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Thinking Fast Increases Framing Effects in Risky Decision Making

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Abstract
Every day, people face snap decisions when time is a limiting factor. In addition, the way a problem is presented can influence people's choices, which creates what are known as framing effects. In this research, we explored how time pressure interacts with framing effects in risky decision making. Specifically, does time pressure strengthen or weaken framing effects? On one hand, research has suggested that framing effects evolve through the deliberation process, growing larger with time. On the other hand, dual-process theory attributes framing effects to an intuitive, emotional system that responds automatically to stimuli. In our experiments, participants made decisions about gambles framed in terms of either gains or losses, and time pressure was manipulated across blocks. Results showed increased framing effects under time pressure in both hypothetical and incentivized choices, which supports the dual-process hypothesis that these effects arise from a fast, intuitive system.

Keywords
risky decision making, time pressure, framing effects, dual-process theory, open data

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Every day, people find themselves in situations in which speeded, or "snap," decisions need to be made. The stakes vary: For example, one person might encounter a yellow light while driving and have to decide whether to risk getting caught running a red light or safely slowing down, whereas another person might work at a fast-paced Wall Street brokerage, where high-velocity strategic decisions separate the bankrupt from the successful. Regardless of the situation, time constraints often place a premium on rapid decision making.

Researchers have also been intrigued by the finding that decision makers respond in different ways to objectively equivalent variations of the same problem. For example, imagine you win $300, and you have a choice between receiving an additional $100 for sure and taking a gamble offering a 50% chance to gain $200 and a 50% chance to gain nothing. Suppose you prefer the sure option of receiving the additional $100. Now, consider a different situation in which you win $500 and have a choice between losing $100 from your winnings for sure and taking a gamble offering a 50% chance to lose nothing and a 50% chance to lose $200. In this situation, you find yourself selecting the gamble. This pattern of choices demonstrates a *framing effect* because your preferences between the sure option and the gamble change depending on the description of the problem, even though the expected value of the outcomes is the same.

According to theories of rational decision making (including expected-utility theory), people's decisions should be *description invariant*. That is, the manner in which the options are presented should not influence choices. A classic finding in risky decision making is that people tend to be risk averse when a problem is presented as a gain and risk seeking when the same problem is presented as a loss (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981). These types of framing effects have been documented in a variety of situations, including medical and clinical decisions (O'Connor, Boyd, Warde, Stolbach, & Till, 1987; O'Connor, Pennie, &

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Dales, 1996), consumer choices (Levin & Gaeth, 1988; Loke & Lau, 1992), and social dilemmas (Brewer & Kramer, 1986; Fleishman, 1988). The goal of the present research was to explore how time pressure interacts with framing effects in risky decision making. In particular, does time pressure exacerbate or mitigate framing effects? Previous research provides support for both of these possibilities.

Svenson and Benson (1993) examined the influence of time pressure in choices among lotteries as well as the famous Asian disease problem (Kahneman & Tversky, 1979). Their results showed that time pressure (a 40-s response deadline) reduced framing effects, which suggests that the effects evolve over time. These results are consistent with findings in multialternative, multiattribute choice situations that have shown context effects, such as the attraction (Huber, Payne, & Puto, 1982), compromise (Simonson, 1989), and similarity (Tversky, 1972) increase with longer deliberation time. These effects illustrate how choices between a fixed set of options can be altered by the inclusion of other options. Recent work by Pettibone (2012) and Trueblood, Brown, and Heathcote (2014) has shown that context effects emerge with increased deliberation, in line with predictions from sequential-sampling models of decision making (Roe, Busemeyer, & Townsend, 2001; Trueblood et al., 2014).

Some researchers have suggested that framing effects may be the result of two different systems of reasoning—the intuitive and deliberative systems. The intuitive system is responsible for fast processes that are affective, emotional, and automatic, while the deliberative system is responsible for slower processes that are more analytical, rational, and calculating in nature (Chaiken & Trope, 1999; Kahneman & Frederick, 2002; Mukherjee, 2010; Sloman, 1996; Stanovich & West, 2000). In a recent neuroimaging study, De Martino, Kumaran, Seymour, and Dolan (2006) found that in risky decision making, framing effects were associated with increased activation in the amygdala, whereas activity in the orbital and medial prefrontal cortex was related to a reduction of these effects. In particular, increased activation in the amygdala was associated with participants' tendency to choose sure options when the problem was framed as a gain and risky options when the problem was framed as a loss. Participants who behaved more rationally showed greater activation in the orbital and medial prefrontal cortex. These results support dual-process theory, which proposes that there is conflict between deliberative processes and an intuitive, "emotional" amygdala-based system. If framing effects are mainly driven by the fast, intuitive system, then they should increase under time pressure. With restricted deliberation time, the deliberative system is less likely to be engaged.

Our aim was to distinguish between these two competing hypotheses related to the origin of framing effects. On one hand, framing effects could evolve through the deliberation process as described by Svenson and Benson (1993) and in a similar manner as context effects in preferential choice (Pettibone, 2012; Trueblood et al., 2014). On the other hand, framing effects could result from an intuitive system that produces quick automatic responses to stimuli. We tested these hypotheses in three experiments.

Experiment 1

The stimuli were adapted from those used by De Martino et al. (2006). At the start of each trial, participants were given an initial amount of money. They then chose between a sure option to keep a portion of the initial amount and a gamble to possibly keep the entire initial amount, with the sure option presented in either a gain or loss frame. In both frames, the gamble was identical and presented in a pie chart color-coded to represent the probability of winning and losing. Participants completed two blocks of trials, one of which they performed under time pressure. Four variations of this task were run, manipulating several "tuning variables" (e.g., color of the pie chart) that were expected to have no influence on the results. These variations were included to make sure that our findings were attributable to the actual framing effect rather than to some arbitrary experimental variables. This procedure would provide evidence of the robustness of the phenomenon and its replicability.

Method

Participants. A total of 195 individuals (159 female, 36 male; mean age = 20.24 years) from the University of California, Irvine, received course credit for participating in the experiment (regardless of performance). All participants were undergraduate students and English speakers. We set a target sample size of about 50 participants for each of the four experimental variants. This sample size was selected on the basis of previous experiments using a within-subjects time-pressure manipulation in decision making (Trueblood et al., 2014). The lab could accommodate up to 6 participants during a single session. We stopped data collection with the session that would meet (and potentially exceed) the target sample size. For this final session, we allowed up to 6 participants to sign up in anticipation of no-shows. Thus, some experimental variants had slightly fewer than 50 participants, and others had slightly more than 50 participants.

Stimuli and design. The experiment was run in two blocks, each block consisting of 144 test trials: 72 with gain frames and 72 with loss frames. We also included 16 catch trials in each block to assess accuracy and engagement in the task, for a total of 160 trials per block (320 trials total). The catch trials had nonequivalent "sure" and "gamble" options, one of which had a significantly larger expected value.

