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Framing Effects are Robust to Linguistic Disambiguation: A Critical Test of Contemporary Theory

Christina F. Chick, **Valerie F. Reyna**, and **Jonathan C. Corbin**
Cornell University

Abstract

Theoretical accounts of risky choice framing effects assume that decision makers interpret framing options as extensionally equivalent, such that if 600 lives are at stake, saving 200 implies that 400 die. However, many scholars have argued that framing effects are caused, instead, by filling in pragmatically implied information. This linguistic ambiguity hypothesis is grounded in neo-Gricean pragmatics, information leakage, and schema theory. In two experiments, we conducted a critical test of the linguistic ambiguity hypothesis and its relation to framing. We controlled for this crucial implied information by disambiguating it using instructions and detailed examples, followed by multiple quizzes. After disambiguating missing information, we presented standard framing problems plus truncated versions, varying types of missing information. Truncations were also critical tests of prospect theory and fuzzy trace theory. Participants were not only college students, but also middle-aged adults (who showed similar results). Contrary to the ambiguity hypothesis, participants who interpreted missing information as complementary to stated information none the less showed robust framing effects. Although adding words like "at least" can change interpretations of framing information, this form of linguistic ambiguity is not necessary to observe risky choice framing effects.

Keywords

ambiguity; decision making; framing effect; fuzzy trace theory

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According to traditional theories of decision making, framing effects challenge assumptions about human rationality by violating the axiom of descriptive invariance: Decision preferences should be consistent across superficial changes in how the options are worded (Kahneman, 2003; Tversky & Kahneman, 1981). In risky choice framing effects, people often reverse their risk preferences based on whether the same outcome is described in terms of gains or losses (Kuhberger & Wiener, 2012). In particular, people tend to be risk-averse when options are framed as gains, but risk-seeking when options are framed as losses. Notwithstanding theoretical explanations for framing effects, many scholars have argued that framing effects are explained, instead, by linguistic ambiguity in the option descriptions. Okder (2012) summarizes the lack of consensus: "The quarter-century history of the

Correspondence concerning this article should be addressed to Christina F. Chick, Human Neuroscience Institute and Cornell Magnetic Resonance Imaging Facility, Cornell University, Ithaca, NY 14850, cfc53@cornell.edu.
Christina F. Chick, Department of Human Development, Cornell University.

research has accumulated the findings in the framing phenomena, but the underlying psychological processes are still in controversy" (p. 72).

On the one hand, theories such as prospect theory, extended prospect theory, and fuzzy-trace theory treat the framing effect as a reversal of preferences for equivalent options based on superficial changes in wording (Kuhberger & Tanner, 2010; Reyna, Chick, Corbin & Hsia, 2014). Although these theories predict different mechanisms for framing effects, they all assume extensional equivalence. In other words, they assume that the description of an outcome in one frame (e.g., 200 out of 600 are saved) implies the complementary outcome as described in the other frame (e.g., 400 out of 600 die). If decision makers perceive the options as extensionally equivalent, then the preference reversal is argued to be irrational, since the both complements describe an identical outcome.

On the other hand, a parallel line of current work has taken exception to the extensional equivalence assumption. Far from demonstrating human irrationality, according to this account, framing effects simply reflect a preference for the option that maximizes the gain or minimizes the loss. This alternative account, which we call the linguistic ambiguity hypothesis, proposes that decision makers do not perceive partially specified options the same way they perceive fully specified options. Instead, they make assumptions about unstated information (Kuhberger & Gradl, 2013). For example, if 600 people are at stake, and option A states that 200 can be saved for sure, then, according to the linguistic ambiguity hypothesis, this option is ambiguous as to the fate of the remaining 400 people. If subjects perceive an incompletely specified option as lower-bounded (e.g., interpreting "200 are saved" as "at least 200 are saved"), then the sure option, which includes the possibility that more people might be saved, is preferable to the completely specified risky option (1/3 chance 600 people saved, 2/3 chance no one saved). Given this perceived inequality between the sure and risky options, most subjects would pick the sure option in the gain frame and the risky option in the loss frame, producing the same pattern as the standard framing effect. According to this ambiguity hypothesis, framing effects do not violate descriptive invariance, since it is rational to prefer the option with the higher value (Mandel, 2014). Scholars have cited multiple theories to support this hypothesis, including neo-Gricean pragmatic implicature (Mandel, 2014), information leakage (Sher & McKenzie, 2008), and schema theory (Okder, 2012).

This debate has implications for major theories of risky choice. If the ambiguity hypothesis is correct, then framing effects do not represent irrational behavior, after all. This would challenge prospect theory, extended prospect theory, and fuzzy trace theory accounts of framing effects, all of which assume that decision makers show valence-dependent preferences despite perceiving options as extensionally equivalent. According to prospect theory, preference reversals are driven by non-linear number perception of quantities such as probabilities and outcomes (Tversky & Kahneman, 1981). For example, 200 lives saved is perceived as larger than a 1/3 chance of 600 lives saved (gain frame); alternatively, 400 lives lost is perceived as smaller than a 2/3 chance of 600 lives lost (loss frame). In contrast to prospect theory, fuzzy-trace theory predicts that framing effects are driven by categorical distinctions between some people being saved and no one being saved (gain frame), or between some people dying and no one dying (loss frame; Reyna, 2012).

These dueling assumptions—that subjects perceive framing options as lower-bounded (linguistic ambiguity hypothesis), and that subjects perceive framing options as extensionally equivalent (prospect theory and fuzzy-trace theory)—have co-existed for nearly three decades (Frisch, 1993). Only recently have they been directly compared (Mandel, 2014), but, as we argue, the results of this comparison were inconclusive.

Ambiguity as a Defense of Rationality

In a typical framing problem, 600 lives are at stake. In the gain frame, subjects are instructed to choose between (a) saving 200 people for sure, or (b) a 1/3 chance of saving 600 people, and a 2/3 chance of saving no one. In the loss frame, the choice is between (a) 400 people dying for sure, or (b) a 1/3 chance that no one dies, and a 2/3 chance that 600 die. In this traditional version, both logical complements of the risky option are stated; that is, there is no ambiguity about the risky option. However, the logical complement of the sure option is unspecified, and scholars have argued that the fate of the remaining 400 people remains unclear. This has led to widespread speculation about what subjects assume about the unstated logical complement in the sure option.

> [T]he riskless option is ambiguous, and, presuming specific inferences, this option could be better (gain frame) or worse (loss frame) than the risky option, which is unambiguous because it is completely specified. (Kuhberger & Gradl, 2013, p. 116)

> Only with full explication is it explicit that the exact number of lives expected to be saved [200] and to die [400] sum to the total set of 600. (Mandel, 2014, p. 6)

> [I]t is not obvious that people interpret saving 200 people as exactly 200 will be saved. (Kuhberger & Tanner, 2010, p. 316)

> [T]he illusion of framing in the Asian disease problem arises owing to preconceptions on the part of the experimenters, who expect the decision makers to have the same schema as theirs when making decisions. (Okder, 2012, p. 65)

Unspecified options in both the sure and the risky options have been interpreted as potentially ambiguous. Regarding the sure option, even if 200 are saved now, it is not clear whether the remaining 400 will die now, will be rescued later, or will simply be left to be fend for themselves, leaving open the possibility that they, too, will survive. These different possibilities converge on a lower-bounded hypothesis, such that “at least” 200 will survive. This would produce the typical framing effect by increasing the value of the sure option in the gain frame (leading to risk aversion) and decreasing the value of the sure option in the loss frame (leading to risk seeking).

Since the risky option is fully specified in the typical version of the framing problem, there has been less discussion in the literature of ambiguity in the risky option than in the sure option. Nonetheless, Kuhberger and Tanner (2010) note that subjects might assume a partially specified risky option to be ambiguous. As Kuhberger and Tanner (2010) explain, “[S]ubtracting a risky complement is even more likely to create ambiguity than subtracting a sure complement…. Any number of lives, and any probability level, is possible.” (Kuhberger & Tanner, 2010, p. 320). We note that only assumptions that decrease the magnitude gained or lost in the risky option would produce the standard pattern of framing effects (i.e., risk aversion in the gain frame and risk seeking in the loss frame). Nonetheless, since Kuhberger and Tanner do not advocate a specific directional hypothesis, we address both possible directions (i.e., assumptions that decrease the value of the risky option, and assumptions that increase it).

Evidence of Perceived Ambiguity?

Multiple experimenters have argued that decision makers do not perceive unspecified specified information as complementary to stated information. Although suggestive, this evidence has been inconclusive. In an early example, Kuhberger (1995) reports that 60% of participants understood the numbers as “estimated figures,” compared to 40% who understood the numbers as“exact numerical values.” Kuhberger and Tanner (2010) and Kuhberger and Gradl (2013) argue that the ambiguity hypothesis has not been ruled out.

Similarly, Mandel (2001) reports that, for both the sure and the risky option, about one-third of subjects said they did not take the stated complement to imply the unstated one. This is consistent with data reported by Mandel (2014), in which participants tended to interpret the sure option as lower-bounded (e.g., “at least” 200 people will be saved) when only one complement was presented, but not when both complements were presented. Taken together, these experiments suggest that missing information affects some decision makers' perceptions of the framing options.

Theoretical Accounts of Ambiguity

Multiple theoretical accounts have been cited to support the linguistic ambiguity hypothesis. Neo-Gricean accounts emphasize pragmatic inferences, such as that people often mean “at least” when they specify a number (Breheny, 2008). This has led some scholars to predict that subjects interpret the sure option as lower-bounded (Geurts, 2006; Mandel, 2014). Similarly, the information leakage hypothesis assumes that listeners infer additional information from a speaker's decision to include certain information and exclude other information (Sher & McKenzie, 2006; Kuhberger & Tanner, 2010). For example, it has been argued that listeners interpret partial information as implying a direction of change (e.g., describing the glass as half full means that it used to be half empty), which also suggests a lower-bounded interpretation of framing options (e.g., describing 200 people saved means that the number saved is increasing; Sher & McKenzie, 2008). Finally, arguments based on schema theory predict that individuals place the framing scenario in a real world context, which also supports a lower-bounded interpretation. For example, since rescue efforts take time, it is plausible that additional people could be saved in the future, even if only 200 are saved now (Okder, 2012). Therefore, empirical and theoretical evidence suggest that decision makers do not always perceive partially specified framing options as equivalent to the fully specified version of those options. In particular, this evidence converges on the hypothesis that decision makers perceive the sure option as lower-bounded. Having reviewed theoretical support for the ambiguity hypothesis, we next review evidence about how, if at all, the perception of options as lower-bounded relates to framing decisions.

Does Ambiguity Predict Framing Effects?

Direct evidence about the necessity of ambiguity to framing effects is lacking; hence, scholars have come to opposite conclusions. Kuhberger (1995) summarizes his own results as follows: “Although there is considerable ambiguity in the problems, it seems that framing effects and ambiguity judgments were totally unrelated” (p. 238). However, other studies do report evidence that ambiguity predicts framing. Mandel (2001) reports eliminating framing effects for certain combinations of partially and completely specified options.

Also in favor of the ambiguity hypothesis, Kuhberger and Gradl (2013) found that attractiveness ratings of the sure option, but not of the risky option, predicted framing effects. The authors argue that the missing information in the sure option might drive this effect. Consistent with this interpretation, Okder (2012) invokes schema theory to argue that framing effects depend on ambiguity in the sure option. In Okder's experiment, specifying the number of lives at stake (e.g., 600) made subjects more likely to interpret the explicit (e.g., 200) and implicit (e.g., 400) parts of the sure option as complementary. Okder (2012) takes these results to suggest that subjects do not typically interpret the options as exact values, and that framing effects arise from this failure to interpret the implicit information in the sure option as complementary to the stated information.

