Title

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Which Is More Probable—"25% + 25%" or "40% + 10%"? : Effect of the Distribution of Focal Outcomes on Gut-level Perception of Certainty

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Abstract

Previous studies reveal that the distribution of alternative outcomes plays an important role in the probability judgment of focal outcomes. Based on this finding, the present study addresses the following question: does the distribution of *focal outcomes* affect probability judgment? A total of 313 participants (66 in Experiment 1 and 247 in Experiment 2) estimate fictitious results of slot machines with many winning letters. Results of the two experiments indicate that with the exception of a few cases, people estimate a higher probability for focal outcomes that are distributed more uniformly.

Introduction

One of the central concerns in studies of probability judgment is the distribution of multiple outcomes that are related to it. A typical case of probability judgment involves a focal outcome and alternative outcomes: the former is the target of probability judgment, while the latter may not be the target. For example, when people predict that "The weather will be fine tomorrow," there exist other possibilities of the weather condition (cloudy, rainy, or snowy). Recent studies have revealed that probability judgment is often sensitive to variations in the distribution of alternative outcomes, even when such variations are not related to the objective probability of the focal outcome (Gonzalez & Frenck-Mestre, 1993; Teigen, 1988; Windschitl & Wells, 1998; Windschitl & Young, 2001; Windschitl, Young, & Jensen, 2002). The effect of the variations in the distribution of alternative outcomes on probability judgment is referred to as the alternative-outcome effect.

The study of Windschitl and Wells (1998) clearly demonstrated the alternative-outcome effect. In one of their experiments, 21 raffle tickets were distributed to participants and they were asked to estimate their probability of winning the raffle. In the first scenario, 5 other raffle players possessed 14, 13, 15, 12, and 13 tickets, while in the second, they possessed 52, 6, 2, 2, and 5 tickets. Although the objective probability of winning in the two scenarios was the same, participants who considered the first distribution of alternative outcomes estimated a higher probability of winning than those who considered the second distribution. Windschitl and Wells (1998) termed this effect the alternative-outcome effect and replicated it under various experimental conditions (Windschitl & Wells, 1998; Windschitl & Young, 2001; Windschitl, Young, & Jenson, 2002; Windschitl & Krizan, 2005).

Windschitl and coworkers emphasize that the alternative-outcome effect does not indicate that people are necessarily deceived or mistaken about the objective probability of a focal event. Rather, it assumes the existence of a dissociation between a person's belief in the objective probability of an outcome and his/her intuitive or "gut-level" perceptions of certainty. In other words, variations in the distribution of evidence across alternative outcomes can implicitly affect the gut-level perceptions of certainty, even when the variations do not affect the beliefs about the objective probability of the focal outcome. Their emphasis is based on recent research on other phenomena such as the ratio-bias phenomenon (Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992) or context effects (Windschitl & Weber, 1999).

In this study, we also assume the dissociation between the belief in the objective probability of an outcome and the intuitive perception of certainty. Moreover, based on the abovementioned studies, we examine a new problem of the effect of the distribution of multiple outcomes. That is, this study aims to investigate whether the shape of the distribution of focal outcomes affects probability judgment.

Focal-outcome effect

Not only alternative outcomes but also focal outcomes can be divided into multiple possible sub-outcomes with variations in their distribution. For example, consider a case in which we estimate the probabilities for carrying an umbrella. The focal outcome is "you had better take an umbrella," and the alternative outcome is "you had better not take an umbrella." Both the focal and alternative outcomes can be divided into several probability components that are useful for making the final decision. In this case, "rain" and "snow" are the focal outcomes and "sunny" and "cloudy" are the alternative outcomes. Variations can exist in the distribution of both the focal and alternative outcomes. For example, even when the sum of the percentages of the focal outcomes is 50%, various combinations of the probabilities of "rain" and "snow" are possible, such as 40% and 10% or 25% and 25%. Therefore, the following question arises: which subjective probability of the focal outcome is higher—40% of rain and 10% of snow or 25% of rain and 25% of snow? In other words, does the distribution of the focal outcome affect its subjective probability?