For the test trials, 72 dollar amounts were selected randomly from a uniform distribution ranging from \$20 to \$90 to serve as the initial starting values. In addition, 72 probabilities were drawn randomly from a pool of three normal distributions (*M*s = .28, .42, and .56; *SD*s = .20) to serve as the probability of winning the gamble. The initial amounts and probabilities of winning the gamble were randomly paired to form 72 unique test trials. From these pairs, we created the sure option for each trial to match the expected value of the gamble, depending on whether the gamble was framed in terms of a gain or a loss. For instance, for an initial amount of \$78 and a winning-gamble probability of .26, the sure option would either be "keep \$20" (gain frame) or "lose \$58" (loss frame). There were also 32 total catch trials, 16 with a gain frame and 16 with a loss frame. The initial starting values for these trials ranged from \$20 to \$90, as in the test trials. In half of the catch trials, the sure option had a higher expected value than the gamble option. In the other half, the gamble option had a higher expected value than the sure option. Note that all gambles were hypothetical because there were no real consequences for participants' decisions. Previous research has shown that there are no differences in the framing effect in hypothetical and real choices (Kühberger, Schulte-Mecklenbeck, & Perner, 2002).[1]

We were interested in the framing effect that occurs with risky decision making between sure and gamble options. For this experiment, a framing effect would occur when (a) in the gain frame, the decision maker chose the sure option and (b) in the loss frame for the same problem, the decision maker chose the gamble option. Thus, we categorized risk-averse behavior in gain trials and risk-seeking behavior in equivalent loss trials as a framing effect.

The two blocks were differentiated by the presence or absence of time pressure. In the time-pressure (TP) block, participants were told that their goal was to respond quickly, and in each trial, they were given 1,000 ms to make a choice. A latent but unstated goal of the TP block was to earn money. To ensure that participants felt time pressure, we gave them only one direction: to respond quickly. If they failed to make a choice within 1,000 ms, they received a feedback message stating that they did not earn any money on that particular trial because they did not respond in time. If the participant made a choice within the allotted time frame, they did not receive any feedback.

In the no-time-pressure (NTP) block, participants were told that they should "maximize [their] money" (in all but the losses variation; see Variations in Design) and were not penalized for the amount of time they took to respond. In this block, we reinforced the goal of maximizing earnings by providing feedback after every trial explaining the amount of money earned on that trial.

Our experimental design was based on ones used in perceptual decision making to study the speed/accuracy trade-off (Wickelgren, 1977). In accuracy conditions, participants are typically instructed to maximize accuracy and often receive feedback related only to accuracy. In speed conditions, participants are typically told to maximize speed and often receive feedback related only to speed.

Procedure. During the main task, the order of the two blocks and the 160 trials in each block was randomized. At the start of each trial (in both the gain and loss frame, shown in Figs. 1c and 1d, respectively), participants were given an initial starting amount (e.g., "You are given \$78") and the goal for that block (e.g., "Respond Quickly"). Participants were told that they would not be able to retain the entirety of the initial amount but would have to choose between a sure option and a gamble option. Two seconds after the initial amount was displayed, the screen automatically progressed to this choice screen. The choice screen contained two pie charts, one of which presented the sure option and one of which presented the gamble. In the gain frame, participants selected between keeping a portion of the initial amount for sure and taking a gamble that could result either in their keeping or losing all of the initial starting amount (equivalent to getting \$0 for the trial). The probability of winning the gamble varied on each trial. For example, in Figure 1c, the sure amount was \$20, whereas the gamble involved a .26 probability of keeping the starting amount (\$78) and a .74 probability of losing it. Note that the expected value of the gamble was .26 × \$78 = \$20, which was the same outcome as the sure option. In the loss frame, the procedure was identical to that in the gain frame. For example, in Figure 1d, the gamble outcomes involved either a .26 probability of keeping the initial starting amount of \$78 and a probability of .74 of losing the entire amount.

The only difference between the gain and loss frames was the framing of the sure option. In the loss frame, the sure option was framed in terms of losing a portion of the initial amount. For example, a sure loss of \$58 was equivalent to a sure gain of \$20. Thus, the payoffs in the gain and loss frames were identical. In the gain frame, the sure option was presented in a fully light-gray pie chart (e.g., \$20). In the loss frame, the sure option was presented as an amount lost in a fully dark-gray pie chart (e.g., –\$58). For both the gain and loss frames, the gamble option was presented in a pie chart representing the probability of keeping the entirety of the initial amount or losing the initial amount (e.g., .74 dark gray: –\$78 and .26 light gray: \$78).

Before starting the experiment, participants completed three guided practice trials in which they were told to select specific options (i.e., the gamble or sure thing). After the guided practice, participants completed an additional 10 practice trials in which they could respond freely. Practice trials were the same as test trials, except