More direct evidence for the ambiguity hypothesis comes from Mandel (2014), who increased framing effects by cuing subjects to interpret partially specified options as lower-bounded. When Mandel added the words “at least” to the sure option (cuing subjects to interpret the option as lower-bounded), framing effects increased compared to the unmodified version of the sure option. In contrast, when Mandel added the word “exactly” to the sure option (cuing subjects to interpret the sure option as extensionally equivalent across frames), framing effects were reduced relative to the unmodified version of the sure option (i.e., the trend was in the direction of framing but was not significant).

Moreover, Mandel (2014) found that participants' interpretations of the partially specified sure option predicted framing effects. Those who interpreted the unmodified sure option as “at least” showed standard framing effects, those who interpreted it as “at most” showed reverse framing effects, and those who interpreted the option as “exactly” showed no framing effects. Combined with the other findings from this study, this suggests that framing effects may result from participants' interpretation of partially specified options as lower-bounded.

Although Mandel's finding demonstrates that a lower-bounded interpretation is sufficient to produce framing effects, it does not demonstrate that such an interpretation is necessary to produce framing effects. In addition, potential demand effects limit the generalizability of Mandel's results. Mandel only asked subjects about their interpretation of the sure option after they made the decision, at which point answers may have been motivated more by justifying the decision than by indicating the naïve interpretation of the options. This means that participants who did not make assumptions regarding the missing complement may have been motivated to choose the option that made their decision look most reasonable, which would explain the pattern of results reported.

In summary, the relationship between linguistic ambiguity and risky choice framing effects is suggestive but inconclusive. Although research has shown that ambiguity is sufficient to produce framing effects (by changing the values of the options), methodological limitations raise questions about the interpretations of these data. Moreover, no study has directly tested whether the forms of linguistic ambiguity hypothesized in the literature are necessary to framing effects. Thus, the critical assumption of the ambiguity hypothesis remains untested. We emphasize, however, that this summary is limited to risky choice framing effects. Ambiguity has been shown to play an important role in other types of framing effects, such as attribute framing (Sher & McKenzie, 2006).

Fuzzy-Trace Theory: A Selective Attention Explanation of Framing Effects

Rather than assuming linguistic ambiguity, fuzzy-trace theory assumes that framing effects are due to selective attention. Focusing on different elements of the problem leads to alternative mental representations of the problem information, which can lead to different preferences (Reyna et al., 2014). Specifically, fuzzy-trace theory predicts that individuals base their decision on the lowest level gist representation sufficient to produce a decision. In the gain frame, the bottom-line gist is a categorical distinction between saving some lives for sure and possibly saving some lives or no lives. Since most subjects prefer saving some over saving none, they tend to choose the sure option in the gain frame (i.e., the traditional framing effect). Analogously, in the loss frame, the preference is for possibly losing no lives (or some lives) over losing some lives for sure, leading most subjects to choose the risky option.

The zero complement in the risky option (e.g., 2/3 chance nobody is saved) is of critical importance for this some-none categorical distinction. Research has shown that removing the non-zero complement increases framing (by emphasizing the some-none categorical distinction in the problem), and removing the zero complement reduces framing (by de-emphasizing the categorical distinction and prompting individuals to represent the problem in a more precise manner; Kuhberger & Tanner, 2010; Reyna, et al., 2014). When one complement has been removed, we refer to the remaining partially specified option as “truncated.” According to fuzzy-trace theory, the truncation effects found in previous research are due to selective attention (focusing on the information at hand) rather than assumptions about missing information.

The hypothesis that we set out to test, therefore, is that when subjects understand the exact numerical value of all information, stated or implicit, they still show framing effects. Thus, this study distinguishes ambiguity from selective attention in truncation effects. People can selectively pay attention to parts of a decision problem, even though the problem information is not ambiguous to them. If it can be demonstrated that subjects perceive the options unambiguously (such that stated and unstated information about each option are treated as complementary), yet framing effects occur at typically reported levels, then risky choice framing can no longer be argued to depend on the forms of linguistic ambiguity that have been discussed in the literature.

In the current work, we report several critical tests of ambiguity hypotheses. To preview, in two experiments, we provided detailed instructions, with worked examples, for interpreting unstated information as complementary to stated information. We then tested forms of linguistic ambiguity that have been hypothesized in the literature, both before and after subjects made framing decisions. In Experiment 1, the framing decisions were within-subjects, whereas in Experiment 2, the framing decisions were between-subjects. Furthermore, in Experiment 2, we added the word “exactly” to the sure option as an additional disambiguation cue. Analyses tested whether framing effects were still significant even among those participants who rejected commonly hypothesized forms of ambiguity prior to completing framing problems (thereby avoiding the demand effect that subjects would answer in a way that would justify their framing decisions). An affirmative finding would disconfirm the hypothesis that linguistic ambiguity (in the forms hypothesized in the literature) is necessary to framing.

Generalizability Across Age Groups

In both experiments, we account for controversy over whether data collected from college students generalizes to other populations (Peterson, 2001). This is pertinent given age differences in risk preferences and framing effects (Reyna et al., 2014). In particular, it is important to characterize decision processes of middle-aged adults, whose decisions bear considerable economic impact and who, due to potential age-related declines in memory, may recruit different cognitive processes compared to college students (Reyna & Brainerd, 2011). Therefore, an additional aim of this study is to characterize the relationship of ambiguity to risky choice framing effects in both young and middle-aged adults.

Experiment 1

Method

Procedure—Experiment 1 included the following phases: Instruction, initial ambiguity questionnaire, framing problems, post-framing ambiguity questionnaire, and debriefing. In the instruction phase, subjects received an instruction sheet (Appendix A) explaining how to interpret both stated and unstated information in the options. An initial ambiguity survey was administered to assess comprehension of these instructions. Next, additional written instructions were administered in order to explain the correct answer to each question on the initial ambiguity survey. Participants were instructed that there would be a time limit for their response to each framing problem, and they completed two practice problems with unrelated content (e.g., “Who is the President of the United States?”) in order to become familiar with the pace of the questions. Each participant then completed 60 framing problems, followed by a post-framing ambiguity questionnaire. Demographic measures and individual difference scales were collected after this questionnaire, but only the demographic variables are reported in these analyses. At the end of each session, subjects were debriefed.

Participants—Cornell undergraduates were recruited via an online experiment sign-up system. Cornell alumni and parents were recruited during an alumni weekend. Additional participants were recruited from Columbia University (via flyers posted on campus) and online via Amazon's Mechanical Turk (www.mturk.com). Cornell students were compensated with course credit; all other participants were compensated monetarily.

Subjects ranged in age from 18 to 56 years; in order to account for the potential effects of cognitive aging on memory and information processing, subjects were categorized as either college students (age <22) or post-college adults (age >=22). College students (*n*=37) were 46% female, mean age=19.51 (*SD*=1.07). They identified as 51% Caucasian, 11% African-American, and 38% Asian/Asian-American; 3% identified as Hispanic. Post-college adults (*n*=44) were 39% female, mean age=31.55 (*SD*=10.76). They identified as 57% Caucasian, 14% African-American, 25% Asian/Asian-American, and 4% Native American/American Indian/Alaska Native; 5% identified as Hispanic.

The full sample included 81 participants (34 female), mean age=26.05 years (*SD*=9.96). Of these, 39 (16 female, mean age=21.95, *SD*=4.99) received the gain frame version of the ambiguity questionnaires, and 42 (18 female, mean age=29.86, *SD*=11.81) received the loss frame version of the ambiguity questionnaires. Of the gain frame group, 25 were college students, and 14 were post-college adults. Of the loss frame group, 21 were college students, and 21 were post-college adults. Group means for demographic variables and framing are presented in Table 1. Participants receiving the loss frame version of the ambiguity questionnaire were, on average, slightly older than those receiving the gain frame version (see means and *t*-test in Table 1). For this reason, we control for age group (college versus post-college) in all analyses.

Design—The ambiguity questionnaires were administered according to a 2 × 2 × 2 × 2 factorial design. Within-subjects factors were the framing option to which each ambiguity question referred (sure option or risky option), as well as the time point at which each ambiguity questionnaire was completed (before and after the 60 framing problems).Between-subjects factors were the frame of ambiguity questionnaire (gain or loss) and age group (college or post-college). Crucially, although each participant answered the ambiguity questionnaires in either the gain or the loss frame, all participants subsequently completed framing decisions in both frames (30 problems in each frame; see “framing problems”). The design of the 60 framing problems completed by each participant, explained below, is separate from the design of the ambiguity questionnaires described here.

Materials

Instruction sheet—Before viewing stimuli, subjects were given an instruction sheet explaining what they should assume about the stated and unstated information in the truncated sure and risky options (Appendix A). The instruction sheet provided two example scenarios, each with a detailed explanation of the sure and risky options. Regarding the sure option, participants were told that the number was “exact,” with particular emphasis that the number would not increase or decrease. For example, regarding the sure option, participants were instructed, “If you select option A, EXACTLY 500 people will be saved; no fewer, no more.”

The instructions emphasized two points about the risky option. First, the unstated probability was the mathematical complement of the stated probability: “All probabilities in Option B are complementary and add up to 100%.” Second, each probability referred to the chance that either all of the money or lives at stake would be gained (lost), or none would be gained (lost). In other words, in order to address the bidirectional hypothesis noted by Kuhberger and Tanner (2010), the instructions emphasized that each risky complement was neither upper- nor lower-bounded. For example, “Option B means that there is ½ probability (50% chance) that ALL 1,000 people will be saved and ½ probability (50% chance) that NO people will be saved.” “All” and “no” were capitalized in order to emphasize that there was no probability that “some” would be gained or lost.

Initial ambiguity questionnaire—After reading the instruction sheet, participants completed an initial ambiguity survey (described as an “entry questionnaire”) designed, as described below, to address the forms of ambiguity that have been posited in the literature.

Each ambiguity survey included one framing problem with options in either the gain or the loss frame. Only the non-zero complement of the risky option was presented in this example problem. The problem was followed by three multiple choice questions about how subjects interpreted missing information in the options. We asked two questions about the sure option, since this has received the most attention in the ambiguity literature, and one question about the risky option (Table 2). Two multiple-choice questions about the sure option addressed the hypothesis that subjects add “or more” to the sure option (Kuhberger & Gradl, 2013; Mandel, 2001, 2014; Sher & McKenzie, 2008).

The multiple choice question about the risky option addressed the hypothesis that subjects assume an indeterminate quantity to be gained or lost in the unstated risky complement (Kuhberger & Tanner, 2010). This corresponds to our emphasis in the instructions that each probability refers to an outcome in which “all” or “none,” but not “some,” are gained or lost (i.e., the amount is neither lower- nor upper-bounded). We tested subjects' interpretation of the condition in which only the non-zero complement was presented, since this is the one discussed by Kuhberger and Tanner (2010). However, the full set of 60 framing problems (completed after the initial ambiguity questionnaire, and before the post-framing ambiguity questionnaire) included an equal number of risky options with both complements presented, only the zero complement presented, and only the non-zero complement presented (20 each).

Additional instructions with worked example—After completing the initial ambiguity questionnaire, participants were given a detailed explanation of the correct answer to each of the three questions (Appendix B). The explanation emphasized that the number in the sure option was “exact,” for example: “If you select option A, 300 people will be saved. No fewer, and no more. These 300 people will be the only ones saved. No others may be saved, might be saved, or could be saved.”