Although this question is not addressed in previous studies, those of decision making suggest a possibility that the distributive nature of the focal outcome would affect probability judgment. Support theory (Tversky & Koehler, 1994) assumes that when an outcome *A* is unpacked into a disjunction of exclusive constituents, $A_1 \vee A_2$, the judged probability generally increases because unpacking increases the total support for the outcome. In other words, when $A_1 \vee A_2$ is identified as a partition of *A*,

$$s(A) \leq s(A_1 + A_2) \quad (1)$$

This formulation indicates that the description of focal outcomes affects the judged probability. For example, Fox and Tversky (1997) demonstrate that judged probabilities increase when the outcome "Eastern conference team wins the NBA championship" is unpacked into a list that mentions the four strongest teams in the conference. If the shape of the distribution of focal outcomes is an important source for describing the focal outcome, its judged probabilities would change depending on the distribution.

The above example of Support theory also suggests a possibility that the shape of the distribution of focal outcomes plays an important role in their probability judgment. In the present study, we investigate whether the shape of the distribution of focal outcomes affects probability judgment.

Index for distribution

In addition to the determination of the focal-outcome effect, the present study also investigates another problem: how does the distribution of focal outcomes affect probability judgment in which it plays an important role? Although several indexes exist for representing the shape of the distribution of multiple outcomes, previous studies of the alternative-outcome effect do not consider the problem of representing the effect of the distribution. In this study, we consider the following two possibilities.

The strength of the strongest alternative outcome. In the first possibility, people assess the strength of only the strongest alternative outcome. Windschitl and Wells (1998) present an interesting account of the alternative-outcome effect. They propose that people use "the comparison-to-the-strongest heuristic." According to their explanation, people tend to compare the strength of a focal outcome with that of the strongest alternative outcome in order to judge the probability of the focal outcome. When this comparison is in strong favor of the focal outcome, its judged probability is higher. For example, in the study of Windschitl and Wells (1998), the probabilities of winning estimated by the participants in the first scenario are higher than those estimated in the second. This is because the evidence for winning is stronger than the strongest alternative outcome in the first scenario (21 > 15) in comparison with that in the second (21 < 52). Windschitl and Young (2001) refer to this comparison as a heuristic because it is relatively efficient and serves as an approximately accurate guide for determining whether one should be optimistic or pessimistic about the possibility of the focal outcome. This heuristic presents a specific example of cognitive processes of probability judgment and can explain why the distribution of alternative outcomes affects the probability judgment of the focal outcome.

The distance from uniform distribution. In the second possibility, people consider the shape of the distribution for probability judgment. Although previous studies assume the effect of the alternative outcome, it is not necessary to assume that the strength of each alternative outcome affects probability judgment. This is because many different indexes can be used to represent the shape of the distribution of alternative outcomes. For example, not only the strength of the alternative outcome but also the distance from the uniform distribution, such as the chi-square value, Kullback-Leibler divergence, or local representativeness (Rapoport & Budescu, 1997) can be used to represent the distribution of alternative outcomes. In particular, we consider the local representativeness of multiple outcomes (Rapoport & Budescu, 1997) as an index for representing the shape of the distribution of multiple outcomes. Local representativeness describes the randomness of multiple outcomes that is quantified by the following formula:

$$Q(h) = \sum_{i=1}^{n} \left| p_i - p_{ih} \right| \quad (2)$$

In this formula, the summation index Q(h) represents the randomness or uniformity of the distribution, n denotes the number of probable outcomes, p_{ih} denotes the observed probability, and p_i is equal to 1/n. Local representativeness is defined as the sum of the differences between 1/n and the observed probabilities of outcomes. This index can also be used to represent the effect of the shape of the distribution, and it provides specific cognitive processes of probability judgment. In other words, it indicates that people consider all multiple outcomes for probability judgment.