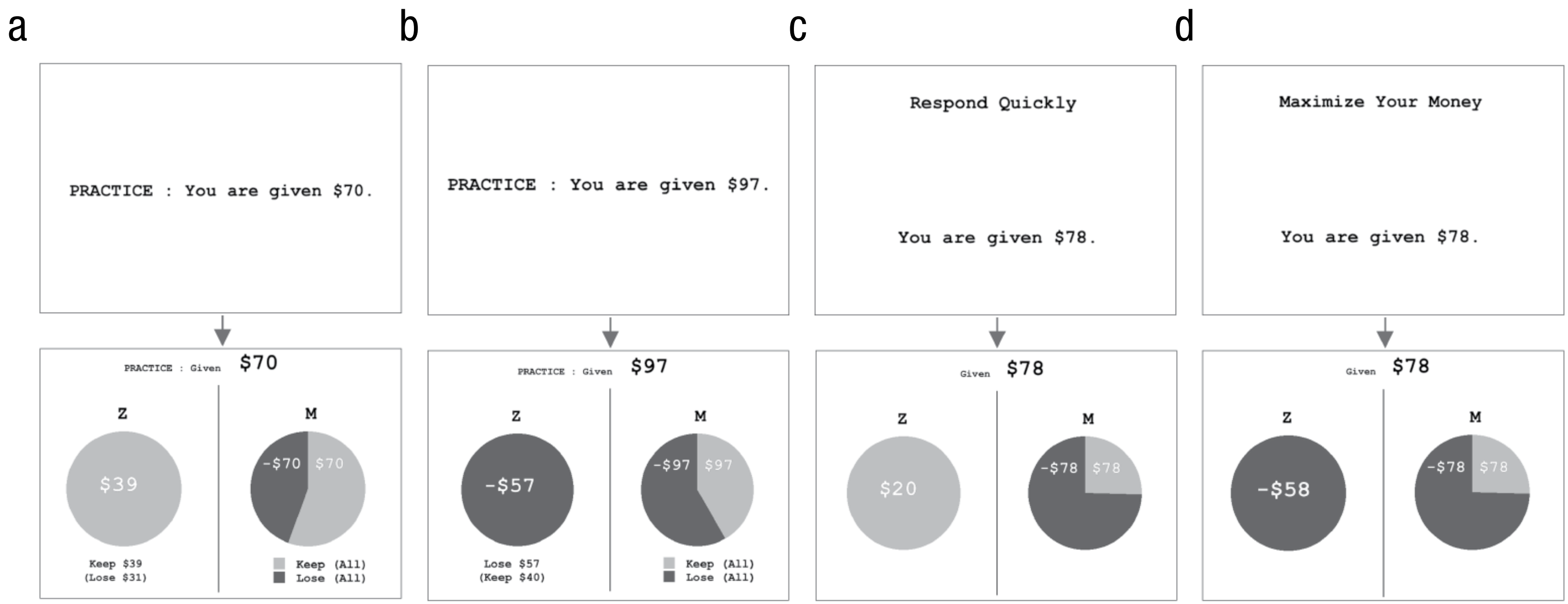

Fig. 1. Screenshots from example practice trials (a, b) and test trials (c, d) in Experiment 1. On each trial, participants were first told how much money they would start with (top row); participants were also given an instruction on test trials. After 2 s, the initial screen was replaced with a decision screen (bottom row). On trials with a gain frame (a, c), participants were given two choices: a sure option (left pie chart), in which there was a 100% chance that they would gain the money indicated, and a gamble (right pie chart), in which there was a probability (which varied from trial to trial and which was indicated by the size of the wedges in the pie chart) of keeping the full starting amount or losing all of it. Trials with a loss frame (b, d) worked the same way, except that the sure option was framed in terms of how much money would be lost rather than gained. Decision screens in practice and test trials differed primarily in that on practice trials, on-screen text reminded participants of the values of each option. There were four variations of the experiment. In Variations 1, 3, and 4, potential gains were presented in green, and potential losses were presented in red; in Variation 2 (shown here), potential gains were presented in light gray, and potential losses were presented in dark gray. The locations of the pie charts showing the sure and gamble options (left vs. right) were always the same in Variations 1, 2, and 4, but they changed randomly from trial to trial in Variation 3. Finally, the framing of the on-screen instructions differed: In Variations 1 through 3, participants were told to “Maximize Your Money,” a more positive goal, whereas in Variation 4, they were told to “Minimize Your Losses,” a more negative goal.

that (a) no instruction was given before the task appeared and (b) a legend appeared below the pie charts for each option explaining the amounts that could be won or lost (see Figs. 1a and 1b).

Variations in design. In this experiment, we aimed to test participants across a range of different tuning variables, and thus ran four variations of the experiment. In Variation 1 (49 participants), the wedges of the pie chart were color-coded to indicate keeping an amount (represented by green) and losing an amount (represented by red). Additionally, the sure option was always placed on the left-hand side of the screen, while the gamble option was always placed on the right-hand side of the screen. Variation 2 (49 participants) was identical to Variation 1 except that the wedges of the pie chart were rendered in gray-scale to indicate keeping an amount (represented by light gray) and losing an amount (represented by dark gray), as shown in Figure 1. Variation 3 (53 participants) was identical to Variation 1 except for the placement of the sure and gamble options. In this variation, the sure option was randomly placed on either the left-hand or right-hand side of the screen. Finally, Variation 4 (44 participants) involved changing the framing of the instructions from "maximize your money," a more positive goal, to "minimize your losses," a more negative goal. This variation was otherwise identical to Variation 1.

Results

We analyzed the data from all 195 participants, removing the catch trials. The average proportion of catch trials answered correctly was .85. We found that there was no significant difference in the between-subjects variations, $F(3, 191) = 0.24$, $p > .250$, $\eta^2 < .01$, and therefore collapsed the results for the remaining analyses. Next, we ran a 2 (block: TP, NTP) × 2 (frame: gain, loss) analysis of variance on the probability of selecting the gamble. As Table 1 shows, there was a significant effect of frame, $F(1, 194) = 339.394$, $p < .001$, $\eta^2 = .635$. This suggests that behavior was consistent with the framing effect (i.e., the tendency to be risk seeking when presented with a loss frame and risk averse when presented with a gain frame). There was also an interaction between block and frame, $F(1, 194) = 76.175$, $p < .001$, $\eta^2 = .285$, which showed that there was an increase in the framing effect for the TP block compared with the NTP block. The mean response time for the NTP block was 2,096 ms (SD = 3,010 ms), while the mean response time for the TP block was 558 ms (SD = 408 ms). The data used in this analysis are available on the Open Science Framework at https://osf.io/9gyvd/.

Figure 2 shows the proportion of individual choices for the gamble in the TP and NTP blocks for the gain frame and loss frame. In the gain frame, the majority of participants (138 out of 195, or .71) selected the gamble more often in the NTP block than in the TP block, showing increased risk aversion under time pressure. In the loss frame, the majority of participants (113 out of 195, or .58) selected the gamble more often in the TP block than in the NTP block, showing increased risk seeking under time pressure. In the gain frame, the mean proportion of gambles selected in the NTP block was .40, compared with .31 in the TP block. In the loss frame, the mean proportion of gambles selected in the NTP block was .59, compared with .65 in the TP block. Table 2 shows the proportions of participants who selected the gamble in each of the variations. As mentioned earlier, these variations manipulate tuning variables that should have been irrelevant to the task. Our results confirmed this prediction. Frame and time pressure had similar influences on behavior in all four between-subjects variations.

We also analyzed the framing effect on the problem level. For each participant and each pair of corresponding gain-loss choice problems, we calculated a *framing-effect score* for the TP and NTP conditions. This score was calculated by subtracting the proportion of times the gamble was chosen in the gain frame from the proportion of times the gamble was chosen in the loss frame. A positive score indicates evidence for the standard framing effect,

Table 1. Results From Experiment 1: Repeated Measures Analysis of Variance on the Probability of Selecting the Gamble

Effect	Sum of squares	Mean square	F	p	η^2
Block	0.067	0.067	$F(1, 194) = 2.317$	.130	.012
Block × Variation	0.020	0.007	$F(3, 191) = 0.234$	.872	.004
Residual	5.496	0.029	—	—	—
Frame	13.298	13.298	$F(1, 194) = 339.394$	< .001	.635
Frame × Variation	0.147	0.049	$F(3, 191) = 1.250$	.293	.007
Residual	7.484	0.039	—	—	—
Block × Frame	1.186	1.186	$F(1, 194) = 76.175$	< .001	.285
Block × Frame × Variation	0.008	0.003	$F(3, 191) = 0.168$	.918	.002

