

Framing effect in evaluation of others' predictions

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Abstract

This paper explored how frames influence people's evaluation of others' probabilistic predictions in light of the outcomes of binary events. Most probabilistic predictions (e.g., "there is a 75% chance that Denver will win the Super Bowl") can be partitioned into two components: A qualitative component that describes the predicted outcome ("Denver will win the Super Bowl"), and a quantitative component that represents the chance of the outcome occurring ("75% chance"). Various logically equivalent variations of a single prediction can be created through different combinations of these components and their logical or numerical complements (e.g., "25% chance that Denver will lose the Super Bowl", "75% chance that Seattle will lose the Super Bowl"). Based on the outcome of the predicted event, these logically equivalent predictions can be categorized into two classes: Congruently framed predictions, in which the qualitative component matches the outcome, and incongruently framed predictions, in which it does not. Although the two classes of predictions are logically equivalent, we hypothesize that people would judge congruently framed predictions to be more accurate. The paper tested this hypothesis in seven experiments and found supporting evidence across a number of domains and experimental manipulations, and even when the congruently framed prediction was logically inferior. It also found that this effect held even for subjects who saw both congruently framed and incongruently framed versions of a prediction and judged the two to be logically equivalent.

Keywords: framing effect, predictions, probabilistic judgment, decision making.

1 Introduction

Probabilistic predictions about events with binary outcomes are frequently encountered in everyday life. For example, weather forecasts are often made in probabilistic terms (e.g., "chance of rain is 80%"). When the outcomes of these probabilistic events are known, we can assess the accuracy of the predictions by comparing these predictions against the actual outcomes. To be able to properly evaluate other people's predictions is important because it would then allow us to learn how good the predictors are in making predictions, to judge whether or to what degree should we trust future predictions, and to make decisions accordingly, etc.

In the present research, I focus on one particular aspect

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of prediction evaluation—how the framing of predictions affects people's evaluations. Framing effect refers to a phenomenon in which *description invariance* is violated (Tversky & Kahneman, 1981). According to the principle of description invariance, different representations of the same judgment problem should yield the same output, in terms of judgments or decisions. However, much prior research has found that judgments, decisions, and actions are often influenced by frames—the presentation of information and its context (for example, see, Tversky & Kahneman, 1981; Levin, Schneider, & Gaeth, 1998; Kühberger, 1998). In this paper I demonstrate a novel framing effect in how people evaluate probabilistic predictions about events with binary outcomes. While the evaluation of predictions has been studied extensively, these studies have been mainly concerned with using formal methods to evaluate predictions. Instead, here I focus on how laypeople evaluate predictions.

Although there have been studies of framing effects on probabilities and predictions (e.g., Kuhn, 1997; Mandel, 2005; Mandel, 2008), to my knowledge evaluation of predictions about binary-outcome events have not been investigated from the perspective of framing (but see Teigen & Nikolaisen, 2009, for a study on how people evaluate predictions that over- or under-shoot the outcome).

In the following sections I will first detail the background of and my hypothesis about a novel framing effect. I will then present the experiments that explore the effect and examine the conditions under which it occurs. Finally

I will discuss the implications of the findings, the limitations of the current study, and some future directions.

2 Background

In decision theory, scoring rules are used to assess the accuracy of probabilistic predictions (Brier, 1950; Murphy & Winkler, 1977; Savage, 1971). While scoring rules are intended to be objective standards by which predictions can be evaluated and compared, the question of whether people, especially laypeople, would evaluate predictions based on similar standards is less well understood.

Much evidence suggests that how people evaluate predictions, and decisions in general, is influenced by contextual factors. One of the most well-known of these findings, the risky choice framing effect, induces a choice reversal effect between two logically equivalent gambles (Tversky & Kahneman, 1981). For example, in the Asian disease problem, people were risk-averse when the problem was presented in a gain frame (“200 people will be saved” is preferred to “there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved”), whereas they were risk-seeking when the problem was presented in a loss frame (“there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die” is preferred to “400 people will die”). A number of other contextual factors have also been found to produce other kinds of framing effects (Levin & Gaeth, 1988; Meyerowitz & Chaiken, 1987). More recent research has suggested that framing effects can in turn be moderated by a number of factors. For example, ambiguities in the descriptions, and whether the valence of the predictions are congruent with those of the outcomes (e.g., “will be saved” vs. “will die”), have been found to moderate the risky choice framing effect (Mandel, 2001; Mandel, 2008).

The valence, or directionality, of events has been shown to be one important factor influencing framing effects. Verbal probability expressions of opposite valence were shown to induce different judgments even when these expressions were judged to be equivalent in terms of their numerical probabilities (Teigen & Brun, 1999). More generally, the valence of events has been shown to change people’s estimates of the probability of those events (Mandel, 2005).

These results suggest that the framing of predictions, and especially the directionality of these predictions, might also influence how people evaluate the accuracy of predictions in light of the outcomes. One theory that provides suggestions on how people evaluate predictions is the fuzzy-trace theory (Reyna & Brainerd, 1991). Fuzzy-trace theory was originally proposed to explain the risky choice framing effect. According to it, this effect is a re-

sult of people using gist information instead of verbatim information. It also states that people have a preference for fuzzy processing at the crudest possible level necessary to distinguish different choices. In the context of the risky choice framing effect, people distinguish between options using the contrasts among the gist representations, *some*, *all*, and *none*, instead of more precise numeric probability values. Take the Asian disease problem as an example. In the gain frame, the verbatim representations of the two options “200 will be saved” versus “a 1/3 probability that 600 will be saved” are represented by people based on the gist information instead, and become “some people will be saved” versus “some chance that some people will be saved”. As a result, people favor the sure option. Similarly, in the loss frame, the choices of “400 will die” versus “a 2/3 probability that 600 will die” become “some people will die” versus “some chance that some people will die”, and consequently, people prefer the risky option. This explanation of the framing effect received support from a series of research studies (Kühberger & Tanner, 2010; Reyna & Brainerd, 1991; Reyna & Brainerd, 1995).

If we apply the fuzzy-trace theory to the evaluation of predictions, then we can construct a hypothesis about how frames might influence people’s judgments of prediction accuracy concerning binary events. We will use a prediction about Super Bowl 2014 as an example. This particular American football game was between two teams, the Denver Broncos and the Seattle Seahawks, and could not result in a tie—one of the teams must win the game and the other must lose. Let’s say there are two logically equivalent predictions: “there is an 80% chance that the Denver Broncos will win” and “there is a 20% chance that the Denver Broncos will lose”. While these two predictions are logically equivalent, according to fuzzy-trace theory people might evaluate the predictions by relying on the gist information. As a result, the predictions would be translated as “there is some probability that the Denver Broncos will win” and “there is some probability that the Denver Broncos will lose”, respectively. Since Denver eventually did lose the game, if people evaluate predictions based on these gist representations, then it seems likely that they may rate the first prediction to be less accurate than the second one.

To facilitate exposition, I will call the outcome described in the prediction (e.g., “the Denver Broncos will win”) the *qualitative component*, and the predictor’s judgement about how likely a particular outcome is to occur (e.g., “80% chance”) the *quantitative component*. In more general terms, the above analysis suggests that when people evaluate the accuracy of predictions, they might rely more on whether the qualitative components matches the outcome, than on the magnitude of the quantitative component. I will refer to predictions in which the qualitative component is logically equivalent with the outcome

as predictions in a *congruent* frame. In contrast, predictions in which the qualitative component is not logically equivalent with the outcome are referred to as predictions in an *incongruent* frame. For example, a prediction of “it will rain” is congruent with an outcome of “rain” while a prediction of “it will not rain” is not congruent. Note that the quantitative component of the prediction does not factor into the determination of congruency. Moreover, while there are similarities between valence and congruency, valence mainly concerns whether a description is positive or negative in absolute terms, whereas congruency involves the matching between the prediction and the outcome.

A group of statements is logically equivalent if each member statement of the group necessarily entails any other member statements (e.g., Sher & McKenzie, 2006). Therefore, a prediction can be stated in several different ways without changing its meaning. Going back to the Super Bowl example, if the outcome is (counterfactually) a Denver win (or equivalently, a Seattle loss), then predictions of “Denver will win”, “Seattle will lose”, “Denver will not lose”, and “Seattle will not win” are all congruent with the outcome, whereas predictions such as “Denver will lose”, “Seattle will not lose”, etc., are incongruent with the outcome. Therefore I hypothesize that among a set of logically equivalent predictions, predictions that are congruent with the outcome would be judged to be more accurate than predictions that are incongruent. To differentiate this from previously reported types of framing effects, I will call this hypothesized phenomenon the *prediction-assessment congruency effect* (or congruency effect for short).

As probabilistic predictions can take on a wide variety of forms, we will focus on predictions under the following conditions: *a*) the predictions are about an event with exactly two possible outcomes (e.g., coin flips, sports games with no ties); *b*) the predictions are each stated with a quantitative component, or subjective probability (e.g., “80%”); *c*) the qualitative components of the predictions involves one or two *subcomponents*. Since the meanings of the conditions *a* and *b* are relatively straightforward, we can move on to a discussion about condition *c*.