Experiments

As mentioned above, this study investigates the following two questions: (1) does the shape of the distribution of focal outcomes affect probability judgment and (2) if so, what property of the distribution of focal outcomes plays an important role in this effect? For this purpose, we used slot machines that exhibited six characters (A, B, C, D, E, and F), and three of them (A, B, and C) represented winning letters; the outcomes of the machines were used as experimental stimuli.

Participants estimated the subjective certainty of winning in the fictitious slot machines. First, they read the following instructions:

> You work for an electronics company that manufactures slot machines. These machines exhibit a letter of the alphabet in each trial; some letters are winning letters, while the others are not. However, some machines may tend to exhibit a specific character very frequently. Your task is to state how certain you are that the next character to be exhibited is a winner. In each trial of the machines, you will indicate your level of certainty on a scale of 0 (impossible) to 9 (very certain).

Then, participants were asked to indicate their subjective certainty for the probability that the next trial of the machine would produce a winning letter by encircling a line. Their responses were scored from 0 (impossible) to 9 (very certain) according to the position of the circle on the line. For example, a machine exhibited A five times, D four times, and E one time, and it did not exhibit B, C, and F. Its experimental trial was presented as follows:

> This machine exhibited A 50 times, B 20 times, C 0 times, D 30 times, E 0 times, and F 0 times.
>
> How certain are you that this machine will produce a winning letter?

The percentages of the focal outcome were set at 30%, 50%, and 70%. Participants in Experiment 1 estimated under all the three conditions, while those in Experiment 2 estimated under only one of the three conditions.

Experiment 1

Participants. 66 Japanese undergraduates participated in Experiment 1. Their mean age was 19.58 years (SD = 1.26 years).

Stimuli. We used 160 types of the outcomes of the fictitious slot machines as stimuli. They exhibited six characters of the alphabet (A, B, C, D, E, and F), and three of them (A, B, and C) represented winning letters. An example of the stimuli was shown in the "Experiments" session. According to the number of outcomes, the following combinations of the distribution of focal outcomes and alternative outcomes were chosen: for the 30% condition, 6 (30, 10, 10; 25, 5, 0; 20, 10, 0; 20, 5, 5; 15, 15, 0; 10, 10, 10) * 8 (70, 0, 0; 60, 10, 0; 60, 5, 5; 50, 20, 0; 50, 10, 10; 40, 15, 15; 30, 30, 10; 25, 25, 20) combinations; for the 50% condition, 8 (50, 0, 0; 45, 5, 0; 40, 7, 3; 35, 9, 6; 30, 20, 0; 30, 10, 10; 25, 12, 13; 18, 16, 16) * 8 (50, 0, 0; 45, 5, 0; 40, 7, 3; 35, 9, 6; 30, 20, 0; 30, 10, 10; 25, 12, 13; 18, 16, 16) combinations; and for the 70% condition, 8 (70, 0, 0; 60, 10, 0; 60, 5, 5; 50, 20, 0; 50, 10, 10; 40, 15, 15; 30, 30, 10; 25, 25, 20) * 6 (30, 10, 10; 25, 5, 0; 20, 10, 0; 20, 5, 5; 15, 15, 0; 10, 10, 10) combinations. The participants estimated a total of 160 (6 * 8 + 8 * 8 + 8 * 6) types of distributions.

