

## The Effect of Inference Order and Experience-Related Knowledge on Diagnostic Conjunction Probabilities

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Ideally, a decision maker's diagnostic probability judgments should not be affected by making predictive judgments before making diagnostic inferences. The purpose of this study is to investigate how experience-related knowledge and the inference presentation order affect a decision maker's diagnostic conjunction probability judgments. Specifically, when decision makers are asked to make diagnoses in different judgment domains with which they have different levels of experience, we examine how making predictions first affects their subsequent diagnostic judgments in a standard conjunction paradigm. Professional auditors with experience in the auditing domain and MBA students with little or no auditing experience participated in the experiment. The results indicate that when the task involves a domain with which people have experience, making predictions prior to diagnoses has a significant influence on their subsequent diagnostic conjunction probabilities. When auditors made diagnoses in a familiar audit task situation, they were strongly influenced by whether or not they were asked to make predictions in advance. However, there was no influence of inference order on auditors' diagnoses in a medical task, with which they do not have experience-related knowledge. Similarly, MBA students, having no experience-related knowledge in either audit or medical domains, were not affected by the inference order in making diagnoses. In the discussion of these exploratory results, we suggest that this inference order effect may be due to subjects' anchoring on the predictive probability and insufficiently adjusting it to yield the diagnostic probability judgment. © 1994 Academic Press, Inc.

People use causal knowledge to reason in two different directions. They think from known causes to unknown effects in making *predictions* and from known effects to unknown causes in making *diagnoses*. Sometimes, in a single decision situation, these two types of inference modes are used concurrently. For example, a potential home buyer may make a prediction of the likelihood of various future selling prices of a home given the

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current economic status and also may diagnose the likelihood that certain previous events have occurred given the current asking price of the house (e.g., if the price has been lowered, it is likely no offers were received in the last 2 months). Einhorn and Hogarth (1987) posited that people may incorrectly apply these two inference modes in making judgments by using the prediction mode in diagnostic judgments and the diagnosis mode in making predictions. Such errors can have serious impacts in decision-making domains which routinely require probabilistic reasoning, such as when auditors must judge the probability of a firm being a going concern from evidence collected during an audit.

A considerable body of heuristics research reveals that people use heuristics in making decisions and that heuristics sometimes lead to judgmental biases (e.g., Tversky & Kahneman, 1974; Nisbett, Krantz, Jepson & Kunda, 1983; Kleinmuntz, 1985). However, there is an emerging view that experts' reasoning processes, in more natural and familiar contexts, are not subject to the same kind of cognitive limitations and biases as reported by using students performing abstract tasks (e.g., Murphy & Winkler, 1974; Phelps & Shanteau, 1978; Christensen-Szalanski, Beck, Christensen-Szalanski, & Koepsell, 1983). The purpose of this study is to investigate how experience-related knowledge and the inference presentation order affect a decision maker's diagnostic conjunction probability judgment. Specifically, when decision makers with different levels of experience-related knowledge in two judgment domains are asked to make diagnoses, we examine how making predictions first affects their subsequent diagnostic conjunction judgments. Since, in the typical audit setting, professional auditors have numerous opportunities to make both diagnostic and predictive probability assessments, they were selected as participants of this study. The results indicate that for an auditing task with which auditors had professional experience, making predictions prior to diagnoses had a significant influence on auditors' subsequent diagnoses. This effect was not obtained with a less familiar medical task. Further, for MBA student participants with less experience than auditors in the audit case, no order effect was observed. Also, there is no inference effect on students' diagnoses in the medical case. These results contradict other findings that experience helps avoid biased judgments. In the discussion of these exploratory results we suggest a possible explanation for this inference order effect.

## BACKGROUND

A person normally has incomplete causal knowledge and situational information. When making causal judgments, a decision maker searches for and retrieves information from memory and outside sources to integrate into his/her causal schema, which contains events and causal con-

nections between events (Einhorn & Hogarth, 1986). The development of the causal schema depends on a decision maker's domain-specific knowledge (Chi, Glaser & Rees, 1982; Newell & Simon, 1972), task-specific knowledge (Bonner & Lewis, 1990), and the inference mode involved (Waller & Felix, 1989). In a diagnostic inference mode, a person attempts to associate observed effects with prior events, while in a predictive inference mode, the person attempts to predict outcomes. Moreover, predictions and diagnoses may trigger different ways of processing information about causal judgments and, thereby, may cause different assessments of relations between causes and effects (Burns & Pearl, 1981; Bjorkman & Nilsson, 1982; Einhorn & Hogarth, 1986). In an auditing context, for example, Waller and Felix (1989) demonstrated that auditors focus mainly on sufficiency (conditionality of the causality) when predicting an effect and on necessity (multiplicity of the causality) when diagnosing the causes of an effect.<sup>1</sup>

Research on causal judgments has revealed that the initial problem representation affects both the acquisition of and procedures for using causal knowledge (Carroll, Thomas & Malhotra, 1980; Chi, Feltovich, & Glaser, 1981) and that the representation of causal knowledge affects reasoning processes which operate on it (see Einhorn & Hogarth, 1986, for a review). Pennington and Hastie (1988) reported that the information presentation order determines how easily causal explanations are developed and what types of decisions are made. Carlson and Schneider (1989) observed that their subjects' procedures for using causal rules were affected by both the initial representation of instruction and the type of judgment required during the practicing stage. In a medical context, Kassirer and Kopelman (1989) reported that the way diagnosticians represent or categorize cases affects the quality of hypotheses generated during diagnosis. Perhaps this is because when a person activates a particular portion of memory, the possibility of activating a related portion of memory increases (Collins and Loftus, 1975; Meyer and Schvaneveldt, 1976).