Many predictions involve drawing a link between two concepts in the outcome. In this paper I focus on predictions in which an agent—an individual or a group—is associated with a particular result. A common example of this kind of prediction is the win/loss outcome of a sports game. In many sports, a game involves two agents (two opposing players or two opposing teams) and at the end of the game, each of the agents will be associated mutually exclusively with an outcome (a win or a loss). I will call predictions of this type as predictions with two qualitative subcomponents (the agent subcomponent and the outcome subcomponent).¹

¹The two-subcomponent condition does not require one of the sub-

Predictions about the outcome of the game such as “there is an 80% chance that the Denver Broncos will win the Super Bowl” involve two qualitative subcomponents—the agent (“Denver Broncos”) and the outcome (“winning the Super Bowl”)—and one quantitative component (“80%”). Because all predictions studied in this paper contain exactly one quantitative component, the number of qualitative subcomponents will be used to characterize predictions (i.e., “one-subcomponent prediction” or “two-subcomponent prediction”). The above prediction about Super Bowl 2014 is therefore categorized as a two-subcomponent prediction. In a sports game, each team can be predicted either to win or to lose. In these predictions, one of the outcomes is matched to one of the agents, and this entails the other outcome to be matched to the other agent. In the Super Bowl example, because one of the teams must win, predicting that Denver will win is logically equivalent to predicting that Seattle will lose. It also can be seen that given a binary prediction, all logically equivalent predictions are either congruent or incongruent, regardless of the outcome.

Moreover, we can create logically equivalent variations of any specific prediction, by exchanging (sub-)components of this prediction with the logical complements of its qualitative subcomponents and/or the numerical complement of its quantitative component. For example, in the Super Bowl example, the prediction “there is an 80% chance that the Denver Broncos will win the Super Bowl” can be restated equivalently as “there is a 20% chance that the Denver Broncos will lose the Super Bowl”. Because both the qualitative subcomponents and the quantitative component of these predictions can be considered as binary-valued,² replacing any two (sub-)components with their logical or numerical complements would create a new but logically equivalent prediction, as the example shows. Consequently, many logically equivalent predictions can be made about a specific event.

I now examine the case for one-subcomponent predictions, which have only one qualitative subcomponent (in addition to the quantitative component). In contrast to two-subcomponent predictions, one-subcomponent predictions involve an indivisible outcome. For example, in the prediction “there is an 80% chance that it will rain tomorrow”, the qualitative component of the prediction is “it will rain tomorrow”. This event is indivisible because the subcomponent is a meaningful outcome in and of itself (in contrast, one cannot predict “will win” without

components to be an agent. It simply requires the two subcomponents to be crossed in a mutually exclusive fashion. I focus on predictions of the type agent \times outcome because these are the most commonly encountered. The findings can readily be generalized to predictions without agents.

²A quantitative component is considered as binary-valued in the context of this paper, as I am contrasting only its original value ($p\%$) and its numerical complement ($1 - p\%$).

specifying an agent). Other predictions of this type include “there will be a depression next year”, “the world is ending”, etc. While logically equivalent predictions can also be created from one-subcomponent predictions, the number of possible variations is more limited compared to two-subcomponent predictions.

One of the ways to empirically test whether framing influences assessment of prediction accuracy is to elicit accuracy judgments for a group of logically equivalent predictions with different frames, and to examine whether these judgments indeed do differ. The hypothesized framing effect is supported if accuracy assessments of logically equivalent predictions systematically differ along lines of the congruency of these predictions.

To determine whether a group of predictions are logically equivalent (especially for predictions involving different quantitative components), I evaluate each prediction based on their Brier score. The Brier score, a commonly used measure of prediction accuracy, is defined as the mean squared difference between the probability assigned to the predicted outcome and the actual outcome defined as 1 or 0 (Brier, 1950). As I investigate only one-shot predictions in the present research, the Brier score simplifies to:

$$BS = \begin{cases} (1 - p)^2 & \text{: if the qualitative component} \\ & \text{is correct} \\ p^2 & \text{: if the qualitative component} \\ & \text{is incorrect} \end{cases}$$

where p represents the quantitative component of the predictions.

The value of a Brier Score is between 0 (best) to 1 (worst) that rewards predictions that are correct, and penalizes predictions that are incorrect. It also rewards strong beliefs (probabilities closer to 1 or 0) more when they are correct, and penalizes them more when they are incorrect. For example, let’s say someone made a prediction “there is an 80% chance that the Denver Broncos will win the Super Bowl”. Since Denver lost the Super Bowl, the Brier score for this prediction is 0.8^2 , or 0.64. Had Denver won, the Brier score would have been 0.2^2 , or 0.04. Here it can be seen that both the qualitative and quantitative components of the prediction contributed uniquely to the Brier score. While the Brier score is usually used to evaluate the accuracy of predictions, in this paper the main focus is on how laymen evaluate accuracy of predictions. Therefore the Brier score is merely used to set up logical equivalence for predictions with different frames.

If people do evaluate predictions in ways consistent with the formulation of the Brier score, then given a specific outcome, logically equivalent predictions stated in different frames should be given similar evaluations con-

cerning their accuracy. However, as discussed earlier, I hypothesize that people will judge predictions that are congruent with the outcome to be more accurate. I note that, however, as human reasoning is exceedingly complex, this hypothesis in no way represents the entirety of how people process such judgments. In particular, the quantitative component is likely to be used in some capacity not described here. However, I argue that this characterization captures an important aspect of evaluations of probabilistic predictions, and is particularly important because it deviates from the principle represented by many scoring rules that measure the accuracy of probabilistic predictions, including the Brier score. Here I focus on comparisons between predictions that are logically equivalent (or close to it), as determined by having the same (or similar) Brier scores. Evaluations of non-logically equivalent prediction pairs (those with meaningfully different Brier scores) are not investigated.

In this paper I report seven experiments that were carried out to investigate whether people do indeed consider congruent predictions to be more accurate than logically equivalent incongruent predictions.

3 Experiments 1A and 1B

Experiments 1A and 1B were designed to provide initial evidence of the congruency effect—whether a congruent prediction would be rated as more accurate than an incongruent one.

3.1 Methods (Experiment 1A)

I recruited subjects for Experiment 1A using Amazon Mechanical Turk (MTurk). Only workers who were residing in the United States, were at least 18 years old, and had a lifetime acceptance rate with MTurk of 95% or over were allowed to participate (the same requirements applied to all MTurk experiments in this paper). Previous research has found that MTurk workers are likely to participate across multiple related experiments (Chandler, Mueller, & Paolacci, 2013). Not only might this weaken the representativeness of the sample, but subjects who have participated in multiple experiments might also become aware of the true intentions of the experiments. Therefore, I disallowed subjects from participating in more than one experiment in this paper by checking their MTurk ID before their participation. Over the six MTurk experiments presented here, there was a total of 633 unique MTurk workers.³

In order to detect subjects who might have been inattentive during the experiment, an attention check was employed after the subjects had given their consent to

³14 workers participated in two different experiments because of a programming error.

the experiment. This procedure was designed to identify whether or not participants had read the entirety of the instructions, thus providing an indirect measure of whether the subjects had been inattentive during the experiment (Oppenheimer, Meyvis, & Davidenko, 2009).

The actual content of the experiment took place after the attention check. The experiment focused on two-subcomponent predictions, and employed a 2×2 (congruency \times outcome frame) between-subjects design. The hypothesized difference between the two congruency conditions—predictions in congruent or incongruent frames—was the main focus of this experiment. Additionally, I set up two counter-balanced outcome-frame conditions to control for how the outcome was stated, as it is possible that this might moderate people's judgments.

Previous research has found that desirability of outcomes (e.g., "will be saved" vs. "will die") could moderate people's evaluation of prediction (Teigen & Nikolaisen, 2009). This potential issue was avoided (in all experiments in this paper) by using artificial cover stories in which the subjects should not have a preference towards either one of the two possible outcomes.

The stimuli in this particular experiment used the cover story of a college football game in the United States. Ties are extremely rare in American football and therefore it satisfies the two-outcome condition. The instructions were as follows. In the stimuli, double brackets (¶ and ¶) demarcate the wordings that were different between conditions and vertical lines (||) separate the conditions, which are named inside the parentheses.

Imagine that you have just arrived a little early for a new class on the first day of the semester. Another student was already there. The two of you started talking and the conversation turned to an upcoming college football game between universities A and B. The other student predicted that ¶ (Prediction frame: Congruent) University B has a 30% ¶ (Prediction frame: Incongruent) University A has a 70% ¶ chance of winning.

The game took place later that week and ¶ (Outcome frame: A) University A lost to University B ¶ (Outcome frame: B) University B defeated University A ¶.

Following this vignette, the subjects were asked to give a judgment about whether the prediction was wrong ("Was the prediction made by the other student wrong?") using choices of either "Yes, the prediction was wrong" or "No, the prediction wasn't wrong". They were then asked, "How accurate was the prediction?" This question used a 9-point scale with levels from "Extremely Inaccurate" to "Extremely Accurate". Finally, the subjects answered a

short demographics survey, including one question about the level of their football knowledge.

3.2 Results (Experiment 1A)

There was a total of 112 subjects (41.1% female), after discarding data from eight individuals (6.7%) for failing the attention check. Average age was 28.62 (*s.d.* = 11.95) and 84.8% had at least some college education.

The two prediction frames, "University B has a 30% chance of winning" and "University A has a 70% chance of winning", are logically equivalent. Similarly, the two outcome frames, "University A lost to University B" and "University B defeated University A" represent the same outcome. Moreover, we can see that the Brier score was the same ($0.7^2 = 0.49$) in all combinations of conditions. Therefore, if subjects evaluated the predictions based on a standard similar to the Brier score, then across all conditions, the predictions should be categorized as wrong in similar proportions, and receive similar accuracy ratings. However, as discussed earlier, I hypothesize that predictions stated in congruent frames would be rated as more accurate, compared to those in incongruent frames. Whether a prediction is congruent or not is determined by the combination of the qualitative component of the prediction (i.e., whether A or B will win) and the outcome of the event. In this experiment, the two outcome-frame conditions contains the same logical outcome (University A lost or University B won). Therefore, while congruency varied between the two prediction-frame conditions, congruency was the same for both outcome-frame conditions.