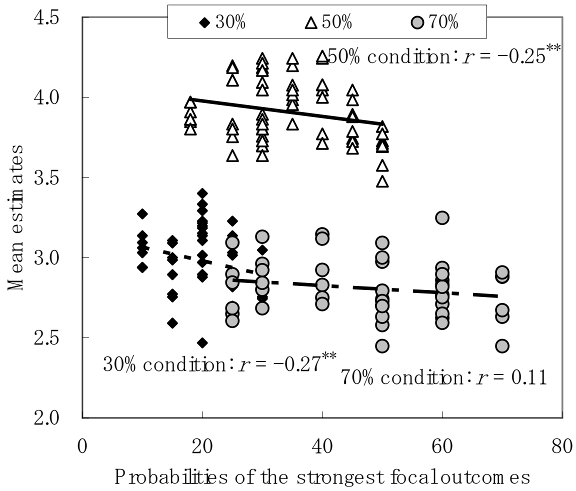
Procedure. The participants were tested in a group setting. Each participant worked on a booklet that indicated the variations of the estimation task. The booklet also contained an instruction that described the experimental task and the stimuli mentioned above. On the first page of the booklet, participants were given the instruction. The 66 participants estimated winning probabilities for 160 raffles.

Results and discussion. Figure 1 shows the scatter plots of the mean ratings for each item. The x-axis denotes the probabilities of the strongest focal and alternative outcomes, and the y-axis denotes the mean ratings for each item. Multiple regression analyses were performed in which the probabilities of both the strongest focal and alternative outcomes were independent variables and the means were dependent variables. Results of these analyses are shown in Table 1. As shown in Table 1, the objective probabilities of both the strongest focal and alternative outcomes significantly affected the mean ratings of the certainty for winning in the 30% (–0.268, $p < 0.05$ and –0.410, $p < 0.05$ for focal and alternative outcomes, respectively) and 50% (–0.251, $p < 0.05$ and –0.393, $p < 0.05$ for focal and alternative outcomes, respectively) conditions. However, in the 70% condition, the regression coefficients of both the strongest focal (0.108, $p > 0.10$) and alternative (–0.198, $p > 0.10$) outcomes were not significant. Thus, the results of the multiple regression analyses indicated that in the 30% and 50% conditions, variations in the distribution of both focal and alternative outcomes affected the probability judgment of the focal outcome, while in the 70% condition, these effects were not evident.

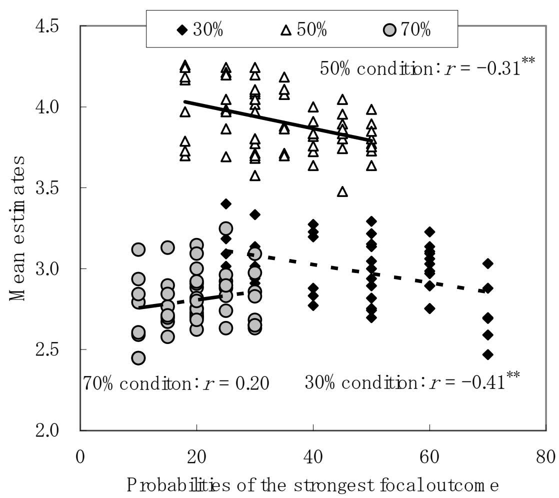
Further, we performed multiple regression analyses in which the local representativeness of focal and alternative outcomes was an independent variable and the mean ratings of certainty were dependent variables in each condition. Results of these analyses are shown in Table 1. As shown in Table 1, the local representativeness of both focal and alternative outcomes significantly affected the mean ratings of the certainty for winning in the 30% (–0.308, $p < 0.05$ and –0.440, $p < 0.05$ for focal and alternative outcomes, respectively) and 50% (–0.277, $p < 0.05$ and –0.410, $p < 0.05$ for focal and alternative outcomes, respectively) conditions. However, in the 70% condition (0.086, $p > 0.10$ and –0.087, $p > 0.05$ for focal and alternative outcomes, respectively), the regression coefficients of the local representativeness of both focal and alternative outcomes were not significant. The results of these analyses also exhibited the same trends as those in which the strongest focal outcome was an independent variable. Thus, these results suggest that the distance from the uniform distribution can be used as an index for representing the effect of multiple outcomes.