Domain-specific knowledge affects individuals' information processing (cf. Johnson & Russo, 1984) and facilitates their learning a relationship between existing knowledge and new information (Chase & Simon, 1973). The role of experience in causal judgments has been investigated in a number of contexts (e.g., Dawes, 1979; Johnson et al., 1981, 1984; Schoenfeld & Hermann, 1982; Shanteau, 1988). The evidence suggests that an expert's memory structure and the way the knowledge is organized affect his/her judgment processes. Several recent auditing studies

<sup>1</sup> Sufficiency means that event *X* must occur when effect *E* occurs and necessity means that event *X* cannot occur when effect *E* does not.

provide indirect evidence supporting the notion that the representation process depends on domain-specific knowledge (cf. Ricchiute, 1990). Frederick and Libby (1986), for example, demonstrated that experienced auditors possess more knowledge and have a different memory structure than novices. Because of the different memory structure, experienced auditors are affected by representativeness, but students, lacking knowledge of the relationships between internal control weaknesses and errors, are unaffected by differences in representativeness. In another experiment, Libby and Frederick (1990) showed that experience plays a crucial role in the memory-based plausibility assessment process. Furthermore, research in expert judgment has revealed that individuals use "general or default" heuristics in situations where information or familiarity to the task is lacking. However, influenced by training and experience, individuals may develop "specialized" heuristics in situations with which they have expertise (See Smith & Kida, 1991, for a review). Such specialized heuristics may offer the advantage of aiding experienced decision makers in making many routine judgments but, as with all heuristics, they may have the disadvantage of sometimes leading to biased judgments.

When making causal judgments, people form a causal schema depending on their varying experience with the context (Bourne, 1971). Ho and May (1993) reported that experienced auditors and inexperienced students were not different in their overall conformity with the conjunction rule, but that the two groups responded quite differently to the manipulated variables. Hence, they suggest that experienced auditors and students may activate causal schemata with the same basic structure. However, due to their different levels of experience with the task, they may look for different aspects of the situation to match with components of their individual causal schemata. In other words, as experience is gained, naive schemata are revised and become more sophisticated schemata.

Based on the research reviewed above, our conceptual framework for the effect of inference order on diagnostic judgments is as follows. A decision maker's prior knowledge affects his/her use of the two inference modes. When making predictions, a decision maker activates an existing causal schema by associating from causes to effects. An experienced decision maker has a richer memory structure than a less experienced decision maker. Immediately after the predictions, if an experienced decision maker is asked to make a diagnosis in the same context, the coherent, complete, and still active initial predictive cognitive schema biases him/her away from use of the correct inference mode (Einhorn & Hogarth, 1987). Therefore, an experienced decision maker anchors on a predictive judgment and insufficiently adjusts when making diagnostic judgments. On the other hand, if a decision maker makes a diagnosis on which domain knowledge or experience is not possessed, there is no

well-developed causal schema to support diagnostic reasoning. Then, making a prediction first does not bias any subsequent diagnostic judgment.

### EXPERIMENT 1

To examine whether the inference order affects individuals' diagnoses, an experiment based on the standard conjunction paradigm was conducted using both auditing and medical tasks. Auditing tasks have proven to be rich settings for the examination of causal reasoning (Anderson & Wright, 1988; Waller & Felix, 1989) and conjunction effects (Frederick & Libby, 1986; Ho, Anderson & Marchant, 1990). The audit setting, contrasted with a medical setting, provided an opportunity to investigate whether the same pattern of conjunction violations, in general, and any inference order effects, in particular, occurs across situations with which the person has different levels of experience. Since this study used a standard conjunction paradigm to investigate the research questions of interest, the plausibility effect was also checked.

#### Subjects

Seventy-six experienced auditors from a large multinational public accounting firm participated in the study. They were all at the same level in the firm, with responsibility for the on-site conduct of audits including supervision of staff auditors. Mean audit experience was 3.2 years and ranged from 2 to 6 years. Abdolmohammadi and Wright (1987) and Cohen and Kida (1990) document the expertise of audit professionals with this level of experience in performing the audit task used in this study. The auditors completed the experiment during a regularly scheduled training session held by the firm.

#### Procedure and Experimental Design

The instrument includes two judgment cases: an audit case and a medical case. Experienced auditors are assumed to have domain-specific knowledge and experience in the audit case but to have neither domain-specific knowledge nor experience in the medical case. Each subject received the audit case first, then the medical case.

##### *Audit Case*

The audit context requires numerous judgments which involve causal reasoning. In particular, analytical procedures provide a natural setting for examining diagnoses and predictions (Waller & Felix, 1989) and conjunction effects (Ho, Anderson & Marchant, 1990). In performing analytical procedures, the auditor examines financial statement information, forms his/her expectations for the financial relationships either from in-

formation stored in memory (Biggs, Mock, & Watkins, 1988) or from external sources (Daroca & Holder, 1985), determines if there has been an unusual fluctuation and if the unexpected value is sufficiently large to warrant further investigation, infers the possible cause(s) of the difference, and then structures audit procedures to investigate the cause(s). Analytical procedures have been used increasingly in place of, and as a supplement to, more traditional audit tests, such as tests of details (Tabor & Willis, 1985). In the experiment task, subjects were presented with the following information about a hypothetical audit client:

Alpha Company, a medium-size manufacturing company located in southeastern Texas, is engaged in the manufacture and distribution of athletic uniforms, men's casual clothes, work clothes, and jump suits. These products are made of basic fabrics, principally cotton and blends, and are moderately priced. Distribution is through Alpha salesmen to approximately 1,500 retail accounts located primarily in the southeast and southwest.

The experimental materials were designed to allow manipulation of inference order. Inference order was varied to lead subjects to make either diagnoses first or predictions first. So, half of the subjects made diagnostic probability judgments followed by predictions and the other half made predictive probability judgments followed by diagnoses. A subject who made diagnoses (predictions) first in the audit case also made diagnoses (predictions) first in the subsequent medical case. In the DIAGNOSIS part, subjects were presented with the following information:

The industry averages for gross margin percentage are as follows:

	1984	1985	1986	1987
Gross Margin Percentage	30.6	30.7	30.8	30.4

A detailed analytical review of Alpha company's revenue cycle has just been completed and the following fluctuation was discovered for 1987:

	Audited			Unaudited
	1984	1985	1986	1987
Gross Margin Percentage	32.6	33.7	31.8	39.4

After conducting the analytical procedures, you observe that Alpha Company's gross margin percentage has increased 24% from 31.8 in 1986 to 39.4 in 1987. On the next page are several events, each consisting of one or more events or conditions which may have affected Alpha Company's gross margin percentage. Given this increase in the gross margin percentage, please indicate how likely it is that each event or condition or set of events and conditions may have occurred.

