Journal of Behavioral Decision Making
J. Behav. Dec. Making, **14**: 257–278 (2001)
DOI: 10.1002/bdm.376

Managers' Variance Investigation Decisions: An Experimental Examination of Probabilistic and Outcome Ambiguity

JOANNA L. Y. HO[1]*, L. ROBIN KELLER[1] and PAMELA KELTYKA[2]
[1]*Graduate School of Management, University of California, Irvine, USA*
[2]*G.W. Daverio School of Accountancy, University of Akron, USA*

ABSTRACT

Information ambiguity is prevalent in organizations and may influence management decisions. This study examines, given imprecise probabilities or outcomes, how managers decide which department's performance to investigate further when they are provided with performance benchmarks expressed in numerical intervals. Seventy-nine MBA students participated in two experiments involving investigation decisions. We presented participants with interval benchmarks of a firm's expenses. Being below or above the benchmark should have been seen as equally negative. We found that, when facing outcome ambiguity, our participants consistently preferred to investigate further those departments whose performance was described as having an ambiguous outcome (when the outcome's range was centered either below or above the interval benchmark). However, when facing probabilistic ambiguity, there were two predominant choice patterns: consistently choosing to investigate the department whose performance is described with an ambiguous probability, or consistently choosing to investigate the department with unambiguous performance. To gain further insight, we conducted a follow-up study collecting written protocols of participants' reasons for making choices involving ambiguous performance information. The results show that our participants displayed similar decision-making processes when facing outcome ambiguity and probabilistic ambiguity. Copyright © 2001 John Wiley & Sons, Ltd.

KEY WORDS decision frame; interval benchmark; outcome ambiguity; probabilistic ambiguity; decision-making process

Studies of decision behavior have shown that ambiguity affects choices in both simple-context tasks, such as choice between monetary gambles (Ellsberg, 1961; Slovic and Tversky, 1974; Curley *et al.*, 1986), and context-rich tasks, such as patient decision making (e.g. Curley *et al.*, 1984), business decisions (e.g. Camerer and Weber, 1992; Einhorn and Hogarth, 1986; Hoch and Ha, 1986; Hogarth and Kunreuther, 1985; Taylor, 1995), and sports and politics (Heath and Tversky, 1991). Most research on the effects of ambiguity in decision making has focused on probability. Nonetheless, both probabilistic and outcome ambiguity are prevalent in managerial settings and may influence management decisions. In this study, we examine how

*Correspondence to: Joanna L. Y. Ho, University of California, Irvine, GSM 350, Irvine, CA 92697-3125, USA. E-mail: jlho@uci.edu

managers make choices about which department's performance to investigate when they are given performance information involving outcome and probabilistic ambiguity.

The managerial context we investigate herein is called variance investigation. In managerial settings, observed deviations of actual results from benchmarks or standards are called 'variances'. These deviations provide a basis for management to take corrective actions where necessary. Variances provide the opportunity to monitor and revise goals, plans, and budgets according to a department's performance. Managers often rely on variance reports compiled and generated by their accounting professionals to identify problem areas in their operations and allocate resources accordingly. When faced with an operational variance, managers must decide if the deviation results from a minor variation not worth further investigation or from a potentially serious problem which might justify further investigation.

While managers' investigation choices among various departments under their leadership are primarily based on possible performance results and their relative likelihoods, their managerial decisions may also be affected by any ambiguity[1] concerning these performance outcomes and probabilities (Curley and Yates, 1985; Kahn and Sarin, 1988). For example, the outcome 'communication expenses were 13% of a laboratory's total expenses' is unambiguous; the outcome 'the expenses were somewhere in the range from 11% to 15%' is ambiguous. The ambiguously described outcome is vague about what the actual expenses were. It is unambiguous to state that 'the probability that there will be a problem in a division's training and development expense process is equal to 40%', but ambiguity does exist when a manager can only conclude that the probability of a problem is between 20% and 60%. In the first case, the stochastic process is precisely known, even though there is probabilistic uncertainty about which outcome will occur: there is exactly a 40% chance that there will be a problem and a 60% chance that there will be no problem. In the second case, in addition to the probabilistic uncertainty, there is ambiguity about what the correct probability is. Thus, ambiguity occurs when there is 'uncertainty about the processes by which the outcomes are determined' (Curley and Yates, 1985, p. 274).

Most prior studies use a single benchmark or a target point to examine the effect of ambiguity on individuals' choices. In this study, we use an interval benchmark to specify an acceptable range within which the divisions' performance in various expense categories is gauged. For example, such a benchmark might set a budget for communication expense to be between 10% and 13% of the total operating expenses. The American Accounting Association (1966, p. 54) recognized that accounting information (a benchmark, for example) used within a company may be communicated 'as a single number [a point estimate], as an interval estimate, [or] a probability distribution'. Accounting systems have traditionally implied that a target or a benchmark used to measure performance will be a single number. Ho *et al*. (2001) investigated ambiguity in probabilities or outcomes when managers have a single number target and are making various investment choices. However, in practice, there are many occasions when management may predetermine an acceptable range of outcomes for costs and revenues, to reflect the dynamic environment and also to incorporate random fluctuations (Horngren *et al*. 1997). For example, top management at Chrysler engages in management-by-exception and investigates variances only when they are outside an 'acceptable range', which allows management to disregard many apparently minor variances (Raiborn *et al.*, 1996). Also, according to Knight (1992), for the past 30 years Emerson Electric has set a yearly target interval for cost improvements at 6%–7% a year. Lentini (1993) reported that the CPA firm of Altschuler, Melvain & Glasser in Chicago allocated 2–6% of their revenues to implement marketing strategies. Therefore, this study examines interval benchmarks, since they are also managerially relevant, but not often studied.

Prior research has shown that whether the actual outcomes are seen as good or bad may affect managers' attitude toward taking risks[2] (Kahneman and Tversky, 1979) and their attitude toward ambiguity (Kahn and

[1]In the decision theory literature, 'ambiguity' and 'vagueness' are often used interchangeably. We use the term 'ambiguity' throughout this paper.

[2]Risk occurs when 'the decision maker does not know for certain what the ultimate outcomes of his choices will be' (Yates and Zukowski, 1976, p. 19), because the outcome will be the result of a probabilistic process.

Sarin, 1988; Ghosh and Ray, 1992). Similarly, whether variances are above or below the interval benchmark may also affect managers' attitude toward ambiguity and their risk attitude. Thus, to better understand how probabilistic and outcome ambiguity in the presence of interval benchmarks affect managers' investigation decisions, we examine above-benchmark and below-benchmark cases in our study.

Camerer and Weber (1992, section 5) review applications of probabilistic ambiguity in decision making in medicine, health, insurance, legal liabilities, taxes, marketing, and financial markets. The results of this stream of research will be of potential use to managers, since the way variance reports are framed (with ranges of outcomes or percentages of time outcomes meet or fail to meet a target) may affect managers' actions.

THEORETICAL ISSUES AND HYPOTHESES DEVELOPMENT

Variance Investigation Decisions

In the course of variance investigations, the target benchmark provides managers the opportunity to monitor results, make corrections, and evaluate performance. Once cost variances (i.e. differences between actual results and targets) are computed and reported, management must decide whether the deviations from plan are significant enough to justify further investigation. When variances are within the interval benchmark, they are often assumed to be caused by minor random factors, and no further investigation is undertaken. However, when a variance falls outside the interval benchmark, the deviation may be assumed to be caused by non-minor factors that managers may attempt to control, and immediate action may need to be taken.

In making variance investigation decisions, managers are assumed to perform a mental cost–benefit analysis of the two alternative actions: investigating the variance or not investigating the variance. The costs of investigation include the managerial time of both the investigating manager and the employees in the department to be investigated, the cost of testing procedures, the disruption of the production process while the investigation is conducted, and the corrective actions taken to eliminate the cause of a variance. In contrast, a benefit might include savings resulting from correcting a system that is found to be out of control, or from not investigating a system that is already in control. Managers may estimate these costs and the associated probabilities and benefits and then implicitly calculate the expected costs in order to arrive at an optimal decision regarding investigation. Although the investigation decision is made *ex ante* (i.e. before the results of the investigation are known), managers' investigation decisions are evaluated by their superiors on the basis of overall *ex post* costs and the results of the investigations.

As discussed above, due to limited resources of time and money, managers can not investigate every variance but must focus on significant variances. Kaplan (1975) provides a detailed explanation of variance selection approaches that range from the very basic (investigate all variances that fall outside a given level) to the very complex (the use of probability theory). However, surveys regarding whether or not a variance should be investigated indicate that these decisions tend to be based on managerial judgment, when a variance exceeds a given dollar amount, or when a variance exceeds a given percent of a standard (Gaumnitz and Kollaritsch, 1991; Laudeman and Schaeberle, 1983; Ricketts and Nelson, 1987). Although several articles (i.e. Davis, 1973; Robbins and Jacobs, 1985) have described the benefits of using a statistical model when making a variance investigation, Chow and Haddad (1989) report that more complex techniques, such as probability theory, are generally not used. Instead, managers tend to use simpler 'rule of thumb' measures. Our aim is to study how ambiguity affects experimental participants' choices about conducting investigations.