Experiment 2

Participants. 247 Japanese undergraduates participated in Experiment 2. 83 participants were assigned to the 30% condition, 85 to the 50% condition, and 78 to the 70% condition.



(a)



(b)

Figure 1. Results of Experiment 1: The top panel (a) shows the effect of the distribution of the strongest focal outcomes , and the bottom panel (b) shows the effect of the distribution of the strongest alternative outcome.

Table 1 Results of multiple regression analyses in Experiments 1 and 2.

		Strongest		Local representativness	
		Focal	Alternative	Focal	Alternative
	30%	−0.27**	−0.41**	−0.31**	−0.44**
Exp. 1	50%	−0.25**	−0.31**	−0.28**	−0.41**
	70%	0.11	−0.20	0.09	−0.09
	30%	−0.46**	−0.41**	−0.39**	−0.42**
Exp. 2	50%	0.62**	−0.59**	0.63**	−0.61**
	70%	0.12	0.03	0.11	0.09

Note: **: p<0.05

Results and discussion. Results obtained under the three conditions in Experiment 2 are shown in Figure 2. We performed multiple regression analyses in which the objective probabilities of both the strongest focal and alternative outcomes were independent variables and the means were dependent variables. Results of these analyses are shown in Table 1. The objective probabilities of both the strongest focal and alternative outcomes significantly affected the mean ratings of the certainty for winning in the 30% (–0.268, $p < 0.05$ and –0.410, p < 0.05 for focal and alternative outcomes, respectively) and 50% (–0.251, $p < 0.05$ and –0.393, $p < 0.05$ for focal and alternative outcomes, respectively) conditions. However, in the 70% condition, the regression coefficients of both the strongest focal (0.108, $p > 0.10$) and alternative (–0.198, $p > 0.10$) outcomes were not significant.

Further, we performed multiple regression analyses in which the local representativeness of focal and alternative outcomes was an independent variable and the mean ratings of the certainty were dependent variables in each condition. The local representativeness of both focal and alternative outcomes significantly affected the mean ratings of the certainty for winning in the 30% (–0.39, $p < 0.05$ and –0.42, $p < 0.05$ for focal and alternative outcomes, respectively) and 50% (0.63, $p < 0.05$ and –0.420, $p < 0.05$ for focal and alternative outcomes, respectively) conditions. However, in the 70% condition (0.11, $p > 0.10$ and –0.09, $p > 0.05$ for focal and alternative outcomes, respectively), the regression coefficients of the local representativeness of both focal and alternative outcomes were not significant.

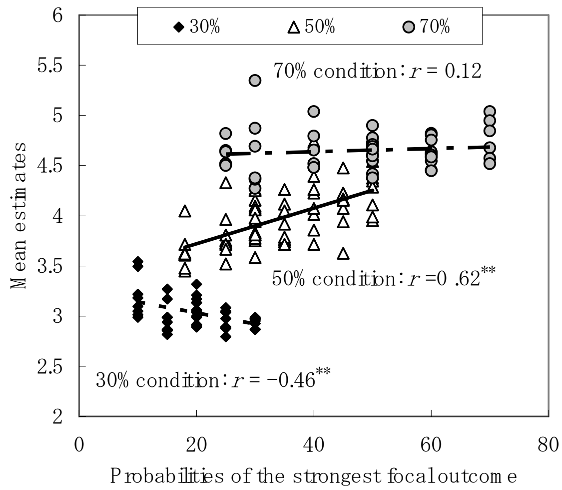
The result of the 50% condition is important because the trend of the effect of the distribution of focal outcomes is opposite to that of Experiment 1. This indicates that the estimated probability for the sum of focal outcomes decreases with an increase in the uniformity of their distribution.