Subjects were then presented with seven possible event items which might have caused the fluctuation in one of two orders as shown below. Each of these items consisted of one or more potential events.

Plausibility <sup>2</sup>	Events
Hi <sub>1</sub> :	Ending inventory is overstated.
Hi <sub>2</sub> :	Some sales were recorded but goods not shipped.
Hi <sub>1</sub> & Lo <sub>1</sub> :	Both (a) interest expense decreased significantly, and (b) ending inventory was overstated.
Lo <sub>1</sub> :	Interest expense decreased significantly.
Hi <sub>1</sub> & Hi <sub>2</sub> :	Both (a) some sales were recorded but goods not shipped, and (b) ending inventory was overstated.
Lo <sub>1</sub> & Lo <sub>2</sub> :	Both (a) interest expense decreased significantly, and (b) recorded depreciation declined as a percentage of sales.
Lo <sub>2</sub> :	Recorded depreciation declined as a percentage of sales.

For example, subjects were asked, "Given the gross margin percentage has increased from 31.8 in 1986 to 39.4 in 1987, the probability that *some sales were recorded but goods were not shipped* is. . . ." The response scale ranged from 0 (no chance that the event or condition occurred) to 1.0 (completely certain that the event or condition occurred).

In the PREDICTION part, subjects were presented with the industry averages and Alpha company's gross margin percentages for the previous 3 years (1984, 1985, 1986). The following instruction was then provided:

Before conducting the analytical procedures for Alpha Company of Year 1987, you observe one or more events or conditions which may affect Alpha Company's gross margin percentage. In assessing the likelihood that the presence of an event or condition or set of events and conditions listed in the next page may have preceded the fluctuation of Alpha Company's gross margin percentage from 31.8 in 1986 to 39.4 in 1987 (i.e., a 24% increase), your experience in auditing similar companies may help you make this judgment. Given the events listed on the next page, please indicate how likely it is that Alpha Company would experience a gross margin increase of this magnitude.

For example, subjects were asked, "Given that Alpha Company has some sales recorded but goods were not shipped, the probability that *there is a gross margin increase in 1987 of about 24% is. . .* ." The response scale ranged from 0 (no chance) to 1.0 (completely certain).

Subjects were explicitly required to consider both problems independently. They were also told that the list might contain items they consider impossible and may have omitted items which they consider likely to have given rise to the fluctuation. In addition, they were instructed that their probability ratings need not sum to 1.0.

<sup>2</sup> For analysis of the experiment, events were coded by plausibility level based on experienced auditors' probability judgments in Ho & May (1993).

### Medical Case

A brief lung cancer case was provided to the subjects. As in the audit case, subjects were asked to make either a diagnosis first or a prediction first. Seven items were presented:

Plausibility	Events
$Hi_1$ :	Has been smoking over 20 years.
$Hi_2$ :	Is a construction worker who received extensive exposure to asbestos in a job twenty years ago.
$Hi_1$ & $Lo_1$ :	Is both overweight, and has been smoking over twenty years.
$Lo_1$ :	Is overweight.
$Hi_1$ & $Hi_2$ :	Is both a construction worker who received extensive exposure to asbestos in a job twenty years ago and has been smoking over twenty years.
$Lo_1$ & $Lo_2$ :	Is both left-handed and overweight.
$Lo_2$ :	Is left-handed.

The DIAGNOSIS part of the medical case was described as follows:

A California Non-profit Organization recently conducted a health survey. The sample included 20,000 adult males of all ages and occupations. One man was selected by chance from the list of the participants and was found to have lung cancer. Call this man John Doe.

Subjects were asked, "Given John Doe was found to have lung cancer, the probability that *he has been smoking over twenty years* is. . . ." The rating ranged from 0 (no chance that the event or condition occurred) to 1.0 (completely certain that the event or condition occurred).

In the *PREDICTION* part, the case was presented as below.

A California Non-profit Organization initiated a study to identify precursors of lung cancer for adult males of all ages and occupations.

Subjects were asked, "Given the information that a male has been smoking over twenty years, the probability that *he has lung cancer* is. . . ." The rating ranged from 0 (no chance) to 1.0 (completely certain).

### Variables

One set of variables of interest in this study includes the probabilities a subject states for various elemental and conjunctive events. Another set of variables indicates whether or not conjunction errors<sup>3</sup> occur in each conjunctive judgment made by a subject. A subject's probability assessments for the compound event and its two component events in the "Diagnosis" version are compared. The presence of the effect is indicated by the probability of the conjunction being incorrectly greater than the probability of one or more of the individual events. When the probability of the

<sup>3</sup> The conjunction rule states that the probability of a conjunction,  $P(A \cap B)$ , cannot exceed the probability of either of its constituents,  $P(A)$  or  $P(B)$ .



conjunction is greater than one elemental event probability, a *single error* is recorded. However, when the probability of the conjunction is greater than both of its constituents' probabilities, a *double error* is recorded. Conformity means that the probability of a conjunction of two causes is not rated higher than the probability of each constituent.

## Results

### *Manipulation Check of Plausibilities of Events*

To assess the effectiveness of the plausibility manipulation, the responses to the probability assessments of each of the elemental events were averaged and analyzed. As desired, the average judged probabilities of the assumed higher probability events was larger than those of the assumed lower probability events, in both the audit and medical cases. In the audit case, the means of the two higher plausibility events were .62 ( $Hi_1$ ) and .61 ( $Hi_2$ ), and the means of the two lower plausibility events were .31 ( $Lo_1$ ) and .39 ( $Lo_2$ ). In the medical case, the means of the two higher plausibility events were .64 ( $Hi_1$ ) and .41 ( $Hi_2$ ), and the means of the two lower plausibility events were .29 ( $Lo_1$ ) and .33 ( $Lo_2$ ).

### *Conformance with the Conjunction Rule across Plausibility Levels*

Research in psychology has shown that people's assessments of conjunctive explanations are affected by the general level of plausibility of constituent events (Leddo, Abelson & Gross, 1984; Einhorn, 1985; Yates & Carlson, 1986). Specifically, people are more likely to have a single error when a conjunction includes one likely event and one unlikely event (labeled hereafter as the "Hi-Lo" condition) and a double error when a conjunction includes both likely events (labeled hereafter as the "Hi-Hi" condition). People conform to the conjunction rule more often when both events are unlikely (labeled hereafter as the "Lo-Lo" condition).

