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Framing Effects in Decision-Making under Time Pressure

by Laura R Marusich and Jonathan Z Bakdash

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14. ABSTRACT
Soldiers are continuously required to engage in decision-making based on uncertain information. We use a simulated military-relevant behavioral task to evaluate the influence of time pressure on framing effects in decision-making under uncertainty. Typical framing effects are a tendency to be risk-averse when the decision is framed in terms of gains and risk-seeking when the decision is framed in terms of losses. Prior research using hypothetical vignette-based decisions suggests that framing effects may reverse under time pressure. Here, we use a more concrete behavioral task with repeated trials for decisions and feedback on decision outcomes. Our findings did not show confirmatory evidence for either typical framing effects or for risk-reversal under time pressure. We describe exploratory findings suggesting that these unexpected results may be explained by multiple differences for descriptive versus experience-based decision-making tasks. We discuss our confirmatory and exploratory findings in the context of the recent literature on framing effects and suggest avenues of future research to disentangle these methodological differences and their influence on framing effects.

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1. Introduction

Soldiers are continuously required to engage in decision-making based on uncertain information. An important aspect of decision-making under uncertainty is the way people reason about risk and in what contexts they tend to display risk-seeking versus risk-averse behavior. Classic decision-making research demonstrates that people tend to be risk-averse when the decision is framed in terms of gains, and risk-seeking when the decision is framed in terms of losses. This phenomenon of a framing effect is explained by Kahneman and Tversky's (1979) Prospect Theory, which explains the perceived value of a gain or loss and how it differs from the values predicted by expected utility theory (Fig. 1).

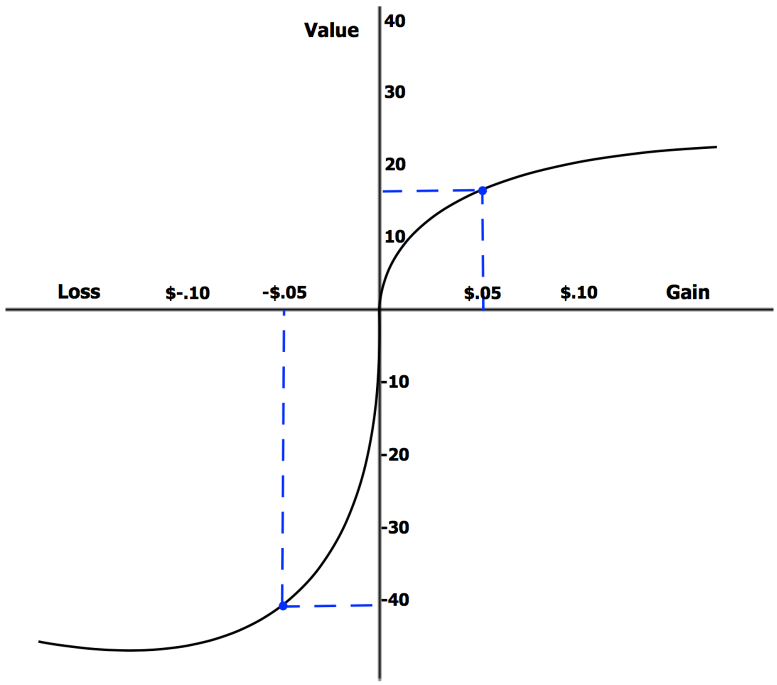

Fig. 1 Classic prospect theory curve, showing the theorized relationship between the gain/loss on the x-axis and the perceived value of the gain/loss on the y-axis. The reference point is at the origin. The concave shape of the gains curve explains why people tend to be risk-averse for gains, while the convex shape of the loss curve explains why people tend to be risk-seeking for losses (imagery from Wikimedia Commons).

Although the original paper (Kahneman and Tversky 1979) and many replications employ finance-based scenarios, one of the more famous tasks used to demonstrate the predictions of Prospect Theory is the Asian Disease Problem (Tversky and Kahneman 1981), in which participants receive the following vignette: "Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume the exact scientific estimate of the consequences of the programs are as follows."

In the *gains*-framing condition, participants are asked to choose between the following options:

- Program A: Two hundred people will be saved.
- Program B: There is a one-third probability that 600 people will be saved, and a two-thirds probability that no people will be saved.

In the *loss*-framing condition, participants instead choose between the following:

- Program A: Four hundred people will die.
- Program B: There is a one-third probability that nobody will die, and a two-thirds probability that 600 people will die.

Note that the outcomes, and therefore the expected utility, of Program A and Program B are the same in the two conditions; they are simply phrased differently in terms of lives saved versus deaths.

