup, such as first-year novices, is a matter to consider either as a possible co-variable in experiments, or, from a practice perspective, in making appropriate staff assignment and training decisions. In such instances, if future research confirms the diversity revealed in this experiment, then "typical" measures will likely be of very limited value, particularly when decisions must be made regarding specific individuals and specific situations. As Barlow & Hersen (1984:53-54) point out, in studies where there is great diversity among subjects, situations, or both, the more adequate the sample in terms of its representativeness of both subjects and situations, the less relevant any findings will be for any specific individual or specific situation.

Second, although this paper is focused on the development of expertise in individual auditors, there is an interesting observation to be made about the three stage process, discussed previously, by which knowledge is acquired and gradually assimilated into an auditor's knowledge base. Given a sample of auditors, each acquiring expertise at a different rate, one would expect that the significant indications of learning would occur in the pattern diagramed in Figure 2. That is, learning would be expected to impact cognitive complexity (l_s) and knowledge content (l_c) before being evident in increased knowledge availability. In fact, the findings summarized in Table 6 suggest just such a pattern. While this observation raises intriguing possibilities, the data are not adequate to make a strong statement on this issue. The matter is left for future research.

Finally, the model permits any auditor's task environment to evolve uniquely, reflecting that auditor's task strategy. This consideration suggests two additional lines of inquiry. One line of inquiry can address the extent to which the observed diversity in learning is attributable to differences in task strategy. Another line of inquiry would study the relationship between these findings and the pre-experiment professional experience and post-experiment professional progress of each subject with a view toward use of the proposed model and methodology as a tool for evaluating training programs, staff assignment decisions, and personnel screening.

APPENDIX A

PROBLEM SOLVING BEHAVIOR CATEGORIES

(Target behaviors are shown in **bold**)

PERCEPTION: Behavior intended to acquire information present in the work environment.

In this experiment, perception behavior consists of **reading** documents requested of others in the task environment and answers to questions, received via the CRT.

EXECUTION: Behaviors intended to transform the task environment.

This category consists of the following behaviors: **requesting** information or a document from someone in the task environment; **calculating**, either verifying a calculation or performing an original calculation; **writing a memo or workpaper** (other than margin notes or underlining during reading or preparing the engagement report), **cross-referencing, indexing or comparing documents**; **reporting**, i.e., writing the draft of the report or organizing the engagement folder; **other execution behaviors**, such as: organizing the work area or searching the work area for a document, and discarding a document.

COGNITION: Conscious mental activity.

This category consists of the following groups of cognitions:

Analysis and Planning - Subject states an objective or an action he/she considers taking, states an assumption or draws a conclusion about the state of the task environment, summarizes for himself/herself personal knowledge of some aspect of the task environment.

Uncertainty - Subject states a question or expresses uncertainty about specific entities, relationships, or processes in the task environment, or expresses uncertainty about the task strategy, objectives, or how to proceed in the task, or expresses a general state of confusion.

APPENDIX B

SELECTED CRITICAL VALUES OF LEARNING RATIOS

$p(l_k)$	0.050	0.075	0.100	0.125	0.500	0.875	0.900	0.925	0.950	0.975	1.000
Subject 1											
l_s	0.841	0.859	0.873	0.886	0.996	1.127	1.140	1.158	1.185	1.224	1.500