Table 1 summarizes the observed numbers and percentages of auditors' judgment behavior by plausibility and inference order for both the audit and medical cases. The data in this table can be averaged across inference orders to examine conformity with the conjunction rule by plausibility level. Specifically, auditors had the highest percentage of double errors when both individual events had high plausibilities. They had the highest percentage of single errors in the Hi-Lo condition, and correctly tended to rate the conjunction less likely than either cause when conjunctions involved only causes with low plausibilities. These within-subject results replicate the results found in experiments with psychology students. In a previous study with auditors, Ho and May (1993) did not find this result in a between-subject design.

TABLE 1  
OBSERVED NUMBERS AND PERCENTAGES OF AUDITORS' JUDGMENT BEHAVIOR BY PLAUSIBILITY AND BY INFERENCE ORDER

Inference order:	Plausibility								
	Hi-Hi			Hi-Lo			Lo-Lo		
	Diagnosis first	Prediction first	Overall	Diagnosis first	Prediction first	Overall	Diagnosis first	Prediction first	Overall
Panel A: Audit case									
Conformity	24 (63.2%)	13 (35.2%)	37 (49.3%)	15 (39.5%)	7 (18.9%)	22 (39.4%)	25 (65.8%)	10 (27.0%)	35 (46.7%)
Single conjunction error	7 (18.4%)	8 (21.6%)	15 (20.0%)	22 (57.9%)	23 (62.2%)	45 (60.0%)	11 (28.9%)	19 (51.4%)	30 (40.0%)
Double conjunction error	7 (18.4%)	16 (43.2%)	23 (30.7%)	1 (2.6%)	7 (18.9%)	8 (10.7%)	2 (5.3%)	8 (21.6%)	10 (13.3%)
	38 (100.0%)	37 (100.0%)	75 (100.0%)	38 (100.0%)	37 (100.0%)	75 (100.0%)	38 (100.0%)	37 (100.0%)	75 (100.0%)
Panel B: Medical case									
Conformity	23 (60.5%)	19 (50.0%)	42 (55.3%)	12 (31.6%)	8 (21.1%)	20 (26.3%)	25 (65.8%)	24 (63.2%)	49 (64.5%)
Single conjunction error	8 (21.1%)	10 (26.3%)	18 (23.7%)	21 (55.3%)	23 (60.5%)	44 (57.9%)	11 (28.9%)	10 (26.3%)	21 (27.6%)
Double conjunction error	7 (18.4%)	9 (23.7%)	16 (21.0%)	5 (13.2%)	7 (18.4%)	12 (15.8%)	2 (5.3%)	4 (10.5%)	6 (7.9%)
	38 (100.0%)	38 (100.0%)	76 (100.0%)	38 (100.0%)	38 (100.0%)	76 (100.0%)	38 (100.0%)	38 (100.0%)	76 (100.0%)

### *Effect of Order of Inference on Conformity with Conjunction Rule*

**Audit case.** In the audit case, the participating auditors' diagnoses were significantly affected by *Inference Order* in the Hi-Hi, Hi-Lo, and Lo-Lo conditions ( $\chi^2(2) = 6.29, p < .04$ ;  $\chi^2(2) = 7.42, p < .025$ , and  $\chi^2(2) = 12.15, p < .002$ , respectively). From Panel A of Table 1, we can observe that auditors, in the audit case, when asked to make a diagnosis first, tended to conform with the conjunction rule more frequently and had double errors less often. On the other hand, when asked to make a prediction first, auditors had less conformity with the conjunction rule and more double errors. For example, in the Hi-Hi condition, when asked to make a diagnosis first, 63.2 percent of the auditors conformed with the conjunction rule; however, when asked to make a prediction first, only 35.2 percent conformed with the rule. Following the same pattern, the auditors were more inclined to conform with the conjunction rule when they were asked to make a diagnosis before making a prediction under both the Hi-Lo (39.5% vs 18.9%) and Lo-Lo (65.8% vs 27.0%) conditions.

**Medical case.** In contrast, in the medical case (with which it was assumed auditors had little experience-related knowledge), the participating auditors' judgment behaviors were not significantly influenced by whether they had been asked to make a diagnosis first or a prediction first in the Hi-Hi, Hi-Lo or Lo-Lo conditions ( $\chi^2(2) = .85, p < .65$ ;  $\chi^2(2) = 1.22, p < .54$ ;  $\chi^2(2) = 1.22, p < .54$ , respectively). The descriptive statistics in Panel B of Table 1 also show that the auditors' judgment behaviors were not much influenced by the inference order. For example, in the Lo-Lo condition, the distributions of auditors' judgment behavior for making a diagnosis first and making a prediction first were almost identical. However, in general, those making diagnoses first still tended to conform with the conjunction rule slightly more often than those doing predictions first.

Taken together, these findings support our conjecture that when decision makers possess experience-related knowledge of the task, making predictions before making diagnoses may cause them to be more biased away from using the correct inference mode.

Next, we examined the probability judgments in more detail to investigate why auditors' diagnostic conjunction probability judgments differ significantly when preceded by predictive judgments in the familiar auditing domain, but not in the less familiar medical domain.