The explanation of the risky option emphasized that each risky option is neither upper- or lower-bounded with respect to the number gained or lost. For example, “if we specify that there is a probability that everyone will be saved, if that does not happen, then no one will be saved. Similarly, if we specify that there is a probability that no one will be saved, if that does not happen, then everyone will be saved.” The explanation continued, “it is not possible that 1 person will be saved, or 2 people will be saved.” Finally, we addressed commonly hypothesized assumptions: “Common mistakes include ‘some might be saved,’ 'some could be saved,' and 'they will swim to shore.' These are all incorrect. We don't want you to assume anything outside of the information that is given to you."

Next, for sessions administered in person, the experimenter emphasized the rationale behind correct answers to any question the participant answered incorrectly on the initial questionnaire. For experiments administered on Mechanical Turk, participants were given an additional set of worked examples following the pre-test ambiguity questionnaire.

Framing problems—The framing paradigm was a 2×2×3×5 within-subjects design with frame (gain, loss), modality (lives, money), truncation (zero complement, both complements, non-zero complement), and replication (1-5) as factors. (Note that the factorial design for the framing problems is distinct from the factorial design for the ambiguity questionnaires, which was described above). Accordingly, in each problem, either lives or money were at stake, the sure and risky options were described as either gains or losses, and the risky option was truncated in one of three ways (described below). Using different scenarios, each type of problem from this factorial design was presented five times, for a total of 60 problems per subject. In all problems, the expected values of the sure and risky options were equal.

Truncation: Keeping the sure option constant, the risky option was manipulated to present only the zero-complement, only the non-zero complement, or both complements (Reyna et al., 2014; Reyna & Brainerd, 1991, 2011). In the typical version of the problem, both complements of the risky option are presented (e.g., 1/3 chance of saving 600, 2/3 chance of saving no one). In this example, the zero complement is the 2/3 chance of saving no one, and the non-zero complement is the 1/3 chance of saving 600. When lives are at stake, the zero complement is the outcome in which no one is saved (gain frame) or dies (loss frame); the non-zero complement is the one in which some number of lives are saved (gain frame) or die (loss frame). Similarly, when money is at stake, the zero complement is the one in which no money is won (gain frame) or no money is lost (loss frame);the non-zero complement is the one in which some amount of money is won (gain frame) or lost (loss frame). See Table 3 for an example of each truncation.

Problem sets: Twenty problems, modeled after the Asian Disease Problem (Reyna, 2012; Tversky & Kahneman, 1981), were used. In half of the problems, lives were at stake, and in the other half, money was at stake. For each problem, six versions of the sure and risky options were created, reflecting a factorial crossing of frame (gain, loss) with truncation (zero complement presented, both complements presented, non-zero complement presented). For a given problem, the expected outcomes of sure and gamble options were mathematically equivalent across frames. The resulting 120 framing problems were divided into two sets of 60 problems each, so that the gain and loss versions of the options for each problem appeared in different stimulus sets. Each subject received problems from only one of the two stimulus sets, so that none received both the gain and loss versions of a given problem with the same truncation. Stimuli from each set were presented in a fixed pseudorandom order, such that the same problem could not appear twice in a row. Thus, each subject completed a total of 60 problems: 30 problems in the loss frame and 30 problems in the gain frame. Subjects completed 20 of the 60 problems in each of three truncations of the risky option (*i.e.*, zero complement presented, non-zero complement presented, or both complements presented).

Trial sequence: We selected the timing of scenarios and decision screens based on repeated piloting. We also obtained feedback from participants. During piloting, we ensured that participants were able to read the scenarios and respond within the allotted time.

Each trial included presentation of a fixation cross (4.5 s), followed by the problem (7 s), presentation of the sure and risky options (up to 8 s, during which participants entered their selection via button press), and a confidence rating for their choice ("How confident are you in your decision?" with response from 1 [not at all] to 5 [completely], up to 3 s). The decision phase (sure vs. risky option) lasted only until a response was entered, at which point the next screen (confidence rating) appeared. Similarly, the confidence phase lasted only until the participant entered a rating, at which point the next screen appeared. The other phases (fixation cross and problem) did not vary in duration.

Post-framing ambiguity questionnaire—Following completion of the framing stimuli, participants completed a second ambiguity survey, labeled an "exit questionnaire." The post-framing ambiguity questionnaire was identical to the initial ambiguity survey, except that a different example problem (within the same frame) was used. The purpose of the post-framing ambiguity questionnaire was to ensure that subjects had retained the instructions about how to interpret each option while making the preceding 60 framing decisions.

Data analysis

Statistical analyses—Statistical analyses were performed in SPSS version 22 (IBM, Armonk, NY, 2010). We ran separate analyses on decision and signed confidence; although these measures are partially redundant, they serve distinct purposes. Much of the framing literature is reported in terms of decision, and following this convention facilitates comparison. However, signed confidence ratings capture degree of preference with higher resolution, allowing us to detect more subtle effects.

Framing index—A measure of each individual's propensity to show standard framing (framing index, FI) was calculated as the average number of risky choices in the loss frame minus the average number of risky choices in the gain frame. The higher the framing index, the larger the proportion of choices that were consistent with the standard framing effect, which is to choose the risky option in the loss frame but to choose the sure option in the gain frame.

A separate framing index was calculated for each truncation condition. For example, each subject answered 20 questions in the zero-complement-presented condition: ten in the gain frame and ten in the loss frame. The number of risky choices in the loss frame was summed and then divided by 10. Then, the number of risky choices in the gain frame was summed and divided by 10. The average number from the gain frame was subtracted from the average in the loss frame. This yielded a possible range of -1 (reverse framing for all 20 questions: 0 risky choices in loss frame and 10 risky choices in gain frame) to +1 (standard framing for all 20 questions: 10 risky choices in loss frame and 0 risky choices in gain frame). In addition, a total framing index was calculated as the average of the three truncation-specific framing indexes. The possible range for total framing index was -1 (reverse framing for all 60 questions) to +1 (standard framing for all 60 questions).

Signed confidence—In the signed confidence measure, each decision is weighted according to the confidence rating for that decision (Reyna et al., 2014). Signed confidence was calculated by multiplying the confidence rating (1-5) for each decision by -1 if the sure option was selected or by +1 if the risky option was selected. Compared to decision, signed confidence is a more sensitive measure of framing behavior because it allows subjects to indicate how strongly they endorse the option they chose, given that each problem requires a forced binary choice (Mandel, 2014; Reyna et al., 2014).

Signed confidence framing index—Signed confidence framing index (SCFI) is a composite measure of framing behavior over all trials, accounting for both choice and confidence rating. The higher the signed confidence framing index, the larger the proportion of choices consistent with the standard framing effect—and the higher the confidence in those choices.

To compute SCFI, signed confidence scores were averaged within each frame, and the average in the gain frame was subtracted from the average in the loss frame. Within each truncation, this yielded a score ranging from -10 (strongest preference for reverse framing for all 20 problems, i.e., 0 risky choices in loss frame, 10 risky choices in gain frame, and confidence=5 for all problems) to +10 (strongest preference for standard framing for all 20 problems, i.e., 10 risky choices in loss frame, 0 risky choices in gain frame, and confidence=5 for all problems). In addition, a total SCFI was calculated as the average of the three truncation-specific SCFIs. The possible range for total SCFI was -10 (maximum confidence in reverse framing for all 60 questions) to +10 (maximum confidence in standard framing for all 60 questions).

Results

Responses to ambiguity questionnaires—Because our argument depends on observing framing effects when decision makers interpret options as exact values, we first verified that our disambiguation instructions were effective. Mean scores for each question on the ambiguity questionnaire are displayed in Table 2. We ran separate analyses on the yes/no question about the sure option and on the three-option questions about the sure and risky options in order to characterize the types of ambiguity perceived by participants who did not perceive implicit information as complementary to stated information. These analyses were not combined because of the different number of response options (hence, different odds of indicating complementarity by chance alone). For all analyses, the dependent variable was response to each ambiguity survey question, coded as 0 (indicating ambiguity) or 1 (indicating complementarity).

Yes/no question: For the yes/no question about the sure option, a 2 × 2 × 2 repeated measures ANOVA was run, with initial versus post-framing ambiguity questionnaire as a within-subjects factor and frame of ambiguity questionnaire (gain or loss) and age group (college or post-college) as between-subjects factors. Significant main effects were found for frame of ambiguity questionnaire, $F(1, 77)=6.91$, $p=.01$, $\eta_p^2=.082$, and for initial versus post-framing, $F(1, 77)=8.08$, $p=.006$, $\eta_p^2=.095$. More subjects indicated complementarity in the gain frame (*M*=.90, *SE*=.05) than in the loss frame (*M*=.73, *SE*=.04), and subjects showed increased complementarity on the post-framing ambiguity questionnaire (*M*=.90, *SE*=.04) compared to the initial questionnaire (*M*=.73, *SE*=.05).

Three-option questions: A repeated measures ANOVA was run on the three-option questions about the sure and risky options. The 2 × 2 × 2 × 2 factorial design included initial versus post-framing and sure versus risky as within-subjects factors, and frame of ambiguity questionnaire (gain or loss) and age group (college or post-college) as between-subjects factors. There were main effects of frame, $F(1, 77)=9.74$, $p=.003$, $\eta_p^2=.044$, and of initial versus post-framing, $F(1, 77)=30.42$, $p<.001$, $\eta_p^2=.280$. The direction of these main effects was the same as for the yes/no question about the sure option: More subjects indicated complementarity in the gain frame (*M*=.89, *SE*=.04) than in the loss frame (*M*=.73, *SE*=.04), and more subjects indicated complementarity on the post-framing ambiguity questionnaire (*M*=.94, *SE*=.03) than on the initial questionnaire (*M*=.69, *SE*=.04).

Necessity of ambiguity to framing effects—The critical test of the ambiguity hypothesis is whether subjects still showed the framing effect even after demonstrating that they followed instructions to interpret missing information as complementary to stated information.

If ambiguity is necessary to framing, then we should not observe framing effects among participants who indicate complementarity of stated and implicit information. Consistent with this logic, we analyzed only participants who answered all three questions on the pre-framing questionnaire in a way that indicated complementarity. 41 subjects met this criterion. See supplemental material for analyses of the full sample (which showed effects consistent with those reported below).

In order to account for repeated measurements within subject, we used a generalized estimating equation for decision and a mixed model for confidence and signed confidence (Baayen, Davidson, & Bates, 2008). These mixed effects regressions allowed us to exclude missing responses (2.8% of choice data, 1.8% of confidence data) without excluding entire subjects on the basis of incomplete data. Fixed variables in each model were frame, truncation, lives/money, order (problem sequence, 1-60), age group, and gender; subject was included as a random variable. The following interaction terms were included in each initial model: Order × Frame, Age Group × Frame, Gender × Frame, and Order × Frame × Truncation. Nonsignificant terms were removed, with the exception that we controlled for age group in all analyses.

Decision: Recall that decision is scored as 0 (sure option) or 1 (risky option). The *N*s reported for chi-square statistics refer to the number of observations (60 decisions per subject, with some missing responses as reported above). For decision, we observed a main effect of frame, Generalized Score $\chi^2(1, N=2{,}314)=25.52$, $p<.001$. Participants showed the standard framing effect, choosing the risky option more often in the loss frame (*M*=.59, *SE*=.