Outcome ambiguity and probabilistic ambiguity in variance investigation decisions

In variance investigation contexts, there are many situations in which a manager is provided with a target benchmark stated as an interval of numerical outcome values, with outcomes above and below the target

being equally negative.[3] For example, consider expenditures used in running a division. Rather than operating on a single-figure benchmark, all divisional managers may be told that the training and development expenditures should be maintained at 9–12% of the direct labor costs; this expresses the importance divisional managers place on training. Too little training expense is bad because employees will be likely to work inefficiently. Similarly, too much training expense is bad because it is too costly and not worth the effort for extra employee efficiency. While reviewing the last 12 months' expenditures, the central manager may observe that division A has consistently operated its training and development program at 13% of direct labor costs, while division B has operated anywhere from between 8% to 18% of direct labor costs. Given limited resources, the central manager has to decide which division he or she would investigate. (By construction, division A's precise outcome of 13% is the midpoint of division B's range of outcomes, from $13\% \pm 5\%$. This is how we construct our outcome ambiguity tasks.)

Probabilities can also be used when discussing a variance from an interval benchmark. In managerial situations, probabilities can vary due to different estimates, different assumptions, and broad department categories including subunits with different probabilities. A manager may be told that there is a 65% chance that divisions C's expenditure will be less than 9% (the lowest level of the 9–12% interval benchmark), while there is a 45–85% chance that division D is spending less than 9% of its direct labor costs on training and development. Once again, the central manager may not have enough resources to investigate both divisions C and D. He or she must decide which division to investigate. (By construction, division C's precise probability of 0.65 is the midpoint of division D's range of probabilities, 0.65 ± 0.20. This is how we construct our probabilistic ambiguity tasks.)

Research approach

Since little or no experimental research has been published on interval benchmarks in which being above or below the benchmark is equally bad, we have developed two pairs of competing hypotheses: the uncertainty resolution hypothesis versus the uncertainty avoidance hypothesis. We chose to start our investigation by collecting data about choices between investigating a division with ambiguous information or investigating one with precise information. To enrich our understanding, we then had another group of subjects give written reasons for their choices (which will be discussed later). We begin by assuming that a similar decision process is involved when managers face either outcome or probabilistic ambiguity in making their variance investigation decisions. Our argument that a similar decision process is involved when facing both kinds of ambiguity is also consistent with the perspective of Camerer and Weber (1992). According to Camerer and Weber, one way of framing a department with an ambiguous outcome is that there is a probability distribution over the stated range of the outcome. This then reduces outcome ambiguity to an unspecified probability distribution over outcomes. In other words, outcome ambiguity is really decision making under risk. In further support of this assumption, Kuhn and Budescu (1996) report that individuals tend to hold congruent attitudes toward ambiguity in the presence of probabilistic and outcome ambiguity.

Uncertainty-resolution hypotheses

Assume that, when making investigation decisions, managers will make choices reflecting (1) their dislike of uncertainty and (2) their tendency to resolve uncertainty associated with ambiguity. Suppose a central manager observes a division with a wide range within which the *outcome* may fall. As discussed above, Camerer and Weber (1992) claim that ambiguity about outcomes should be looked at as a probability distribution over outcomes. In our case, since there is no information about the probability distribution over the possible outcome values, the manager may be concerned about the variability involved and the possibility that the true data point is the one farthest from the target. This will lead a manager to resolve uncertainty by investigating

[3]We will not investigate here the cases in which outcomes below the target are bad and above the target are exceptionally good. This can occur, for example, if there is a target for profits.

the division with an ambiguous outcome (e.g. expenses were somewhere between 8–18% of direct labor costs) rather than an otherwise identical division, which has an unambiguous outcome of expenses (e.g. 13% of direct labor costs). Another possibility is that a manager may tend to focus his or her attention on the 'worst-case scenario' with the high end of the outcome (e.g. 18% of direct labor costs) and feel that the ambiguous department deserves investigation more than the unambiguous one (e.g. having a precise estimate of a 13% of direct labor costs). Furthermore, as discussed above, we expect managers to understand that being either above or below the targeted range is equally bad. Thus, they are expected to make similar managerial choices across the 'below interval' and 'above interval' contexts. The above discussion leads to the following hypothesis:

***Uncertainty-resolution* ambiguous *outcome* investigation hypothesis** Decision makers analyzing expense variances will tend to select the ambiguous department with the *imprecise outcome* (of $x\% \pm 5\%$) for further examination rather than the corresponding unambiguous department (with the midpoint $x\%$ of the imprecise outcome). This will apply when $x\%$ is either *above or below an interval benchmark*.

Following this account of the variance investigation setting, we expect that people will focus their attention on the data variability and therefore tend to resolve uncertainty whether the information involves outcome or probabilistic ambiguity. We next look at probabilistic ambiguity.

There are two reasons that a manager might be more likely to investigate the ambiguous division with the *imprecise probability* than the corresponding unambiguous department. Similar to the outcome ambiguity case, a manager may feel that a range of probabilities (e.g., a 45–85% chance of falling below the lower bound of a performance target) is more uncertain than a point estimate (e.g. a 60% chance of falling below the target). The manager may have a tendency to resolve uncertainty by investigating the ambiguous department to better understand its process. Alternatively, a manager may tend to focus his or her attention on the 'worst-case scenario' with the high end of the probabilities (e.g. 85% chance) and feel that the ambiguous department deserves investigation more than the unambiguous one (e.g. having a precise estimate of a 65% chance). There is some evidence of focusing on the 'worst-case scenario' or 'bad news information' in a protocol study by Ross (1989). Under higher probabilistic ambiguity, subjects took longer to make a decision on a new consumer product and looked longer at 'bad news' information. Therefore, the following hypothesis is proposed:

***Uncertainty-resolution* ambiguous *probability* investigation hypothesis** Decision makers analyzing expense variances will tend to select the ambiguous department with the *imprecise probability* (of $p \pm \Delta$) of missing the interval benchmark by being above it (one case) or below it (second case) for further examination rather than the corresponding unambiguous department (with the midpoint p of the imprecise probability). This will apply when $p>0.5$ is the probability of falling above the interval benchmark (one case), or falling below the interval benchmark (second case).

Next, we describe the competing uncertainty-avoidance hypotheses that are based on findings of prior studies that use reference points to divide gain and loss domains.

Uncertainty-avoidance hypotheses

In some prior experiments on probabilistic ambiguity, (e.g. Kahn and Sarin, 1988), it was found that when there is probabilistic ambiguity, a person prefers the ambiguous option (demonstrating ambiguity proneness) in the loss domain and the unambiguous option in the gain domain (demonstrating ambiguity aversion). Ho *et al*. (2001) also demonstrated domain-contingent investment choices involving outcome ambiguity, managers tend to be ambiguity averse in the gain domain and ambiguity prone in the loss domain. A reason for ambiguity proneness in the loss domain is that there may be a good chance of getting back up to the neutral reference level, or 'zero' point. This also can be explained by the 'hope' effect (i.e. offering a chance of avoiding the adverse event) suggested by Viscusi and Chesson (1999).

The payoff function is single peaked in the context of variance investigation, so there are no distinct gain and loss domains. Instead, an option that performs within the interval benchmark (at the 'peak' of the payoff)

may be considered a neutral or a gain condition, and an option that performs outside (either above or below) the benchmark is considered a loss condition. Our study presents choices involving the loss domain, since both options (ambiguous or unambiguous) lead to some outside-the-benchmark performances.[4] Note that the choice in the prior studies (e.g. Kahn and Sarin, 1988; Ho *et al.*, 2001) is focused on selecting the better option (e.g. choosing an investment). In contrast, the choice in this study is focused on selecting the worse option; that is, the department to be investigated.

Consistent with the ambiguity proneness in the loss domain for investment choices in prior studies, in a context of variance investigation managers may think that a department with ambiguous performance is more natural or is doing better than one with unambiguous performance, since it has the potential to reach the better end of the ambiguous information's range. In this case, a manager may select the unambiguous department to examine why it has consistently overspent or underspent in the past. That is, he or she may choose to investigate the department that is performing poorly with perceived certainty (in an earlier example, expenses at a precise 13% of direct labor costs), even if it is not distant from the benchmark (of 9–12% of direct labor costs) when compared to the department with a wide range for the outcome (e.g. 8–18% of direct labor costs). Similarly, in the probabilistic ambiguity condition, a manager may focus on the precise probability (e.g. a fixed 60% chance of falling below a target) compared with the lower end of the range of probabilities (e.g. the better 40% chance of falling below a target when the range is 40%–80%). Therefore, he or she would prefer to investigate the unambiguous department with a 'perceived' higher chance of falling below a target than the ambiguous department. This leads to alternative 'uncertainty-avoidance' hypotheses.