### *Diagnostic Conjunction Probability Assessments*

Table 2 contains a statistical comparison of the differences, under the two inference orders, in the probability  $P(X_1 \cap X_2 / S)$  of diagnostic conjunctive events, the probability that individual events  $X_1$  and  $X_2$  both preceded the signal  $S$  (the gross margin ratio increases). The results show,

TABLE 2  
COMPARISON OF AUDITORS' DIAGNOSTIC CONJUNCTION JUDGMENTS

Case	Plausibility of events		Inference direction		F	p	Significant difference?
			Diagnosis first	Prediction first			
	$X_1$	$X_2$	Average $P(X_1 \cap X_2/S)$	Average $P(X_1 \cap X_2/S)$			
Audit	Hi <sub>1</sub>	Hi <sub>2</sub>	.59	.69	$F(1, 73) = 3.878$	.05	Yes
	Hi <sub>1</sub>	Lo <sub>1</sub>	.36	.52	$F(1, 73) = 10.720$	.002	Yes
	Lo <sub>1</sub>	Lo <sub>2</sub>	.28	.40	$F(1, 73) = 5.100$	.03	Yes
Medical	Hi <sub>1</sub>	Hi <sub>2</sub>	.43	.49	$F(1, 74) = .799$	.37	No
	Hi <sub>1</sub>	Lo <sub>1</sub>	.51	.57	$F(1, 74) = 1.525$	.22	No
	Lo <sub>1</sub>	Lo <sub>2</sub>	.25	.27	$F(1, 74) = .215$	.64	No

Note. S represents background signal or effect.

in the audit case, that auditors' diagnostic judgments of the conjunctive events were significantly affected by whether the prediction or the diagnosis was presented first in the Hi-Hi, Hi-Lo, and Lo-Lo conditions ( $F(1, 74) = 3.878, p < .05$ ;  $F(1, 74) = 10.72, p < .002$ ;  $F(1, 74) = 5.10, p < .03$ ). When auditors were asked to make predictions before diagnoses, their diagnostic judgments were biased upward across all three plausibility conditions. Such higher diagnostic conjunction judgments can lead to more violations of the conjunction rule. In contrast, in the less familiar medical case, the inference mode did not significantly affect auditors' diagnostic judgments of conjunctive events at any level of plausibility, although those making predictions first still tended to give slightly higher values than did those making diagnoses first.

#### *Further Examination of Inference Order Effect*

To examine further the inference order effect, we compare predictive versus diagnostic judgments involving conjunctions in Table 3. Suppose that the auditors, in the more familiar audit case, are anchoring on the prediction  $P(S/X_1 \cap X_2)$  and are not adjusting sufficiently when making the diagnosis; then, little or no difference between  $P(S/X_1 \cap X_2)$  and  $P(X_1 \cap X_2/S)$  would be expected, even though, in general, the true probabilities will, of course, be different.

The results in Table 3 support this anchoring-adjustment explanation for the inference order effect. When auditors made predictions first for the familiar audit case, there was no significant difference between the prediction,  $P(S/X_1 \cap X_2)$  that the signal  $S$  (gross margin ratio increase) would occur, given both events  $X_1$  and  $X_2$  occurred, and the corresponding diagnosis,  $P(X_1 \cap X_2/S)$ , in any of the three plausibility levels. Thus, auditors may have anchored on their predictive judgments and insufficiently adjusted. In contrast, when auditors made diagnoses first, there

TABLE 3  
COMPARISON OF AUDITORS' DIAGNOSTIC VS PREDICTIVE JUDGMENTS

Case	Plausibility of events $X_1$ $X_2$		Inference direction					
			Diagnosis first			Prediction first		
			Average diagnosis $P(X_1 \cap X_2/S)$	Average prediction $P(S/X_1 \cap X_2)$	Significant difference? ( $p$ )	Average diagnosis $P(X_1 \cap X_2/S)$	Average prediction $P(S/X_1 \cap X_2)$	Significant difference? ( $p$ )
Audit	Hi <sub>1</sub>	Hi <sub>2</sub>	.59	.70	Yes (.04)	.69	.62	No (.10)
	Hi <sub>1</sub>	Lo <sub>1</sub>	.36	.51	Yes (.000)	.52	.55	No (.45)
	Lo <sub>1</sub>	Lo <sub>2</sub>	.28	.35	Yes (.07)	.40	.42	No (.50)
Medical	Hi <sub>1</sub>	Hi <sub>2</sub>	.43	.73	Yes (.000)	.49	.77	Yes (.000)
	Hi <sub>1</sub>	Lo <sub>1</sub>	.51	.63	Yes (.006)	.57	.69	Yes (.004)
	Lo <sub>1</sub>	Lo <sub>2</sub>	.25	.22	No (.21)	.27	.27	No (.96)

Note. S represents background signal or effect.

was a significant difference between the diagnosis  $P(X_1 \cap X_2 / S)$  and the subsequent prediction  $P(S / X_1 \cap X_2)$  in all three plausibility levels.

In the less familiar medical case, there was a significant difference in the diagnostic and predictive judgments in both inference orders for the Hi-Hi and Hi-Lo plausibility levels. In the Lo-Lo case, there was no significant difference, but it appears that the true probabilities may happen to be nearly equal, since the average of  $P(S / Lo_1 \cap Lo_2)$  across inference orders is about the same as the average of  $P(Lo_1 \cap Lo_2 / S)$  across inference orders.

So far, in the more familiar audit case, we have determined that diagnostic judgments of the form  $P(X_1 \cap X_2 / S)$  made after predictive judgments (1) resulted in more violations of the conjunction rule and (2) did not differ significantly from the corresponding predictive judgments  $P(S / X_1 \cap X_2)$ . We next explore whether changes in the elemental judgments used as building blocks to form the conjunctive diagnosis underlie these results.

### *The Einhorn Model of Conjunction Violations*

To account for the prevailing phenomenon of decision makers not conforming to the conjunction rule, Einhorn (1985) proposed a weighted geometric model of conjunctive explanation and illustrated its ability to model violations with some numerical examples. According to Einhorn, the proposed model can identify conjunction errors, as well as the types of errors (i.e., whether the conjunctive event is rated higher than both or one of the constituent events), in both prediction and diagnosis. The model states:

$$P(X_1 \cap X_2 / S) = (P(X_1 / S) \cdot P(X_2 / S))^{1 - P(S / X_1 \cap X_2)}$$

In detail, the fraction  $P(X_1 \cap X_2 / S)$  is a function of  $P(X_1 / S)$  and  $P(X_2 / S)$ , the fraction of the times that  $X_1$  and  $X_2$  precede  $S$ , respectively, among the times  $S$  occurs. It also is a function of the probability  $P(S / X_1 \cap X_2)$ . In fact, the probability that  $S$  would occur given that both events  $X_1$  and  $X_2$  occurred,  $P(S / X_1 \cap X_2)$ , can be seen as a measure of the representativeness of both events  $X_1$  and  $X_2$  to the signal  $S$ . In other words, the higher the representativeness of both events  $X_1$  and  $X_2$  to the signal, which results in a greater weight for the  $P(X_1 / S)P(X_2 / S)$  product (because the product is raised to a smaller power), the higher the probability of the conjunctive events given the signal.