31) than in the gain frame (*M*=.32, *SE*=.28). This main effect was modified, as predicted, by a Frame × Truncation interaction, Generalized Score $\chi^2(2, N=2{,}314)=19.83$, $p<.001$. The difference in mean risky decisions between loss and gain frames was largest when only the zero complement was presented ($M_{diff}=.48$, *SE*=.08, $p<.001$)), intermediate when both complements were presented ($M_{diff}=.23$, *SE*=.04, $p<.001$), and not significant when only the non-zero complement was presented ($M_{diff}=.07$, *SE*=.05, $p=.171$). In other words, presenting only the zero risky complement increased framing relative to the standard condition (in which both risky complements were presented). In contrast, there was no significant framing effect when only the non-zero risky complement was presented.

In addition, there was a main effect of whether money or lives were at stake, Generalized Score $\chi^2(1, N=2{,}314)=6.73$, $p=.009$, such that participants were more risk-seeking with money (*M*=.51, *SE*=.33) than with lives (*M*=.40, *SE*=.30). Finally, there was a main effect of order, Generalized Score χ^2 $(1, N=2{,}314)=5.15$, $p=.023$, such that participants became more risk-seeking over the course of repeated decisions (*B*=.006, *SE*=.002, $p=.017$). All marginal means above are reported at the mean value of order, in order to control for this significant effect. Note, however, that the framing effect (i.e., gain-loss differences in risk behavior) did not differ based on whether lives or money were at stake, nor did the framing effect attenuate over the course of repeated trials (i.e., the Frame × Order interaction was not significant, $p=.83$). Effects of truncation, gender, and age group were not significant.

Confidence: Confidence ratings for each decision ranged from 1 (weakest) to 5 (strongest). Degrees of freedom in the mixed model reflect the number of observations (60 problems for each participant, with some missing data as described above). Mean confidence was 3.53 (*SD*=1.14). There was a main effect of frame, $F(1, 2158)=72.04$, $p<.001$, such that participants were more confident about decisions in the gain frame (*M*=3.65, *SE*=.12) than about decisions in the loss frame (*M*=3.34, *SE*=.12). There was also a main effect of lives versus money, $F(1, 2184)=155.53$, $p<.001$, such that participants were more confident for decisions about money (*M*=3.73, *SE*=.12) than for decisions about lives (*M*=3.27, *SE*=.12). No other main effects or interactions were significant.

Signed Confidence: Recall that for signed confidence, larger positive numbers indicate more confidence in risky choices, and larger negative numbers indicate more confidence in sure choices. Degrees of freedom in the mixed model reflect the number of observations (60 problems for each participant, with some missing data as described above). There was a main effect of frame, $F(1, 2{,}171)=251.01$, $p<.001$. Consistent with the standard framing effect, participants tended to choose the risky option, with higher confidence, in the loss frame (*M*=.72, *SE*=.28), whereas they tended to choose the sure option, with higher confidence, in the gain frame (*M*=-1.31, *SE*=.28). This main effect was modified by a Frame × Truncation interaction, $F(2, 2{,}151)=57.35$, $p<.001$. The difference between confident risk seeking in the loss frame and confident risk aversion in the gain frame was largest when only the zero complement was presented ($M_{diff}=3.78$, *SE*=.22, $p<.001$), intermediate when both complements were presented ($M_{diff}=1.87$, *SE*=.22, $p<.001$), and not significant when only the non-zero complement was presented ($M_{diff}=.43$, *SE*=.22, $p=.055$). In all three truncation conditions, consistent with the standard framing effect, participants tended to choose the risky option, with higher confidence, in the loss frame, but they tended to choose the sure option, with higher confidence, in the gain frame. This trend missed significance when only the non-zero complement was presented. In other words, as was found for decision, presenting only the zero risky complement increased framing, whereas presenting only the non-zero risky complement attenuated framing, relative to the standard condition (in which both risky complements were presented).

There were also main effects of lives versus money, $F(1, 2170)=35.65$, $p<.001$, and of order, $F(1, 764)=6.77$, $p=.009$. Subjects tended to choose the risky option with higher confidence when money was at stake ($M=.09$, $SE=.28$), whereas they tended to choose the sure option with higher confidence when lives were at stake ($M=-.68$, $SE=.28$). Confidence in risky decisions decreased slightly over the course of repeated decisions, $B=-.01$, $t=2.6$, $p=.009$. Nonetheless, the interaction between order and frame was not significant ($p=.53$), indicating that the framing effect itself did not attenuate over the course of repeated decisions. Effects of truncation, gender, and age group were not significant.

Discussion

To summarize, in Experiment 1, we observed a significant framing effect, which was modulated by truncations of the risky option, even though we limited the analyses to those who perceived implicit information as complementary to stated information in each option.

What people assume about missing information—By instructing subjects to interpret unstated information as complementary to stated information, we minimized ambiguous inferences in the initial questionnaire, and all but eliminated them in the post-framing ambiguity questionnaire ($M=.90$ for two-option question about sure option; $M=.94$ for multiple-choice questions about sure and risky options). The higher rate of disambiguation on the post-framing questionnaire reflects the additional instructions (with worked examples) following the initial instructions and questionnaire, and it strongly suggests that subjects retained our instructions that the sure option did not mean “or more” or “at least”—and that the zero risky complement implied the non-zero risky complement—while making framing decisions. Overall, participants indicated complementarity more often in the gain frame than in the loss frame, although this difference disappeared at post-test following worked examples. The initial difference in ambiguity between frames may reflect the conflict between risk aversion (avoiding a gamble) and loss aversion (avoiding a sure loss) when processing the risky option in the loss frame (Gonzalez, Dana, Koshino, & Just, 2005).

Necessity of ambiguity to framing—The results of experiment 1 do not support the claim that ambiguous perceptions of the options are necessary to risky choice framing effects. In order to more clearly test the ambiguity hypothesis, we excluded all participants except those who indicated complementarity between stated and unstated information in all three questions on the pre-framing ambiguity survey. In this sub-sample, we observed a framing effect for both choice and signed confidence. On average, participants in this sub-sample indicated 71% confidence (3.53 out of 5) in their decisions. The analyses of confidence and confidence-weighted choice are important because they indicate that participants were not indifferent, despite making a binary forced choice.

Truncations of the risky option modulated framing effects for both decision and signed confidence. Focusing attention on the zero risky complement increased framing effects, and focusing attention on the non-zero risky complement decreased framing effects, relative to the standard version of the problem (in which both risky complements were presented). Truncations of both the sure and the risky option have been used to test theoretical accounts of framing effects; in particular, truncating the risky option has been used as a critical test of fuzzy-trace theory versus prospect theory (Kuhberger & Tanner, 2010). Because truncations of the risky option have been used to test predictions about the mechanisms of framing effects (Reyna et al., 2014), it is important to underscore our finding that participants showed the interaction between frame and truncation even when they interpreted implied information as complementary to stated information in both the sure and the risky options.

Consistency across age groups—The non-necessity of ambiguity to framing effects was observed not only in college students, but also in middle-aged adults. Middle-aged adults are in their prime earning years and are often in positions of authority, with responsibilities to their families and in their jobs. Therefore, society has a strong interest in understanding the cognitive processes that support decision making in this age group. Some have questioned the generalization of results obtained from a college-aged sample to other age groups (Peterson, 2001). Indeed, developmental differences in risk taking are well documented (Levin & Hart, 2003; Levin, Hart, Weller & Harshman, 2007; Paulsen, Platt, Huettel & Brannon, 2011; Setton, Wilhelms, Weldon, Chick & Reyna, 2014), and risky choice framing effects increase with age and expertise in adults (Chick & Reyna, 2012; Reyna et al., 2014). However, we found that risky choice framing effects were robust to linguistic disambiguation for both college students and middle-aged adults.

Limitations—Although Experiment 1 provides strong evidence against the ambiguity hypothesis, it has several limitations. First, the repeated-measures design may have influenced results, as risk seeking attenuated slightly over the course of repeated decisions. (Importantly, however, the framing effect—gain-loss differences in risk taking—did not attenuate). Second, the time constraint for decision and confidence ratings may have limited participants' ability to apply the disambiguation instructions (Maule, Hockey & Bdzola, 2000). (However, on most trials, participants responded prior to the 8-second time limit for decision and 3-second time limit for confidence, so time limitations are unlikely to account for our results.)

Third, although we tested for understanding of our disambiguation instructions before and after framing decisions, we did not display these instructions on the same screen as the options when participants were making decisions. It could therefore be argued that we relied on participants' memory for the disambiguation instructions in Experiment 1. (However, the ambiguity questionnaires administered before and after the framing problems controlled for instruction memory, and participants who retained the instructions nonetheless showed robust framing effects in Experiment 1; see supplemental material). Fourth, it could be argued that correct answers on the ambiguity questionnaires result from rote memorization as opposed to a true understanding that stated and unstated information are complementary within each option. A test that required participants to reason logically based on their understanding of this complementarity would reduce the likelihood of this potential confound. In order to address these four limitations of Experiment 1, we conducted a second experiment.

Experiment 2

As a follow-up to Experiment 1, we conducted a second experiment, implementing a between-subjects design and eliminating time limits on decision and confidence ratings. We also included an additional disambiguation cue directly in the sure option. Finally, in addition to the ambiguity questionnaires used in Experiment 1, we added a question that more thoroughly assessed transfer of our disambiguation instructions by requiring subjects to reason logically based on their interpretations of missing information.

Method

Participants—Experiment 2 included 291 participants. Of the 291 participants, 268 completed both the initial and post-framing ambiguity questionnaires (i.e., 23 did not complete the post-framing questionnaire). Cornell undergraduates were recruited via an online experiment sign-up system and were compensated with course credit. Additional participants were recruited from Amazon's Mechanical Turk and were compensated monetarily. As in Experiment 1, in order to account for potential age differences, participants were categorized as either college students (age < 22) or post-college adults (age >= 22). College students (n=159) were 76% female, mean age=19.22 years (SD=1.14). College students identified as 60% Caucaisan, 22% Asian (including Chinese, Filipino, Korean, and Taiwanese), 9% Asian Indian, 5% African American, and 2% mixed race (2% indicated “other”). Seven percent of college students identified as Hispanic (including Mexican American, Puerto Rican, Cuban, Central American, and South American). Post-college adults (n=132) were 56% female, mean age=37.77 years (SD=12.45). Post-college adults identified as 68% Caucasian, 20% Asian Indian, 4% Asian (including Chinese, Filipino and Korean), 4% African American, 3% mixed ethnicity, and 1% Native American (1% indicated “other”). Seven percent of post-college adults identified as Hispanic (including Mexican, American, Puerto Rican, Spanish, Central American, and South American). See Table 4 for demographic information of groups receiving the gain frame compared to the loss frame version of the ambiguity questionnaires.

Design and procedure—The ambiguity questionnaires in Experiment 2 were identical to those in Experiment 1. In contrast to Experiment 1, the framing problems used in Experiment 2 were administered following a 2 (Frame) × 3 (Truncation) between-subjects design. Participants were randomly assigned to one of the six conditions. Each participant answered only one framing problem (described below). Each participant completed both ambiguity questionnaires (pre- and post-framing) in the same frame as their framing problem. Following the post-framing ambiguity questionnaire, participants completed individual difference measures (not described in this report). They were then debriefed.

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Materials

Framing problem: Each participant answered one framing problem in either the gain or the loss frame, with one of the three truncations of the risky option (see Experiment 1 for a description of the truncation manipulation). The exact wording of the two framing problems appears in Appendices C and D. With the exception of adding the truncation manipulation to the risky option, we used the identical wording of problem and options as did Mandel (2014, Experiment 2). The problem scenario indicated that 600 lives were at stake in a war-torn region. Note that, in our Experiment 2, the instructions, ambiguity questionnaires, and framing problem presented scenarios in which lives were at stake; for the sake of replicating Mandel's stimuli, we did not include any framing problems about money in Experiment 2. (Note that we did not find any effects of lives versus money on framing effects or ambiguity in Experiment 1). Crucially for replicating Mandel's manipulation, we added “exactly” to the sure option in all conditions (e.g., “If Plan A is adopted, it is certain that exactly 200 people will be saved”). Mandel (2014) argues that this wording encourages subjects to perceive the options as extensionally equivalent. If the ambiguity hypothesis is correct, then we should not observe a significant framing effect when this complementarity is made explicit. Therefore, a significant framing effect would be evidence that this form of linguistic ambiguity is not necessary to framing effects.