Uncertainty-avoidance **unambiguous** ***outcome*** **investigation hypothesis** Decision makers analyzing expense variances will be more likely to select the unambiguous department (with the midpoint $x\%$ of the imprecise outcome) for further examination rather than the corresponding ambiguous one with the *imprecise outcome* (of $x\% \pm 5\%$). This will apply when $x\%$ is *either above or below the interval benchmark*.

Uncertainty-avoidance **unambiguous** ***probability*** **investigation hypothesis** Decision makers analyzing expense variances will be more likely to select the unambiguous department (with the midpoint p of the imprecise probability) for further examination rather than the corresponding ambiguous department with the *imprecise* ***probability*** (of $p \pm \Delta$). This will apply when $p > 0.5$ is *either the probability of being above or below the interval benchmark.*

OUTCOME AMBIGUITY EXPERIMENT

Thirty-nine graduate business students from a large state university in the Western United States participated in this experiment. All had completed at least one statistics course. The participants completed the case materials during the last week of classes. At the time, they were completing a required graduate managerial accounting course, which included in-depth discussions of the concept of variance analysis and variance investigations. They had an average of 3.4 years of business-related work experience.[5] Participants were given 20 bonus points (2% of the final grade) for voluntarily participating in the experiment.

Experimental design

To test for consistency of responses, participants were provided with two cases (see panel A of Exhibit 1): the Communications Expense (CE) and Training and Development Expense (TDE) cases. Each case involves

[4]Some studies would call this a mixed domain option, since losses are combined with inside-the-benchmark options.
[5]The MBA program's admission requires that students have a minimum of two years of business-related experience. An exception was made with two high honors students admitted directly from the University's undergraduate programs.

two versions: one below the benchmark (underexpense) and one above the benchmark (overexpense). The participants were presented the below-benchmark condition first and then the above-benchmark condition. By design, the unambiguous option's outcome of $x\%$ was outside of the interval benchmark by just 1%. The ambiguous option's outcome was centered at $x\%$, and ranged above and below this center by 5%. The ambiguous option could have resulted in an outcome that met the benchmark or fell on either the low or high side of the benchmark. The presentation order of the Communications Expense and Training and Development Expense cases was randomized across all participants. Also, participants were instructed that being below the interval benchmark can be as detrimental as being above the interval benchmark. Panel A of Exhibit 1 summarizes this experiment's design and the descriptions of the two cases. Panel B refers to the parallel 'Probabilistic Ambiguity Experiment', which is described in the next section.

Exhibit 1. Experimental design and scenarios in the outcome and probabilistic ambiguity experiments

A: Outcome ambiguity experiment

Scenario case	Interval benchmark	Domain of unambiguous option	Investigate one option	
			Unambiguous option (UA)	Ambiguous option (A)
Communications Expense (CE)	10–13% of total lab expenses	Above	14%	14% ± 5%
		Below	9%	9% ± 5%
Training and Development Expense (TDE)	9–12% of facility's direct labor costs	Above	13%	13% ± 5%
		Below	8%	8% ± 5%

B: Probabilistic ambiguity experiment

Scenario case	Interval benchmark	Domain of unambiguous option	Investigate one option	
			Unambiguous option (UA)	Ambiguous option (A)
Communications Expense (CE)	10–13% of total lab expenses	Above	0.63 chance of spending higher than 13%	0.63±0.21 chance of spending higher than 13%
		Below	0.60 chance of spending less than 10%	0.60±0.20 chance of spending less than 10%
Training and Development Expense (TDE)	9–12% of facility's direct labor costs	Above	0.68 chance of spending higher than 12%	0.68±0.21 chance of spending higher than 12%
		Below	0.65 chance of spending higher than 9%	0.65±0.20 chance of spending less than 9%

In the Communications Expense case, for example, the participants were asked to assume the role of vice president of communications for a large software development company with labs located throughout the USA Since it was important for the labs to communicate regularly with each other to develop the software effectively, the company had added the ability to have teleconferences, videoconferences, and to send E-mail between labs. Participants were also told that the results of a preliminary study indicated the budget allocation for the communication expense should be between 10% and 13% of the total lab expenses. If Lab A's communication expense was less than 10% of the total lab expenses, it might imply that the lab was completing an initial feasibility analysis on a proposal with insufficient or no input from other labs. It could also mean that Lab A did not fully understand the benefits the technology could provide and thus might have been underutilizing it. However, if Lab B's expense was more than 13%, it could suggest that Lab B either had a rapidly approaching deadline on a large project or that the lab might have been using the technology for nonessential communications.

In the Training and Development Expense case, the participants were asked to assume the role of vice president of human resources, and their task was to evaluate yearly the company's training and development program. The evaluation would provide insight into the employees' job satisfaction and potential employee turnover. Historical results indicated that maintaining training and development expenses equaling 9–12% of direct labor costs provided a low rate of employee turnover. Corporate management was satisfied with the low turnover results and would continue to endorse this policy. Participants were told that Facility A was spending more than 12%, which might imply that new programs had been introduced or that production had been expanded. However, if Facility B's training and development expense was less than 9%, it could suggest that Facility B might be a major employer in a region with few employment opportunities, which results in an extremely stable personnel force.

In both the Communications Expense and Training and Development Expense cases, participants were told that, given the limited resources available, they had to choose to investigate one of the two divisions whose communication expenses or training and development expenses were outside the required range. One division had an ambiguous outcome and the other had an unambiguous outcome (the midpoint of the ambiguous outcome). Also, in the two cases, the presence of ambiguity was motivated in two different ways that allowed us to study a broader span of processes leading to ambiguous outcomes. Specifically, the training and development expense was ambiguous because it had varied throughout the year. For example, participants were told that, reviewing the last 12 months' expenditures, they had observed that in the above (below) benchmark condition Facility A had consistently operated its training and development program at 13(8)% of direct labor costs, while facility B had operated anywhere from 8% to 18(3% to 13)% of direct labor costs. In contrast, the Communications Expense outcome was ambiguous due to a disagreement by accounting staff on the amount. For example, in the above (below) benchmark condition, the unambiguous option is described as 'Your staff all agreed that Lab A will spend 14(9)% of its total lab expense on communications'. The ambiguous option is described as 'They disagreed about Lab B and predicted a range of 9–19(4–14)% percent of total lab expenses would be spent on communications'.

Furthermore, the participants were asked to rate their perceived risk and perceived ambiguity of each of the two options on a seven-point Likert-type scale anchored at 1 ('extremely low') and 7 ('extremely high'). All participants were presented the below-benchmark condition first and then the above-benchmark condition.

Results

Manipulation check

Recall that in both the above- and below-benchmark conditions, subjects were asked to select one of the two options available for further investigation. The two options were designed to exhibit a variation in ambiguity.

One of the options included a precise number, thereby exhibiting no ambiguity. The second option used a range of numbers, indicating more ambiguity. Paired-comparison *t*-tests were conducted to determine if manipulating ambiguity was successful. The results of the *t*-tests show that participants judged the options designed to be 'ambiguous' as more ambiguous than the purported 'unambiguous' ones. Also, the 'ambiguous' options were perceived to be more risky than the 'unambiguous' ones. All the differences are statistically significant at the 0.05 level.

Above/below the interval benchmark

Recall that both the Training and Development Expense and Communications Expense cases were designed to examine how a department being above or below the benchmark affects participants' choices of ambiguous options. To examine whether the scenario and the outcome domain (above versus below) influenced individuals' choices regarding ambiguity, a logistic regression (maximum-likelihood method) was conducted, with option choice (i.e. ambiguous or unambiguous option) as the dependent variable and outcome domain (above versus below), case (TDE versus CE), differences in each subject's perceived risk, and differences in each subject's perceived ambiguity of the two options as the independent variables. The results show that the scenario and perceived difference in ambiguity between the two options affected the participants' choices ($\chi^2(2) = 20.089, p < 0.001$). Participants' choices were not influenced by whether the expenditure was above or below the interval benchmark. This suggests that our participants understood the managerially relevant observation that being either above or below the interval reflected poor performance. Additional analyses were conducted to look at the TDE and CE cases individually. In both cases, perceived difference in ambiguity affected the participants' choices (TDE case—$\chi^2(1) = 9.0504, p < 0.002$; CE case—$\chi^2(1) = 8.256, p < 0.004$).

Looking more closely at why the scenario affected the subjects' response, we find two potential answers (beyond the fact that Communications and Training and Development are different types of expenses that may typically display different patterns). The first was the difference in who provided the estimates. In the CE case the ambiguous outcome was due to the staff disagreeing on the total lab expenditures while the TDE case provided only a range of percentages spent on training and development. In addition, the TDE case occurred during a 12-month time frame, while the CE figures were reported at the end of the third quarter (a nine-month time frame). While a variance should be investigated throughout the year, it may be that our subjects believed a three-month difference could change the ultimate outcome of the lab with the variable expenditures.