It is a highly replicated and robust finding that participants in the gains condition are more likely to choose the "safe" option (Program A), while participants in the loss condition are more likely to choose the "risky" option (Program B). In fact, a recent preregistered, multinational replication of Kahneman and Tversky's (1979) original methodology produced results very similar to the original study, even 40 years later (Ruggeri et al. 2020). Similarly, a recent meta-analysis reported reliable and robust framing effects for risky decision-making (Steiger and Kühberger 2018).

Many variations of this task have been investigated since Kahneman and Tversky's original work. For example, Saqib and Chan (2015) explored the effect of introducing time pressure into the task. Their findings suggest that under time pressure, typical risk preferences may reverse such that individuals tend to be risk-seeking for gains and risk-averse for losses. They theorize that time pressure shifts the reference point from the origin to the maximum possible outcome. As shown in the right panel of Fig. 1, in a losses context the reference point would shift to Point B, while in a gains context it would shift to Point C. In a series of experiments, Saqib and Chan demonstrated that participants assigned to conditions with time pressure displayed the predicted reversal of risk preferences to some extent.

As typified in the previous example, most empirical work into risk preferences (including Saqib and Chan [2015]) tends to rely upon vignette-based tasks, often with an economic context (Steiger and Kühberger 2018). A less typical methodology uses behavioral tasks rather than hypothetical vignettes (Hertwig et al. 2004; Hertwig and Erev 2009), offering several potential benefits. Participants make more concrete decisions rather than hypothetical decisions. Behavioral tasks also lend themselves more easily to multiple trials/repeated decisions, providing more data from each participant and thus more precision in estimating the magnitude of any framing effects. Last, there is a more natural opportunity for feedback on the outcomes of participant decisions, again allowing for a more concrete, instead of hypothetical, experience with the risk probabilities. To our knowledge, there is no empirical work in the literature on framing effects showing the risk reversal phenomenon with a behavior-based rather than vignette-based task. We designed the current study to fill this gap in the literature and explore whether the phenomenon of risk reversal extends to more concrete tasks with potentially greater external validity.

The current study makes use of a military-relevant task to investigate if classic framing effects and/or the risk reversal under time pressure phenomenon extend to military decision-making tasks. If so, this may have implications for how information is presented to the Soldier in order to help them make appropriate decisions about risk in both planning and more time-pressured contexts.

Based on the work of Saqib and Chan (2015), we hypothesize that participants in the no-time-pressure condition will demonstrate the classic pattern of data predicted by Prospect Theory, in which they will make more low-risk choices in the gains condition and more high-risk choices in the loss condition. Conversely, participants in the time-pressure condition will do the opposite: more high-risk choices in the gains condition, and more low-risk choices in the loss condition. Note that this study was preregistered (see https://aspredicted.org/7yj2x.pdf).

2. Methods

2.1 Experimental Task

The experimental task used in this study (Marusich and Bakdash 2022) was adapted from a similar task centered around locating and capturing high-value targets (HVTs), which was used in previous work (Marusich et al. 2016) exploring the effects of information volume on decision-making. In this task, participants viewed a map with icons for four units they could assign to different locations on the map (see Fig. 1). During the experimental block, text information about the location of HVTs/low-value targets (LVTs) appeared on the screen. For each trial, participants could choose to view location information about either an HVT or LVT. They could then assign one or more units to that location to attempt to capture the target. A live demo of the experiment can be accessed at https://lmarusich.github.io/webHVT/.

Additional display elements that were always visible during the task include a Capture Report panel showing outcome information for each target, a Score panel showing the participant's current score in text and as a progress bar, a panel showing the amount of time elapsed/remaining in the task, and checkboxes that allowed the participant to keep track of target outcomes.