SELECTED CRITICAL VALUES OF LEARNING RATIOS											
$p(l_k)$	0.050	0.075	0.100	0.125	0.500	0.875	0.900	0.925	0.950	0.975	1.000
l_c	0.854	0.868	0.882	0.897	1.002	1.118	1.131	1.145	1.168	1.198	1.450
l_e	0.688	0.720	0.748	0.769	0.994	1.288	1.325	1.374	1.443	1.544	2.000
l	0.714	0.743	0.767	0.790	0.982	1.256	1.289	1.327	1.386	1.484	2.000
Subject 2											
l_s	0.859	0.874	0.888	0.902	0.998	1.110	1.125	1.140	1.161	1.193	1.350
l_c	0.882	0.901	0.908	0.916	0.999	1.088	1.097	1.112	1.132	1.158	1.350
l_e	0.761	0.787	0.809	0.826	1.000	1.210	1.234	1.265	1.311	1.379	1.850
l	0.787	0.811	0.829	0.847	0.991	1.182	1.203	1.234	1.273	1.334	1.750
Subject 3											
l_s	0.874	0.892	0.904	0.912	0.997	1.095	1.106	1.122	1.138	1.163	1.350
l_c	0.881	0.901	0.908	0.915	0.999	1.090	1.098	1.115	1.134	1.160	1.350
l_e	0.747	0.773	0.797	0.814	1.000	1.224	1.249	1.289	1.338	1.420	2.000
l	0.765	0.792	0.813	0.830	0.990	1.204	1.232	1.264	1.307	1.374	1.950
Subject 4											
l_s	0.800	0.819	0.838	0.855	0.996	1.172	1.192	1.220	1.255	1.311	1.800
l_c	0.898	0.907	0.915	0.923	1.000	1.084	1.092	1.099	1.122	1.145	1.300
l_e	0.631	0.668	0.700	0.726	0.995	1.358	1.412	1.472	1.555	1.676	2.000
l	0.702	0.729	0.755	0.776	0.987	1.283	1.319	1.366	1.434	1.537	2.000

Note: This table shows the probability of observing a value of l_k or less based on 10,000 simulations of each subject's task behavior under H_0: The distribution of behavior responses and episode complexity for both the N and X behavior groups are the same as those for each subject's complete solution sequence. Certain values in the text are based on linear interpolations from data in this table.

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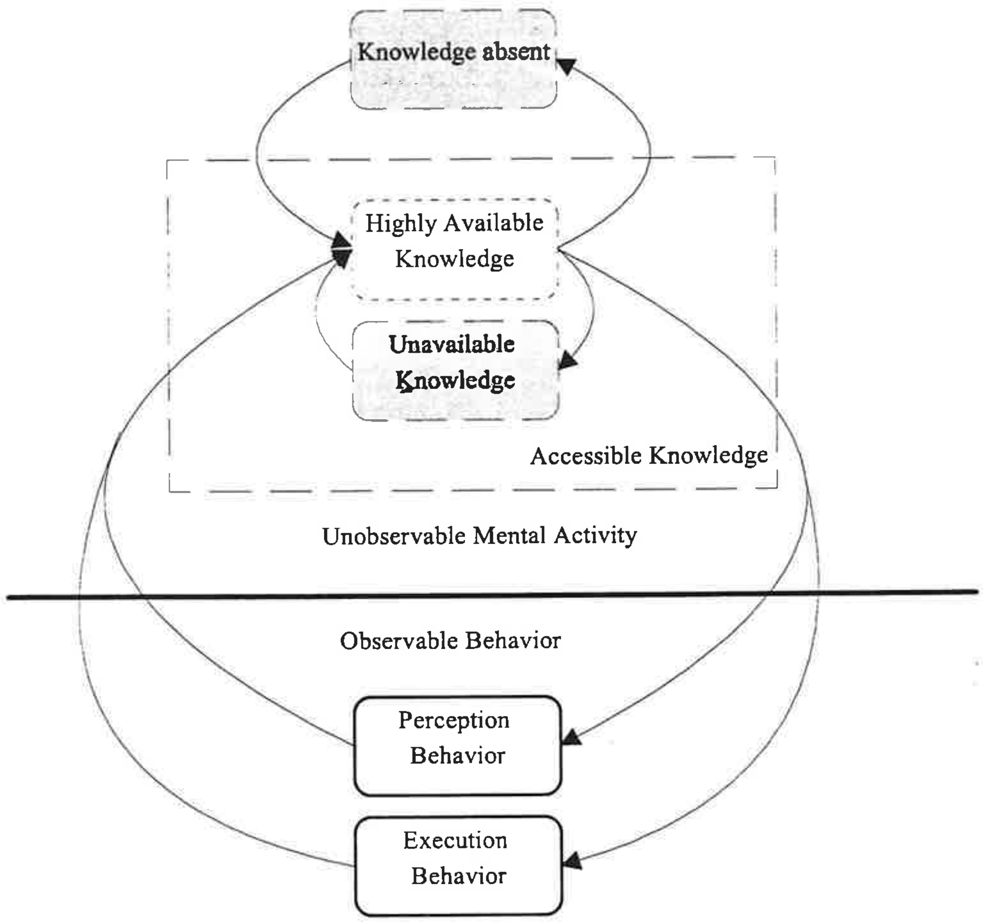
FIGURE 1
ITERATIVE MODEL OF TASK BEHAVIOR