In the congruent condition the qualitative component (University B wins) matches the outcome irrespective of the outcome-frame condition (whether University A lost or University B won). In contrast, in the incongruent condition, the qualitative component of the prediction (University A wins) does not match the outcome for either outcome-frame conditions. Hence I hypothesize that subjects would rate the prediction in the congruent frame as more accurate, compared to that in the incongruent frame. In comparison, the two different outcome frames contains the same gist information. Therefore, I hypothesize that different outcome frames would not influence people's judgments.

I first performed a χ^2 test of independence to examine whether the prediction frames are associated with whether subjects consider the predictions to be wrong. In the congruent condition, 12 of 56 (21.4%) subjects judged the prediction to be wrong, compared to 29 of 56 (51.8%) in the incongruent condition, a difference which was significant ($\chi^2(1, N = 112) = 11.119, p = 0.001, \phi = 0.315$). This indicates that subjects in the congruent condition were less likely to think that the prediction was wrong, even though both predictions had the same Brier score.

Next I examined whether predictions in the congruent frame would be rated as more accurate. The mean rating in the congruent prediction frame was 4.91 (*s.d.* = 1.79), higher than that of the incongruent prediction frame at 3.34 (*s.d.* = 1.47), and this difference was significant ($t(110) = 5.077, p = 0.000, \text{Cohen's } d = 0.968$). This again supports the hypothesis that people would rate the congruent prediction to be more accurate than the incongruent prediction. The upper left panel in Figure 1 illustrates this result graphically.

I then examined the differences in the responses between different counter-balanced conditions in the outcome frames. In the forced-choice question of whether the prediction was wrong, there was no significant difference between different outcome frames ($\chi^2(1, N = 112) = 0.198, p = 0.656, \phi = 0.042$). Moreover, I found the mean accuracy rating—4.25 (*s.d.* = 1.96) for the A frame and 4.00 (*s.d.* = 1.66) for the B frame, respectively—to be quite similar, and there was no significant difference ($t(110) = 0.742, p = 0.460, \text{Cohen's } d = 0.142$). Additionally, there was no interaction between prediction frame and outcome frame ($F(1, 108) = 0.319, p = 0.573, \eta^2 = 0.002$). These results suggest that how the outcome was framed did not influence people's choices and ratings.

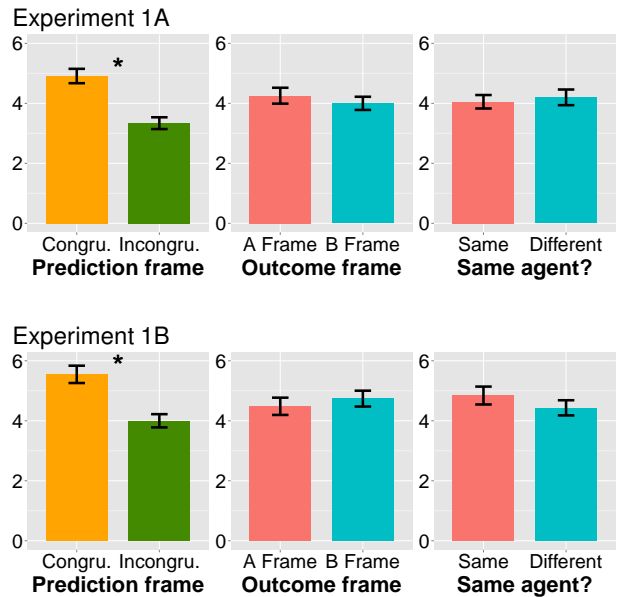
I also carried out a post-hoc analysis on whether having the same agent in the prediction frame and outcome frame would lead to higher accuracy ratings, as it might be easier for people to process prediction/outcome pairs involving the same agents. I found this to not be the case. There were no significant differences in the forced-choice question about whether the prediction was wrong ($\chi^2(1, N = 112) = 0.003, p = 0.958, \phi = 0.005$). Moreover, the mean accuracy rating of subjects who had the same agent in both frames was lower (4.05, *s.d.* = 1.69) than those with different agents (4.20, *s.d.* = 1.94), and the difference was not significant ($t(110) = 0.429, p = 0.669, \text{Cohen's } d = 0.082$). These results are plotted in the top row of Figure 1.

Self-reported football knowledge was quite evenly spread over the 4-point scale. There were 32, 33, 23, and 24 responses, from the least knowledgeable to the most knowledgeable, respectively. To investigate whether there was an interaction between football knowledge and the prediction frame on accuracy ratings, I carried out an ANCOVA analysis. The results indicated that there was no significant interaction ($F(1) = 0.696, p = 0.41$).

3.3 Discussion (Experiment 1A)

This experiment was the first test for the main hypothesis and the results strongly supported it. Although both predictions were logically equivalent—both predicted that there was a 30% chance of the eventual outcome occurring—the prediction in the congruent condi-

Figure 1: Results of Experiments 1A and 1B. The top row shows the results for Experiment 1A and the bottom for Experiment 1B. Each graph plots a comparison of accuracy ratings for a different factor. Orange and green colors represent the ratings for the congruent and incongruent predictions, respectively; salmon and cyan represent un-hypothesized ones. Error bars represent $\pm 1 \text{ s.e.}$ Asterisks indicate significant differences.



tion was less likely to be labeled as wrong, and was rated as more accurate. At the same time, the way the outcome was presented was found to have no influence on how the prediction was rated. Similarly, whether the same agent was used in the prediction and the outcome did not influence people's judgments. The results of Experiment 1A suggest that frames significantly change people's evaluations of those predictions—people consider a prediction that are stated congruently with the outcome to be more accurate than one that are stated incongruently.

Nonetheless, some issues remain that could not be addressed by this experiment alone. The most important is whether this result can be replicated in a more controlled environment, and therefore I carried out a replication in a university lab.

3.4 Methods (Experiment 1B)

The main objective of Experiment 1B was to replicate the results of Experiment 1A in a lab setting. I recruited subjects from a large university in Beijing, China. I kept the design of Experiment 1A unchanged and simply translated the stimuli into Chinese. The only notable difference is that I changed the target of prediction from an American football game to a basketball game. Not only is basketball

a more popular sports in China, it also cannot end in ties, therefore satisfying the two-outcome requirement. The experiment material was translated and back-translated by two native Chinese speakers. Discrepancies in the original and back-translated versions were reviewed and resolved by these two native speakers. Subjects were paid 15 RMB (~US\$2.5) for their participation in a package of several experiments. This experiment was the first within the package. Most finished all experiments in 10-20 minutes.

3.5 Results and discussion (Experiment 1B)

Out of a total of 137 subjects, 62 (45.3%) failed the attention check, leaving 75 data points. The portion of subjects failing the attention check was quite high, which resulted in the experiment having weaker power than expected. However, as we will see, the pattern of results was quite similar to that of Experiment 1A.

I first used a χ^2 test of independence to ask if the prediction frame influenced whether the subjects considered the prediction to be wrong. Although the result was in the right direction—a higher proportion of the subjects in the congruent condition (26 of 31, or 83.87%) considered the prediction to not be wrong than did those in the incongruent condition (30 of 44, or 68.2%)—the effect was not quite significant ($\chi^2(1, N = 75) = 2.367, p = 0.124, \phi = 0.178$). This result was the only one that deviated from the results of Experiment 1A. All other tests concerning the main hypothesis resulted in the same direction and significance as in Experiment 1A.

Congruency had a significant effect on accuracy ratings, with the ratings for the congruent frame ($M = 5.55, s.d. = 1.61$) significantly higher than those for the incongruent frame ($M = 4.00, s.d. = 1.46; t(73) = 4.331, p = 0.000, \text{Cohen's } d = 1.016$). Also similar to Experiment 1A, the outcome frames ($t(73) = 0.634, p = 0.528, \text{Cohen's } d = 0.150$) and whether the prediction and outcome had the same agent ($t(73) = 1.045, p = 0.299, \text{Cohen's } d = 0.241$) had nonsignificant effect. The results are shown in the bottom row of Figure 1. By comparing the top (Experiment 1A) and bottom (Experiment 1B) rows, we can see that the results from these two experiments were quite similar. The similarity of the pattern of results across the two different settings suggests that these results are robust.

3.6 Discussion

The results from these two experiments provide initial evidence supporting the congruency effect. In both the internet-based data collected in the United States and the lab-based data collected in China, predictions stated in the direction congruent with the outcome were rated as

more accurate than those stated in the incongruent direction, even though all predictions were logically equivalent. Moreover, I found that people's judgments were not affected by which agent was used in the outcome or whether the same agent was used in both prediction and outcome.

4 Experiment 2

Experiment 2 used a simple design to address an alternative explanation due to the phrasing in the stimuli of Experiment 1. Negative phrasing ("Was the prediction made by the other student wrong?") was chosen for the forced-choice question in Experiment 1 because the performance of the predictions in both conditions was lower than chance. However, negatively phrased questions may be somewhat unnatural to subjects, and might not be representative of how evaluations are usually elicited in everyday life. Previous research has found that positively and negatively framed procedures do not necessarily give the same result (Yaniv & Schul, 1997; Choi, Dalal, Kim-Prieto, & Park, 2003). Moreover, there is a possibility that the negative phrasing in the forced-choice question could have even influenced how subjects responded to the accuracy ratings question that followed. Therefore I carried out Experiment 2 to eliminate this potential issue.

4.1 Methods

I recruited subjects from Amazon Mechanical Turk and used a procedure that was mostly identical to that in Experiment 1A. The subjects were given the same stimuli about a prediction from another student about an upcoming football game. The only difference lay in how I elicited the forced-choice response regarding the prediction; I asked, "Was the prediction made by the other student right?"

4.2 Results

Experiment 2 had a total of 78 subjects (34.6% female), after discarding data from nine individuals (10.3%) for failing the attention check. The mean age was 29.03 ($s.d. = 12.73$) and 88.5% had at least some college education.