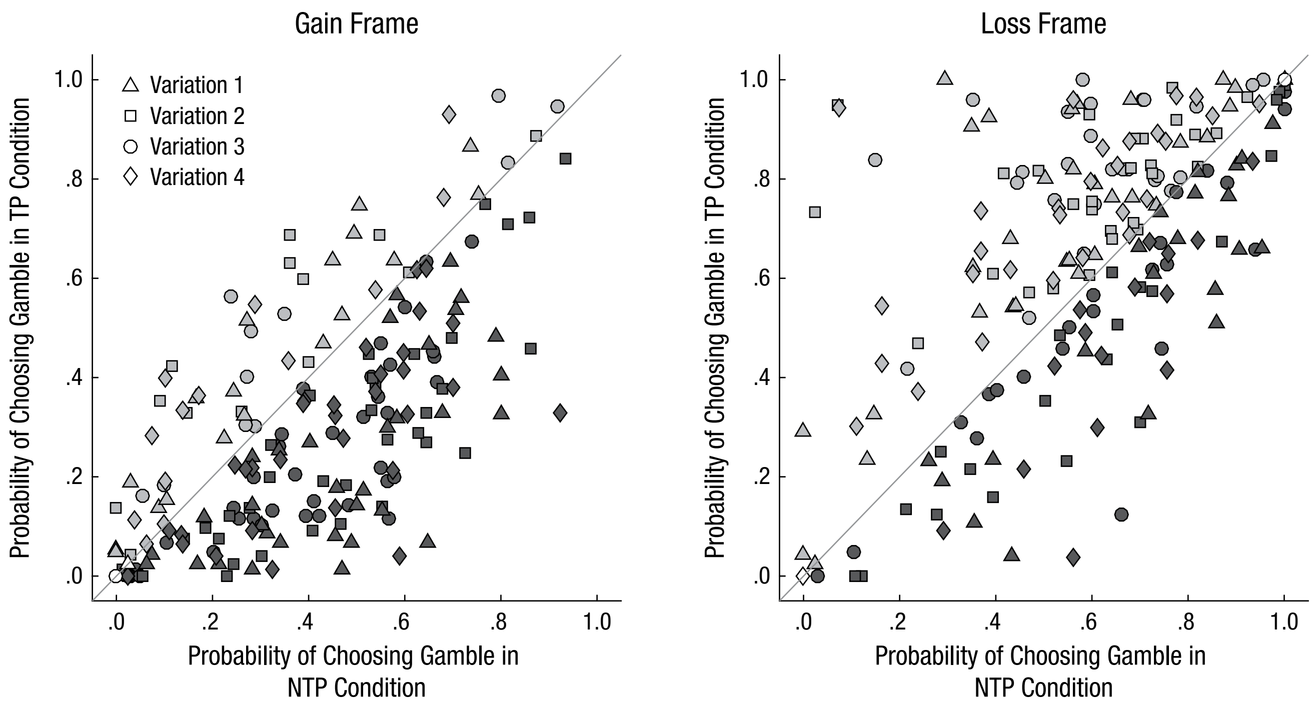

Fig. 2. Scatterplots showing the probability of choosing the gamble in the time-pressure (TP) block as a function of the probability of choosing the gamble in the no-time-pressure (NTP) block in Experiment 1. Results are shown for each of the four experimental variations, separately for trials with a gain frame and a loss frame. Light-gray shading (on data points above the diagonal line) indicates that the probability of choosing the gamble was greater in the TP than in the NTP block, dark-gray shading (on data points below the diagonal line) indicates that the probability of choosing the gamble was greater in the NTP than in the TP block, and no shading indicates that the probability was equal.

in which gambles are preferred more in a loss frame than in a gain frame. A higher score in the TP condition than in the NTP condition shows evidence for an increased framing effect under time pressure.

Figure 3 shows the framing-effect scores for the TP and NTP conditions for each problem, averaged across participants for the four experimental variations. All of the problems in each variation had a positive framing-effect score in the TP condition, and the large majority had a positive framing-effect score in the NTP condition as well (72 out of 72 in Variation 1, 68 out of 72 in the Variation 2, 71 out of 72 in Variation 3, and 70 out of 72 in Variation 4). This shows evidence for the standard framing effect, in which gambles are preferred more often in the loss frame than in the equivalent gain frame. Further, more problems had a larger framing-effect score in the TP condition than in the NTP condition (68 out 72 in the Variation 1, 64 out of 72 in the Variation 2, 71 out of 72 in Variation 3, and 68 out of 72 in Variation 4), which shows an increase in the framing effect under time pressure.

Our main finding that framing effects increase with time pressure was further corroborated by a Bayesian repeated measures analysis of variance performed using the open-source software package JASP (JASP Team, 2016). In Tables 3 and 4, we report Bayes factors (BFs) comparing each model with all other possible models (BF_{model}) as well as with the null model (BF_{10}) along with the BFs for the inclusion of specific variables ($BF_{inclusion}$). A BF greater than 10 is typically considered strong support for the model or variable in question (Kass & Raftery, 1995). The Bayesian analysis supported our earlier claim that the tuning variations had no influence on the experimental results, that is, our results were attributable to the actual framing effect rather than to some arbitrary experimental manipulations ($BF_{inclusion}$ = 0.02). A model that included block, frame, and the interaction of block and frame was preferred to all other models (BF_{model} = 304.86) as well as to the null model (BF_{10} > 1,000). Also, the BF for inclusion of both variables was large, $BF_{inclusion} \approx \infty$ for the inclusion of frame and $BF_{inclusion}$ > 1,000 for the inclusion of block. Thus, the data support the conclusion that a model with both frame (gain vs. loss) and time pressure (present vs. absent) gives the best account for the probability of choosing the gamble in the task.

Conclusions

Participants in Experiment 1 showed risk-averse behavior when presented with a gain frame and risk-seeking behavior when presented with a loss frame, in accordance with the standard framing effect. Further, our results showed an increase in the framing effect under time pressure. These results were supported by both traditional and Bayesian statistical tests. The results held

Table 2. Proportion of Participants Who Selected the Gamble in Each of the Four Variations in Experiment 1

	Gain frame		Loss frame	
Variation and block	*M*	*SD*	*M*	*SD*
Variation 1 (*n* = 49)				
No time pressure	.401	.227	.617	.231
Time pressure	.301	.237	.692	.262
Variation 2 (*n* = 49)				
No time pressure	.430	.255	.590	.246
Time pressure	.327	.244	.637	.280
Variation 3 (*n* = 53)				
No time pressure	.402	.238	.591	.267
Time pressure	.292	.237	.642	.277
Variation 4 (*n* = 44)				
No time pressure	.389	.231	.558	.231
Time pressure	.314	.208	.623	.254

Note: In Variation 1, the wedges of the pie chart were colored green and red to indicate that the amounts shown would be kept or lost, respectively, and the gamble option was always on the right-hand side of the screen. Variation 2 was the same as Variation 1 except that the wedges of the pie chart were rendered in light and dark gray instead of green and red. In Variation 3, the color scheme was the same as in Variation 1, but the placement of the gamble option on the left- and right-hand side of the screen varied across trials. Variation 4 was identical to Variation 1, but the on-screen instructions were framed in a more negative way.

when we accounted for several experimental variations. These results diverge from those of Svenson and Benson (1993). Their time-pressure condition was quite long (40 s) compared with ours (1 s). Thus, participants in the Svenson and Benson (1993) study might have employed different decision strategies than our participants.