Panel A of Exhibit 2 summarizes descriptive statistics for subjects' choice patterns in the Outcome Ambiguity Experiment. Panel B of Exhibit 2 refers to the parallel 'Probabilistic Ambiguity Experiment', which was given to a different group of subjects, and which is described in the next section. With TDE in the above (below) benchmark scenario, 74(72)% of the subjects chose to investigate the ambiguous department. In the CE case, even more participants chose to investigate the ambiguous department (79% in the above condition versus 87% in the below condition). Thus, most subjects conformed with the choice pattern in our *Uncertainty-Resolution Ambiguous Outcome Investigation Hypothesis*. Such choices may be explainable by a preference to resolve uncertainty to better understand why a larger variance exists and investigate whether the division manager has less control over the operation.

Since all participants were asked to respond to both above- and below-benchmark conditions in the TDE and CE cases (a within-subject design), we examined individual choice behavior across these two conditions for both cases. The four possible individual choice patterns are: 'always investigating an ambiguous option (A/A)', 'always investigating an unambiguous option (UA/UA)', 'investigating an unambiguous option in a below-benchmark and an ambiguous option in an above-benchmark condition (UA/A)', and 'investigating an ambiguous option in a below-benchmark and an unambiguous option in an above-benchmark condition (A/UA)'. As shown in Panel A of Exhibit 2, under TDE (CE), 64(77)% of the subjects displayed the uncertainty-resolution hypothesized A/A pattern (i.e. preferring to investigate

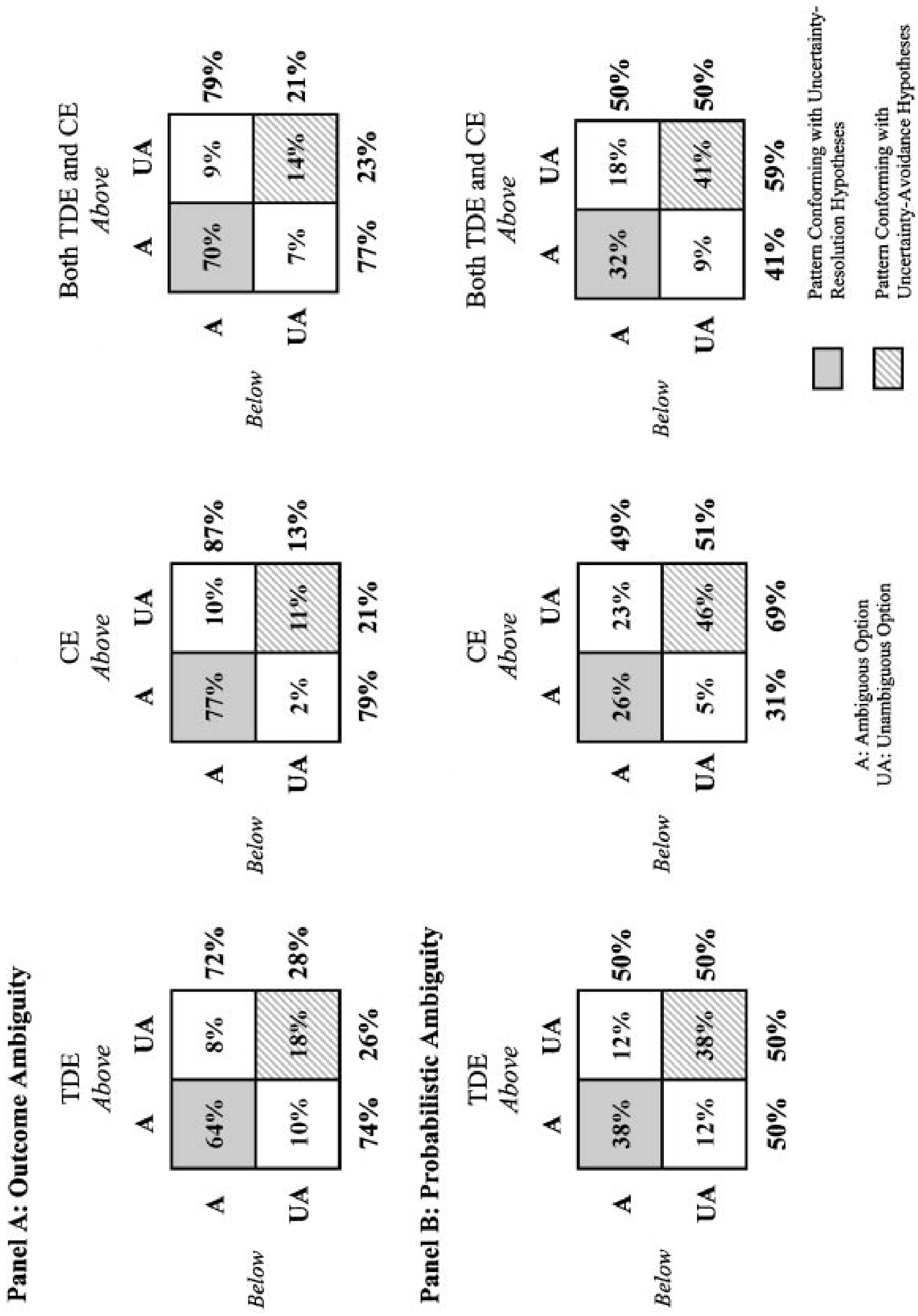

Exhibit 2. Individual choice patterns under outcome and probabilistic ambiguity

the ambiguous option when the possible range of division expenses was centered below or above the interval benchmark). Fewer subjects, 18(11)%, chose the alternative uncertainty-avoidance hypothesized UA/UA pattern in the TDE (CE) case. The difference between the percentage choosing A/A and UA/UA is statistically significant for both the TDE case ($z = 3.01$, $p < 0.003$) and the CE case ($z = 4.29$, $p < 0.000$). Thus, our overall findings support the *Uncertainty-Resolution Ambiguous Outcome Investigation Hypothesis*—decision makers analyzing expense variances both above and below the interval benchmark tend to select the ambiguous department with the imprecise *outcome* for further examination. Our written protocol experiment reported later will give evidence of participants' thoughts as they make such choices.

PROBABILISTIC AMBIGUITY EXPERIMENT

In this experiment, we explored the effects of imprecise probabilities on managers' variance investigation decisions. Forty-two graduate business students from the same university used in the previous Outcome Ambiguity Experiment participated in this experiment. Of the 42 responses received, two were discarded because the participants had not completed all requirements, leaving a final sample of 40 participants. The experimental design and procedures are the same as those in the previous experiment (see panel B of Exhibit 1).

The only difference between these two experiments is that rather than varying the ambiguity of *outcomes* (in the previous experiment), we created the ambiguous options in this experiment with ambiguous *probabilities*. For example, in the Communications Expense case, the target range of communication expense is between 10% and 13%. The unambiguous option in the below (above) benchmark condition is described as 'Based on the last three quarters, your staff all agreed there is a 60(63)% possibility that Lab A will spend less than 10(more than 13)% of the total lab expenses on communications'. The ambiguous option is described as: 'The staff disagreed about Lab B and provided a 40–80(42–84)% chance it would spend less than 10(more than 13)% of the total lab expenses on communications.' By design, the unambiguous probability p is the midpoint of the range $p \pm \Delta$ of the probabilities in the ambiguous option. Subjects were asked if they would investigate the lab with the ambiguous option, with a range from a 40–80(42–84)% chance of falling below (exceeding) the target, or the lab with the unambiguous option, with a 60(63)% probability of falling below (exceeding) the target. Note here that the below-benchmark condition is framed with the probability of falling below the lower end of the benchmark range and the above-benchmark condition is framed with the probability of falling above the upper end of the benchmark range.

Results

Manipulation check

The Probabilistic Ambiguity Experiment was also designed so the two options under each scenario varied with regard to risk and ambiguity. Paired-comparison t-tests indicated significant differences in the perception of risk and ambiguity for the two options. Again, all these differences are statistically significant at the 0.05 level.

Above/below the interval benchmark

As in the outcome ambiguity experiment, we ran a logistic regression to examine the participants' investigation choices. The regression results show that the participants' choices were affected by their perceived risk difference between the two options ($\chi^2(1) = 2.842$, $p < 0.092$). In contrast to this, in the outcome experi-

ment, the participants' choices were influenced by the perceived differences in ambiguity between the two options and by the scenario. Apparently, when probabilities were provided, our subjects were more concerned about the potential riskiness of the option than their perceived ambiguity difference between the two cases. Furthermore, subjects' choices were not influenced by the expenditures being above or below the interval. Evidently, our participants understood that being either above or below the interval implies a potential operational problem or a 'bad' outcome.