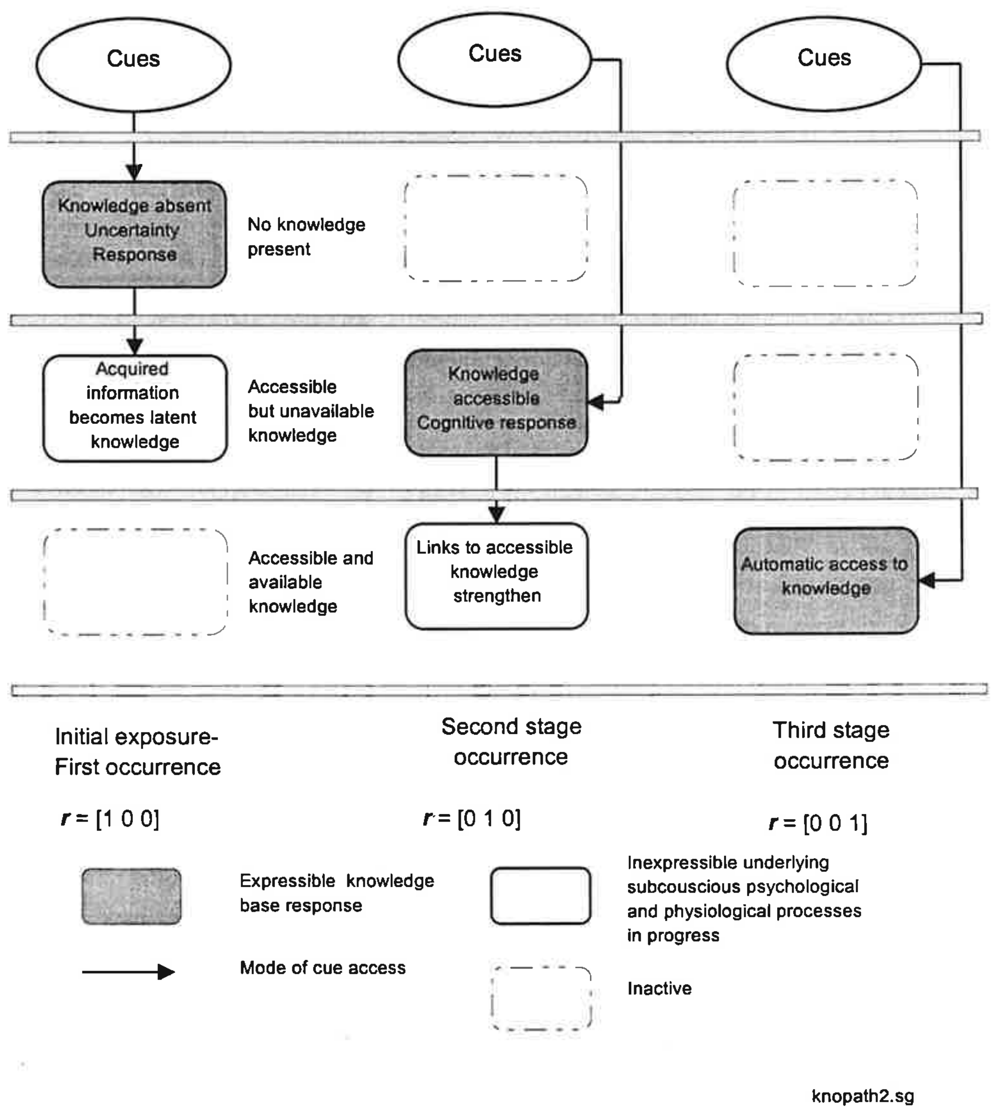
Solid shapes indicate observable behavior
Broken shapes indicate unobservable activity
Arrows indicate temporal sequence of observable behavior and expressed mental activity.
Access to highly available knowledge takes place subconsciously.

Non-cognitive activity

Cognitive activity

d:chart7.sg

FIGURE 2
THREE STAGE LEARNING PROCESS



ENDNOTES

1. The term "expert-like" is more precisely defined later in this paper. For the moment, behavior is considered as being expert-like if it is behavior an observer would expect of an expert performing in a task situation which the observer believes requires special competence.