Experiment 2

In Experiment 1, participants made hypothetical choices among the options. While there is evidence suggesting that hypothetical and incentivized choices are often the same (Kühberger et al., 2002), it is possible that there is an interaction between incentives and time pressure. Thus, we conducted a new experiment to examine the influence of time pressure in incentivized choices. Further, whereas in Experiment 1, participants received different instructions and feedback in the TP and NTP conditions, in Experiment 2, we controlled for possible confounds by providing feedback on all trials (both TP and NTP) and by using similar instructions in both conditions.

Method

Participants. Thirteen individuals (8 female, 5 male; mean age = 20.57 years) from Jacobs University Bremen participated in the experiment; each received €6 per hour for participation plus 0.1¢ for every point she or he won. The experiment was in English, and all participants were undergraduate students and English speakers. The sample size was set to 13 so we could match the number of trials run in the previous experiment (see the next section).

Stimuli and design. We chose a multisession experimental design with fewer participants for modeling purposes (the modeling results will be reported in another article). In this design, each participant completed four experimental sessions on different days. Each session contained four blocks, each block consisting of 80 trials: 36 with gain frames, 36 with loss frames, and 8 catch trials. As before, the catch trials had nonequivalent sure and gamble options in which one option had a significantly larger expected value. The first two blocks were differentiated only by the presence or absence of time pressure. Blocks 3 and 4 were replications of Blocks 1 and 2. This produced a total of 144 gain-frame trials, 144 loss-frame trials, and 32 catch trials, for a grand total of 320 trials per session. Because each trial was repeated four times (during the four different sessions), there were 52 responses per trial (similar to the number of responses per trial in each variation of Experiment 1).

For the test trials, 36 values were drawn randomly from a pool of three normal distributions (*M*s = 30, 60, and 90 points; *SD*s = 2) to serve as the initial starting amounts. In addition, 36 probabilities of winning the gamble were drawn randomly from a pool of three normal distributions (*M*s = .28, .42, and .56; *SD*s = .03). The initial amounts and probabilities of winning the gamble were randomly paired to form 36 unique test trials. From these pairs, we created the sure option for each trial to match the expected value of the gamble, depending on whether the gamble was framed in terms of a gain or a loss.

Participants received feedback about the amount received after each trial (in both the TP and NTP blocks). In the TP block, participants were given 1,250 ms to make a choice. If they did not respond within this time limit, they received zero points on the trial. In the NTP block, participants were not penalized for the amount of time taken to respond. At the beginning of the task, participants were told, "your goal is to maximize the amount of points that you win." At the start of the TP blocks, participants were instructed "to make a decision quickly." At the start of the NTP blocks, participants were instructed to "spend as much time as you need on each trial." Thus, the overall goal of the experiment was to maximize winnings, and the only difference in instructions between the TP and NTP blocks was the amount of time allowed for decisions.

Procedure. Participants first read instructions describing the task and the gamble display. These instructions were administered not only on the computer screen (as in Experiment 1) but also on paper (the paper instruction

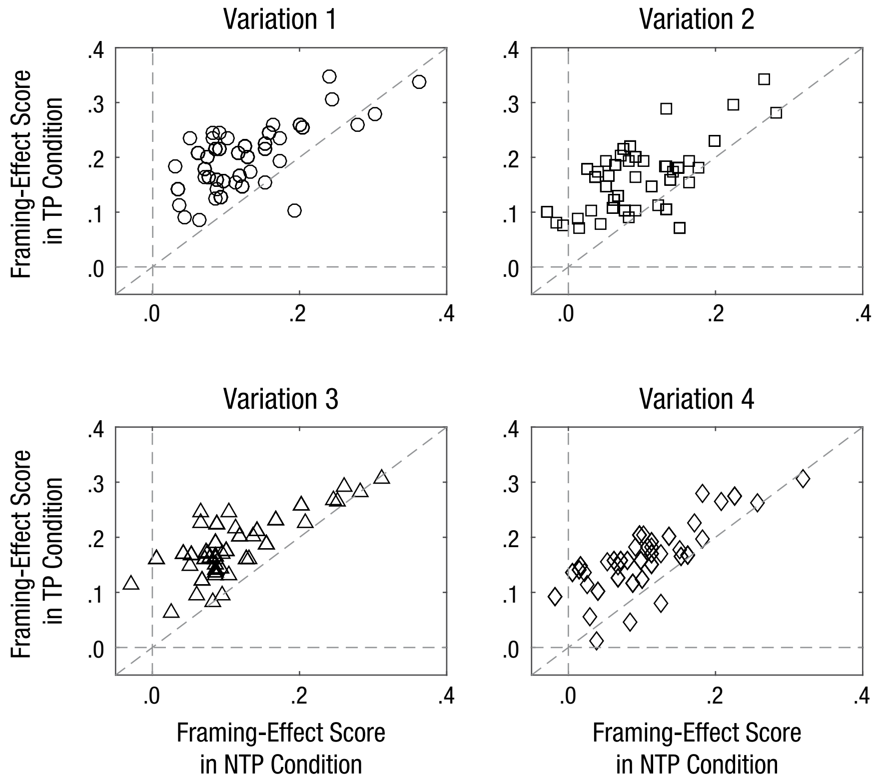

Fig. 3. Scatterplots showing the relationship between mean framing-effect scores in the time-pressure (TP) and no-time-pressure (NTP) conditions at the problem level, separately for each of the four variations in Experiment 1. Framing-effect scores were calculated by subtracting the proportion of times the gamble was chosen in the gain frame from the proportion of times the gamble was chosen in the loss frame. Points above the horizontal dashed line indicate that there was a framing effect in the TP condition, points to the right of the vertical dashed line indicate that there was a framing effect in the NTP condition, and points above the dashed diagonal line indicate that the framing effect was larger in the TP than in the NTP condition.

document is available on the Open Science Framework at https://osf.io/9gyvd/). After reading the instructions, participants first completed six practice trials (an example practice trial is shown in Fig. 4) and then started the main task. The procedure for the main task was similar to the procedure in Variation 2 of Experiment 1, except that the sure option was randomly placed on either the left-hand or right-hand side of the screen on each trial. In addition, the gambles were presented in a nonnegative format in both gain- and loss-frame trials. For example, in the gain-frame trial shown in Figure 4, participants selected between keeping a portion of the initial amount for sure (24 points) and playing a gamble in which there was a .42 probability of keeping all of the initial starting amount (57 points) and a .58 probability of losing all of it. Loss-frame gambles had the same format.