The main objective of this experiment was to test whether the congruency effect could be replicated when the forced-choice question were elicited in positive terms. I first analyzed the results of the forced-choice question in which the subjects were asked whether the prediction was right. In the congruent condition, 22 of 40 (55.0%) responded affirmatively, whereas in the incongruent condition, only 8 of 38 subjects (21.1%) responded so. χ^2 test showed that this difference was significant ($\chi^2(1, N =$

78) = 9.488, $p = 0.002$, $\phi = 0.349$). The accuracy ratings for the two conditions painted a similar picture. The mean accuracy rating for the congruent condition was 5.05 ($s.d. = 2.06$), compared to a rating of 3.39 ($s.d. = 1.72$) for the incongruent condition, a difference that was significant ($t(76) = 3.841$, $p = 0.000$, Cohen's $d = 0.882$).

4.3 Discussion

Experiment 2 focused on whether the congruency effect holds when people are asked to evaluate predictions in positive terms. Results indicated that this is indeed the case—the pattern of results found in Experiments 1A and 1B was replicated in this experiment. This suggests the congruency effect to be robust regardless of the valence in which evaluations were elicited.

5 Experiment 3

The main objectives of Experiment 3 were to extend the findings of Experiments 1 and 2 and to explore whether the congruency effect could be further generalized. Many different logically equivalent predictions can be constructed by altering the components in a prediction. For example, in Experiments 1 and 2, I compared the predictions “University A has a 70% chance of winning” against “University B has a 30% chance of winning”. However, predictions such as “University A has 30% chance of losing” or “University B has a 70% chance of losing” are also logically equivalent to the first two. If the results we have seen are indeed due to the difference in congruency, as I hypothesize, then we should expect the same pattern of results with other logically equivalent predictions as well.

I limited the scope of this experiment to two-subcomponent predictions. In this setup, there are four logically equivalent ways of stating a prediction without using verbal negation (e.g., “not win”). These four ways are shown in Table 1. The first column displays the agents in the predictions and the second column matches them to one of the two possible outcomes. The third column displays the stated probability (p) of the event occurring (we assume $p > 0.5$). The fourth column combines the first three to form a prediction. If congruency indeed influences people's accuracy ratings, then the predictions in the two congruent conditions should be rated as more accurate than the predictions in the two incongruent conditions.

5.1 Methods

I recruited a total of 138 subjects from Amazon Mechanical Turk. Each subject was paid US\$0.40. This experiment used a cover story about an election. Before the experimental section, the subjects completed an attention

check similar to the one described in Experiment 1. The experiment had a 2×2 (congruency \times agent) between-subjects design. The congruency factor indicates whether the prediction frame was congruent, and is the main focus of the experiment. The agent factor indicates whether the agent of the prediction was the eventual winner or loser, and served as a counter-balancing factor. The instructions were as follows:

Acme Inc. is a company that conducts public opinion polls in Europe. Recently there was a general election in a small European country. The two major parties involved were the NRT and CTS parties. Other than these two major parties, all other parties are much smaller and had no chance of winning the election. Before the election Acme Inc. had predicted that the [(Congruent/Winner) CTS party had a 20 percent chance of winning || (Congruent/Loser) NRT party had a 20 percent chance of losing || (Incongruent/Winner) CTS party had an 80 percent chance of losing || (Incongruent/Loser) NRT party had an 80 percent chance of winning].

Results from the election showed that the CTS party has won.

In Experiment 3 I focused on the accuracy ratings given by the subjects and therefore did not give the forced-choice question about whether the prediction was right or wrong, as I did in the Experiments 1 and 2. This has the additional benefit of testing whether the same pattern of results on accuracy ratings would be produced without the forced-choice question appearing prior to the accuracy rating question. The experiment prompted the subjects with a question “How accurate was the prediction?” and the answers were elicited using a 9-point scale (from “Extremely Inaccurate” to “Extremely Accurate”). Finally the subjects completed a demographics survey.

5.2 Results

Five subjects (3.8%) failed the attention check, leaving 133 subjects. The mean age was 30.74 ($s.d. = 10.41$) and 34.59% was female.

I first tested the main hypothesis—whether congruency indeed influenced people's judgments. Although the predictions in all four conditions had the same Brier score (0.8^2), the predictions in the congruent conditions were rated as more accurate as hypothesized: The mean accuracy rating of the two congruent conditions was 4.32 ($s.d. = 2.15$), higher than those of the two incongruent conditions at 2.42 ($s.d. = 1.8$), and the difference was significant, with a strong effect size similar to those

Table 1: Design of Experiment 3.

Agent	Outcome	Probability	Full prediction	Congruency
NRT	Wins	p	NRT wins @ 80%	Incongruent
NRT	Loses	$1 - p$	NRT loses @ 20%	Congruent
CTS	Wins	$1 - p$	CRT wins @ 20%	Congruent
CTS	Loses	p	CRT loses @ 80%	Incongruent

Note: Each row represents a combination of the congruency condition and the agent condition. The first three columns indicate the various parts of the predictions and the fourth gives a schematic representation of the prediction produced by combining the three. The fifth column indicates the congruency for each row, by comparing the qualitative component of the prediction against the actual outcome (the CRT party won).

in previous experiments ($t(131) = 5.528$, $p = 0.000$, Cohen's $d = 0.959$).

I carried out a more stringent post-hoc test of the hypothesis by comparing the lower rated congruent condition against the higher rated incongruent condition. The accuracy ratings of the Congruent/Winner condition was lower among the two congruent conditions ($M = 3.72$, $s.d. = 2.14$) whereas the ratings of the Incongruent/Loser condition was higher among the two incongruent conditions ($M = 2.72$, $s.d. = 2.14$). The difference between the two conditions was in the right direction, although not quite significant ($t(62) = 1.866$, $p = 0.067$, Cohen's $d = 0.466$, two tailed). All other pairwise t -tests between conditions of opposite congruencies resulted in significant differences in the right direction. These results provide further support for the main hypothesis.

I then carried out some additional post-hoc analyses. I first compared the ratings given to predictions between the two counter-balancing conditions in the agent factor—predictions with either the eventual winner or the eventual loser as the agent—and found that there was no significant difference ($t(131) = 0.719$, $p = 0.474$, Cohen's $d = 0.125$).

I also performed a post-hoc check for an interaction between congruency and predicted outcome (whether the prediction was for a win or for a loss) and found that the result was nonsignificant ($F(1, 129) = 0.760$, $p = 0.385$, $\eta^2 = 0.005$).

5.3 Discussion

In Experiment 3 I investigated whether the congruency effect can be generalized more broadly to other variations of congruent and incongruent frames. Predictions in all four conditions in this experiment were logically equivalent, but two were framed congruently and two incongruently. As hypothesized, subjects rated the congruent pre-

dictions to be more accurate than the incongruent predictions. The results demonstrated that the congruency effect can be observed in the contrast between various variations of logically equivalent predictions, and is not limited to the particular pair of predictions used in Experiments 1 and 2.

6 Experiment 4

I carried out Experiment 4 with the following objectives. First, so far I have tested only two-subcomponent predictions: Predictions that involve an agent (e.g., Team A, the NRT party, etc.) and an outcome (e.g., winning). In Experiment 4, I wanted to test the congruency effect in predictions composed of a single qualitative subcomponent, ones with an indivisible outcome.

Second, in Experiments 1–3 the congruent predictions were stated with probability values that were below chance ($< 50\%$) whereas the incongruent predictions, using the numerical complements of the congruent version, were stated with probability values that were above chance. For example, in Experiments 1 and 2 the congruent prediction was stated with a probability of 30%, whereas the incongruent prediction was stated with a probability of 70%. Although there are no a priori reasons that the congruency effect would not apply if these values were reversed, I would like to formally test against this possibility.

Third, while previous experiments investigated people's evaluation of different predictions with respect to one of the two possible outcomes in a binary event, Experiment 4 contrasts the judgments for predictions with respect to both outcomes. In cases concerning binary events, a prediction that is congruent with one outcome would be incongruent with an opposite outcome. It follows that, if there are two logically equivalent predictions about a binary event but with opposite qualitative components ($X\%$ chance of A occurring and $1 - X\%$ chance of $\neg A$ oc-

curing), one of these two predictions would be congruent under one of the possible outcomes, while the other prediction would be incongruent. Therefore, if *A* indeed occurs, the hypothesis predicts that the first prediction will be rated as more accurate than the second one, and vice versa. However, the experiments thus far used either exactly one outcome (Experiment 3), or a group of logically equivalent outcomes (Experiments 1 and 2), and have not compared evaluations of predictions with respect to different outcomes. Therefore in the current experiment I elicited judgments about the accuracy of the same predictions with respect to both possible outcomes in order to directly compare judgments when different outcomes occur, and to test whether the main hypothesis would continue to hold.

6.1 Methods

Amazon Mechanical Turk was again used to recruit subjects for this experiment. The beginning of this experiment was similar to the previous ones. After giving consent, the subjects were given an attention check, and were then given instructions as follows, with the prediction factor and the outcome factor indicated using double brackets and parentheses:

Imagine that you are a college student and you have just arrived a little early for a new class on the first day of the semester. Another student was already there. The two of you started talking and the conversation turned to a closely contested proposition about student bus passes in the upcoming student council election. The other student predicted that there is a [(Prediction: 70% Pass) 70% chance that the proposition will pass || (Prediction: 30% Fail) 30% chance that the proposition will fail].

The election took place later that week and the proposition [(Outcome: Pass) passed || (Outcome: Fail) failed].

I then asked subjects to rate the accuracy of the other student's prediction on a 7-point scale (from "Extremely Inaccurate" to "Extremely Accurate") with respect to the outcome (the *original scenario*). As I was interested in understanding how people would rate the predictions if the outcome was reversed, I then elicited their responses for an *alternative scenario* (which was shown in a new web page so that they cannot see their previous responses):

If instead, the proposition had [(outcome: Fail) failed || (outcome: Pass) passed], how accurate do you think the other student's prediction was?