For each diagnostic conjunction judgment, the probability predicted by the Einhorn model was compared with the actual probability judgment made. The average diagnostic conjunction probabilities  $P(X_1 \cap X_2 / S)$ , along with the average probabilities for the model's independent variables ( $P(X_1 / S)$ ,  $P(X_2 / S)$ , and  $P(S / X_1 \cap X_2)$ ), are in Table 4. The results in Table 4 show that the average probability of each of the model's three indepen-

TABLE 4  
COMPARISON OF ACTUAL AUDITORS' JUDGMENT WITH MODEL AND ELEMENTS IN THE MODEL

Einhorn's model						
Case	Independent variables			Dependent variable $P(X_1 \cap X_2/S)$	Actual average $P(X_1 \cap X_2/S)$	Significant difference between model & actual judgment? ( <i>t</i> , <i>P</i> )
	$P(X_1/S)$	$P(X_2/S)$	$P(S/X_1 \cap X_2)$			
Audit						
<u>Hi<sub>1</sub>-Hi<sub>2</sub></u>						
Diag. 1st	.61	.62	.70	.75	.59	Yes (4.32, .00)
Pred. 1st	.62	.60	.62	.67	.69	No (.57, .57)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.005, .95)	No (.082, .78)	No (1.770, .19)	No (.22)	Yes (3.878, .05)	
<u>Hi<sub>1</sub>-Lo<sub>1</sub></u>						
Diag. 1st	.61	.31	.51	.42	.36	No (1.69, .10)
Pred. 1st	.62	.31	.55	.44	.52	No (1.68, .10)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.005, .95)	No (.000, .99)	No (.352, .56)	No (.42)	Yes (10.720, .002)	
<u>Lo<sub>1</sub>-Lo<sub>2</sub></u>						
Diag. 1st	.31	.38	.35	.28	.28	No (.16, .87)
Pred. 1st	.31	.40	.42	.34	.40	Yes (2.27, .03)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.000, .99)	No (.137, .71)	No (1.760, .19)	No (.32)	Yes (5.100, .03)	
Medical						
<u>Hi<sub>1</sub>-Hi<sub>2</sub></u>						
Diag. 1st	.63	.40	.73	.65	.43	Yes (5.66, .00)
Pred. 1st	.66	.42	.77	.73	.49	Yes (5.45, .00)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.484, .49)	No (.237, .63)	No (1.061, .31)	No (.25)	No (.799, .37)	
<u>Hi<sub>1</sub>-Lo<sub>1</sub></u>						
Diag. 1st	.63	.30	.21	.57	.51	No (1.40, .17)
Pred. 1st	.66	.27	.21	.62	.57	No (1.67, .10)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.484, .49)	No (.197, .66)	No (1.440, .23)	No (.29)	No (1.525, .22)	
<u>Lo<sub>1</sub>-Lo<sub>2</sub></u>						
Diag. 1st	.30	.34	.22	.19	.25	Yes (2.51, .02)
Pred. 1st	.27	.32	.27	.19	.27	Yes (3.65, .001)
Sign. diff.? ( <i>F</i> , <i>p</i> )	No (.197, .66)	No (.703, .40)	No (1.663, .20)	No (.99)	No (.215, .64)	

dent variables did not differ significantly between those who made diagnoses first and those who made predictions first, in either the audit case or the medical case.

Since the independent variables do not differ significantly due to inference order, the model's resulting dependent variable,  $P(X_1 \cap X_2 / S)$ , should not be affected by inference order. In Table 4, each subject's own independent variables were substituted into the equation and the resulting dependent variable was calculated. As seen from the Table 4, there is no significant difference between the model-calculated dependent variable,  $P(X_1 \cap X_2 / S)$ , under the two inference orders for all plausibility levels and for both the familiar audit case and the less familiar medical cases.

So, the observed differences in the actual judgment in the audit case due to inference order can not be explained by differences in the independent variables in the Einhorn model. In particular, two of the independent variables are diagnostic judgments,  $P(X_1 / S)$  and  $P(X_2 / S)$ . For these elemental judgments, there was no inference order effect, although for the more complicated diagnostic conjunction judgment there were inference order effects.

## EXPERIMENT 2

To examine whether the inference order effect observed in Experiment 1 is partly due to differences in the tasks rather than just differences in experience-related knowledge, we conducted another experiment differing from Experiment 1 only in that the subjects were students who have little or no experience-related knowledge in either audit or medical cases. Eighty-three MBA students from University of California, Irvine, enrolled in an introductory management accounting class, voluntarily participated in the experiment.

## Results

### *Manipulation Check of Plausibilities of Events*

Due to a lack of experience-related knowledge, students' assessments of the probabilities of events in the audit case are quite different from those of auditors'. The average judged probabilities of the assumed higher probability events were not different from those of the assumed lower probability events in the audit case. The means of the two higher plausibility events were .45 ( $Hi_1$ ) and .46 ( $Hi_2$ ) and the means of the two lower plausibility events were .45 ( $Lo_1$ ) and .45 ( $Lo_2$ ). In contrast with the audit case, students' assessments of the events in the medical case are very similar to auditors' assessments. The average judged probabilities of the assumed higher probability events was larger than those of the assumed lower probability events. The means of the two higher plausibility events



were .63 ( $Hi_1$ ) and .38 ( $Hi_2$ ), and the means of the two lower plausibility events were .24 ( $Lo_1$ ) and .33 ( $Lo_2$ ). Of course, no matter what students' subjective probabilities are, they still should obey the conjunction rule. For consistency with the analysis of Experiment 1, the events are still coded the same as  $Hi_1$ ,  $Hi_2$ ,  $Lo_1$ , and  $Lo_2$ .

To compare with the results of auditors' judgments by plausibility and inference order in Experiment 1, the observed corresponding numbers and percentages of students' judgment behavior for both the audit and medical cases are shown in Table 5.