We used only the “exactly” modifier from Mandel's Experiment 2 because this provided the strongest test of the ambiguity hypothesis. For example, even if adding “at least” to the sure option were sufficient to increase framing effects, that would not prove that this type of ambiguity is necessary to framing. However, if disambiguation such as “exactly” eliminated framing effects, this would be evidence that ambiguity is necessary to framing.

Transfer problem: In addition to the ambiguity questionnaires (which were identical to those in Experiment 1), we asked subjects a question that tested transfer of the disambiguation instructions. In order to rule out the possibility that correct answers on the ambiguity questionnaires result from rote memorization as opposed to a true disambiguation, the transfer problem required participants to perform a deductive reasoning task based on their understanding of partially specified options (see Appendices E and F for exact wording). Each participant answered one transfer problem in the same frame as the framing problem and ambiguity questionnaire.

In the gain frame version of the transfer problem, participants were told that a hypothetical decision maker named Stuart was playing online poker with $600 at stake, and he had a choice between winning $200 for sure or taking a 1/3 chance of winning $600 and a 2/3 chance of winning nothing. The problem indicated that Stuart had chosen the sure $200 gain, and asked participants whether Stuart would have enough money from these winnings alone to buy an iPad that cost $201. Answer choices were “yes,” “maybe,” or “no.” The answer consistent with disambiguation is “no.” Participants could only give this answer if they assumed that Stuart won *exactly* $200. If the ambiguity hypothesis were correct, and participants assumed that Stuart's winnings would be “at least” $200, then participants should answer “yes” or “maybe,” reflecting the belief that 200 is a lower bound of Stuart's winnings.

In the loss frame version of the transfer problem, participants were told that a hypothetical decision maker named Stuart was playing online poker with $600 at stake, and he had a choice between losing $400 for sure or taking a 2/3 chance of losing $600 and a 1/3 chance of losing nothing. The problem indicated Stuart had chosen sure $400 loss, and asked participants whether Stuart would have enough money left from the $600 endowment to buy an iPad that cost exactly $200. Answer choices were “yes,” “maybe,” or “no.” The answer consistent with disambiguation is “yes.” Participants could only give this answer if they assumed that Stuart lost *exactly* $400. If the ambiguity hypothesis were correct, and participants assumed that Stuart's losses were “at least” $400, then participants should answer “no” or “maybe,” reflecting the belief that 400 is a lower bound of Stuart's losses.

Note that, in Experiment 2, the instructions, ambiguity questionnaires, and framing problem all presented scenarios in which lives were at stake. In contrast, the transfer problem presented a scenario in which money was at stake. By providing disambiguation instructions in which lives were at stake, but testing comprehension in terms of money at stake, we tested participants' ability to apply the logic of complementarity in problems that were superficially dissimilar (but structurally identical) to those about which they received the disambiguation instructions.

Analyses—Statistical analyses were performed in SPSS version 22 (IBM, Armonk, NY, 2010).

Results

Responses to ambiguity questionnaires—Because our argument depends on observing framing effects after options have been disambiguated, as in Experiment 1, we verified that our disambiguation instructions were effective. Mean scores for each question on the ambiguity survey are displayed in Table 5. We ran separate analyses on the yes/no question about the sure option and on the three-option questions about the sure and risky options; these analyses were not combined because of the different number of response options (hence, different odds of indicating complementarity by chance alone). For all analyses, the dependent variable was response to each ambiguity survey question, coded as 0 (indicating ambiguity) or 1 (indicating complementarity). These analyses are restricted to participants who completed both the initial and post-framing ambiguity questionnaires (n=268).

Yes/no question: For the yes/no question about the sure option, a 2 × 2 × 2 repeated measures ANOVA was run, with initial versus post-framing ambiguity questionnaire as a within-subjects factor and frame of ambiguity questionnaire (gain or loss) and age group (college or post-college) as between-subjects factors. A significant main effect was found for initial versus post-framing, $F(1, 264)=4.36$, $p=.038$, $\eta_p^2=.016$. Subjects indicated complementarity more often on the post-framing ambiguity questionnaire (M=.89, SE=.02) compared to the initial survey (M=.83, SE=.02). However, this main effect was modified by an interaction with age group, $F(1, 264)=4.96$, $p=.027$, $\eta_p^2=.018$. Post-college participants indicated higher complementarity on the post-framing questionnaire (M=.88, SE=.03) than on the initial questionnaire (*M*=.76, *SE*=.03), but age differences disappeared on the post-framing questionnaire.

Three-option questions: A repeated measures ANOVA was run on the three-option questions about the sure and risky options. The 2 × 2 × 2 × 2 factorial design included initial versus post-framing and sure versus risky as within-subjects factors, and frame of ambiguity questionnaire (gain or loss) and age group (college or post-college) as between-subjects factors. There was a main effect of initial versus post-framing, $F(1, 264)=35.36$, $p<.001$, $\eta_p^2=.118$. More subjects indicated complementarity on the post-framing ambiguity questionnaire (*M*=.90, *SE*=.02) than on the initial survey (*M*=.77, *SE*=.02). This was modified by a three-way interaction between frame, sure versus risky, and initial versus post-framing, $F(1, 264)=8.73$, $p=.003$, $\eta_p^2=.032$. On the post-framing questionnaire, participants who received the loss frame version of the ambiguity questions indicated more complementarity for the sure option (*M*=.95, *SE*=.03) than for the risky option (*M*=.89, *SE*=.03).

Transfer problem: Among participants who completed the transfer problem (*n*=279), 80% (*n*=222) gave answers indicating complementarity between stated and implicit information. Of participants who answered the gain frame version (*n*=142), 13 answered "yes," 20 answered "maybe," and 109 answered "no." The answer indicating complementarity was "no," since the other two answers required the assumption that "at least" $200 would be won. Of participants who answered the loss frame version (*n*=137), 113 answered "yes," 13 answered "maybe," and 11 answered "no." The answer indicating complementarity was "yes," since the other two answers required the assumption that "at least" $400 would be lost.

In order to determine whether perceived complementarity in the transfer problem differed by age or gender, or was influenced by the frame in which participants completed the problem, we ran a logistic regression with answer to the transfer problem (i.e., whether it indicated ambiguity or complementarity) as the dependent variable and gender, age group and frame of truncation problem as independent variables. None of these variables significantly predicted answers to the transfer problem (all $p>.1$). In other words, perceived complementarity in the transfer problem did not differ based on the frame in which the transfer problem was described (see Table 4) or by age group. However, disambiguated answers to the transfer problem were associated with disambiguated answers on the pre-framing ($r_s[279]=.24$, $p<.01$) and post-framing ($r_s[279]=.30$, $p<.01$) ambiguity questionnaires. In other words, participants who rejected the hypothesized forms of ambiguity in the initial and post-framing ambiguity questionnaires also tended to reject ambiguity in the transfer problem.

Necessity of ambiguity to framing effects—The aim of Experiment 2 was to replicate, in a between-subjects design with an additional disambiguation cue, the frame and Frame × Truncation effects reported in Experiment 1 for participants who indicated disambiguation prior to completing the framing problems. If ambiguity is necessary to framing, then we should not observe framing effects among participants who indicate that implicit information is complementary to stated information. Consistent with this logic, as in

Experiment 1, we analyzed only data from participants who answered all three questions on the pre-framing questionnaire in a way that indicated disambiguation. 154 subjects met this criterion. We ran separate univariate ANOVAs on decision, confidence, and signed confidence, with frame, truncation, gender and age group (college or post-college) as factors. We controlled for age group in all analyses. See supplemental materials for analyses of the full sample (which showed effects consistent with those reported below).

Decision: Recall that decision was coded as 0 (sure) or 1 (risky). For decision, there was a main effect of frame, $F(1, 147)=4.30$, $p=.04$, $\eta_p^2=.028$, and a frame × truncation interaction, $F(2, 147)=3.47$, $p=.03$, $\eta_p^2=.045$. Consistent with the standard framing effect, more participants chose the risky option in the loss frame ($M=0.51$, $SD=0.50$) than in the gain frame ($M=0.35$, $SD=0.48$). Planned comparisons revealed significant framing effects when only the zero risky complement was presented ($M_{diff}=0.29$, $SE=0.13$, $p=.03$) and when both complements were presented ($M_{diff}=0.33$, $SE=0.14$, $p=.02$). No significant framing effect was observed when only the non-zero risky complement was presented ($M_{diff}=0.13$, $SE=0.14$, $p=.33$). There were no significant effects of gender or age group.

Confidence: Confidence ratings for each decision ranged from 1 (weakest) to 5 (strongest). Mean confidence was 3.58 ($SD=1.03$). There was a main effect of age group, $F(1, 152)=11.94$, $p=.001$, $\eta_p^2=.073$, such that, on average, post-college adults ($M=3.86$, $SE=0.12$) were more confident than were college students ($M=3.30$, $SE=0.11$). No other main effects or interactions were significant.

Signed confidence: Recall that, for signed confidence, larger positive values indicate higher confidence in risky decisions, and larger negative values indicate higher confidence in sure decisions. For signed confidence, there was a main effect of frame, $F(1, 147)=5.41$, $p=.02$, $\eta_p^2=.036$, and a frame × truncation interaction, $F(2, 147)=3.81$, $p=.02$, $\eta_p^2=.049$. Consistent with the standard framing effect, participants chose the risky option more often, and with higher confidence, in the loss frame ($M=0.012$, $SD=3.63$) than in the gain frame ($M=-1.30$, $SD=3.30$). Planned comparisons revealed significant framing effects when only the zero risky complement was presented ($M_{diff}=2.39$, $SE=0.98$, $p=.02$) and when both complements were presented ($M_{diff}=2.58$, $SE=1.03$, $p=.01$). No significant framing effect was observed when only the non-zero risky complement was presented ($M_{diff}=-.93$, $SE=1.00$, $p=.35$). There were no significant effects of gender or age group.

Discussion

Experiment 2 addressed limitations of Experiment 1 by including a disambiguation cue directly in the problem (i.e., adding "exactly" to the sure option), in addition to the disambiguation instructions and worked examples provided in both experiments. Even after such thorough disambiguation of the sure option, participants who indicated that they perceived implicit information as complementary to stated information in each option showed a robust framing effect ($p<.001$) for both choice and signed confidence. These participants also showed an interaction of frame with truncation, such that framing effects were significant when both risky complements or only the zero risky complement were presented, but were not significant when only the non-zero risky complement was presented.

This pattern was present for both choice and signed confidence. Note that presenting only the zero complement has been found to increase framing effects relative to the typical version of the problem in many published experiments, which have presented more problems and used both within- and between-subjects designs (Kuhberger & Tanner, 2010; Reyna et al., 2014; Reyna & Brainerd, 1991).

It might be argued that the truncated risky option remained ambiguous in Experiment 2 (despite detailed pre-task instructions), since no modifiers such as “exactly” were added to the risky option. However, in planned comparisons, participants showed framing effects when the risky option was fully specified (i.e., both risky complements were presented; $p<.001$), so ambiguity in the risky option cannot account for the framing effects we observed.