Note that in the alternative scenario the subjects were always given an outcome that was the opposite of what they read previously. This second accuracy rating was also elicited using the same 7-point scale. Finally, subjects were given a short demographics survey.

6.2 Results

There was a total of 136 subjects. Twelve individuals (8.8%) failed the attention check and therefore their data were not used in the following analyses, leaving 124 subjects.

Results from Experiment 4 are shown in Table 2. Each row of the table crosses a prediction condition with an outcome condition (both between-subjects). The two column groups in the table represent the original and the alternative scenarios (within-subjects), each associated with one of the two possible outcomes.

In this experiment, the predictions in all conditions, listed in the left-most column, were either "70% pass" or "30% fail", and were thus logically equivalent. The top two and bottom two rows are separated, however, to emphasize that not only the outcome conditions are different, the order of the presentation of the outcomes was different—subjects in the conditions represented by the top two rows were told that the result was *pass* in the original scenario, and *fail* in the alternative scenario, and the results were reversed for the bottom two rows. Within each column group, the prediction and the outcome were compared to determine congruency, which was followed by the mean and *s.d.* of the accuracy ratings.

I first analyzed the overall difference between congruencies by aggregating the responses over all scenario and outcome conditions. Here the mean accuracy rating of the congruent condition ($M = 4.84$, $s.d. = 1.64$) was higher than that of the incongruent condition ($M = 3.27$, $s.d. = 1.61$), and the difference was significant ($t(246) = 7.570$, $p = 0.000$, Cohen's $d = 0.961$). The result here showed that taken altogether, predictions that are congruently framed are indeed rated as more accurate than those incongruently framed.

I then examined the simple effects organized by the scenario and outcome factors. I begin by analyzing the judgments under the original scenario, separately at each of the two levels of the outcome factor (either *pass* or *fail*). For the conditions in which the outcome is *pass*, the contrast is displayed in the first and second rows in Table 2, under the original scenario column group. Similar to previous experiments, I predicted that the congruent prediction to be rated as more accurate. As expected, between these two high accuracy conditions (Brier score = 0.3²), the congruent condition ($M = 5.97$, $s.d. = 1.02$) was rated significantly higher in accuracy than the incongruent condition ($M = 3.79$, $s.d. = 1.61$; $t(58) = 6.294$, $p = 0.000$,

Table 2: Design and results of Experiment 4.

Prediction	Original scenario				Alternative scenario			
	Outcome	Congruency	Mean	s.d.	Outcome	Congruency	Mean	s.d.
70% Pass	Pass	Congruent	5.97	1.02	Fail	Incongruent	2.74	1.24
30% Fail	Pass	Incongruent	3.79	1.61	Fail	Congruent	4.07	1.58
70% Pass	Fail	Incongruent	2.64	1.39	Pass	Congruent	5.49	1.28
30% Fail	Fail	Congruent	3.74	1.55	Pass	Incongruent	4.00	1.75

Note: Each row represents a combination of the prediction condition and the outcome condition. The top two and bottom two rows are separated to emphasize the difference in the order the outcomes were given to the subjects. Each subject gave judgments to both possible outcomes—the first listed under *Original scenario* and the second under *Alternative scenario*. The stated prediction is shown in the left-most column. The outcomes, congruency, ratings are indicated within each column groups. All predictions were logically equivalent: 70% chance of passing or 30% chance of failing.

Cohen’s $d = 1.626$). I then compared the two conditions in which the original scenario was *fail*, represented in third and fourth rows under original scenario. Between these two low accuracy conditions ($BS = 0.7^2$), the congruent condition ($M = 3.74, s.d. = 1.55$) was also rated significantly higher in accuracy than the incongruent condition ($M = 2.64, s.d. = 1.39; t(62) = 3.011, p = 0.004$, Cohen’s $d = 0.753$).

The responses for the alternative scenario were almost a mirror image of those for the original one. I first examined the simple results in which the outcome was *pass* (third and fourth rows under alternative scenario column group). Between these high accuracy conditions ($BS = 0.3^2$), the congruent prediction was rated as more accurate ($M = 5.49, s.d. = 1.28$) than the incongruent prediction ($M = 4.00, s.d. = 1.75$), and this difference was significant ($t(58) = 3.635, p = 0.001$, Cohen’s $d = 0.939$). I then compared the low accuracy conditions in which the outcome was *fail* ($BS = 0.7^2$; first and second rows). Here the accuracy ratings for the congruent prediction ($M = 4.07, s.d. = 1.58$) were also significantly higher than those of the incongruent prediction ($M = 2.74, s.d. = 1.24; t(62) = 3.892, p = 0.000$, Cohen’s $d = 0.973$). In all four simple effects tested, and overall, the congruently framed prediction was rated as more accurate than the incongruently framed prediction, demonstrating that the congruency effect to be robust across different outcomes. I aggregated the responses across the two scenarios, and displayed the results graphically in Figure 2.

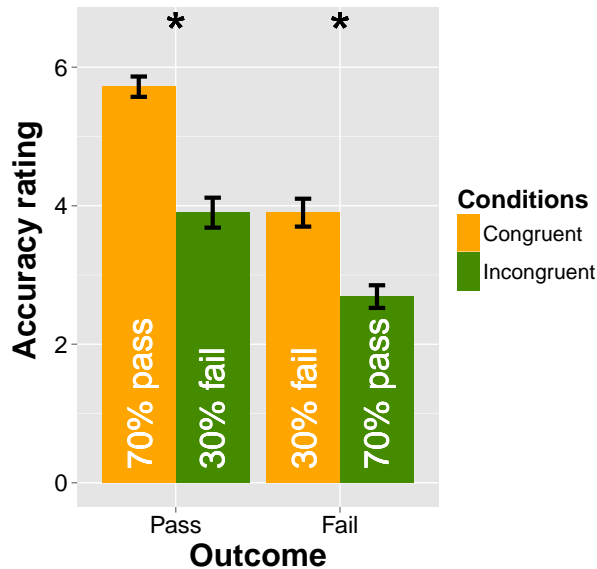
Next I evaluated the overall effects between the two predictions, “70% pass” and “30% fail”. I aggregated over all results for both outcome conditions and for both the original and the alternative scenarios. The overall mean accuracy rating of the predictions “70% pass” ($M = 4.2,$

$s.d. = 1.96$) and “30% fail” ($M = 3.9, s.d. = 1.61$) were not significantly different ($t(246) = 1.325, p = 0.186$, Cohen’s $d = 0.168$), indicating that there was no overall prediction effect. I then tested whether the two different predictions might interact with congruency using a 2×2 ANOVA. The results showed that the interaction was significant, suggesting that the congruency effect is stronger with the “70% Pass” condition than with the “30% Fail” condition ($F(1, 244) = 68.948, p = 0.000, \eta^2 = 0.177$).

I also tested if the order of the response—whether the prediction was evaluated first or last—might influence people’s assessment of the predictions. The order had no effect ($t(246) = 0.352, p = 0.726$, Cohen’s $d = 0.045$). A 2×2 ANOVA on congruency and order show that there was no interaction effect either ($F(1, 244) = 0.297, p = 0.587, \eta^2 = 0.001$). These results suggest that the effect observed cannot be explained by the experimental design (namely, the fact that two responses were elicited from each subject).

Although the primary objective of this paper is to contrast differently framed predictions that are logically equivalent (that is, predictions with identical Brier scores), comparing predictions that have different Brier scores could give us insights about people’s behavior in more general cases. Hence, I conducted a post-hoc analysis comparing the accuracy assessment for predictions that had the “pass” outcome with predictions that had the “fail” outcome. For both predictions, a “pass” outcome is associated with a better Brier score, therefore I expected predictions would be evaluated as being more accurate when the outcome was “pass” ($BS = 0.3^2$), compared to when the outcome was “fail” ($BS = 0.7^2$). The result confirmed my expectation, with a mean rating of 4.84 ($s.d. = 1.7$) when the outcome was “pass”, compared to a mean rating of 3.27 ($s.d. = 1.55$) when the outcome was “fail”. A

Figure 2: The accuracy ratings organized by outcome and congruency, and aggregated over the scenario factor, in Experiment 4. The white wordings inside the bars indicate the predictions. Given an outcome, predictions framed congruently were rated as significantly more accurate. Note that congruency depends on the interaction between the prediction and the outcome. Error bars represent ± 1 *s.e.*



t-test confirmed that the difference was indeed significant ($t(246) = 7.570$, $p = 0.000$, Cohen's $d = 0.961$). This result confirms the intuition that people's evaluation of the accuracy of predictions depend greatly on the outcome.

6.3 Discussion

In this experiment I tested the congruency effect on one-subcomponent predictions. I elicited people's accuracy judgments about various logically equivalent predictions with respect to both possible outcomes of a binary-outcome event. I found that, first, the congruency effect holds for one-subcomponent predictions as well—people's accuracy ratings for congruent predictions are higher than for logically equivalent incongruent predictions, both with respect to specific outcomes and overall. Together with the results from the previous experiments, this shows that the congruency effect applies to both one- and two-subcomponent predictions.

Second, the congruency effect is not limited to cases in which the congruent predictions are stated with lower probabilities than those for the incongruent predictions.

Third, when aggregated over the two possible outcomes, there is no overall difference in accuracy ratings between a pair of logically equivalent predictions that are opposite in their qualitative component. Fourth, if a pair of

logically equivalent predictions are made about a binary-outcome event and their qualitative component are logical complements of each other, one of the predictions would be rated as more accurate if one outcome occurs, and the other predictions would be rated as more accurate otherwise. These two findings illustrate that the consequences of the congruency effect can be observed only with respect to a specific outcome.