The descriptive statistics at the aggregate and individual levels are summarized in Panel B of Exhibit 2. Since the logistic regression results show no significant differences between the TDE and CE case scenarios, these two cases were pooled for some further data analysis. For both cases combined, 50(41)% of the participants chose the ambiguous option when below (above) the interval target. Thus our *Uncertainty-Resolution Ambiguous Probability Investigation Hypothesis*—decision makers are more likely to select the ambiguous option with the imprecise probability for further examination—is at best weakly supported with 50% of the participants in the below-benchmark condition and 41% of the participants in the above-benchmark condition. In the above-benchmark condition, 59% chose to investigate the unambiguous option, as did 50% in the below-benchmark condition. These subjects conformed with our *Uncertainty-Avoidance Unambiguous Probability Investigation Hypothesis*. To gain deeper insight into participants' choice behavior, we also examined the investigation preferences at the individual level.

As shown in the far right of panel B in Exhibit 2, across both expense scenarios only about one-third (32%) of the participants consistently demonstrated the uncertainty-resolution hypothesized A/A pattern, i.e. investigating divisions with ambiguous probabilities across both the below- and above-benchmark domains. Across both cases, 41% of the subjects always chose the uncertainty-avoidance hypothesized UA/UA pattern, i.e. investigating those divisions with unambiguous probabilities. There is no significant difference between those choosing A/A and UA/UA. Thus our results suggest that when facing probabilistic ambiguity, a sizable number of participants followed the *Uncertainty-Resolution Ambiguous Probability Investigation Hypothesis* and a similar number followed the *Uncertainty-Avoidance Unambiguous Probability Investigation Hypothesis*.

We also probed deeper by splitting the participants' responses into two groups: those for whom the difference in the perceived risk for the two options in the below-benchmark domain was low, and those for whom the difference was high.[6] Recall that the *Uncertainty-Avoidance Unambiguous Probability Investigation Hypothesis* posited the choice pattern UA/UA (choosing to investigate the unambiguous department when below or above the benchmark). As seen in Exhibit 3, the number of participants consistently selecting to investigate UA/UA increases from 31.3% to 41.7% in the TDE case, and from 31.3% to 56.5% in the CE case (as we move from the high-risk difference group to the low-risk difference group). Similar movement occurs for those participants who consistently select the A/A option for investigation. In the CE case, participants consistently selecting to investigate A/A increases from 12.5% to 34.8% as we move from the high-risk difference group to the low-risk difference group, while the TDE case moves from 25% to 45.8%. Taken together, our results show that when there was a low perceived risk difference in the two options, both the *Uncertainty-Avoidance Unambiguous Probability Investigation Hypothesis* and the *Uncertainty-Resolution Ambiguous Probability Investigation Hypothesis* matched more managers' investigation choices than when there was a high perceived risk difference.

Note in Exhibit 3 that there was much switching of choices between the below-benchmark and above-benchmark domains for those with high perceived risk differences between options. For the CE case, 43.8%

[6]The logistic regression revealed that the difference in perceived risk of the two options significantly affected the choice. For the TDE (CE) case, 24 (23) participants had a low difference in perceived risk for the two loss domain options, with an average absolute difference of 0.552 (0.511), which is the absolute value of the difference between the risk of the ambiguous option and the risk of the unambiguous option. The difference ranges from zero to six. The remaining 16 (16) participants had a high difference in perceived risk, with an average absolute difference of 2.109 (2.109). We also split the participants' responses into two groups based on the difference in perceived risk of the two options in the above-benchmark domain and similar results were obtained.

Exhibit 3. Participants' choices categorized by perceived difference in riskiness of options in probabilistic ambiguity experiment

		Consistent		Switch	
	n	UA/UA	A/A	A/UA	UA/A
A: Training and Development Expense					
Low perceived risk difference	24	41.7%	45.8%	8.3%	4.2%
High perceived risk difference	16	31.3%	25%	18.8%	25%
Overall	40	38%	38%	12%	12%
B: Communications Expense					
Low perceived risk difference	23	56.5%	34.8%	8.7%	0%
High perceived risk difference	16	31.3%	12.5%	43.8%	12.5%
Overall	39	46%	26%	23%	5%

Key:
n: Number of participants in two subgroups (those reporting low or high perceived risk differences between options) and in overall group (low and high subgroups combined). One subject made a choice in the TDE scenarios but was indifferent in the CE case. Therefore, that person was omitted in all data analyses for CE.
UA/A: Choose the unambiguous option in the below-benchmark condition and the ambiguous option in the above-benchmark condition; other cases defined similarly. Columns with dark shaded (light shaded) background are choice patterns conforming with uncertainty resolution (uncertainty avoidance) hypotheses, when interpreted at the within-subjects level.

investigated the ambiguous below-benchmark option and switched to the unambiguous option when above the benchmark, exhibiting an A/UA pattern. An added 12.5% switched the reverse way, UA/A. For the TDE case, 18.8% switched with A/UA, and 25% switched with UA/A. Such switching behavior may suggest that some participants in the high perceived risk difference group were thinking differently about being below or above the benchmark. Our written protocol experiment in the next section sheds some light on participants' thoughts when making choices.

WRITTEN PROTOCOL EXPERIMENT ON PROCESSING OF AMBIGUOUS INFORMATION

The results of the above two experiments show that managers tend to investigate departments with ambiguous information about performance, particularly under the condition of outcome ambiguity. We conducted one additional experiment using a written protocol approach to better understand the decision-making processes involving information with outcome and probabilistic ambiguity. In this experiment we recruited 18 graduating MBA students from the same state university as in the previous two experiments to participate in this experiment, and each of them received a $20 participation fee. Their work experience averaged around 5 years.

We used a within-subjects design and each subject responded to seven tasks. First, they did two pairwise choices involving outcome ambiguity, and one ranking of all four options, in that order. Each of these three tasks was done for above- and below-benchmark conditions, with the order of the two conditions randomized across subjects. Finally, the subjects did a probabilistic ambiguity pairwise-choice task. All seven tasks were framed within the Communications Expense scenario. After each task, the participants wrote down the main factors behind their decisions. Each of the tasks is described in turn.

The outcome ambiguity condition consisted of three parts. The first task was the Communications Expense case, which was used in the outcome ambiguity experiment (in panel A of Exhibit 1). For example, in the above-benchmark condition, subjects were told that the budget allocation for communication expenses was between 10% and 13% of the total lab expenses. They were first asked to choose between an unambiguous-certain (labeled $UA_{certain}$ or, briefly, UA_c) option (e.g. a division with an estimated 14% of the total

expenses) and an ambiguous-certain (labeled $A_{certain}$ or, briefly, A_c) option (e.g. an estimated 9–19% of its total expenses). (These are labeled as 'certain' options, since no probabilities are explicitly introduced in framing the problem.[7]) The purpose of using this question is to provide insights into why people make investigation choices in the certainty condition when either above or below the benchmark.

The second part added a new task to expand beyond our experimental findings to introduce outcome ambiguity to a decision under risk. Before, we considered outcome ambiguity or probabilistic ambiguity but not both. Here we introduced both in one scenario. Subjects chose between two options: an unambiguous-risky (UA_{risky} or UA_r) option and an ambiguous-risky (A_{risky} or A_r) option in both above- and below-the-benchmark cases. For example, in the unambiguous-risky scenario, a division has a 50% probability of using 16.5% and a 50% probability of using 22.5% of its total expenses in the above-the-benchmark case (UA_r^+). In the ambiguous-risky scenario, a division (A_r^+) has a 50% probability of spending between 14% and 19% of its total expenses and a 50% probability of spending between 9% and 13.9% of its total expenses for the communications expense. This task is to examine how probabilistic risk affects decision makers' choices of ambiguous/unambiguous outcome options. Our original two hypotheses apply to this new task also: the *uncertainty-resolution ambiguous outcome investigation hypothesis* versus the *uncertainty-avoidance hypothesis*. Since in our original outcome ambiguity experiment the majority displayed uncertainty resolution behavior (choosing to always investigate the ambiguous outcome option), we expect that to occur here.

In each case, above or below the benchmark, after completing the above two tasks, the third part was to consider the four options (i.e. UA_c, A_c, UA_r, and A_r) together and to rank them. One of the researchers randomly distributed one of the two instrument versions to each participant (the above-the-benchmark condition presented first versus the below-the-benchmark condition presented first).

After completing the outcome ambiguity task, the participants were asked to respond to a probabilistic ambiguity task. Since there was no significant effect of the above/below condition on managers' investigation decisions in our prior experiment, we only asked the participants to respond to the below-the-interval benchmark condition in the Communications Expense scenario (in panel B of Exhibit 1).

A. Outcome ambiguity—certainty condition

Exhibit 4 summarizes the choices made in this experiment. As seen in panel A of Exhibit 4, the results of the first task (framed as a decision under certainty) supported what was reported in the outcome ambiguity experiment: decision makers generally chose to investigate ambiguity, preferring an ambiguous–certain option (A_c) to an unambiguous–certain option (UA_c) in both the above and below conditions. Specifically, 83(72)% of the subjects in the above (below) condition desired to investigate the A_c option. This conforms, as expected, with the *Uncertainty-Resolution Ambiguous Outcome Investigation Hypothesis*. The written comments suggest that variability and uneasiness with ambiguity played important roles when subjects made investigation choices. Although there is no probabilistic risk specified in the frame of the certainty condition, subjects perceived a risk associated with the ambiguous department. They also felt that investigating a department with variability results in more information. The following quotes illustrate these factors.[8]

> 'The wide range of 4% to 14% raises a big red flag.'