General discussion

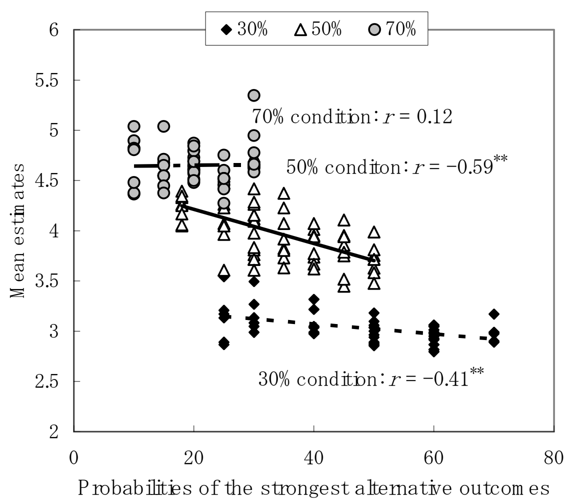
Determination of focal-outcome effect

This study investigated whether the shape of the distribution of focal outcomes would affect probability judgment under various conditions. The results of the two experiments revealed that the distribution of focal and alternative outcomes affected probability judgment under conditions in which the probabilities of focal outcomes were below 50%. However, this effect was not observed in the 70% condition. These results showed that not only the distribution of alternative outcomes but also the focal outcomes would affect subjective probability judgment. This is a new finding in probability judgment.

One other noteworthy finding in the present results is a direction of the effect of the distribution of the focal outcomes. Studies of the alternative-outcome effect (Windschitl & Wells, 1998; Windschitl & Young, 2001; Windschitl, Young, & Jenson, 2002) reveal that the compa-



(a)



(b)

Figure 2. Results of Experiment 2: The top panel (a) shows the effect of the distribution of the strongest focal outcomes , and the bottom panel (b) shows the effect of the distribution of the strongest alternative outcome.

-rison between the strengths of the focal outcome and the strongest alternative outcome is in strong favor of the focal outcome, the subjective probability of focal outcomes is higher. In other words, the subjective probability for the sum of alternative outcomes decreases with an increase in the uniformity of their distribution. Thus, the results of previous studies of the alternative-outcome effect lead to the prediction that a more uniform distribution of focal outcomes should result in a lower subjective probability for the sum of focal outcomes.

However, the results of the present study were in contrast to this prediction. The directions of the effect from the focal outcome are negative, with the exception of the 50% condition in Experiment 2. This indicated that the subjective probability of focal outcomes increased with the uniformity of their distribution. The estimated probability of focal outcomes also increased with the uniformity of their distribution. These trends were not in agreement with the prediction of the studies of the alternative-outcome effect (Windschitl & Wells, 1998; Windschitl & Young, 2001; Windschitl, Young, & Jensen, 2002). These results were important because they suggested that cognitive processes mediating the focal-outcome effect differed from those mediating the alternative-outcome effect. These patterns of focal- and alternative-outcome effects might reflect an adaptive decision strategy for humans (e.g., Payne, Bettman, & Johnson, 1988). However, this assumption requires further research.

Another result is that both focal- and alternative-outcome effects disappear in the 70% condition. This implies a boundary condition of the focal and the alternative outcomes effect. That is, these effects occur only when the probabilities of focal outcomes are small. This possibility also remains an empirical question.

Index for representing the shape of the distribution

Thus far, several methods have been developed for explaining how focal and alternative outcomes are assessed for probability judgment. According to Windschitl and Young (2001), the examples of possible processes include (a) analysis of individual components followed by aggregation to assess the overall strength, (b) sampling of a part of the evidence obtained from each component to estimate the strength, and (c) global assessment of the strength without its assessment for individual outcomes. The study of Windschitl and coworkers supports the first method, and Dougherty and Hunter (2003a, b) support the second.

The present study suggests that the distance from the uniform distribution such as local representativeness can also be used for the judgment of focal outcomes. By definition, local representativeness includes the individual probabilities of all alternative outcomes. It is defined as the sum of the absolute deviations between the relative frequencies of multiple outcomes and the corresponding probability governing the random process (Rapoport & Budescu, 1997). This implies that people must consider all alternative outcomes to estimate the distance from the uniform distribution. Thus, the present result suggests a possibility that participants consider all the focal and alternative outcomes for probability judgment.