7 Experiment 5

The first four experiments in this paper have demonstrated that when people are asked to evaluate the accuracy of predictions, those presented in a congruent frame would be judged to be more accurate. Experiment 5 investigates whether this can be extended to choice tasks—here two predictions, one in a congruent frame and one in an incongruent frame, were presented simultaneously, and subjects were asked to choose which of the two was the more accurate.

In addition, this experiment explores two other factors that might shed light on the mechanism of the congruency effect. First, much prior research suggested that numeracy plays an important role in judgment and decision making. One example is the attribute-framing effect, in which a single attribute presented in two logically equivalent frames of opposing valence (e.g., beef that was labeled as “75% lean” or “25% fat”) can change people's evaluations about the target (Levin & Gaeth, 1988). Subjects higher in numeracy were found to be less susceptible to the attribute framing effect (Peters, Västfjäll, Slovic, Mertz, Mazzocco & Dickert, 2006). Although the framing effect studied in the current paper concerns different kinds of judgments, it is possible that numeracy similarly moderates the link between frames and choice.

Second, when two logically equivalent predictions are being evaluated with respect to the outcome, the one stated with higher strength of belief might be thought to be made by someone more confident about his or her prediction, and this might potentially influence assessment of the accuracy ratings. Specifically, it is possible that due to their higher perceived confidence, they are judged more harshly (Paulhus, 1998; Tenney, Spellman, & MacCoun, 2008). To investigate the influence of these two factors, in Experiment 5 I also assessed subjects' numeracy and perceptions about the predictor's confidence.

7.1 Methods

Subjects were recruited through Amazon Mechanical Turk. In previous experiments, logically equivalent predictions of different congruencies were presented between-subjects. However, in this experiment I presented

subjects a choice task with both congruent and incongruent frames side-by-side as two options; a setup with such total equivalence might seem contrived. Furthermore, I wanted to test whether the congruent frame would be favored even if it was logically inferior. Hence the stimuli were set up so that the prediction in the incongruent frame was logically superior to that of the congruent frame. Additionally, in order to make the scenarios more realistic, I added two distractor predictions to each option. The instructions in one of the conditions read:

Imagine that you are an analyst at an investment firm. Currently you are evaluating predictions made a year ago by two of your subordinates concerning a technology company called Acme Corp.

Analyst A predicted that in the coming year:

- Acme would buy out their supplier SuperTech Company.
- Acme would expand into the European Union.
- There was an 80% chance that Acme would become a public company.

Analyst B predicted that in the coming year:

- Acme would license crucial technology patents from their competitor CompX Company.
- Acme would build another manufacturing plant within the U.S.
- There was a 15% chance that Acme would not become a public company.

The last predicted outcome—whether Acme would become public or not—was common for both analysts, and was the focus of the current experiment. In addition to the common predicted outcome (expressed as an incongruently framed prediction by one analyst and as a congruently framed prediction by the other), there were two unique distractor predictions from each analyst. Therefore there were six different predictions, but only five distinct predicted outcomes.

There were four (2×2) counter-balanced conditions. First, the order of the congruent and incongruent options was randomized between subjects. Second, one of the two distractors from each of the analysts would turn out to be true, and they are counter-balanced. For roughly half of the subjects the supplier buyout and new U.S. manufacturing plant turned out to be true, and European Union expansion and patent licensing turned out to be false; for the other half the predictions that were correct (and those that were incorrect) were reversed.

In all conditions, Acme would not become public. In the counter-balancing condition shown above, Analyst A

predicted that there was an 80% chance of the target event (Acme becoming a public company) occurring. Analyst B, in contrast, predicted that there was a 15% chance of the target event not occurring. Since the target event did not occur, the prediction by Analyst A ($BS = 0.8^2$) was logically superior to the analogous prediction by Analyst B ($BS = 0.85^2$). As the outcomes and accuracy about the distractor predictions were balanced, Analyst A should be evaluated as being more accurate, if prediction frames had no influence on people's judgments.

After the subjects had read about the outcome, I asked them "Which analyst do you think made the better predictions?" and "Which analyst do you think was more confident about the predictions?" Both questions were forced-choice questions with the two analysts as response options. Following these questions I presented (in a new web page) a memory test, in which I asked the subjects to indicate whether each of the five predicted events actually occurred. In the instructions for the memory test I explicitly informed the subjects that they would not be penalized even if they did not remember correctly. Then, to investigate the influence of subjects' numeracy on their judgments, I gave the 8-item abbreviated numeracy scale (Weller, Dieckmann, Tusler, Mertz, Burns, & Peters, 2013). After the numeracy section, subjects answered a few demographic questions, including two questions about their level of knowledge concerning stock trading and technology.

7.2 Results

There were 110 subjects (60% female, with one who declined to self-identify along this dimension). I discarded data from 25 (22.7%) subjects: 24 for failing the attention check and 1 for leaving over 80% of the answers blank,⁴ resulting in 85 subjects used in the following analysis. The mean age was 33.1 (*s.d.* = 12.87), and 87.1% had at least some college education.

The portion of workers who failed the attention check was somewhat higher than those of previous experiments.⁵ To alleviate concerns about the quality of the current sample, and to better assess whether subjects who passed the attention check were attentive during the experiment, I examined the results of the memory test. The possible range of the memory score was from 0 to 5, representing the

⁴No other subjects left more than one of the answers blank, outside the optional questions in the demographics section.

⁵There was no a priori reason to suspect that the subjects in this experiment were different in any meaningful way from those in the previous ones. Moreover, in all MTurk experiments in the current paper, the attention check was the second question in the entire experimental procedure, after only a question eliciting their MTurk ID. Therefore up to the attention check, the experimental procedures of all the MTurk experiments were essentially the same. These observations suggest that the higher attention check failure rate might be due to factors exogenous to the experimental design.

number of test questions answered correctly. The mean memory score of the remaining subjects was quite high at 4.25, indicating that the subjects paid attention during the experiment and remembered most details about the stimuli. I also note that subjects were not informed of the memory test prior to it. Hence it is likely that they did not memorize the outcomes for the purpose of passing the memory test, but have remembered them as a result of having processed the stimuli in order to make the accuracy and confidence judgments. Based on these results, I believe that the subjects who passed the attention check likely did pay sufficient attention to the task, and proceeded with the analysis using the data from these subjects.

The main objective of this experiment was to test whether the congruency effect could be extended to a choice task. More subjects ($n = 56$; 65.9%) chose the analyst in the congruent condition as more accurate than the one in the incongruent condition ($n = 29$; 34.1%). A χ^2 test showed that this result was significantly different from chance ($\chi^2(1, N = 85) = 8.576, p = 0.003, \phi = 0.318$), indicating that the congruency effect applies to choice tasks as well.

I then examined whether perception of confidence was related to the congruency effect. If the lower evaluation of the accuracy of incongruent options was due to a perception of overconfidence on the part of the analyst, then subjects' choice of the more accurate analyst and the more confident analyst would not be independent. Of the 56 subjects who chose the congruent option as being more accurate, 32 (57.1%) judged the incongruent analyst to be the more confident, compared to 18 of the 29 (62.0%) subjects who chose the incongruent option. This result was not significant ($\chi^2(1, N = 85) = 0.191, p = 0.662, \phi = 0.047$), which suggests that perception of predictors' confidence was not a factor in subjects' judgments of prediction accuracy.

A post-hoc analysis is then carried out to study the effects of order of presentation. When the incongruent option was presented first, the number of subjects who chose the incongruent option ($n = 20$) as being the more accurate was approximately the same as the number who chose the congruent option ($n = 21$). However, when the congruent option was presented first, 35 subjects judged the congruent option to be more accurate, while only 9 chose the incongruent option. This interaction was significant ($\chi^2(1, N = 85) = 7.576, p = 0.006, \phi = 0.299$), indicating that order of presentation significantly influenced evaluation of accuracy. In contrast, order of presentation did not have a significant effect on the evaluation of confidence ($\chi^2(1, N = 85) = 0.243, p = 0.622, \phi = 0.053$).

I then investigated the effect of numeracy on people's judgments. As there are eight questions in the abbreviated numeracy scale, the range of possible scores is

Table 3: Relationship between numeracy and the congruency effect in Experiment 5.

Numeracy score	1	2	3	4	5	6	7
Congruent choice	1	3	14	8	15	10	4
Incongruent choice	1	0	2	4	4	12	6

Note: This contingency table displays, for each numeracy score, the number of subjects who chose either the congruent or the incongruent option as the more accurate one.

from 0 to 8. On average the subjects answered 4.76 questions correctly, compared to 4.09 for the subjects in Study 1 of Weller et al. (2013). I compared the percentages of subjects who answered each question correctly for Weller et al.'s and the present results. On a per-question basis, the mean absolute difference was 11.34%, and this small difference suggests that the numeracy and motivation of the subjects in this experiment were comparable to those in Weller et al.'s experiment.

Table 3 displays a contingency table of the numeracy scores crossed with subjects' judgments about who was the more accurate analyst. The mean (and *s.d.*) of the numeracy score for subjects who chose the congruent or incongruent options as more accurate were 4.43 (*s.d.* = 1.45) and 5.41 (*s.d.* = 1.45), respectively. I performed a logistic regression analysis with the choice of the more accurate analyst as the dependent variable. A likelihood ratio test comparing a model with numeracy against a model with only the intercept showed that the difference was significant ($B = 1.64, p < 0.01$), indicating that there is an association between numeracy and choosing the congruent option—people of lower numeracy are more likely to judge the analyst in the congruent condition to be more accurate.

The effect of self-reported knowledge about stock trading and technology on choice of the more accurate analyst was found not to be significant in either case ($p = 0.80$ and $p = 0.56$).