> 'The risk assumed by not investigating A_c is greater than the risk assumed by not investigating option UA_c'

> 'Option A_c will provide more information in the investigation because there is greater variance from the 10–13 range. Option UA_c has a simpler expense model and therefore will provide less information.'

[7]Kahn and Meyer (1991) use the 'riskless choice' when investigating ambiguity in multiple attribute consumer products.
[8]We have recorded the option names from A and B, which subjects saw, to our coding, UA_c or A_c, in all protocols. In Task 2, option C and D were recorded as UA_r or A_r, etc.

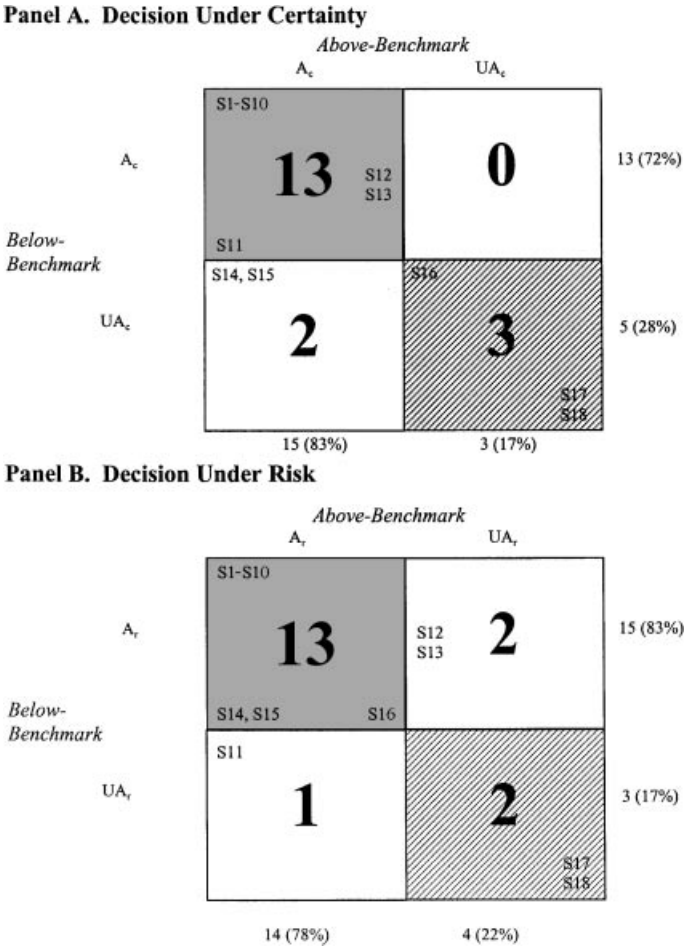

Exhibit 4. Written protocol experiments: participants' choices of ambiguous outcome option A or unambiguous outcome option UA under certainty and risk. Subjects listed by subject S#. When a subject is placed close to two cells' border in Panel A, responses moved across the border in the decision under risk in Panel B. Shaded cell shows hypothesized uncertainty-resolution hypothesis at within-subject level. Diagonal shading shows uncertainty-avoidance hypothesis. Subjects 1–10 showed the anticipated uncertainty resolution preference in both certainty and risk

On the other hand, three (five) subjects in the above (below) condition chose the UA_c option. These subjects were more concerned with the certainty of not meeting the interval benchmark and lack of variation from the interval benchmark. Below are typical explanations for this choice:

'Option UA_c has 100% certainty that the expense will not meet budget while there is a probability that option A_c will be within budget.'

'I chose option UA_c because there seems to be more uncertainty related to option A_c.'

'The factor I found key was the variation in the expense. I think a variation around the range is good because it shows the changes in expense based on the phase of project completion. In case of option UA_c people felt the expense would always be at 14%, which is something I need to look into because it means that they are overspending it even during proposal phases the expense is higher than the normal range.'

Note that the minority of subjects who chose to investigate the unambiguous option did not appear to do this because of uncertainty avoidance but rather because they chose to investigate the option that was sure to miss the budget target and which did not display the variation in possible outcomes seen with the ambiguous option. Such a variation was seen as an indicator of good performance by the last subject's quote, since it is more likely to naturally occur.

Outcome ambiguity–risk condition

Similar to the results of the certainty condition, our results show that subjects in the decision under risk condition preferred to investigate the ambiguous-risky option (A_r) rather than the unambiguous option (UA_r) in both the above and below conditions. As shown in panel B of Exhibit 4, 78(83)% of the subjects chose the A_r option in the above (below) benchmark condition. This again conforms with the hypothesized uncertainty-resolution ambiguous outcome investigation behavior pattern. The written comments suggest that subjects placed more weight on variability associated with the ambiguous option and were less influenced by risk associated with these options. Subjects also believed that a wide range implied a control problem. The following quotes illustrate these concepts:

> 'Regarding option UA_r, we at least know there is 50% probability using 11.5% percent of its total expenses. . . .Although there is a 50% probability for option A_r to use 9% to 13.9% of its total expense, we don't know the distribution of probability in this range.'

> 'Both labs have a 50% probability of using their allocated communication budget, or very close to it. Also, both labs have a 50% probability of falling below their allocation. Again, because of the ranges associated with option A_r, I am more inclined to investigate option A_r.'

> 'While both labs have a 50% probability of falling within, or close to, their allocated budgets, my staff was able to establish concrete figures for each probability relevant to option UA_r. This leads me to believe that option UA_r has more predictable usage patterns and I would be less likely to investigate.'

Although a large majority of subjects chose to investigate the A_r option, four (three) subjects in the above (below) condition indicated a preference for investigating the UA_r option. As shown in the following quotes, subjects were concerned about the constant overspending or underspending behaviors and thus would have investigated the unambiguous option. They considered a fluctuation to be normal. The typical comments are as follows:

> 'I would investigate option UA_r because there is less uncertainty.'

> '. . . I observed that option UA_r will always have expense $>10\%$ which is questionable because projects must have a proposal phase–and hence a period of expense lower than 10%. On the other hand, option A_r has an expense variation over a wider and more reasonable range (less than 10% at times and more than 13% at times). Hence I think that option UA_r may be overspending, and I would want to investigate it.'

> 'Option UA_r has less risk. . .Option A_r may have the highest potential in both probabilities, it also has the potential for the lowest of the two alternatives.. . . These are practically the same as option UA_r, so I am more inclined to select the less risky option UA_r.'

In summary, subjects exhibited similar investigation behaviors in the presence of certainty and risk conditions. As seen in Exhibit 4, more than half of the subjects (subjects 1 through 10 out of 18 total) of the subjects consistently selected the ambiguous department for further investigation in both certainty and risk conditions. Only two subjects (S17, S18) were consistent in selecting the unambiguous departments across the certainty and risky conditions. Perhaps subjects' selecting the ambiguous option, in all of the cases, can be attributable to their desire to reduce uncertainty and gain information. Thus, adding actual probabilistic risk did not lead to much change. The strong impact of ambiguity on investigation choices under certainty

makes any potential extra effect of risk associated with both options less apparent when the participants faced a decision under risk.

Overall rank ordering of the four options

When subjects were asked to consider the four options together and provide a ranking, similar results were observed in the above and below conditions: Subjects preferred to investigate the two ambiguous options. As shown in Exhibit 5, about 78% (14 out of 18) of the subjects in the above condition and 83% (15 out of 18) in the below condition selected either A_r or A_c as their first choice. Again, these subjects indicated variability, uncertainty, and distance from the interval benchmark to be important factors in ranking their investigation choices. The following comments illustrate their decision processes:

> 'Total range of expense:- the wider the range the greater the need for investigation—hence, options A_c and A_r would be the top two since their range is from 9% to 19%. Certainty: the lower the degree of certainty, the greater the need for investigation—hence, option A_c is the #1 choice.'

> '. . .The problem with option A_c is that they are not only running high variability, there are no probabilities offered increasing the concern. . .However, we simply are not given the information to calm the nerves. . . The more definitive the assessment, the more likely I would be comfortable**.** Variability enters in a whole slew of potential causes for alarm. This would be the reason for the investigation.'

> 'I am more inclined to investigate labs whose estimate falls furthest from their budget allocation. . .'

> '*Risk* I considered the risk of each choice. I was more sensitive to the wider variations, even though some of the observations were acceptable. I was more comfortable being wrong some of the time, because when I was right, the value would be extremely high. *Ambiguity.* I was also sensitive to the ambiguity because even though these percentages are 50%, I didn't know what the more specific percentages were for each state of the world. Also, in cases where I didn't have any kind of probability distribution, I was far less likely to seriously evaluate that possibility, or give it much weight. *The rank of uncertainty.* The most uncertain numbers have to be investigated first and then the lab with a projected range that is enclosing the allocated budget (option A_c). Option UA_c ranked the last because I do not feel that any more investigation is needed for it.'