It should be noted that the present study does not disprove the explanation of Windschitl and Wells (1998). In this study, the probabilities of the strongest focal and alternative outcomes effectively predict the data; hence, the explanation of Windschitl and Wells (1998) is still valid. This study only describes an example that demonstrates the plausibility of assuming the effect of all focal and alternative outcomes. Further experimental research including a more comprehensive explanation of the participants' judgment process is required.

Methodological limitation

A methodological problem of this study is that it ignores an individual difference in the strategy for probability judgment. The studies of the alternative-outcome effect (Windschitl & Wells, 1998; Windschitl & Young, 2001; Windschitl, Young, & Jensen, 2002), including the present study, analyze group data that is summarized among individual participants. However, it is possible that each participant adopts a different strategy for probability judgment. In fact, Dougherty and Hunter (2003) suggest a possibility that cognitive processes of probability judgment may differ depending on the working memory capacity. Therefore, in order to examine the comparison hypothesis in detail, an investigation of the individual difference factor that would affect probability judgment is required.

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References

Denes-Raj, V., & Epstein, S. (1994). Conflict between intuitive and rational processing: When people behave against their better judgment. *Journal of Personality and Social Psychology*, **66**, 819–829.

Dougherty, M. R. P., & Hunter, J. E. (2003a). Hypothesis generation, probability judgment, and individual differences in working memory capacity. *Acta Psychologica*, **113**, 263–282.

Dougherty, M. R. P., & Hunter, J. E. (2003b). Probability judgment and subadditivity: The role of working memory capacity and constraining retrieval. *Memory and Cognition*, **31**, 968–982.

Gonzalez, M., & Frenck-Mestre, C. (1993). Determination of numerical versus verbal probabilities. *Acta Psychologica*, **83**, 33–51.

Kirkpatrick, L. A., & Epstein, S. (1992). Cognitive-experiential self-theory and subjective probability: Further evidence for two conceptual systems. *Journal of Personality and Social Psychology,* **63,** 534–544.

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1988). Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning*, *Memory*, *and Cognition*, **14**, 534–552.

Rapoport, A., & Budescu, D. V. (1997). Randomization in individual choice behavior. *Psychological Review*, **104**, 603–617.

Rottenstreich, Y., & Tversky, A. (1997). Unpacking, repacking, and anchoring: Advances in support theory. *Psychological Review*, **104**, 406–415.

Teigen, K. H. (1988). When are low-probability events judged to be "probable"? Effects of outcome-set characteristics on verbal probability estimates. *Acta Psychologica*, **67**, 157–174.

Tversky, A., & Koehler, D. (1994). Support theory: A nonextensional representation of subjective probability. *Psychological Review*, **101**, 547–567.

Windschitl, P., & Krizan, Z. (2005). Contingent approaches to making likelihood judgment about polychotomous cases: The influence of task factors. *Journal of Behavioral Decision Making*, **18**, 281–303.

Windschitl, P. D., & Wells, G. L. (1998). The alternative-outcome effect. *Journal of Personality and Social Psychology*, **75**, 1411–1423.

Windschitl, P. D., & Young, M. E. (2001). The influence of alternative outcomes in gut-level perceptions of certainty. *Organizational Behavior and Human Decision Processes*, **85**, 109–134.

Windschitl, P. D., Young, M. E., & Jenson, M. E. (2002). Likelihood judgment based on previously observed outcomes: The alternative-outcome effect in a learning paradigm. *Memory and Cognition*, **30**, 469–477.

Windschitl, P. D., & Weber, E. U. (1999). The interpretation of "likely" depends on the context, but "70%" is 70%—right?: The influence of associative processes on perceived certainty. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **25,** 1514–1533.