Results

We analyzed the data from all 13 participants, removing the catch trials. Because of a computer error, 5 participants' data from the first session were not recorded correctly and were therefore not included in the analysis. Across all sessions, the average proportion of catch trials answered correctly was .94. The mean response time in the NTP condition was 1,573 ms (*SD* = 649 ms), and the mean response time in the TP condition was 668 ms (*SD* = 61 ms). There was a significant effect of frame, $F(1, 12) = 29.51$, $p < .001$, $\eta^2 = .71$, which indicates that participants preferred the gamble more often in the loss frame than in the gain frame. There was also a significant interaction between block and frame, $F(1, 12) = 5.47$, $p = .038$, $\eta^2 = .31$, which shows that the framing effect was greater in the TP condition than in the NTP condition. Bayesian analyses also confirmed these results, showing that a model including block, frame, and the interaction of block and frame was preferred to the null model ($BF_{10} > 1{,}000$). The proportion of participants who selected the gamble in the TP and NTP conditions, separately for gain-frame and loss-frame blocks, is shown in Table 5. The data used in this analysis are available on the Open Science Framework at https://osf.io/9gyvd/.

Table 3. Results of Bayesian Repeated Measures Analysis of Variance on the Probability of Selecting the Gamble in Experiment 1

Model	Prior probability of the model	Posterior probability of the model given the data	Bayes factor for support of the model compared with all other models	Bayes factor for support of the model compared with the null model
Null model (including participant)	.053	7.897E–79	1.421E–77	1.000
Block	.053	1.221E–79	2.197E–78	0.155
Frame	.053	5.286E–8	9.515E–7	6.694E+70
Block + Frame	.053	1.303E–8	2.345E–7	1.650E+70
Block + Frame + Block × Frame	.053	.944	304.861	1.196E+78
Variation	.053	1.947E–80	3.505E–79	0.025
Block + Variation	.053	2.975E–81	5.356E–80	0.004
Frame + Variation	.053	2.477E–9	4.458E–8	3.136E+69
Block + Frame + Variation	.053	6.302E–10	1.134E–8	7.980E+68
Block + Frame + Block × Frame + Variation	.053	.051	0.959	6.406E+76

As in Experiment 1, we also analyzed the framing effect on the problem level by calculating a framing-effect score for the TP and NTP conditions. Figure 5 shows the relationship between the framing-effect scores for the TP and NTP conditions for each problem, averaged over participants. All of the problems had a positive framing-effect score in the TP condition, and the majority (32 out of 36) had a positive framing-effect score in the NTP condition as well, which shows the standard framing effect, in which gambles are preferred more in the loss frame than in the equivalent gain frame. Further, most problems (27 out of 36) had a larger framing-effect score in the TP condition than in the NTP condition, which shows that the framing effect increased under time pressure.

Conclusions

Experiment 2 showed that time pressure increases the framing effect in incentivized choices. One important difference between the findings of Experiments 1 and 2 was the increased level of risk-seeking behavior in Experiment 2. In the gain frame, participants in Experiment 2 tended to select the gamble about 50% of the time, compared with about 30 to 40% of the time in Experiment 1. Thus, the framing effect in Experiment 2 is best described as a preference shift rather than a preference reversal. The difference in risk-seeking behavior between the two experiments could be the result of incentivized choices in Experiment 2.

Experiment 3

In Kahneman and Tversky's (1979) demonstration of the framing effect, they compared sure gains with gambles with nonnegative outcomes (and sure losses with gambles with nonpositive outcomes). In the present Experiments 1 and 2, we used slightly different formulations of the problem. To illustrate, let *X* be the initial amount, *Y*

Table 4. Effects From the Bayesian Repeated Measures Analysis of Variance on the Probability of Selecting the Gamble in Experiment 1

Effect	Prior probability of inclusion	Posterior probability of inclusion given the data	Bayes factor for inclusion
Block	.737	1.000	6.423E+6
Frame	.737	1.000	∞
Variation	.737	.056	0.021
Block × Frame	.316	1.000	3.126E+7
Block × Variation	.316	7.537E–4	0.002
Frame × Variation	.316	.005	0.010
Block × Frame × Variation	.053	1.569E–6	2.824E–5

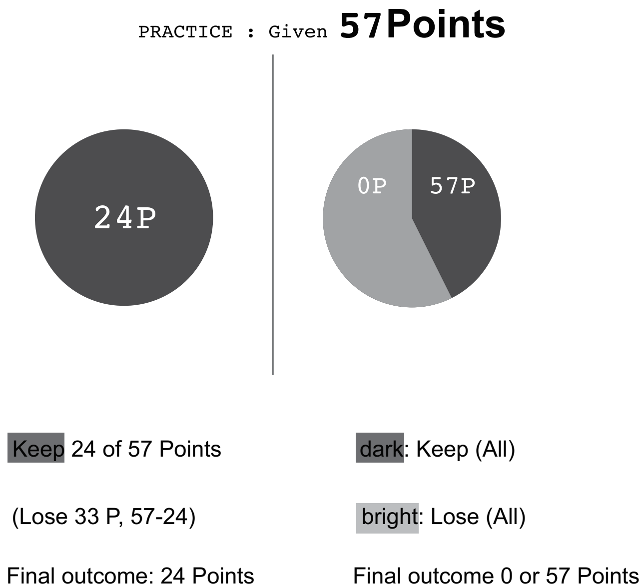

Fig. 4. Screenshot showing an example of a practice gain-frame trial in Experiment 2. Trials were similar to those in Variation 2 of Experiment 1 (see Fig. 1), but gains and losses were presented in points (rather than dollars), and the instructions accompanying the pie charts on practice trials were more explicit. In addition, the gamble was presented in a nonnegative format (i.e., gamble outcomes consisted of keeping a positive number of points or losing 0 points).

be the amount of the sure option, and *p* the probability of winning the initial amount in the gamble. In Experiment 1, the gambles were presented as "*Y* for sure versus *X* with probability *p* or −*X* with probability 1.0 – *p*" (see Fig. 1). This presentation made it appear that the choice was between a sure gain or a sure loss versus a probabilistic gain or loss (containing both positive and negative outcomes). In Experiment 2, the gambles were presented as "*Y* for sure versus *X* with probability *p* or 0 with probability 1.0 – *p*" (nonnegative outcomes; see Fig. 4). In the third experiment, we used a more traditional approach, following Kahneman and Tversky (1979). We also examined the influence of short and long time pressure, rather than comparing responses under time pressure and no time pressure as in the previous experiments.