#### *Effect of Order of Inference on Conformity with Conjunction Rule*

*Audit case.* In the audit case (with which it was assumed students had little experience-related knowledge) the students' diagnoses were not significantly affected by *Inference Order* in any of the Hi-Hi, Hi-Lo or Lo-Lo conditions ( $\chi^2(2) = 2.16, p < .34$ ;  $\chi^2(2) = .63, p < .73$ , and  $\chi^2(2) = 2.09, p < .35$ , respectively). As can be seen from Panel A of Table 5, in the audit case, students' conformity with the conjunction rule was not influenced by whether they were asked to make a diagnosis first or a prediction first. For example, in the Hi-Hi condition, when asked to make a diagnosis first, 36.6% of the students conformed with the conjunction rule; similarly, when asked to make a prediction first, 33.3 percent conformed with the rule. Following the same pattern, the subjects were not more significantly inclined to conform with the conjunction rule when they were asked to make a diagnosis before making a prediction under both the Hi-Lo (36.6% vs 35.7%) and Lo-Lo (46.3% vs 31.0%) conditions.

*Medical case.* Similar to the audit case, in the medical case (with which it was assumed students also had little experience-related knowledge), the students' judgment behaviors were not significantly influenced by whether they had been asked to make a diagnosis first or a prediction first in any of the Hi-Hi, Hi-Lo or Lo-Lo conditions ( $\chi^2(2) = 2.29, p < .32$ ;  $\chi^2(2) = 3.16, p < .21$ ;  $\chi^2(2) = 2.54, p < .28$ , respectively). The descriptive statistics in Panel B of Table 5 also show that the students' judgment behaviors were not much influenced by the inference order. For example, in the Hi-Hi condition, when asked to make a diagnosis first, 56.1% of the students conformed with the conjunction rule; similarly, when asked to make a prediction first, 52.4% conformed with the rule.

#### *Diagnostic Conjunction Probability Assessments*

A statistical comparison of the differences in the probability  $P(X_1 \cap X_2 / S)$  of diagnostic conjunctive events under the two inference orders is shown in Table 6. Recall that auditors' assessments of the joint explanations were biased upward across all three plausibility conditions when they made predictions first; in contrast, students' judgments

TABLE 5  
OBSERVED NUMBERS AND PERCENTAGES OF STUDENTS' JUDGMENT BEHAVIOR BY PLAUSIBILITY AND BY INFERENCE ORDER

Inference order:	Plausibility								
	Hi-Hi			Hi-Lo			Lo-Lo		
	Diagnosis first	Prediction first	Overall	Diagnosis first	Prediction first	Overall	Diagnosis first	Prediction first	Overall
Panel A: Audit case									
Conformity	15 (36.6%)	14 (33.3%)	29 (34.9%)	15 (36.6%)	15 (35.7%)	30 (36.2%)	19 (46.3%)	13 (31.0%)	32 (38.6%)
Single conjunction error	18 (43.9%)	14 (33.3%)	32 (38.6%)	19 (46.3%)	17 (40.5%)	36 (43.3%)	14 (34.2%)	19 (45.2%)	33 (39.8%)
Double conjunction error	8 (19.5%)	14 (33.3%)	22 (26.5%)	7 (17.1%)	10 (23.8%)	17 (20.5%)	8 (19.5%)	10 (23.8%)	18 (21.7%)
	41 (100.0%)	42 (99.9%)	83 (100.0%)	41 (100.0%)	42 (100.0%)	83 (100.0%)	41 (100.0%)	42 (100.0%)	83 (100.0%)
Panel B: Medical case									
Conformity	23 (56.1%)	22 (52.4%)	45 (54.2%)	7 (17.1%)	14 (34.2%)	21 (25.6%)	32 (78.0%)	28 (68.3%)	60 (73.2%)
Single conjunction error	14 (34.1%)	11 (26.2%)	25 (30.1%)	27 (65.8%)	21 (51.2%)	48 (58.5%)	7 (17.1%)	11 (26.8%)	18 (22.0%)
Double conjunction error	4 (9.8%)	9 (21.4%)	13 (15.7%)	7 (17.1%)	6 (14.6%)	13 (15.9%)	2 (4.9%)	2 (4.9%)	4 (4.8%)
	41 (100.0%)	42 (100.0%)	83 (100.0%)	41 (100.0%)	42 (100.0%)	82 (100.0%)	41 (100.0%)	41 (100.0%)	82 (100.0%)

TABLE 6  
COMPARISON OF STUDENTS' DIAGNOSTIC CONJUNCTION JUDGMENTS

Case	Plausibility of events		Inference direction		F	p	Significant difference?
			Diagnosis first	Prediction first			
	X <sub>1</sub>	X <sub>2</sub>	Average $P(X_1 \cap X_2/S)$	Average $P(X_1 \cap X_2/S)$			
Audit	Hi <sub>1</sub>	Hi <sub>2</sub>	.50	.48	$F(1, 81) = .007$	.93	No
	Hi <sub>1</sub>	Lo <sub>1</sub>	.42	.47	$F(1, 81) = 1.410$	.24	No
	Lo <sub>1</sub>	Lo <sub>2</sub>	.46	.48	$F(1, 81) = .141$	.71	No
Medical	Hi <sub>1</sub>	Hi <sub>2</sub>	.46	.36	$F(1, 81) = 2.291$	.13	No
	Hi <sub>1</sub>	Lo <sub>1</sub>	.56	.49	$F(1, 81) = 1.787$	.19	No
	Lo <sub>1</sub>	Lo <sub>2</sub>	.22	.20	$F(1, 81) = 1.60$	.69	No

Note. S represents background signal or effect.

were not affected by whether they were asked to make predictions before diagnoses or not. As seen from Table 6, the inference mode did not significantly affect students' diagnostic judgment of conjunctive events in the Hi-Hi, Hi-Lo or Lo-Lo conditions ( $F(1, 81) = .007, p < .93$ ;  $F(1, 81) = 1.410, p < .24$ ;  $F(1, 81) = .141, p < .71$ ).

Similarly, in the medical case, students' diagnostic judgments of the conjunctive events were not affected by whether the prediction or the diagnosis was presented first in the Hi-Hi, Hi-Lo or Lo-Lo conditions ( $F(1, 81) = 2.291, p < .13$ ;  $F(1, 81) = 1.787, p < .19$ ;  $F(1, 81) = .160, p < .69$ ).