The significant frame and Frame × Truncation effects were observed for both college students and post-college adults; age group was not significant as a main effect or interaction in the framing analyses. This replicates the finding from Experiment 1 that linguistic ambiguity (in the forms hypothesized in the literature) is not necessary to framing effects in either age group. Moreover, disambiguation as measured by the transfer problem —which varied in format from the materials used to instruct participants about extensional equivalence—was equally high among young and middle aged adults.

The high percentage of disambiguated responses to the transfer problem (80%) indicates that participants were not merely memorizing the answers to our disambiguation instructions and regenerating the surface form when answering the ambiguity questionnaires. Rather, they encoded our instructions with sufficient depth to perform logical reasoning based on the instructed information. Demonstration through appropriate use is evidence of transfer (Chick, 2014; Lloyd & Reyna, 2009). Since deeper learning is more likely to be transferred to new contexts (Barnett & Ceci, 2002), the high rate of transfer suggests that participants encoded the gist of our instructions and therefore may also have applied this understanding while making their framing decisions. Frame of the disambiguation instructions was unrelated to performance on the transfer problem, suggesting that participants encoded our instructions equally well in all conditions. Furthermore, the correlation, $r_s(279)=.30$, $p<.001$, between answers to the post-framing ambiguity questionnaire and answers to the transfer problem, though modest, suggests that performance on the ambiguity questionnaire reflected more than rote memorization. This supports our interpretation of the results of both experiments as a rejection of the assumption that linguistic ambiguity is necessary to framing effects.

Conclusion

Many current explanations of framing effects hold that framing depends on ambiguity about unstated information (e.g., Kuhberger & Gradl, 2013; Okder, 2012; Mandel, 2001; Mandel, 2013; Sher & McKenzie, 2008). For example, these scholars have argued that subjects add “or more” to the sure option, resulting in a higher value for the sure gain relative to the risky gain (leading subjects to be risk averse in the gain frame) or a lower value for the sure loss relative to the risky loss (leading subjects to be risk seeking in the loss frame). We corrected this particular type of ambiguity, as well as two types of ambiguity in the risky option, addressing current controversies in the literature. Problems included the traditional incompletely specified sure option as well as truncated risky options (in which either the zero complement, the non-zero complement, or both complements were presented). Subjects answered two multiple-choice questionnaires (one before and one after the framing problems) testing their comprehension of our instructions about unstated information in both sure and risky options. Although initial perception of complementarity between stated and implicit information was high, disambiguation increased after the worked examples, and it remained high while subjects completed all 60 framing problems in Experiment 1 (as well as the single framing problem in Experiment 2), as indicated by the post-framing cambiguity questionnaire. Moreover, in Experiment 2, we added a disambiguation cue (the word “exactly”) directly to the sure option, and participants saw this cue on the options screen while making their decision. The results do not support the ambiguity hypothesis: Subjects who rejected the forms of ambiguity that have been hypothesized in the literature nonetheless showed robust framing and truncation effects in both experiments. Notably, framing effects survived disambiguation of both the sure and truncated risky options. This is strong evidence against the claim that risky choice framing effects are caused by inferences about missing information.

Non-Necessity of Ambiguity to Framing Effects

Our results speak directly to recent work by Mandel (2014), who showed that linguistic ambiguity (i.e., lack of complementarity between stated and implicit information) is sufficient to cause risky choice framing. In contrast to Mandel's argument about sufficiency, we make an argument about necessity: Our results are novel in demonstrating that this type of ambiguity is not necessary to risky choice framing effects.

Although Mandel increased framing effects by manipulating interpretations of unstated information in order to reduce complementarity (e.g., adding “at least” to the sure option), we argue that this does not demonstrate that such interpretations are necessary in order to achieve framing effects in the typical version of the problem. Specifically, Mandel reports that adding “at least” to the sure option increased framing effects, but these results reflect changes to the problem information, rather than ambiguity in unspecified information. Adding “at least” to the sure option makes the value of the sure option higher than that of the risky option in the gain frame, and lower than that of the risky option in the loss frame. Naturally, subjects choose the option with the higher value, resulting in most subjects choosing the sure option in the gain frame and the risky option in the loss frame. That the “at least” modifier can increase framing by rendering the values of the options unequal does not mean that this assumption is necessary in order to create the bias under ordinary circumstances.

In addition, Mandel reports that framing effects decreased when the sure option was described in both positive and negative terms (e.g., “200 are saved and 400 are not saved”) compared to the typical version of the option (e.g., “200 are saved”). However, by describing the sure option as both positive and negative, Mandel does more than disambiguate it; he changes the cognitive representation, changing the gist to “some saved and some not saved.” Since this eliminates the some-none categorical contrast between the sure and risky options, fuzzy-trace theory predicts that this manipulation should reduce framing effects (see Kuhberger & Tanner, 2010). Therefore, ambiguity in the typical version of the problem is not necessary in order to explain this result.

Nevertheless, Mandel reports that adding the word “exactly” to the sure option reduced framing effects relative to the standard version of the problem. (Note that, based on the reported means, Mandel's manipulation affected only the loss frame, and that the trend was in the direction of framing effects). We acknowledge that this finding supports the hypothesis that some people do show framing effects because of ambiguity. For this reason, in Experiment 2, we attempted to replicate Mandel's result by adding the word “exactly” to the sure option.

However, instead of reducing framing effects, we observed a main effect of frame as well as a Frame × Truncation interaction, replicating our results from Experiment 1. Our disambiguation was more thorough than that provided by Mandel, as we also provided pre-task instructions (with worked examples) indicating how to interpret unstated information in both the sure and the risky options. We verified that subjects interpreted unstated information as complementary to stated information by quizzing them both before and after they completed the framing problems. By documenting subjects' interpretations of the options before they made framing decisions, we avoided the demand effect that might have influenced results reported by Mandel (2014). In both experiments, when we limited the analysis to subjects who indicated disambiguation, we nonetheless observed a significant framing effect (and a significant interaction with the truncation manipulation, as predicted).

These results contradict the conclusions reported by Mandel (2014). In our Experiment 2, when we added “exactly” to the sure option and presented both risky complements, our stimuli were identical to those used by Mandel (2014, Experiment 2). In this condition, we found a mean difference in risk taking between frames of 0.33 (p =.02). Thus, even following our disambiguation instructions, when we presented a framing problem identical to the disambiguated version used by Mandel (i.e., with “exactly”), we found a significant framing effect that was highly similar to Mandel's result for the typical version of the problem (i.e., without “exactly;” M=.32, p=.005).In this condition, we found an effect size of *Cohen's d*=.63, which is consistent with the typical effect size of d=.60 (and is within the 95% confidence interval of .56 to .64), as reported in a meta-analysis of 69 studies of framing effects (Kuhberger, 1998, Table 10, p. 42).

Our results are consistent with the results of an attempt to replicate Mandel's Experiment 2, which was reported by Simmons and Nelson (2013). Simmons and Nelson found no difference in framing effects between the “exactly” manipulation and the standard wording in a sample approximately 2.5 times the size of Mandel's. Simmons and Nelson found a framing effect of 0.34 (p< .001)when “exactly” was included, which is nearly identical to the effect we report for that condition in our Experiment 2 (M_{diff}=0.33, p=.02).

Importantly, we observed these effects even when controlling for age group. Among participants who perceived implicit information as complementary to stated information in each option, framing and truncation effects were equally robust in young adults and middle-aged adults (i.e., there was no main effect or interaction with age). Given concerns that data collected from college students might not generalize to the broader population (Peterson, 2001), as well as documented age differences in risky decision making, including framing effects (Levin et al., 2007; Setton et al., 2014), it is important to rule out the possibility that the necessity of ambiguity to risky choice framing effects varies by age. Our data suggest that this is not the case.

These results do not rule out the possibility that linguistic ambiguity explains some portion of the framing effects reported in the literature. Indeed, other studies have shown that some forms of ambiguity are associated with framing (Mandel, 2014). We agree with Mandel that this alternative mechanism is not a true framing effect among options of equal expected value. Instead, adding wording such as “at least” and “at most” as described by Mandel may alter the perceived value of the options, resulting in decisions that maximize gains or minimize losses (Mandel, 2014). Given that we observed framing effect sizes consistent with those reported in the literature (for a meta-analysis of framing effect sizes, see Kuhberger, 1998), even among participants who rejected commonly hypothesized versions of linguistic ambiguity, it is unlikely that the forms of linguistic ambiguity that have been hypothesized in published work account for the bulk of the framing effects reported in the literature.

Fuzzy-Trace Theory's Selective Attention Hypothesis

If linguistic ambiguity is not necessary to observe framing effects, then an alternative theoretical explanation of framing effects is required. Such an account must explain not only typical framing effects, but also the effects of truncating (versus completely specifying) the options. Fuzzy trace theory's selective attention explanation of truncation effects predicts that participants do not focus on unstated information while making decisions, even when they believe that this “missing” information is complementary to (i.e., redundant with) stated information. Reyna et al. (2014) argue that by presenting only a portion of each option in truncation conditions, the experimenters selectively focus subjects' attention on one of two complementary outcomes, cuing different cognitive processes for comparing the options. These processes result in different decisions (as predicted by fuzzy trace theory), but the results of this study suggest that this is not attributable to lack of complementarity between stated and unstated information.

Consistent with this argument, we predicted that, on the one hand, highlighting categorical differences between the sure and risky options (by presenting only the zero complement of the risky option) should increase framing effects. On the other hand, highlighting the numerical equivalence between the sure and risky options (by presenting only the non-zero risky complement) should eliminate framing effects. Note that presenting only the non-zero complement (e.g., 1/3 chance all 600 saved) does not allow for discrimination based on simplified categorical comparisons; instead, subjects must process the options in greater numerical detail, ultimately multiplying probabilities by outcomes (leading to indifference between the sure and risky options). When only the non-zero complement is presented, the observed result of approximately equal preference for sure and risky options is consistent with multiplying probabilities and outcomes. These predictions are borne out in the data presented here and in other reports (see summary by Setton et al., 2014). Note that these results contradict the prediction by prospect theory and expected utility theory that framing effects should occur when only the non-zero complement is presented. According to these theories, the values of the options are identical when the zero complement is included or excluded because its value is zero. Therefore, framing effects should be the same for truncated and non-truncated versions of the risky option (Kuhberger & Tanner, 2010).

Crucially, our argument regarding truncation effects is not that subjects make different assumptions about the unstated risky complement when only one or the other complement is presented. Rather, it is that each risky complement, presented without the other, prompts a different cognitive contrast between the sure and risky options, resulting in either increased or decreased framing effects. This does not imply that subjects do not understand that the unstated information is complementary to the stated information. As we have reported, subjects showed robust framing and truncation effects even when they demonstrated that they interpreted unstated information as complementary to stated information. That subjects indicated this on the ambiguity questionnaires and transfer problem after completing all framing problems suggests that they retained our disambiguation instructions during the time that they were making framing decisions. Since framing effects are observed even when subjects perceive unstated information as complementary to stated information, linguistic ambiguity of this variety cannot be necessary to produce risky choice framing effects.

These data do not undermine the important role of pragmatic inferences in judgment and decision making. For example, Sher and McKenzie (2006) demonstrated that information leakage, a type of pragmatic inference, accounts for other types of framing effects, such as attribute framing. However, our results are inconsistent with the hypothesis that pragmatic inferences are necessary to produce risky choice framing effects.

Instead, the current results are consistent with fuzzy-trace theory's account of risky choice framing and truncation effects, which disconfirms predictions of both expected utility and prospect theory (Kahneman, & Tversky, 1979; Kuhberger & Tanner, 2010; Reyna, 2012; Reyna et al., 2014). Our results therefore support the hypothesis that risky choice framing effects are caused by gist-based categorical contrasts between some and none (e.g., some people are saved for sure vs. some people are saved or no one is saved; Reyna et al., 2014), rather than by interpreting incompletely specified information as ambiguous with respect to the value of the options.