Table 5. Proportion of Participants Who Selected the Gamble in Experiments 2 and 3

	Gain frame		Loss frame	
Experiment and block	*M*	*SD*	*M*	*SD*
Experiment 2 (*N* = 13)				
No time pressure	.537	.205	.663	.215
Time pressure	.494	.204	.675	.232
Experiment 3 (*N* = 52)				
Long time pressure	.579	.113	.617	.133
Short time pressure	.514	.150	.651	.139

Method

Participants. A total of 74 individuals (38 female, 36 male; mean age = 24.4 years) from Jacobs University Bremen participated in the study; each received €6 per hour for participation plus 0.1¢ for every 20 points he or she won. The experiment was in English, and all participants were undergraduate students and English speakers. We targeted a sample size of 50 participants with a minimum catch-trial accuracy of 75% correct. After running 74 participants, we had 52 who met the catch-trial accuracy criterion and thus stopped data collection.

Stimuli, design, and procedure. Participants completed four blocks of 80 trials each: 32 with gain frames, 32 with loss frames, and 16 catch trials. There were 16 unique gain-frame trials created by combining four different initial starting amounts (25, 50, 75, and 100 points) with four different probabilities of winning the gamble (.30, .40, .60, and .70). Sixteen unique loss-frame trials were created in the same fashion. From these pairs, we created the sure option for each trial to match the expected value of the gamble, depending on the frame. Each test trial was shown twice in each block. As before, the catch trials had nonequivalent sure and gamble options in which one option had a significantly larger expected value. All trials within a block were presented in a random order. In this experiment, participants were under either a short time pressure (STP) or a long time pressure (LTP) to complete each trial. Blocks 1 and 3 were LTP blocks, in which participants were given 3,000 ms to make a choice. Blocks 2 and 4 were STP blocks, in which participants were given 1,000 ms to make a choice. The only difference between STP and LTP blocks was the amount of time allowed for decisions. In total, there were 128 gain-frame trials, 128 loss-frame trials, and 64 catch trials for a grand total of 320 trials (the same total number of trials as in Experiments 1 and 2).

Participants received feedback about the amount received after each trial (in both the STP and LTP blocks). If they did not respond within the time limits, they received zero points on the trial. As in Experiment 2, at the beginning of the task, participants were told, "your goal is to maximize the amount of points that you win." In both the STP and LTP blocks, participants saw countdown bars (i.e., vertical bars displayed below the pie charts, as illustrated in Fig. 6). As the trial progressed, the vertical bars would disappear one at a time, counting down toward the time limit.

The procedure was similar to that used in Experiment 2, except that there was time pressure (either short or long) on every trial. Another important difference between this experiment and the previous two was the presentation of the gambles as either nonnegative (gain frame) or nonpositive (loss frame). For example, in the

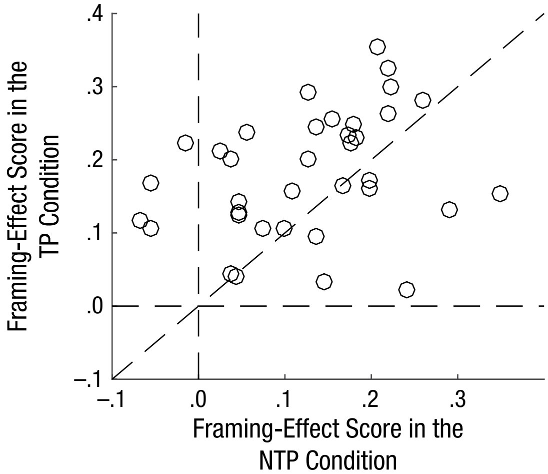

Fig. 5. Scatterplot showing the relationship between mean framing-effect scores in the time-pressure (TP) condition and no-time-pressure (NTP) conditions of Experiment 2. Framing-effect scores were calculated by subtracting the proportion of times the gamble was chosen in the gain frame from the proportion of times the gamble was chosen in the loss frame. Points above the horizontal dashed line indicate that there was a framing effect in the TP condition, points to the right of the vertical dashed line indicate that there was a framing effect in the NTP condition, and points above the dashed diagonal line indicate that the framing effect was larger in the TP than in the NTP condition.

gain-frame trial shown in Figure 6a, participants selected between keeping a portion of the initial amount for sure (45 points) or playing a gamble in which they could either keep all of the initial starting amount (75 points) or lose all of this amount (0 points). In the loss-frame trial shown in Figure 6b, participants selected between losing a portion of the initial amount for sure (−30 points) or playing a gamble in which they could either lose all of the initial starting amount (−50 points) or lose none of this amount (0 points). As before, the probabilities of losing and winning the gamble in both gain- and loss-frame trials were indicated by the size of the wedges of the pie chart.

Results

We analyzed the data from the 52 participants who had a minimum catch-trial accuracy of 75% correct. The average proportion of catch trials answered correctly was .83. These catch trials were removed for all subsequent analyses. The mean response time in the LTP condition was 1,429 ms (*SD* = 316 ms), and the mean response time in the STP condition was 665 ms (*SD* = 64 ms). There was a significant effect of frame, $F(1, 51) = 26.34$, $p < .001$, $\eta^2 = .34$, which revealed that participants preferred the gamble more often in the loss frame than in the gain frame. There was also a significant interaction between block and frame, $F(1, 51) = 22.92$, $p < .001$, $\eta^2 = .31$, which shows that the framing effect was greater in the STP than in the LTP condition. Bayesian analyses also confirmed these results, showing that a model with block, frame, and the interaction of block and frame was preferred to the null model ($BF_{10} > 1,000$). The proportion of participants who selected the gamble in the two conditions is shown in Table 5. The data used in this analysis are available on the Open Science Framework at https://osf.io/9gyvd/.

As in Experiments 1 and 2, we also analyzed the framing effect on the problem level by calculating a framing-effect score for STP and LTP conditions. Figure 7 shows the framing-effect scores for the STP and LTP conditions for each problem, averaged over participants. All of the problems