Only four (three) subjects in the above (below) condition indicated that they would choose the unambiguous option (UA_r or UA_c) as their first choice. The written comments suggest that choosing the unambiguous options was due to those subjects' uncertainty-avoidance attitude. The quotes are as follows:

> 'Since option UA_c is always spending beyond the range of 10% to 13%, I would investigate it first. Option UA_r is always above 10% (sometimes within the range and sometimes over) and so I would investigate it second. Between options A_c and A_r my reasoning is less obvious.'

> 'Option UA_c has a 100% probability of not meeting budget, option A_r has a 66.6% probability, option A_c has a 63.6% probability, and option UA_r has a 50% probability. The higher the probability the more desirable it is to conduct the investigation.'

Probabilistic ambiguity

Recall that, in the earlier Probabilistic Ambiguity Experiment, 49% of the participants chose the ambiguous option in the Communication Expenses case when it was below the interval target. For the same question, while Exhibit 5 shows a somewhat higher percentage 61% (11 out of 18) of participants preferred the ambiguous option ($A_{probability}$ or A_p); a sizeable minority of 39% chose to investigate the unambiguous option ($UA_{probability}$ or UA_p). The written comments suggest that participants choosing the ambiguous option focused on variability, the higher end of the likelihood (which is the 'worst-case scenario'), and the amount

Exhibit 5. Descriptive statistics of written protocol experiment

Subject code		Outcome ambiguity: Certainty Above	Certainty Below	Risk Above	Risk Below	Overall choices rank order Above	Overall choices rank order Below	probabilistic ambiguity: Risk below
S1	Consistently selecting ambiguous outcome options (Uncertainty-resolution preference)	A*	A	A	A	a	a	A
S2		A	A	A	A	a	a	A
S3		A	A	A	A	a	a	A
S4		A	A	A	A	a	a	A
S5		A	A	A	A	a	a	UA
S6		A	A	A	A	a	a	UA
S7		A	A	A	A	d	f	UA
S8		A	A	A	A	d	d	A
S9		A	A	A	A	d	d	A
S10		A	A	A	A	f	d	A
S11	Other choice patterns	A	A	A	UA	b	c	A
S12		A	A	UA	A	d	f	A
S13		A	A	UA	A	a	d	UA
S14		A	UA	A	A	d	e	A
S15		A	UA	A	A	i	a	UA
S16		UA*	UA	A	A	g	g	UA
S17	Consistently selecting unambiguous outcome options	UA	UA	UA	UA	h	h	UA
S18		UA	UA	UA	UA	h	h	A
*A: Ambiguous option		15(**83%**)	13 (**72%**)	14 (**78%**)	15 (**83%**)			11(**61%**)
*UA: Unambiguous option		3 (17%)	5 (28%)	4 (22%)	3 (17%)			7 (39%)

Rank order: Pattern codes and number choosing pattern

First choice Ambiguous Certain	a†: A_c,	A_r,	UA_r,	UA_c	7	7
	b: A_c,	UA_c,	A_r,	UA_r	1	0
	c: A_c,	UA_c,	UA_r,	A_r	0	1
First choice Ambiguous Risky	d: A_r,	A_c,	UA_r,	UA_c	5	4
	e: A_r,	UA_c,	A_c,	UA_r	0	1
	f: A_r,	A_c,	UA_c,	UA_r	1	2
First choice Unambiguous	g: UA_c,	A_r,	A_c,	UA_r	1	1
	h: UA_c,	UA_r,	A_c,	A_r	2	2
	i: UA_r,	A_c,	A_r,	UA_c	1	0

14 = 7 + 0 + 1 + 4 + 2; 15 = 7 + 0 + 1 + 5 + 1; 4 = 1 + 2 + 1; 3 = 1 + 2 + 0

† UA_c: Unambiguous-certain option; A_c: Ambiguous-certain option; UA_r: Unambiguous-risky option; A_r: Ambiguous-risky option

of information to be revealed by the investigation through resolution of uncertainty. These explanations are similar to those stated in the outcome ambiguity task. The following quotes illustrate these factors.

> 'They should investigate the one that they are most unsure of. Since there is a large variability in the 40 to 80% possibility means that they do not have as good a grasp on what is going on as in A_p.'

> 'Disagreement of probability range I would be more inclined to investigate A_p. While the mean chance that A_p will spend less than 10% is equal to UA_p, the investigation may lead to discovering not only why they may use less than 10%, but also why there is disagreement which could help in estimates going forward.'

> 'Probability—I view both labs as having an equal chance of falling below 10% when taking into account the range of A_p. Because the extreme estimate of 80% chance of A_p using less than 10% of their budget, I would be more inclined to investigate it.'

Among the seven (39%) participants selecting the unambiguous option for further investigation, uncertainty-avoidance is an important factor in their choice process. Also, a participant indicated that a point estimate (60%) is less credible and would warrant investigation. The participants' typical comments explaining their choices are as follows:

> 'Because everyone seems to agree on a 60% chance of less than 10% expense on communications. . . this implies that people in UA_p naturally under-use communication media.' 'While the expected possibility of A_p spending less than 10% is 60%, I feel there is more certainty with UA_p although it also has a 60% probability of spending less than 10%. The range of chance (40% to 80%) for A_p makes it seem more like a gamble as opposed to UA_p.'

> 'Given the uncertainty of the project, I am more comfortable with choosing UA_p since, in this project, we know with certainty that there is a 60% certainty that we will not spend more than 10% on communications.'

> A single number of probability of 60% just does not seem very believable. How can one be so sure that it is 60%? Why not 55%? Or 65%? A narrow range of probability, i.e. 55% to 65%, is more believable.'

In summary, the above discussions indicate that the decision-making process involved in the probabilistic ambiguity condition is very similar to that in the outcome ambiguity condition. This similar decision process used by the participants is also evidenced in one participant's comments that he or she used a general heuristic in all choice tasks, i.e. choosing to investigate the option with the higher degree of uncertainty or variance.

GENERAL DISCUSSION

This study examined how managers make variance investigation choices involving probabilistic and outcome ambiguity given an interval benchmark of a firm's expenses. The experimental results show that in the same managerial contexts, our participants exhibit somewhat different choice behaviors in the presence of probabilistic and outcome ambiguity. However, by conducting a written protocol experiment, we observed that the decision-making processes involved in the probabilistic and outcome ambiguity conditions are similar.

First, we examined whether people consistently chose to investigate departments with performance described with ambiguous probabilities or outcomes in the presence of interval benchmarks, where being above or below the benchmark should be seen as equally negative. Our participants generally appeared to consider being above or below the target to be equally bad, as intended in the scenario design. In the ambiguous outcome condition, our results show that participants consistently preferred to investigate the ambiguous performance departments, regardless of whether the domain of outcomes was centered above or below the benchmark, at both the aggregate and individual levels. These results support the *Uncertainty-Resolution Hypothesis*. The results also suggest that the participants recognized a possible implication of ambiguous options—that the larger the possible dispersion of expenditures away from a target benchmark, the more likely it is that a divisional manager has less operational control.

In the imprecise probability condition, the uncertainty-resolution hypothesized pattern (consistently choosing to investigate ambiguous departments to resolve uncertainty) was not the only popular pattern. The other predominant choice pattern was the alternate uncertainty-avoidance hypothesized pattern, i.e. consistently choosing to investigate the unambiguous option in both domains. Furthermore, when the perceived risk difference in the two options was low, these two hypothesized patterns matched better with managers' investigation choices than when the perceived risk difference was high.

In the business community, both probabilistic and outcome ambiguity are prevalent in managerial settings. Due to limited resources available to managers, they have to decide what variances are significant. Our findings contribute to the extant literature and have direct implications to managerial decision makers. As discussed earlier, when facing outcome ambiguity, managers tend to investigate the department whose performance was described as having an ambiguous outcome. In contrast, when facing probabilistic information in the same decision context, managers did not exclusively choose the department with ambiguous performance to investigate. Instead, they also investigated the department with unambiguous performance. Furthermore, in the presence of probabilistic ambiguity managers' variance investigation decisions were influenced by the perceived risk differences between the two target departments. Thus, this suggests that the presentation of information ambiguity affects managers' variance investigation decisions and their resource allocation. The way variance reports are framed, as ranges of outcomes or as percentages of time outcomes meet or fail to meet a target, may affect decisions.

The results of our written protocol experiments indicate that managers generally dislike uncertainty and tend to resolve uncertainty in the variance investigation context. Although there is no probabilistic risk specified in the condition framed as under certainty, subjects perceived a risk associated with the department whose performance outcome was described ambiguously. Large majorities of participants chose the ambiguous department for further investigation in the certainty condition. This caused any extra risk effect on the investigation choice to be unclear in the risk condition, because people already would choose to investigate an ambiguous option in the certainty condition. In contrast, a few participants also indicated a clear uncertainty-avoidance attitude, especially in the probabilistic ambiguity condition. In sum, the results of the written protocol experiments suggest that the decision-making process involved in making investigation choices when facing these two types of ambiguity is similar. This is most clearly documented in one participant's written comments that he or she used a general heuristic (i.e. chose to investigate the most ambiguous one) in all choice tasks.