7.3 Discussion

The key objective of this experiment was to investigate whether the congruency effect would hold in a choice task. I also put the main hypothesis to a stronger test by presenting the congruent option against a logically superior incongruent option. Significantly more subjects chose the logically inferior congruent option, suggesting that the congruency effect applies to choice tasks as well as rating tasks. I also found that the evaluators' perception of the predictors' confidence did not explain the congruency effect. However, numeracy was a moderating factor. The

result suggested that people who are higher in numeracy might be less susceptible to the congruency effect, corresponding to a similar finding about the attribute framing effect (Peters et al., 2006).

8 Experiment 6

So far in this paper I have asserted that the congruent and the incongruent frames are logically equivalent. However, I have not confirmed that people in general would agree with this assertion. Therefore, the first objective in the final experiment is to examine whether naïve subjects do indeed consider these frames to be logically equivalent. For the ease of exposition, I call this condition—whether logically equivalent statements of different congruencies are considered to be equivalent by the general population—*naïve equivalence*.

Secondly, while we know from previous experiments that evaluations of prediction accuracy depend on which of the two possible frames, the congruent frame or the incongruent frame, is presented, we do not have data on whether their ratings would deviate from the observed pattern if people are aware of both ways to frame a prediction. To explore this question, in Experiment 6 I first give subjects a prediction stated in either a congruent or incongruent frame, elicit their accuracy judgment, then restate the prediction using the opposite frame while bringing to their attention the correspondence between the two, and finally, elicit their accuracy judgments again. While there could be a spectrum of possible outcomes, here I will sketch two extremes. One possibility is that people would maintain their original evaluation even after being exposed to the second and alternative frame. This would suggest that people have adopted the first frame as their frame of reference. At the other end of the spectrum is the possibility that people would completely integrate the two frames, in which case their second judgment would likely to be different from their first. Using this experimental design, we can find out which one of these two possibilities (or one lying between the two extremes) corresponds more closely to people's behavior.

Finally, I also used this experiment to explore a few secondary objectives concerning people's perception and beliefs about frames, including the naturalness of frames of different congruencies, and the degree to which people think the frames influence their own and other people's judgments.

8.1 Methods

Subjects were recruited from Amazon Mechanical Turk. The beginning of the experiment was essentially identical to the previous ones—subjects were asked to give consent

and were given an attention check. Afterwards they read a cover story that was similar to that of Experiment 3. The instructions for the first judgment task were as follows:

Imagine that some time in the past there was a general election in a European country. The two major parties involved were the NRT and CTS parties. All other parties besides these two were much smaller and had no chance of winning. Therefore one of these two parties would definitely win the election.

You talked to your friend Chris about this election before it was held. Chris predicted that there was [(CI condition) a 20% chance that the NRT party would win || (IC condition) an 80% chance that the CTS party would win] the election.

Results from after the election indicated that the NRT party won.

The names of the conditions indicate the order of the frames given: Whether subjects were first shown a congruent frame followed by an incongruent one (CI), or an incongruent frame followed by a congruent one (IC). I note that, at this point in the experiment, the subjects were not aware that they would be given a second prediction later. All responses in the experimental section used a 7-point scale. Unless otherwise specified, the level labels ranged from “Extremely Inaccurate” to “Extremely Accurate”. For the first judgment, I began by eliciting subjects' ratings about the accuracy of the prediction: “How accurate do you think Chris' prediction was?” Then, in the next screen, I revealed the alternative frame. For example, subjects in the CI condition read:

In the previous page, the prediction was given to you as follows:

Chris predicted that there was a 20% chance that the NRT party would win the election.

However, as only two parties had the chance to win this election, there is another way that this prediction could be stated:

Chris predicted that there was an 80% chance that the CTS party would win the election.

Subjects in the IC condition read similar instructions but with the appropriate terms reversed.

I was interested in whether subjects would consider the two frames to be logically equivalent and therefore I then asked “Do you agree that these two ways of stating the prediction are logically the same?” (labels here ranged from “Strongly Agree” to “Strongly Disagree”), and I asked subjects to explain their judgments. To study which frame

the subjects found more natural, I next asked “Which of the two statements sounds more natural to you?” using a 7-point scale. The labels were “Chris predicted that there was a 20% chance that that the NRT party would win the election” on one end, and “Chris predicted that there was an 80% chance that the CTS party would win the election” on the other, with the middle one labeled “About the same”.

I then asked subjects to give a second judgment about the accuracy of the prediction that they first read (i.e., the congruently framed prediction for the CI group and the incongruently framed one for the IC group), using the same question as in the first judgment. The subjects were informed that they were free to change or not change their answers. However, they were not reminded of what their previous answers were. Next I asked two questions about subjects’ perception of the influence of the frames on themselves and on their peers: “How much do you think that these two different ways of stating the prediction affected your evaluations?” and “Imagine that one of your friends also participated in this experiment. How much do you think that the different ways of stating the prediction might affect his or her judgments?” (labels ranged from “Not at all” to “Extremely”, with “Moderately” in the middle). Finally, subjects were given a short demographics survey similar to those given in previous experiments.

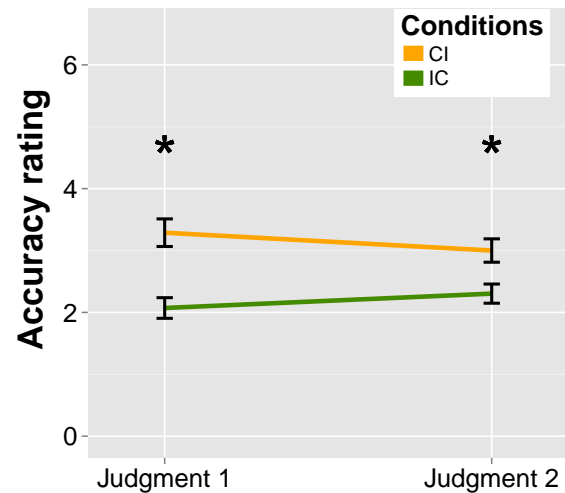
8.2 Results

There were 125 respondents. Ten individuals (8%) failed the attention check and their data were removed from analysis, leaving 115 subjects, 59 in the CI condition and 56 in the IC condition.

I first compared the accuracy ratings from the CI and IC conditions in the first judgment. As the prediction was congruent in the CI condition but incongruent in the IC condition, I expected that the accuracy ratings would be higher in the CI condition. Indeed, the accuracy ratings in the CI condition ($M = 3.29$, $s.d. = 1.71$) were higher than those in the IC condition ($M = 2.07$, $s.d. = 1.25$), and a t -test indicated that the difference was significant ($t(113) = 4.334$, $p = 0.000$, Cohen’s $d = 0.809$). This replicated the results from previous experiments.

More interesting, however, was whether this difference persisted after the alternative frames were revealed to subjects. At this point subjects in both conditions had seen the same two predictions, with the major difference being the target of judgment (congruently framed prediction for the CI condition and incongruently framed prediction for the IC condition). Results showed a difference still in the same direction (congruent: $M = 3.00$, $s.d. = 1.45$; incongruent: $M = 2.30$, $s.d. = 1.16$) and still significant ($t(113) = 2.836$, $p = 0.005$, Cohen’s $d = 0.529$), although the effect size did become somewhat smaller. The

Figure 3: Subjects’ judgments about the accuracies of the prediction before and after the alternative frame were revealed (Judgements 1 and 2, respectively). In both judgments, the prediction in the congruent frame (the CI condition) was rated as significantly more accurate. Error bars represent ± 1 *s.e.*



results are shown in Figure 3.

To investigate whether congruency moderated subjects’ change in judgments before and after I revealed the alternative frames, I compared between the two conditions the difference in each subject’s two judgments. I found that the mean rating in the CI condition decreased by 0.29 ($s.d. = 1.3$) while the mean rating in the IC condition increased by 0.23 ($s.d. = 1.09$). The difference in changes between the two conditions was significant ($t(113) = 2.314$, $p = 0.022$, Cohen’s $d = 0.432$), indicating that the ratings changed in different directions after I revealed the alternative frames. However, 67 (58.26%) of the subjects did not change their rating between the first and second judgments. Together with the result that showed congruency remains significant in the second judgment, these findings suggest that, while the effect weakened when alternative frames were brought to the subjects’ attention, congruency remained a strong influence on subjects’ judgments.

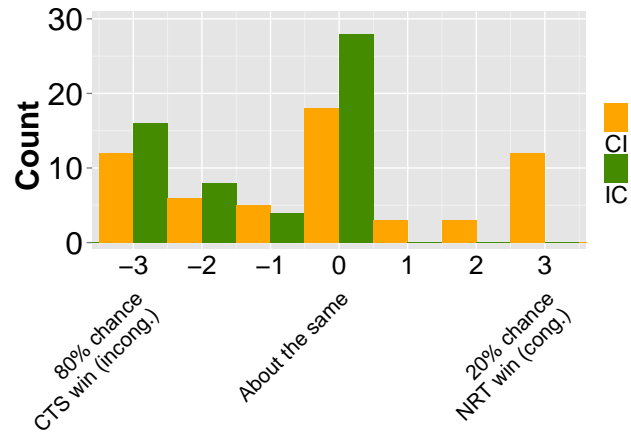
I then examined the issue of naïve equivalence—whether the subjects considered the two frames to be equivalent. Overall, most subjects agreed that the two frames were logically equivalent, with 42 (36.52%) responding with “Strongly Agree”, and 43 (37.39%) responding with “Agree”. The mean rating, from 1 (Strongly Agree) to 7 (Strongly Disagree), was 2.2. This result suggests that the subjects largely agreed that predictions in congruent and incongruent frames were logically equivalent, and therefore the stimuli I used throughout this paper satisfied the naïve equivalence condition.