2. Knowledge utilized during performance of a task, that is, *what* an auditor knows, has often been described in terms of knowledge "domains." For example, Bonner & Lewis (1990) study auditors' use of knowledge in the following domains: general world knowledge, general business knowledge, subspecialty knowledge, and knowledge of problem solving. These categories reflect knowledge in what I will call a "substantive" sense. That is, they represent the teleological, nomological, normative, factual, and evaluative content of an auditor's knowledge, all of which can potentially be expressed verbally. However, to better understand the thrust of the research reported in this paper, it is more useful to begin by considering the knowledge employed during performance of a task as capable of being ranked in terms of its applicability across a wide range of personal and social situations, and to include learned behavioral skills for which verbal expression would be difficult or impossible. Knowledge at the highest level (the "global" level) is that which is the most widely applicable. With each successive descent to a lower level, knowledge becomes progressively narrower in application and more task specific. For example, with particular reference to the context of an auditing task, an auditor employs knowledge of generally accepted social relationships and norms of behavior (society's, within the latter, the auditor's profession, within that, the firm's, within the preceding, the auditor's peer group, etc.); knowledge of business, economics, commercial law, accounting principles and practices, transactions, documents and documentation, work flow, and auditing objectives and techniques at a macro, generic, or abstract level progresses to similar knowledge regarding a particular industry and, within that, to similar knowledge regarding a specific client operating in a particular industry, etc., etc. At the very bottom of such a hierarchy, an auditor utilizes knowledge related to a given task within a very specific context (e.g., performance of *this* task, for *this* client, at *this* moment, relying on knowledge of *this* particular system and *this* set of records, interacting with *these* client employees, etc.)

Given the conceptual organization described above, and regardless of substantive content, the presence/absence and accessability of knowledge determines what behaviors take place during performance of a particular task. For example, in a particular context, an auditor may be observed performing behaviors whose substantive purpose relates to confirmation of accounts receivable. From this observation, we may imply the presence of such substantive knowledge as the nature of the client's business, concepts of materiality, systems of internal check and control, etc., and the requirements of generally accepted auditing standards. However, *how* those behaviors are carried out, that is, their instantiation within the particular context of their performance, requires knowledge at a much lower level than that of the items of substantive knowledge just mentioned. This low level knowledge is reflected in aspects of behavior such as which information sources are approached, the way in which they are approached, which documents are used, the manner in which accounts are selected, the process by which the confirmation documents are prepared, etc. In the research reported in this paper, the concern is not with discovering what substantive knowledge an auditor possesses when performing a task, e.g., knowledge of why and how accounts receivable are confirmed. Such substantive knowledge generally is drawn from knowledge at a more global level than that which is the proximal driver of the observed behavior taking place. Rather, the concern here is with evidence supporting the presence and degree of accessability of *whatever* knowledge an auditor employs when an action is taken. *That* the auditor approached an information source, *that* inquiries were made, *that* documents were requested, *that* a specific mode of document preparation was used, etc., and *that these behaviors were sequenced and executed in a certain way,* is what is of the essence in this research, not the fact that the substantive interpretation of all the foregoing constitutes a confirmation of accounts receivable as required in the circumstances by GAAS. Were the knowledge required to instantiate and perform any of these behaviors not present and accessible at the moment they were performed, they would not have taken place and another sequence of behaviors would have been observed. From the perspective of an auditor from whom professional performance is demanded, without high level knowledge, there can be no task because the "demand" can have no meaning. One function of an auditor's education is to assure that such a condition will not obtain.

Consequently, the higher the level of knowledge utilized by an auditor during performance of a task, the more likely it is that that knowledge was brought to the task and the less likely it is that it was acquired while performing the task.

The application of this principle is much broader than the previous sentence appears to indicate. For example, Bedard and Chi (1991) cite research showing that in task-specific measures of expertise, novice auditors are more consistent with professional standards than they are with firm standards, while expert auditors are equally consistent with both. The explanation for this observation is found in the different levels of accessible knowledge that novice and expert auditors possess and bring to a task. Novices, by education, bring knowledge of professional standards (a high level knowledge) to the firm, but have yet to learn the standards of the firm (a lower level of knowledge.) Experts (i.e., those with extensive tenure and experience in the firm), on the other hand, can be expected to have and to bring to a task knowledge of both the profession's and the firm's standards. Hence they do not show the performance difference exhibited by the novices.