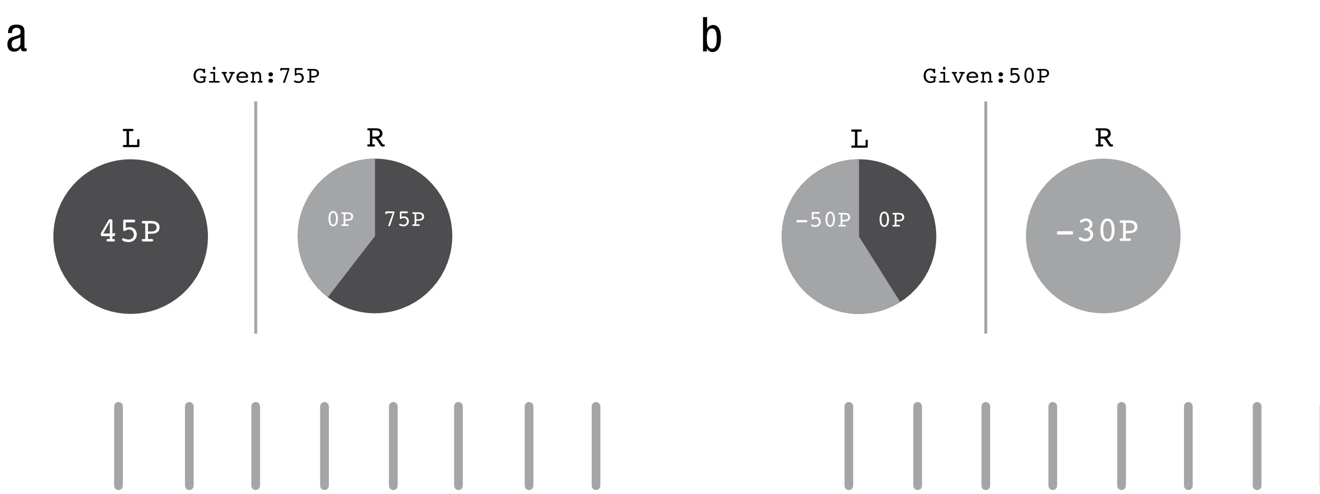

Fig. 6. Screenshots showing examples of the beginning of (a) a gain-frame test trial and (b) a loss-frame test trial in Experiment 3. Trials worked the same way as in Variation 2 of Experiment 1 (see Fig. 1), but gains and losses were presented in points (rather than dollars), and the vertical bars at the bottom of the screen disappeared one by one to count down the time remaining on that trial. Depending on the block, time pressure was either short (participants had 1,000 ms to make a decision) or long (participants had 3,000 ms to make a decision). Participants indicated their choice by pushing the left (L) or right (R) key on a response box.

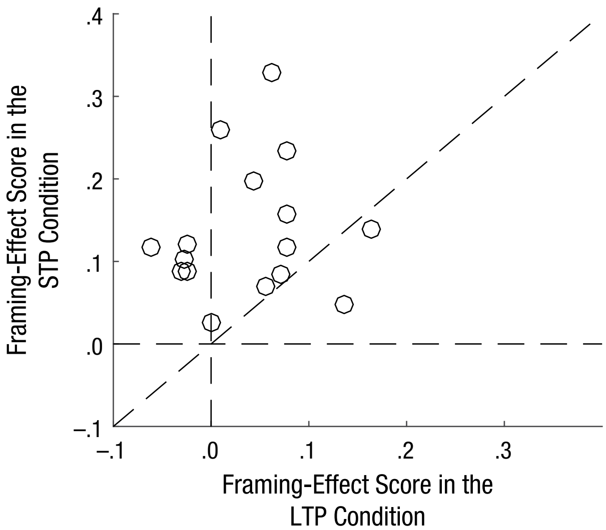

Fig. 7. Scatterplot showing the relationship between mean framing-effect scores in the short-time-pressure (STP) and long-time-pressure (LTP) conditions of Experiment 3. Framing-effect scores were calculated by subtracting the proportion of times the gamble was chosen in the gain frame from the proportion of times the gamble was chosen in the loss frame. Points above the horizontal dashed line indicate that there was a framing effect in the STP condition, points to the right of the vertical dashed line indicate that there was a framing effect in the LTP condition, and points above the dashed diagonal line indicate that the framing effect was larger in the STP than in the LTP condition.

had a positive framing-effect score in the STP condition, and the majority (11 out of 16) had a positive framing-effect score in the LTP condition as well, which provides evidence for the standard framing effect, in which gambles are preferred in the loss frame more than in the equivalent gain frame. Further, most problems (14 out of 16) had a larger framing-effect score in the STP condition than in the LTP condition, showing an increase in the framing effect under increased time pressure.

Conclusions

Experiment 3 showed that the results from Experiments 1 and 2 held when sure gains were compared with gambles having nonnegative outcomes and sure losses were compared with gambles having nonpositive outcomes. The results also held for the manipulations involving short and long time pressure, which further generalizes the results of Experiments 1 and 2.

General Discussion

The present experiments showed that participants more frequently chose the sure option for gains and the gamble option for losses when there was greater pressure to make quick decisions. These results are consistent with a dual-process explanation of framing effects, in which the effect is driven by the quick, intuitive system. Our findings are complementary to neuroimaging results of De Martino et al. (2006), which showed increased activation in the amygdala when participants exhibited framing effects.

Our results are also consistent with the predictions of a dual-process model recently proposed by Loewenstein, O'Donoghue, and Bhatia (2015), which assumes that choices arise from the interaction of the deliberative system (a utility function) and the intuitive system (an affective motivation function). Their model also incorporates a willpower function, in which the depletion of willpower results in increased weight on the intuitive system. They show that the model can account for a wide range of phenomena in the domains of intertemporal choice, risky decision making, and social preferences. Notably, the model predicts that when willpower is depleted, framing effects will increase in risky decision making. Time pressure provides one avenue to restrict willpower. Thus, our experiments provide empirical support for their model predictions. Note that some of our results (such as risk aversion in gains and risk seeking in losses) are also consistent with prospect theory (Kahneman & Tversky, 1979). However, prospect theory cannot explain why framing effects increase with time pressure.

While our results are consistent with a dual-process explanation, we cannot rule out single-process accounts. Our results could have arisen from a single process that involves an attention-switching mechanism as proposed in models derived from decision-field theory (Busemeyer & Townsend, 1993; Roe et al., 2001) and the multistage attention-switching model (Diederich, 2016). In these models, preference evolves over time and is modulated by changes in attention. Preference for a given option might depend on the order of attended attributes or the time spent attending to an attribute. Time pressure might alter the attention process (e.g., by altering the time spent attending to different features), which would result in changes of behavior. In particular, time pressure could change attention to the lowest ranked payoff, as suggested by the transfer-of-attention-exchange (TAX) model (Birnbaum & Chavez, 1997).

Future work could examine other manipulations aimed at distinguishing intuitive and deliberative processes, such as decreasing deliberation with cognitive load (e.g., see Whitney, Rinehart, & Hinson, 2008) or manipulating affect (Pachur, Hertwig, & Wolkewitz, 2014; Suter, Pachur, & Hertwig, 2016). In general, we encourage researchers to use direct manipulations (such as time pressure) in testing ideas from dual-process theory. As discussed by Krajbich, Bartling, Hare, and Fehr (2015), using response time data alone to infer that choices are "intuitive" is inherently flawed because of the multiple sources of variability in data. Direct manipulations avoid the problems with reverse inference and lend more direct support for dual-process accounts.

Action Editor

Gretchen Chapman served as action editor for this article.

Author Contributions

All authors contributed to the study concept and design. Testing and data collection, along with data analyses for Experiment 1, were performed by L. Guo under the supervision of J. S. Trueblood. Data collection for Experiments 2 and 3 was led by A. Diederich. Data for Experiments 2 and 3 were analyzed by J. S. Trueblood. L. Guo and J. S. Trueblood drafted the manuscript, and A. Diederich provided critical revisions. All authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Open Practices

All data have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/9gyvd/. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797616689092. This article has received the badge for Open Data. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

Note

1. In Experiments 2 and 3, we examined the framing effect in decisions with real consequences.

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