A post-hoc analysis was carried out to address a potential alternative explanation originally raised concerning the risky choice framing effect and related effects (Mandel, 2014; Teigen & Nikolaisen, 2009). In the context of the current research, it might be possible that numeric quantifiers (probabilistic terms in predictions) are spontaneously interpreted by most people as lower bounded, e.g., “80%” could be interpreted as “at least 80%”. If this was indeed the underlying factor driving the results, then we should expect to see this given as explanations by the subjects who did not agree that about the equivalence of the frames. Of the 16 cases who disagreed or were neutral regarding the equivalence of the frames, 5 mentioned minor parties (thus ignoring the instructions, which stated that one of the two parties would win), 3 explained why the statements were in fact the same (thus indicating that they had responded incorrectly to the question), 3 referred to intuition without further specifics, and the remaining 5 gave unclear answers. No subject mentioned that the numbers were meant as upper or lower bounds (as found by Mandel, 2014, Experiment 3, for the Asian disease problem).

Next I analyzed subjects’ responses about the naturalness of the predictions. As subjects in both conditions had seen the same two frames in different orders the result of this analysis could inform us whether the order of presentation influences judgments of naturalness. The results were roughly in a tri-modal distribution (Figure 4). The major mode was the neutral response (“About the same”), followed by the extreme end of the “80% CTS” frame (“an 80% chance that the CTS party would win”), then the extreme end of the “20% NRT” frame (“a 20% chance that the NRT party would win”). There was more mass on the “80% CTS” side of the graph ($p = 0.001$ by Wilcoxon test). I coded the responses from -3 (“80% CTS”) to 3 (“20% NRT”), with the neutral response as 0 . The mean naturalness response for the CI condition was -0.14 ($s.d. = 2.11$), whereas the mean naturalness response for the IC condition was -1.21 ($s.d. = 1.33$), and the difference here was significant ($t(113) = 3.256$, $p = 0.001$, Cohen’s $d = 0.607$).⁶ As subjects in both conditions had seen the same two frames, the major difference between these two conditions lies in which frame was presented first. This indicates an order of presentation effect—that people’s judgments about the naturalness of frames depend on which frame they were exposed to first. Moreover, it implies that the first exposure might change how they process subsequent predictions.

Finally, I examined the degree to which subjects believed the frames influenced their own and other people’s judgments. The mean rating as to the influence on selves was 2.55 ($s.d. = 1.60$; with a higher value representing a larger influence), whereas the mean rating as

Figure 4: Subjects’ judgments about which of the two frames sounded more natural (Experiment 6). Bars of different colors indicate the frequency of judgments in each condition.



to the influence on friends was 3.30 ($s.d. = 1.61$). A paired t -test comparing the difference between these two ratings was significant ($t(114) = 6.693$, $p = 0.000$, Cohen’s $d = 0.466$), indicating that subjects believed that the frames would have a bigger effect on their friends than on themselves. This result agrees with previous research in which people have been shown to believe that they have greater abilities and better performance than other people (Alicke & Govorun, 2005; Moore & Healy, 2008; Svensson, 1981).

8.3 Discussion

Logical equivalence does not necessarily entail naïve equivalence—whether people in general would consider logically equivalent predictions to be so. Without naïve equivalence, the findings in this paper would not be very surprising—predictions that are different, as might be expected, should lead to different evaluations. However, this experiment demonstrated that subjects indeed agreed that the congruently and incongruently framed predictions in the present experiments were equivalent. Moreover, I found no evidence of people interpreting probability terms as lower bounds. Consequently, I argue that the findings from this experiment, and the paper as a whole, demonstrate inconsistency in subjects’ judgments and choices.

The result of the first judgment replicated findings from previous experiments—predictions framed congruently were rated as more accurate. Before the second judgment, I revealed to subjects the prediction framed with the opposite congruency, thus exposing the same two predictions to both groups. I then elicited judgment ratings from subjects again for the prediction that they read first. Sub-

⁶A Mann-Whitney U test gave similar results.

jects in the congruent condition again rated the prediction to be more accurate than did those in the incongruent condition. This result indicates that the congruency effect persisted even after subjects were explicitly informed of and had processed the alternative frames.

Additionally, the order of presentation influenced subjects' judgment about the naturalness of the frames. This finding corroborates what I found in Experiment 5—the order of presentation moderates the effect of frames.

Kühberger (1998) found that one of the contributing factors of the risky choice framing effects is that people fail to infer the logical complement of options. The current experiment provided some indirect evidence as to whether this applies to prediction evaluation as well. Here subjects were given frames in which both the qualitative and quantitative components were logical complements to each other. Moreover, their complementary relationship was explicitly brought to the subjects' attention. While the subjects agreed that the two predictions were logically equivalent, the prediction stated in the congruent frame was rated as more accurate. This suggests that the failure to infer logical complements cannot explain the congruency effect.

9 General discussion

In this paper I proposed and tested a hypothesis about how predictions about binary-outcome events are judged in light of their outcomes. I decomposed probabilistic predictions into qualitative and quantitative components, and theorize that these predictions can be categorized into two classes—congruent and incongruent—based on whether the qualitative component of the prediction agrees with the eventual outcome. I hypothesized that predictions made in congruent frames would be evaluated as more accurate compared to logically equivalent predictions made in incongruent frames. I labeled this phenomenon the prediction-assessment congruency effect, and carried out seven experiments to test it.

All experiments strongly supported this effect, regardless of whether the judgments were elicited using a rating task (all experiments except for Experiment 5) or a choice task (Experiment 5); whether the instructions were phrased in positive valence (Experiment 2 and others) or not (Experiment 1); whether the predictions involved one (Experiments 4) or two subcomponents (the rest). It even persisted when the prediction in the congruent frame was logically inferior to the one in the incongruent frame (Experiment 5), and after the alternative frames were revealed to the subjects (Experiment 6). A similar pattern of results was observed in samples composed of university students in China (Experiment 1B) and internet users in the United States (the rest), and the effect might be especially

strong for people who are low in numeracy (Experiment 5). Throughout these experiments, I found consistent supporting evidence with large effect sizes in favor of the main hypothesis. Taken together, this demonstrates a robust and reliable result that should be broadly generalizable.

The results of these experiments suggest that overall, people do not evaluate the goodness of predictions in ways consistent with the principle captured in the Brier score. Instead, they overweigh the qualitative component of a prediction while underweighing its quantitative component. While the Brier score was never intended as a characterization of how predictions are evaluated by people, a gap between a scoring rule designed by experts and judgments by laymen is an interesting finding in and of itself. The findings in this paper might have important implications in domains where evaluation of predictions play an important role, such as medical decision-making (Reyna, Nelson, Han, & Dieckmann, 2009) and personal and corporate finances (Johnson, Jamal, & Berryman, 1991).

I developed and tested the main hypothesis based on the concept of logical equivalence, which refers to the condition that any one member from a group of statements necessarily entails the others. Moreover, Experiment 6 established that the experimental paradigm satisfied naïve equivalence—subjects recruited from the general population agreed that predictions of different congruencies were equivalent. McKenzie and colleagues argued that there is a distinction between logical equivalence and information equivalence (Sher & McKenzie, 2006; McKenzie & Nelson, 2003). Information equivalence requires that, in addition to satisfying logical equivalence, no choice-relevant information can be drawn from the speaker's choice of using one frame instead of others (Sher & McKenzie, 2006). According to this view, there are no general normative problems with logically equivalent descriptions leading to different choices, as long as the descriptions are information non-equivalent.

Having established the core results concerning the congruency effect in the present paper, I am currently investigating approaches towards building a comprehensive theory that integrates these different perspectives. However, I emphasize that, even with a lack of information equivalence, the violation of invariance in judgments and choices under logical and naïve equivalence is problematic with respect to prediction evaluation.

In order to further our understanding of the congruency effect, it would be useful to examine its relationship with several related theories, in addition to the fuzzy-trace theory that motivated the main hypothesis. One such theory is the compatibility theory, which has been shown to exert great influence on people's behavior (Shafir, 1995). In the realms of judgment and choice, the principle of compatibility suggests that people overweigh attributes that

are compatible with the required response, and studies have found this compatibility phenomenon to indeed influence people's judgment and choices (Tversky, Sattath, & Slovic, 1988; Slovic, Griffin, & Tversky, 1990). In the context of the present research, it might be easier to map the qualitative components (e.g., "A will win") to the outcomes (e.g., "A won"), than to map the quantitative components (e.g., "70%") to these outcomes. Consequently, the goodness of the match between the qualitative component and the outcome can be compared more easily, relative to the match between the quantitative component and the outcome. As a result, the match between the qualitative component and the outcome would be overweighed. This point might be especially relevant in interpreting the results of Experiment 5, as subjects compared the two predictions to the outcome.⁷ Furthermore, process models could yield important insights and help contrast various qualitative models that make similar predictions (Bhatia, 2013).

Prior research has suggested that important personal decisions are less influenced by frames (Marteau, 1989) and therefore this would be a good test for the boundary conditions of this effect. It would also be interesting to explore whether experts might be influenced by frames in the same way as the naïve subjects studied in the current paper. Additionally, I am also currently examining what roles selective attention (Levin, 1987) and the encoding of information (Levin & Gaeth, 1988) might play in bringing about the congruency effect.

Understanding the relationship between these results and past findings will give us a fuller picture of the mechanism, the antecedents, and the boundary conditions of the effect, and can ultimately help us to develop interventions to reduce the effect, or to take advantage of it to improve people's decision-making (Thaler & Sunstein, 2008).

The findings in this paper demonstrate the psychological impact of frames on the way people evaluate predictions with respect to outcomes. When predictions are described in frames that are congruent with the eventual outcome, people consider the predictions as more accurate than if they were described in incongruent frames. This observation is not captured by previous literature and highlights the need for a better understanding of the processes that underlie this phenomenon.

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⁷We thank an anonymous reviewer for suggesting this connection.

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