Most, but, to a varying degree, not all of the knowledge required to perform a specific task in a specific context, and thereby make high level knowledge effective, is knowledge at a very low level. However, regardless of level, the objective of this research is to understand the unobservable process by which *any* new knowledge required by an auditor during performance of a task is identified, acquired, and assimilated into that auditor's knowledge base, and how the accessability of any knowledge present in that auditor's knowledge base affects an observer's perception of that auditor's expertise during performance of that task.

3. In psychology, "neobehavioral" is applied to the less radical and widely accepted psychological sense of the term "behavioral research." Neobehavioral psychology comprehends behavioral research as the examination of the *observable* actions of organisms, allowing for the use of unobservable and covert processes as explanatory devices (Reber 1985: 467). Traditional behavioral psychologists (in the spirit of Watson and Skinner) express disdain for any data which cannot be obtained by means of physiological techniques. In particular, they object to introspective and retrospective self-reports of mental phenomena for which objective data cannot be obtained. Recently, cognitive psychology has developed and adopted models and techniques (e.g., concurrent verbal protocols) which yield objective measures of unobservable phenomena and avoid introspective and retrospective reporting. This broader notion of behaviorism is often referred to as "neobehaviorism" and has significantly advanced understanding of problem solving and cognitive phenomena. See Galotti (1994: 9-11) for a brief discussion.

4. Alba and Hutchinson (1987) cite extensive research attesting to the common observation that as one gains familiarity and expertise in a task, one's behaviors are performed with diminishing effort and *without conscious control.* Increasing automaticity of behavior with experience is a central concept in artificial intelligence and learning theory (e.g., Anderson 1982, 1987; Mayer 1992: 305). Davis & Solomon (1989) employ the term "expert" to describe one whose behavior during performance of a task displays a high degree of automaticity. Bedard (1989) notes that experts exhibit little self-insight into how their decisions are made because most are made subconsciously.

5. The identification of who are experts and who are novices is an important one to make in expertise research. Although expertise is usually associated with experience, this criterion has recently been challenged (e.g., Ashton 1991.) However, automaticity is to a large degree a reflection of an auditor's familiarity with a task situation (see citations in previous endnote and Russo 1995). From the standpoint of the automaticity of task behavior as a criterion for making this distinction, all auditors, regardless of title or organizational rank, encounter situations with which they are to a certain extent unfamiliar. In such situations, it has been shown that the performance of "experts" and "novices," classified under the more traditional notions, is the same (Bedard 1989). Consequently, the approach to examining the development of expertise advocated in this paper can make valuable contributions to our understanding of the phenomenon of expert behavior in auditors at all levels of accomplishment.

6. In the laboratory, tasks used in auditing research have tended to lack the environmental interaction characteristic of field tasks, and to require solutions represented by intellectual commitments (i.e., judgments and decisions) rather than by environmental transformations (i.e., the creation or modification of entities, relationships, and

processes in a task environment). Further, the cognitive emphasis of recent auditing research becomes increasingly less informative with growing task expertise. Verbal protocol methodology, for example, does not provide evidence about automatic behaviors or subconscious processes. This cognitive focus and its slighting of the interactive nature and social context of field tasks has been noted to varying degrees in literature reviews by Russo (1997b), Bamber (1993), Hogarth (1991), and others.

7. Russo's (1994: 49) original model listed the following mental activities: construct task environment, formulate task demand, formulate strategy, and evaluate strategy. These activities were categorized as "cognitive." Other researchers utilize similar schema in which the classifications assigned to cognitions are based on interpretations of their intentionalities or purposes. For example, O'Donnell's (1997: 102) process model considers the following cognitive intentionalities during formulation of judgments: establish or reevaluate the decision objective, determine what information will be needed, acquire the information, evaluate the information, and decide whether the objective has been accomplished. Other researchers classify cognitive activity during performance of tasks in terms of operations on data. For example, Biggs & Mock (1983), Meservy et al. (1986), and Biggs et al. (1988) use variations of the following basic schema: task structuring, information acquisition, analytical, and action/choice. Finally, some researchers classify cognitive activity in terms that are specifically related to the topics of their research. For example, Peters (1990), in a study of risk hypothesis generation, classifies cognitions in terms of hypotheses generated, support offered, and uncertainty strategy used, and Bedard & Biggs (1991), in studying pattern recognition and hypothesis generation, uses several categories of performance, errors in interpretation, pattern recognition, and hypothesis generation.