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Appendix A

Instructions

Hello, welcome to our study. We are interested in how people make decisions. You will be asked questions about disease prevention programs, disease treatment programs, environmental conservation programs, gambling, etc. You will be given two options for each question: Choice A or B. You can select only one choice. Here are some example problems.

Sample Problem #1

A boat with 1,000 people is stranded in the middle of the ocean. There is not enough food left on the boat.

A captain suggests two rescue programs. Please indicate which program you prefer.

A: 500 people saved for sure.

B: ½ probability no one saved.

For Option A, the number given is the EXACT number of people that will be saved. In other words, there is NO probability that fewer than 500 people will be saved and NO probability that more than 500 people will be saved. If you select option A, EXACTLY 500 people will be saved; no fewer, no more.

Option B means that there is 1/2 probability (50% chance) that ALL 1,000 people will be saved and 1/2 probability (50% chance) that NO people will be saved. All probabilities in Option B are complementary and add up to 100%.

Sample Problem #2

A massive oil spill in the ocean is expected to kill 500 turtles. Please indicate which of the following conservation program you prefer.

A: 200 turtles saved for sure.

B: 2/5 probability 500 turtles saved and 3/5 probability no turtles saved.

For Option A, the number given is the EXACT number of turtles that will be saved. In other words, there is NO probability that fewer than 200 turtles will be saved and NO probability that more than 200 turtles will be saved. If you select option A, EXACTLY 200 turtles will be saved; no fewer, no more.

Option B means that there is 2/5 probability (40% chance) that ALL 500 turtles will be saved and 3/5 probability (60% chance) that NO turtles will be saved. All probabilities in Option B are complementary and add up to 100%.

To select option A, use your right *index* finger to press the “2” key.

To select option B, use your right *middle* finger to press the “3” key.

Please answer every single question. Note that you will have a LIMITED amount of time to select your option. Please do your best to make a decision in the allotted time frame. There are no “right” answers. Please make the decisions that you feel are best.

Appendix B

Additional instructions presented after initial ambiguity survey

As stated in the instructions that you read, all of the information that we give you in the preamble is exactly what happens. Therefore, when we say:

A boat with 500 people has a hole in it and will inevitably sink. You have a choice between two options.

We mean that there are exactly 500 people on the boat who are in jeopardy.

Additionally, when we give you the option of:

A: 300 people saved for sure

We mean that option A saves exactly 300 people. If you select option A, 300 people will be saved. No fewer, and no more. These 300 people will be the only ones saved. No others may be saved, might be saved, or could be saved.

For the other option:

B: 3/5 probability that everyone will be saved

We mean that option B has a 3/5 probability that everyone (all 500 people at risk) will be saved. If you select option B, that also means that there is a probability that no one would be saved.

The correct response to the question, “what did you assume about the other 2/5 probability in option B,” is:

The 2/5 probability indicates that NO ONE will be saved.

Common mistakes include “some might be saved,” “some could be saved,” and “they will swim to shore.” These are all incorrect. We don't want you to assume anything outside of the information that is given to you. Therefore, if we specify that there is a probability that everyone will be saved, if that does not happen, then no one will be saved. Similarly, if we specify that there is a probability that no one will be saved, if that does not happen, then everyone will be saved.

The correct response to the question, “did you assume that more than 300 people would be saved in option A,” is:

NO.

As stated before, when we say "for sure," we mean exactly. This means that there is no way that more than 300 people, or less for that matter, could be saved in option A. We are not trying to trick you, so we don't want you to make assumptions.

The correct response to our question, "which of the following did you assume about option A," is:

A: Exactly 300 people would be saved.

See explanation for question above.

The correct response to the question, "which of the following did you assume about option B," is:

C: There is a 2/5 probability that no one will be saved.

As stated before, if the 3/5 probability that everyone will be saved does not happen, then there is a 2/5 probability that NO ONE will be saved. Given the 2/5 probability, it is not possible that 1 person will be saved, or 2 people will be saved. No one will be saved.

Does this make sense? If not, feel free to ask questions of the experimenter.

Appendix C

Experiment 2 gain frame problems by truncation

Both risky complements presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options:

If Plan A is adopted, it is certain that exactly 200 people will be saved.

If Plan B is adopted, there is a one-third probability that 600 will be saved and a two- thirds probability that nobody will be saved.

Zero risky complement presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options:

If Plan A is adopted, it is certain that exactly 200 people will be saved.

If Plan B is adopted, there is a two-thirds probability that nobody will be saved.

Non-zero risky complement presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options: If Plan A is adopted, it is certain that exactly 200 people will be saved.

If Plan B is adopted, there is a one-third probability that 600 will be saved.

Appendix D

Experiment 2 loss frame problems by truncation

Both risky complements presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options:

If Plan A is adopted, it is certain that exactly 400 people will die.

If Plan B is adopted, there is a two-thirds probability that 600 will die and a one-third probability that nobody will die.

Zero risky complement presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options:

If Plan A is adopted, it is certain that exactly 400 people will die.

If Plan B is adopted, there is a one-third probability that nobody will die.

Non-zero risky complement presented

In a war-torn region, the lives of 600 stranded people are at stake. Two response plans with the following outcomes have been proposed. Assume that the estimates provided are accurate.

You have a choice between two options:

If Plan A is adopted, it is certain that exactly 400 people will die.

If Plan B is adopted, there is a two-thirds probability that 600 will die.

Appendix E

Transfer problem, gain frame

Stuart is playing online poker, and he has $600 at stake. He has two options:

A. Win $200 for sure

B. 1/3 chance of winning $600 and 2/3 chance of winning nothing

Stuart chooses Option A: Win $200 for sure.

Using ONLY his winnings from THIS round of online poker, will Stuart be able to afford a new iPad that costs exactly $201 (including tax)?

a. Yes

b. Maybe

c. **No [correct answer]**

Appendix F

Transfer problem, loss frame

Stuart is playing online poker, and he has bet $600. He has two options:

A. Lose $400 for sure

B. 2/3 chance of losing $600 and 1/3 chance of losing nothing

Stuart chooses Option A: Lose $400 for sure.

Using ONLY the money remaining after THIS round of online poker, will Stuart be able to afford a new iPad that costs exactly $200 (including tax)?

a. **Yes [correct answer]**

b. Maybe

c. No

References

Baayen RH, Davidson DJ, Bates DM. Mixed-effects modeling with crossed random effects for subjects and items. Journal of Memory and Language. 2008; 59(4):390–412.10.1016/j.jml.2007.12.005

Barnett SM, Ceci SJ. When and where do we apply what we learn? A taxonomy for far transfer. Psychological Bulletin. 2002; 128(4):612–637.10.1037/0033-2909.128.4.612 [PubMed: 12081085]

Breheny R. A new look at the semantics and pragmatics of numerically quantified noun phrases. Journal of Semantics. 2008; 25:93–139.10.1093/jos/ffm016

Chick CF. Basic mechanisms of numerical processing: Cross-modal number comparisons and symbolic versus nonsymbolic numerosity in the intraparietal sulcus. Journal of Neuroscience. 2014; 34(5):1567–1569.10.1523/JNEUROSCI.4771-13.2014 [PubMed: 24478340]

Chick, CF.; Reyna, VF. A fuzzy trace theory of adolescent risk taking: Beyond self-control and sensation seeking. In: Reyna, VF.; Chapman, SB.; Dougherty, MR.; Confrey, J., editors. The adolescent brain: Learning, reasoning, and decision making. Washington, DC US: American Psychological Association; 2012. p. 379-428.

Frisch D. Reasons for framing effects. Organizational Behavior and Human Decision Processes. 1993; 54(3):399–429.10.1006/obhd.1993.1017

Geurts, B. Take "five:" The meaning and use of a number word. In: Vogeleer, S.; Tasmowski, L., editors. Non-definiteness and plurality. Philadelphia, PA: Benjamins; 2006. p. 311-329.

Gonzalez C, Dana J, Koshino H, Just M. The framing effect and risky decisions: Examining cognitive functions with fMRI. Journal of Economic Psychology. 2005; 26(1):1–20.10.1016/j.joep.2004.08.004

Jou JW, Shanteau J, Harris RJ. An information processing view of framing effects: The role of causal schemas in decision making. Memory & Cognition. 1996; 24(1):1–15.10.3758/bf03197268 [PubMed: 8822154]

Kahneman D. A perspective on judgment and choice: Mapping bounded rationality. American Psychologist. 2003; 58(9):697–720.10.1037/0003-066X.58.9.697 [PubMed: 14584987]

Kahneman D, Tversky A. Prospect theory: Analysis of decision under risk. Econometrica. 1979; 47(2): 263–291.10.2307/1914185

Kuhberger A. The framing of decisions: A new look at old problems. Organizational Behavior and Human Decision Processes. 1995; 62(2):230–240.10.1006/obhd.1995.1046

Kuhberger A, Gradl P. Choice, rating, and ranking: Framing effects with different response modes. Journal of Behavioral Decision Making. 2013; 26:109–117.10.1002/bdm.764

Kuhberger A, Tanner C. Risky choice framing: Task versions and a comparison of prospect theory and fuzzy-trace theory. Journal of Behavioral Decision Making. 2010; 23(3):314–329.10.1002/bdm.656

Kuhberger A, Wiener C. Explaining risk attitude in framing tasks by regulatory focus: A verbal protocol analysis and a simulation using fuzzy logic. Decision Analysis. 2012; 9(4):359–372.10.1287/deca.1120.0254

Kühberger A. The influence of framing on risky decisions: A meta-analysis. Organizational Behavior and Human Decision Processes. 1998; 75(1):23–55.10.1006/obhd.1998.2781 [PubMed: 9719656]

Levin IP, Hart SS, Weller JA, Harshman LA. Stability of choices in a risky decision-making task: A 3-year longitudinal study with children and adults. Journal of Behavioral Decision Making. 2007; 20:241–252.10.1002/bdm

Lloyd FJ, Reyna VF. Clinical gist and medical education: Connecting the dots. Journal of the American Medical Association. 2009; 302(12):1332–1333.10.1001/jama.2009.1383 [PubMed: 19773570]

Mandel DR. Gain-loss framing and choice: Separating outcome formulations from descriptor formulations. Organizational Behavior and Human Decision Processes. 2001; 85(1):56–76.10.1006/obhd.2000.2932 [PubMed: 11341817]

Mandel DR. Do framing effects reveal irrational choice? Journal of Experimental Psychology: General. 2014; 143(3):1185–1198.10.1037/a0034207 [PubMed: 23978186]

Maule AJ, Hockey GRJ, Bdzola L. Effects of time-pressure on decision-making under uncertainty: changes in affective state and information processing strategy. Acta Psychologica. 2000; 104(3): 283–301.10.1016/S0001-6918(00)00033-0 [PubMed: 10900697]

Okder H. The illusion of the framing effect in risky decision making. Journal of Behavioral Decision Making. 2012; 25(1):63–73.10.1002/bdm.715

Paulsen DJ, Platt ML, Huettel SA, Brannon EM. Decision-making under risk in children, adolescents, and young adults. Frontiers in Psychology. 2011; 2(72):1–6.10.3389/fpsyg.2011.00072 [PubMed: 21713130]

Peterson PA. On the use of college students in social science research: Insights from a second-order meta-analysis. Journal of Consumer Research. 2001; 28(3):450–461.10.1086/323732

Reyna VF. A new intuitionism: Meaning, memory, and development in fuzzy-trace theory. Judgment and Decision Making. 2012; 7(3):332–359. [PubMed: 25530822]

Reyna VF, Brainerd CJ. Fuzzy-trace theory and framing effects in choice: Gist extraction, truncation, and conversion. Journal of Behavioral Decision Making. 1991; 4(4):249–262.10.1002/bdm.3960040403

Reyna VF, Brainerd CJ. Dual processes in decision making and developmental neuroscience: A fuzzy-trace model. Developmental Review. 2011; 31(2-3):180–206.10.1016/j.dr.2011.07.004 [PubMed: 22096268]

Reyna VF, Chick CF, Corbin JC, Hsia AN. Developmental reversals in risky decision making: Intelligence agents show larger decision biases than college students. Psychological Science. 2014; 25(1):76–84.10.1177/0956797613497022 [PubMed: 24171931]

Setton RA, Wilhelms EA, Weldon RB, Chick CF, Reyna VF. An overview of judgment and decision making research through the lens of fuzzy trace theory. Advances in Psychological Science. 2014; 22(12):1837–1854. doi:10.3724.SP.J.1042.2014.01837.