The results of this study and a prior study (Ho, Keller and Keltyka, 2001) on ambiguity with single-figure benchmarks suggest that future research should explore the following two issues. First, in the business world two types of benchmarks (single-figure and interval) are commonly used to measure managers' performance. In this study, we used the expense context to explore the effects of interval benchmarks on managerial choices. In such a context, being above or below the interval benchmark would indicate poor performance. Such a peaked pay-off should be investigated with single-figure benchmarks. Ho, Keller and Keltyka (2001) examined single-figure targets of a firm's returns, where being above the benchmark is a gain and being below the benchmark is a loss. The results of that study show that, in a decision framed under certainty involving an ambiguous outcome, the majority of the subjects were ambiguity prone in the loss condition and switched to ambiguity aversion in the gain condition. In contrast, in the presence of probabilistic ambiguity in a decision under risk condition, this expected switching pattern was shown only when the difference in riskiness between the two choice options (in the loss condition) was perceived to be relatively small. An interval benchmark with gains above and losses below the benchmark should also be studied. Further, future research should use a single managerial context to directly assess the effect of different types of benchmarks on managerial choices.

Second, future research should further investigate the decision processes involved in the ambiguous probability and ambiguous outcome conditions. It is normally assumed that people process probabilistic and outcome information differently. Our participants in the first two experiments responded somewhat differently

to imprecise probabilities and imprecise outcomes. Our participants were faced with either outcome ambiguity or probabilistic ambiguity, but not both. To better understand the decision processes involved, we conducted a written protocol experiment that confronted people with both forms of ambiguity. In the investigation context, we found that the decision-making processes involved are similar for the outcome ambiguity and probabilistic ambiguity conditions. Future studies should include richer scenarios and different decision contexts with both outcome and probabilistic ambiguity to further examine the decision-making process involved. Furthermore, Weber and Milliman (1997) reported that differences in risky choices can be traced to differences in risk judgments (versus differences in risk attitudes). Future studies can also explore how differences in ambiguity choices are related to people's ambiguity attitudes.

Finally, in managerial contexts, when data points are found to be far from a target expense, this may imply that a division manager has less control over the operation. Having less control over the operation may lead to a wider range of data, and to more variability within the data, and may eventually adversely affect the company's performance. Future studies should investigate how ambiguous information or large variances are related to a perceived lack of managerial control.

ACKNOWLEDGMENTS

The authors thank the anonymous referees, Janie Chang, Tanya Lee, Sandra Vera-Muñoz, and William Wright for their helpful comments and suggestions. We also acknowledge the helpful comments of participants at the 1998 Accounting, Behavior, and Organizations Research Conference, and the 1998 American Accounting Association Annual Meeting. The data, supporting appendices, and all experimental materials used in this study can be acquired upon request from the corresponding author.

REFERENCES

American Accounting Association. 1966. *A Statement of Basic Accounting Theory.* American Accounting Association: Evanston, IL.

Camerer C, Weber M. 1992. Recent developments in modeling preferences: uncertainty and ambiguity. *Journal of Risk and Uncertainty* **5**: 325–370.

Chow CW, Haddad K. 1989. Beware of pitfalls when evaluating standard cost variances, *Healthcare Financial Management* **43**: 84–86.

Curley SP, Eraker SA, Yates FJ. 1984. An investigation of patients' reactions to therapeutic uncertainty. *Medical Decision Making* **4**: 501–511.

Curley SP, Yates FJ. 1985. The center and range of the probability interval as factors affecting ambiguity preferences. *Organizational Behavior and Human Decision Processes* **36**: 273–287.

Curley SP, Yates FJ, Abrams RA. 1986. Psychological sources of ambiguity avoidance. *Organizational Behavior and Human Decision Processes* **38**: 230–256.

Davis KR. 1973. Research and development expenditure control. *Cost and Management* **47**: 11–16.

Einhorn HJ, Hogarth RM. 1986. Decision making under ambiguity. *Journal of Business* **59**: S225–S250.

Ellsberg D. 1961. Risk, ambiguity, and the Savage axioms. *Quarterly Journal of Economics* **75**: 643–669.

Gaumnitz BR, Kollaritsch FP. 1991. Manufacturing variances: current practice and trends. *Cost Management Practice* **5**: 58–64.

Ghosh D, Ray MR. 1992. Risk attitude, ambiguity intolerance and decision making: an exploratory investigation. *Decision Sciences* **23**: 431–444.

Heath C, Tversky A. 1991. Preference and belief: ambiguity and competence in choice under uncertainty. *Journal of Risk and Uncertainty* **4**: 5–28.

Ho JL, Keller LR, Keltyka P. 2001. Effects of probabilistic and outcome ambiguity on managerial choices, working paper, University of California, Irvine.

Hoch JS, Ha Y-W. 1986. Consumer learning: advertising and the ambiguity of product experience. *Journal of Consumer Research* **13**: 221–223.

Hogarth RM, Kunreuther H. 1985. Ambiguity and insurance decisions. *American Economics Review Papers and Proceedings* **75**: 386–390.
Horngren CT, Foster G, Datar SM. 1997. *Cost Accounting* (9th edn). Prentice Hall: Englewood Cliffs, NJ.
Kahn BE, Meyer RJ. 1991. Consumer multiattribute judgments under attribute-weight uncertainty. *Journal of Consumer Research* **17**: 508–522.
Kahn BE, Sarin RK. 1988. Modeling ambiguity in decisions under uncertainty. *Journal of Consumer Research* **15**: 265–272.
Kaplan RS. 1975. The significance and investigation of cost variances: survey and extensions. *Journal of Accounting Research* **13**: 311–337.
Kahneman D, Tversky A. 1979. Prospect theory: an analysis of decision under risk. *Econometrica* **47**: 263–291.
Knight CF. 1992. Emerson Electric: consistent profits consistently. *Harvard Business Review* **70**: 57–70.
Kuhn KM, Budescu DV. 1996. The relative importance of probabilities, outcomes, and vagueness in hazard risk decisions. *Organizational Behavior and Human Decision Processes* **68**: 301–317.
Laudeman M, Schaeberle FW. 1983 The cost accounting practices of firms using standard costs. *Cost and Management* **57**: 21–25.
Lentini F. 1993. Accounting for marketing success. *Journal of Accountancy* 44–48.
Raiborn CA, Barfield JT, Kinney MR. 1996. *Managerial Accounting* (2nd edn). West Publishing Company: St Paul/ Minneapolis, MN.
Ricketts JA, Nelson RR. 1987. Management-by-exception reporting: an empirical investigation. *Information and Management* 12: 235–246.
Robbins WA, Jacobs FA. 1985. Cost variances in health care: when should managers investigate? *Healthcare Financial Management* **39**: 36–41.
Ross WT. 1989. The effect of ambiguity on strategic marketing decision making, Working paper, Wharton School, University of Pennsylvania.
Slovic P, Tversky A. 1974. Who accepts Savage's axiom? *Behavioral Science* **19**: 368–373.
Taylor K. 1995. Testing credit and blame attributes as explanation for choices under ambiguity. *Organizational Behavior and Human Decision Processing* **64**: 128–137.
Viscusi WK, Chesson H. 1999. Hopes and fears: the conflicting effects of risk ambiguity. *Theory and Decision* **47**: 153–178.
Weber EU, Milliman RA. 1997. Perceived risk attitudes: relating risk perception to risky choice. *Management Science* **43**: 123–144.
Yates JF, Zukowski LG. 1976. Characterization of ambiguity in decision making. *Behavioral Science* **21**: 19–25.

Authors' biographies:

Joanna L. Y. Ho is an associate professor of accounting at UC Irvine. She received her PhD in 1986 from the University of Texas at Austin. Her research interest is in the application of decision theories to managerial accounting and auditing settings.

L. Robin Keller is an associate professor of operations and decision technologies at UC Irvine and is Chair of the Decision Analysis Society of INFORMS. Her recent research is funded by the US EPA on intertemporal models for environmental attributes and the NSF on decision making in China and North America.

Pamela K. Keltyka is an assistant professor of accounting at the University of Akron. Her research interest is in the use of cost/managerial accounting information in business decisions.

Authors' addresses:

Joanna L. Y. Ho, Graduate School of Management, University of California, Irvine, GSM 350, Irvine CA 92697-3125. *jlho@uci.edu, http://www.gsm.uci.edu/∼ho*

L. Robin Keller, Graduate School of Management, University of California, Irvine, GSM 350, Irvine CA 92697-3125. *lrkeller@uci.edu, http://www.gsm.edu/∼keller*

Pamela K. Keltyka, George W. Daverio School of Accountancy, College of Business Administration, Business Administration Building, University of Akron, Akron, OH 44321-4802, *pkeltyk@uakron.edu*