The research presented in this paper is directed at a lower, more fundamental level than that at which the bulk of extent expertise research is directed. None of the research cited above, for example, considers either knowledge accessability as a matter in its own right, independent of the substantive subject matter of the experimental task or judgment/decision making process (e.g., evaluation of internal control, knowledge organization by transaction cycle, etc.), or the insights which may be gained through explicit consideration of the relationships between subconscious mental activity and observable task behavior. Yet, knowledge accessability is a common denominator of all the preceding cognitive schemata as well as of the observed consequences of subconscious mental activity.

8. Perception behaviors are all those observable behaviors and covert means by which stimuli are received from a task environment. In auditing, these behaviors typically are reading, listening, and observing. Execution behaviors are those whereby an auditor transforms a task environment. In auditing, these behaviors typically include requesting, writing, using mechanical devices such as calculators and telephones, searching, etc.

9. Given a set of cues related to a specific domain of performance, the term "knowledge base" is used to represent all the information accessible from memory to an individual performing in that domain.

10. In the interests of readability, mathematical notation is kept to a minimum and used only when required for precision and clarity of expression or in notes where additional explanation will aid those interested in greater detail.

11. Elements of a state vector are $\sum^i r_{ki}$, the subscript k having the same meanings as are used for elements of the response vector and the sum is taken over the range of all i response vectors in the solution sequence or subset.

12. Cues arising from stimuli received from the task environment are situational cues. Cues arising from knowledge evoked from the knowledge base by cognitive processes (e.g., inferences and other indirectly linked knowledge) are internal cues. In all empirically intense tasks, internal cues ultimately have their basis in stimuli received from the environment. Thus, while an empirical behavior may be the proximal response to an internal cue, ultimately, all empirical behaviors are responses to situational cues. A third type of cue, those arising from internal physiological

sensors, are beyond the scope of this paper and are not considered.

13. The knowledge "content" of a knowledge base is latent until it is expressed. By use of sampling procedures which elicit knowledge expression, such as interrogation, classroom examination, and behavior observation during performance of a task, it is possible to approximate the average state of a knowledge base in the specific context in which the sampling was conducted. See discussion later in the text and Russo (1997a) for additional development of this point.

14. Additional responses to an absence of knowledge include the physiological manifestations generally associated with stress. Consideration of such responses are beyond the scope of this paper.

15. The adjectives "reportable" and "expressible" refer to the potential to make salient to an observer other than the "thinker" (i.e., to the external environment) an otherwise ongoing but hidden phenomenon. Conscious mental activity (e.g., "thinking") is normally hidden from the external environment unless the "thinker" communicates or reports his/her experience of that activity. Extensive research (see Ericsson & Simon 1993 for an review) shows that concurrent verbal reports of thoughts at the "focus of attention" are valid expressions of the underlying cognition.

More generally, Reber (1985) describes the term "cognition" as a broad, almost unspecifiable term referring to thinking, reasoning, and a long list of other "mental behaviors." Such ambiguity in terminology, which is a consequence of the word's use by many researchers in many contexts and the extensive evolution in understanding mental processes, is of little use in science. Hence in any particular usage there is a need to more precisely focus its meaning. Most pragmatically for current purposes, cognition can be thought of as vicarious activation of those areas of the brain through which sensory input, most particularly audio input, is expressed. For example, the experience of thinking during problem solving is often described as "private speech" and is hypothesized to originate out of self-directed speech engaged in by children at around age 4 or 5 (Ellis& Siegler 1994, 343-4). Even during adult problem solving, it is an almost universal experience that one will often overtly address imperatives and other verbalizations at the self, particularly at moments of stress or surprise ("Wait a minute!" or "This can't be right!"). Dennett (1991) also cites research supporting the "private speech" hypothesis and argues that cognition, along with speech, writing, and other forms of behavior, is one means which has evolved for indirectly accessing knowledge that is not directly (neurologically) linked in memory. Finally, Russo (1997b) reviews research supporting a point of view consistent with both the foregoing and the automaticity literature in that cognition is the exception rather than the rule for mental activity governing behavior while performing a task. In this conceptualization, cognition is brought to bear only when there is a failure of memory to automatically supply required knowledge.