In general, these findings support our conjecture that when decision makers do not possess experience-related knowledge of the task, making predictions before making diagnoses does not affect their diagnostic judgments. Since students' diagnoses were not affected by the inference order in both the audit case and the medical case condition, there is no need for us to make further examination of the inference order effect as we did in Experiment 1.

## GENERAL DISCUSSION

Ideally, a decision maker's diagnostic probability judgments should not be affected by the inference presentation order. However, our findings indicate that auditors' diagnostic conjunctive probability judgments were strongly influenced by making a prediction in advance in the audit case, with which they had experience-related knowledge. Conversely, in the medical context, with which auditors had little or less experience, their diagnoses were not affected by earlier predictions at all. It appears that experience-related knowledge contributed to the differences between the results of the two cases. Although somewhat simplistic, the audit case is familiar to auditors and is job related. In Experiment 2, we found that

students, lacking experience-related knowledge in both the audit and the medical cases, were not influenced by the inference order in making diagnoses. Thus differences between the audit and medical tasks as a potential explanation for auditors' diagnoses being affected by the inference order in the audit case but not in the medical case can be discounted by the second experiment's results with student subjects. Combining the findings of these two experiments, we can conclude that when the task involved a domain with which people had experience, making predictions prior to diagnoses had a significant influence on their subsequent diagnostic conjunction probabilities.

Our finding of inference order effects for more familiar tasks is related to Frederick and Libby's (1986) finding that experienced auditors' probability judgments are affected by the representativeness of an event, but students are not affected by differences in representativeness. Previous studies, across a range of tasks and auditor-experience levels, suggest that auditors are more motivated and tend to give more attention to more realistic and job-related experimental cases (Smith & Kida, 1991). Paradoxically, familiarity with the judgment domain was a liability in our experiment, since making a prediction before a diagnosis altered the diagnosis only when the participants were familiar with the domain.

One explanation for why inference order affected diagnostic conjunction judgments in the more familiar audit case seems quite plausible. Auditors probably have richer mental schema for such audit-context judgments. In particular, our auditor subjects may have had more experience in making predictive judgments due to the nature of the audit process, and thus may have stronger links in directions requiring predictive judgments than in directions requiring diagnoses. So, when first asked to make a series of predictive judgments of the form  $P(S/X_1)$ , the subjects would have activated a set of nodes and arcs in their mental associative network for auditing events. By doing this, they would have made judgments conditioned on conjunctive events occurring, i.e.,  $P(S/X_1 \cap X_2)$ , which may then have served as anchors for subsequent diagnostic judgments. In particular, judgments conditioned on conjunctive events may be especially affected since conjunctions may be harder to reason about than elemental events such as when estimating  $P(S/X_1)$ . When asked later to make a diagnostic judgment of the form  $P(X_1 \cap X_2/S)$ , the auditors may have anchored incorrectly on the predictive judgment  $P(S/X_1 \cap X_2)$  and made insufficient adjustment to the diagnostic judgment. This is related to Beyth-Marom's (1980) possible explanation for the conjunction effect which hypothesizes anchoring on the conditional probability,  $P(X_1/X_2)$ , and insufficient adjustment in estimating the probability of the conjunction,  $P(X_1 \cap X_2)$ . On the other hand, in the less familiar medical case, both diagnostic and predictive judgments may be constructed without the aid

of a pre-existing detailed mental schema, so inference order would not show the strong effect seen with the more familiar audit case.

Previous studies suggest that when the experimental tasks are more analogous to typical audit judgments, and therefore more familiar to auditors, anchoring and adjustment heuristics were completely eliminated or significantly mitigated (see Smith & Kida, 1991). Furthermore, they attribute this phenomenon to the level of expertise of the subjects and the extent to which the experimental task is job-related and familiar to the subjects. However, in this study, we observe the opposite, i.e., in making diagnoses, auditors may have used anchoring and adjustment heuristics in the familiar audit case but not in the less familiar medical case. It appears that training and experience-related knowledge benefits some, but not all, tasks. Future research should explore how task-related experience affects diagnoses and predictions.

An alternative explanation for the inference order effect would be linguistic confusion: subjects don't understand the difference between the probability of an event given a signal has occurred and the probability of the signal, given that an event has occurred. But Locksley and Stangor (1984) and Morier and Borgida (1984) found linguistic confusion did not appear to underlie conjunction violations in standard conjunction paradigm experiments. Future research should investigate these and other alternative explanations for the inference order effect found in this study.

It was found that Einhorn's weighted geometric model captures moderately well the general pattern of departures from the conjunction rule in both the audit and medical cases. However, the model tends to give calculated values for the diagnostic conjunctive probability which are too extreme, being too high when both elemental events are highly likely and too low when both are quite unlikely. A simple modification is to adjust the model's calculated conjunctive probability  $P(X_1 \cap X_2/S)$  by multiplying it by  $1.50 - P(X_1 \cap X_2/S)$ . If Einhorn model's calculated value is near .50, then this original value is larger (smaller) than .50, then the original value will be decreased (increased). This proposed modification to Einhorn's original model needs examination in future research. Also, the inference order effect could be incorporated directly into Einhorn's model. Future research should first replicate the effect before considering whether and how to model it.

Judgment research has shown that people make likelihood judgments according to a wide variety of heuristic procedures (cf. Einhorn & Hogarth, 1981; Pitz & Sachs, 1984). That is, even if people use the conjunction rule on one problem, they may not necessarily apply that strategy to other problems. It is very interesting to note that the auditors in this study apparently used different procedures within the same problem context and in different problem contexts. This finding suggests that decision

makers' use of the conjunction rule in assessing the likelihoods of conjunctive events is a contingent behavior. This is similar to the proposal by Yates and Carlson (1986) that people have a broad repertoire of likelihood judgment procedures. Our finding that the more experience a person has with the judgment context, the more likely it is that his/her diagnosis will be affected by making a prediction first, raises serious concern about audit efficiency (due to use of incorrect investigation strategies) and highlights the need for decision aids. In addition to receiving general assistance in probabilistic reasoning, auditors may want to make diagnostic and predictive judgments in separate sessions to avoid possible effects on judged probabilities due to making both diagnostic and predictive inferences during the same audit session.

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