Sher S, McKenzie CRM. Information leakage from logically equivalent frames. Cognition. 2006; 101(3):467–494.10.1016/j.cognition.2005.11.001 [PubMed: 16364278]

Sher, S.; McKenzie, CRM. Framing effects and rationality. In: Chater, N.; Oaksford, M., editors. The probabilistic mind: Prospects for Bayesian cognitive science. New York: Oxford University Press; 2008. p. 79-96.

Simmons, J.; Nelson, L. “Exactly”: The most famous framing effect is robust to precise wording. Data Colada. 2013. Retrieved from http://datacolada.org/2013/12/19/11-exactly-the-most-famous-framing-effect-is-robust-to-precise-wording/

Tversky A, Kahneman D. The framing of decisions and the psychology of choice. Science. 1981; 211(4481):453–458.10.1126/science.7455683 [PubMed: 7455683]

Table 1

Age, Gender, Framing Index, and Signed Confidence Framing Index by Frame of Ambiguity Questionnaire (Experiment 1)

	Min/Max Possible	Gain	Loss	Omnibus
N		39	42	
Age		21.95 (4.99)	29.86 (11.81)	F (1, 79)=14.98**, p<.001, η_p^2=.159
Gender		41% female	43% female	$\chi^2(1)$=0.03, p=.87
Framing Index				
All truncations	-1 to 1	.27 (.034)	.25 (.032)	F (1, 79)=0.28, p=.60, η_p^2=.004
Zero complement presented	-1 to 1	.50 (.30)	.46 (.30)	F(1, 79)=0.41, p=.53, η_p^2=.005
Non-zero complement presented	-1 to 1	.06 (.34)	.06 (.26)	F(1, 79)=0.003, p=.96, η_p^2<.001
Both complements presented	-1 to 1	.25 (.28)	.22 (.25)	F(1, 79)=0.23, p=.63, η_p^2=.003
Signed Confidence Framing Index				
All truncations	-10 to 10	2.11 (1.80)	2.01 (1.51)	F(1, 79)=0.082, p=.78, η_p^2=.001
Zero complement presented	-10 to 10	3.90 (2.23)	3.64 (2.39)	F(1, 79)=0.25, p=.62, η_p^2<.001
Non-zero complement presented	-10 to 10	.42 (2.63)	.45 (1.89)	F(1, 79)=0.004, p=.95, η_p^2=.003
Both complements presented	-10 to 10	2.01 (2.36)	1.92 (1.90)	F(1, 79)=0.04, p=.85, η_p^2<.001

Note. Values are presented as *M (SD)* for each condition (gain or loss frame version of ambiguity questionnaire). Framing index was calculated as mean risky choices in loss frame minus mean risky choices in gain frame. Possible framing index scores range from -1 (reverse framing in all decisions) to +1 (standard framing in all decisions). Framing index of zero corresponds to no framing effect. Signed confidence wass calculated by multiplying confidence rating by +1 for risky decisions and -1 for sure decisions. Large positive values of signed confidence indicate a strong preference for the risky option; large negative values of signed confidence indicate a strong preference for the sure option. *Omnibus* refers to a univariate ANOVA with age or framing index as dependent variable and frame of ambiguity survey as independent variable. For gender, *omnibus* refers to a chi square test with gender as dependent variable and frame of ambiguity survey as independent variable.

* p<.05.

** p<.001 (two-tailed).

Table 2

Mean Correct Responses to Ambiguity Survey (Experiment 1)

			Gain Frame			Loss Frame		
	Response Format	**Possible Scores**	***N***	**Initial *M* (*SD*)**	**Post-framing *M* (*SD*)**	***N***	**Initial *M* (*SD*)**	**Post-framing *M* (*SD*)**
Sure Option								
Did you assume that more than 300 people would be saved in option A?	Yes/**No**	0-1	39	.85 (.37)	.95 (.22)	42	.62 (.49)	.83 (.38)
Which of the following did you assume about option A?	Multiple choice	0-1	39	.79 (.41)	1 (0)	42	.57 (.50)	.90 (.30)
a. **Exactly 300 saved**								
b. At least 300 saved								
c. Some of the other 200 saved								
Risky Option								
Which of the following did you assume about option B?	Multiple Choice	0-1	39	.85 (.37)	1 (0)	42	.60 (.50)	.86 (.35)
a. 2/5 probability some saved								
b. 2/5 probability all saved								
c. **2/5 probability none saved**								
Sure + Risky								
Total correct (initial **or** post-framing)	Sum	0-3	39	2.49 (.82)	2.95 (.22)	42	1.79 (1.14)	2.60 (.80)
Total correct (initial + Post-framing)	Sum	0-6	39	5.44 (.82)		42	4.38 (1.48)	

Note.“Initial” refers to ambiguity surveys completed prior to framing problems; “post-framing” refers to ambiguity surveys completed after the completion of framing problems. Responses were scored as 0=incorrect, 1=correct. Correct responses are bolded.

Table 3

Example of Risky Options for the Asian Disease Problem in Each Truncation

Condition	Sure option	Risky option	Prediction (FTT)
Zero complement presented			
Text	200 people saved for sure	2/3 probability no one saved	Increased framing
Categorical gist	SOME	NONE	
Mixed (Both complements presented)			
Text	200 people saved for sure	1/3 probability 600 saved, or 2/3 probability no one saved	Standard framing
Categorical gist	SOME	SOME or NONE	
Non-zero complement presented			
Text	200 people saved for sure	1/3 probability 600 saved	No framing
Categorical gist	SOME	SOME	

Note. The sure option was held constant. The traditional version presents both risky complements. For each problem, only one sure and one risky option were presented (i.e., only one truncation condition per problem). The options in this example are framed as gains; analogous manipulations were created for the loss frame.

Table 4

Age, Gender, Framing Index, and Signed Confidence Framing Index by Frame of Ambiguity Questionnaire (Experiment 2)

	Min/Max Possible	Gain Frame Ambiguity Questionnaire	Loss Frame Ambiguity Questionnaire	Omnibus
N		148	143	
Age		29.68 (12.92)	27.92 (12.89)	$F(1, 267)=0.88$, $p=.27$, $\eta_p^2=.005$
Gender		68% female	64% female	$\chi^2(1)=0.32$, $p=.57$
Ambiguity Questionnaire Pre	0 to 3	2.28 (.89)	2.41 (.82)	$F(1, 289)=1.62$, $p=.20$, $\eta_p^2=.006$
Ambiguity Questionnaire Post	0 to 3	2.61 (.79)	2.73 (.59)	$F(1, 278)=2.05$, $p=.15$, $\eta_p^2=.007$
Transfer problem	0 to 1	.77 (.42)	.82 (.38)	$\chi^2(1)=1.40$, $p=.24$
Framing Index				
All truncations	0 to 1	.28 (.45)	.56 (.50)	$\chi^2(1)=22.70^*$, $p<.001$
Non-zero complement presented	0 to 1	.34 (.48)	.38 (.49)	$\chi^2(1)=.18$, $p=.67$
Both complements presented	0 to 1	.27 (.45)	.71 (.46)	$\chi^2(1)=19.76^*$, $p=.001$
Zero complement presented	0 to 1	.25 (.44)	.57 (.50)	$\chi^2(1)=10.79^*$, $p=.001$
Signed Confidence Framing Index				
All truncations	-5 to 5	-1.70 (.29)	.35 (.30)	$F(1, 289)=24.15^*$, $p<.001$, $\eta_p^2=.077$
Non-zero complement presented	-5 to 5	-1.19 (3.46)	-.98 (3.71)	$F(1, 92)=0.08$, $p=.77$, $\eta_p^2=.001$
Both complements presented	-5 to 5	-1.94 (3.33)	1.51 (3.39)	$F(1, 96)=25.79^*$, $p<.001$, $\eta_p^2=.212$
Zero complement presented	-5 to 5	-1.92 (3.47)	.47 (3.59)	$F(1, 97)=11.36^*$, $p=.001$, $\eta_p^2=.105$

Note. Values are presented as *M (SD)* for each condition (gain or loss frame version of ambiguity questionnaire). Decision refers to sure (0) or risky (1). Framing index was calculated as mean risky choices in loss frame minus mean risky choices in gain frame. Possible framing index scores range from -1 (reverse framing in all decisions) to +1 (standard framing in all decisions). Framing index of zero corresponds to no framing effect. Signed confidence was calculated by multiplying confidence rating by +1 for risky decisions and -1 for sure decisions. Large positive values of signed confidence indicate a strong preference for the risky option; large negative values of signed confidence indicate a strong preference for the sure option. For age and signed confidence, *omnibus* refers to a general linear model with age or signed confidence as dependent variable and frame of ambiguity questionnaire as independent variable. For gender and decision, *omnibus* refers to a chi square test with gender or decision as dependent variable and frame of ambiguity questionnaire as independent variable.

* $p<.05$ (two-tailed).

Table 5

Mean Correct Responses to Ambiguity Survey (Experiment 2)

			Gain Frame			Loss Frame		
	Response Format	**Possible Scores**	***N***	**Initial *M* (*SD*)**	**Post-framing *M* (*SD*)**	***N***	**Initial *M* (*SD*)**	**Post-framing *M* (*SD*)**
Sure Option								
Did you assume that more than 300 people would be saved in option A?	Yes/**No**	0-1	148	.83 (.38)	.87 (.34)	143	.82 (.39)	.89 (.31)
Which of the following did you assume about option A?	Multiple choice	0-1	148	.75 (.43)	.86 (.35)	143	.78 (.42)	.94 (.23)
(d) Exactly 300 saved								
(e) At least 300 saved								
(f) Some of the other 200 saved								
Risky Option								
Which of the following did you assume about option B?	Multiple Choice	0-1	148	.70 (.46)	.89 (.32)	143	.81 (.39)	.90 (.30)
(d) 2/5 probability some saved								
(e) 2/5 probability all saved								
(f) 2/5 probability none saved								
Sure + Risky								
Total correct (initial **or** post-framing)	Sum	0-3	148	2.28 (.89)	2.61 (.79)	143	2.41 (.82)	2.73 (.59)
Total correct (initial + Post-framing)	Sum	0-6	148	4.89 (1.33)		143	5.16 (1.19)	

Note.“Initial” refers to ambiguity surveys completed prior to framing problems; “post-framing” refers to ambiguity surveys completed after framing problems. Responses were scored as 0=incorrect (indicating ambiguity), 1=correct (indicating complementarity between stated and unstated information). Correct responses are bolded.