16. "Automatic" does not necessarily imply "instantaneous" or "fast." The term indicates only the absence of cognition. Inexpressible processes are not cognitions as defined in the text. Perceptible lags between observable behaviors which are not occupied by expressible mental activity (cognition) are considered in this research to be within the purview of automatic activity.

17. A response is an observable, reportable, or expressible instantiation of accessed knowledge. More precisely, and theoretically, complexity is the minimum number of knowledge base accesses mediating the transition between two observable behaviors. Accessed knowledge is expressed either in passively observable behavior, such as observation of a subject's behavior from a position out of the subject's view and without the subject's awareness (e.g., clandestine video taping), or with the subject's cooperation, as is the case with responses to examination questions, retrospective reports, and concurrent verbalizations of thoughts during performance of a task. At the current state of technology, individual instances of subconscious mental activity are not recognizable as knowledge base accesses. Hence, non-cognitively mediated transitions between observable behaviors (e.g., non-cognitive episodes) evidence *at least* one knowledge base access.

18. The "strength" of an association between cues and expressions of the knowledge they elicit is a perception one forms based upon the "difficulty" experienced in effecting the knowledge evocation. Difficulty is normally thought of in terms of time or cognitive effort (e.g., O'Donnell 1997). Tulving (1992) discusses this matter in detail and cites extensive relevant research by both himself and others. In summary, Tulving accounts for the perceived strength of the association between cues and elicited knowledge by a combination of (1) the semantic vs. episodic content of knowledge, (2) the closeness of the match between cues encoded at the time the knowledge was acquired and cues presented at the time of retrieval, (3) the extent to which the demand for knowledge can be satisfied by recognition or recall, and (4) the knowledge search strategies employed by the rememberer. All of these factors, but particularly the second and third, are largely a function of the context in which knowledge retrieval is required.

19. In this research, a connectionist view of memory organization and function is assumed (see Rumelhart 1989 for a review). In this view, the content of a knowledge base is distributed throughout memory in the form of microfeatures (nodes), which are linked together to form networks of varying complexity. Knowledge base content, therefore, is represented in the patterns of linked nodes that are activated at the moment any knowledge is accessed. This content may be thought of as directly linked in memory if it can be accessed automatically, i.e., by subconscious neurological processes. Unlinked knowledge cannot be accessed directly, and is, therefore, unavailable. Cognition, along with speech, writing, and other forms of behavior, is one means by which knowledge that is not directly (neurologically) linked in memory is accessed (see previous notes regarding thinking and cognition). The terms "virtually linked" and "virtually accessed" may be used to represent these forms of indirect knowledge access. Functionality, each virtual link potentially evokes a new context or modifies an existing context, either of which, in turn, alters the permissible range and selectivity of subsequent knowledge responses.

From a connectionist perspective, knowledge organization is defined as the extent to which information is linked in memory. At a structural rather than logical level, connectionist models of memory organization account for strength of association in terms of the number of links among knowledge elements (microfeatures) and their natures (direct vs. indirect, neurological vs. virtual, etc.) Manifestations of the strength of linkages among the microfeatures producing and giving expression to knowledge is an observer's perceptions arising out of the combination of (1) the consistency (i.e., predictability) of the association between a given set of cues and the observed response, and (2) the availability of the knowledge expressed. The more consistent the stimulus/response association and the faster the observed response, the "stronger" the perceived association and, by extension, the linkages among the response-determining microfeatures. Each cognition in a cognitive episode signals the use of a virtual link to connect otherwise neurologically unlinked elements of information in memory. Consequently, increasing the number of neurological links among knowledge microfeatures results in decreasing cognitive complexity, an increased perception of "strength" in the associations between cues and responses, and an increased perception of knowledge organization. The highest degree of organization is evidenced by the absence of any need for virtual links.

20. The two concepts of knowledge organization described in the text are also quite different in terms of how change in one affects the other. First, while an observer may impose on a physical organization some logic which unites part or all of it, changing the logical organization does not necessarily change the physical. In contrast to the foregoing, changing the physical linkage among knowledge elements may very well change the ability to perceive and, indeed, the very perception of a logical organization. Second, logical organizations are learned structures or strategies for knowledge retrieval. In this use, such structures are evident in cognitive processes during problem solving.

21. This is not to say that the physical structure produced is related to the logical structure in the same way as a compiled program is related to its human-readable high level source code. As stated previously in the text, subconscious processes, and their physical correlates, are inexpressible and unobservable. At the present state of technology, there is no reason to believe that the literal logical structure becomes automated. One implication of the gradual reduction in the complexity of cognitive episodes is that only a linkage between input (cues) and output (evoked knowledge) becomes physically implemented, omitting intermediate steps which would have occurred at a cognitive level. However, the issue is in any event moot.

22. It should be noted that changes in knowledge organization are recognizable only through changes in cognitive complexity since the complexity of subconscious knowledge access are not observable or expressible. Extinguishment of cognition, e.g., the conversion of simple cognitive episodes to non-cognitive episodes, signals increasing automaticity of behavior rather than increasing knowledge organization.

23. There is considerable philosophical debate regarding knowledge, beliefs, opinions, and intentionality which is not relevant to the discussion in this paper (e.g., see Gregory 1987, Dennett 1993, esp. 19, and others). Suffice for present purposes that one's beliefs are what one knows and accepts as true, and one's opinions are what one is willing to accept in the face of some chance that one's knowledge is not true. Both beliefs and opinions, therefore, reflect knowledge. Consequently, for purposes of discussing knowledge-driven behavior, no harm results from stipulating that for the remainder of this paper, the term "beliefs" will be understood to include opinions. Intentionality is concerned with the outward objects (as opposed to the affective natures) of one's beliefs or with the purposes of one's behaviors.

24. Specific interpretations of this definition taken by various researchers reflect the particular focus of their research. For examples of various interpretations and applications see Rumelhart 1989, 148-52; Newell 1991, 305; VanLehn 1993, 530-44; Dennett 1993, 193.

25. The probability that l_s decreases in a given instance of knowledge assimilation is positively related to the complexity of cognitive episodes preceding the target behavior in the naive group. It is important to note that a reduction in complexity is not necessarily equivalent to an increase in automaticity. For example, reduction in the complexity of a cognitive episode from, say two to one, does not increase automaticity. However, converting the complexity of a simple cognitive episode to an automatic episode, while not altering complexity (both are of complexity = 1), does increase automaticity.

26. The extent of an individual auditor's latent knowledge may vary from minimal to extreme. Hence the relationship between learning and repeated interactions among cues and elements of a knowledge base is not a simple one. For example, an auditor may have considerable well-organized but latent knowledge about certain aspects of a task situation and yet lack any direct means for accessing it. In such a case, a single exposure to the cues which virtually link to that knowledge may be sufficient to establish the direct link needed for future automated accesses. At the other extreme, lacking any knowledge of a task situation, a lengthy sequence of repeated exposures may be required before an auditor is even able to construct a usable schema (organization) for the situation he/she currently faces. First year auditors can be expected to fall somewhere between these two extremes.

27. If a particular target behavior occurs an odd number of times, the occurrence at the median is omitted to avoid bias in arbitrary group assignment.

28. Behavior categories reference definitions found in the Appendix A.

29. In comparative tests for significance, such as is required here, systematic error in the observation and coding of behavior is not addressed. This type of risk, though not entirely eliminated by the dual coding of protocols, is nonetheless minimized by that procedure. The sources of error of concern in tests of significance are non-systematic (i.e., random) coding error and non-systematic over/under recognition of the cognitive and automatic elements of mediating episodes. For purposes of testing whether the difference from unity of the ratios obtained from this experiment could be the result of such sources of error, the simulations hypothesize that, for each subject, the distributions of episode complexity and knowledge base response of both the naive and experienced groups are the same as are those distributions for each subject's complete solution sequence. Therefore, the expected value of all learning ratios specified by the model is unity. Empirical probability distributions were created for both simple and complex

mediating episodes using the data in Table 4. For purposes of these distributions and the objectives of this paper, no distinction need be made, nor was any actually made, among target behaviors. The question of whether or not mediating episodes are or should be in any way conditional upon the target behavior is beyond the scope of this paper and will be addressed in a future paper. Graphs of the resulting simulated probability distributions were plotted and found to be well formed, smooth, and, as expected, evaluate to an expected value of one.

30. Biddle, et al. (1990) discuss the use of computer intensive methods in auditing.

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