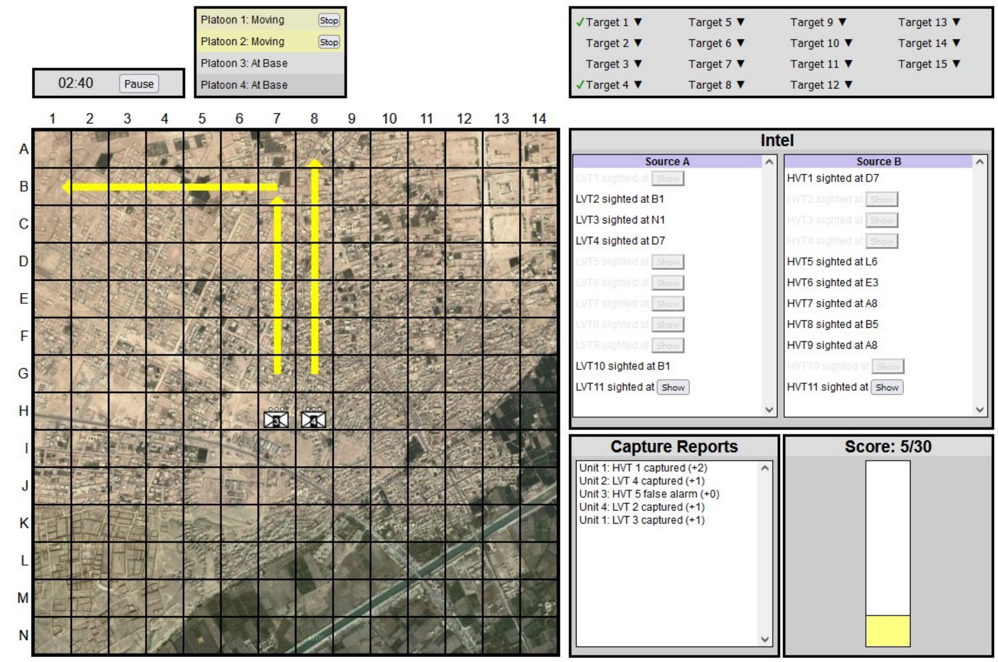

Fig. 2 Screenshot of experimental task. This example shows gameplay in the no-time-pressure and gains conditions

The gameplay mechanics of the task were as follows. New target information became available to the participants every 15 s. Units travelled by Manhattan distance (only horizontally or vertically) at a rate of one grid square every 2 s, with the initial direction assigned randomly for each unit movement. If a unit encountered a target along its path, it automatically returned to the base location. At the base, capture or false alarm information was revealed in the capture reports panel and the score panel was updated. To make the task more game-like and challenging, there was some imprecision to the location information. Targets were 50% likely to be found on the grid square indicated in the intelligence information; otherwise, they were on one of the immediately surrounding grid squares. Participants were given this information in the tutorial phase of the experiment.

2.1.1 Time-Pressure Manipulation

In the no-time-pressure condition, the timer panel displayed the elapsed time and counted up from zero in 1-s intervals. In the time-pressure condition, it displayed the remaining time, counting down from the total allowed time (8 min) in 1-s intervals and turning red when there were 2 min left.

To determine an appropriate amount of time pressure for this task, we examined pilot data from 10 participants (5 in each framing condition) who completed the task with no time pressure. For both the practice and test blocks, we computed the pilot participants' median completion time and rounded up to the nearest minute. We used these values (3 min for the practice block and 8 min for the test block) as time limits in the time-pressure condition.

2.1.2 Framing Manipulation

Framing was manipulated in terms of whether participants started with 0 points and attempted to earn as many as possible during the task (*gains condition*) or, conversely, started with a set number of points and attempted to lose as few as possible (*loss condition*). In the gains condition, participants tried to capture as many targets as possible, and each successful capture added points to the score. In the losses condition, targets were described as "escaping" from the area, and participants could reduce the number of points lost by capturing targets before they escaped.

Choosing HVT information was the high-risk/high-reward choice in this task. In the gains condition, capturing an HVT was worth 2 points, but there was a 50% chance of a "false alarm" instead of a capture, which would mean 0 points earned. In the loss condition, capturing an HVT meant no points were lost, but a false alarm meant a loss of 2 points from the total score.

Choosing LVT information was the low-risk/low-reward choice in both framing conditions. There was no risk of false alarms with LVTs, but in the gains condition, an LVT capture meant only 1 point earned, and in the loss condition, it meant only 1 point lost.

Participants were not given the exact probabilities of capture versus false alarm in their instructions. In the walk-through/tutorial, they were forced to make two low-risk choices, which both resulted in captures, and two high-risk choices, only one of which resulted in a capture. In the practice (4 targets) and test block (15 targets), the capture/false alarm outcome of each high-risk choice was stochastically chosen.

These contingencies ensured an equivalent expected value of +1 (or –1 in the loss condition) for either an HVT choice or an LVT choice. There is no "optimal" choice in this task averaged over repeated stochastic outcomes. As a result, the proportion of high-/low-risk choices for each participant should indicate their risk preferences.

2.2 Design

This study used a between-subjects 2 × 2 design, with time pressure (time pressure/no time pressure) and framing (gains, losses) as the two independent variables and proportion of high-risk choices as the primary dependent variable.

We planned to recruit 45 participants for each condition for a total of 180 participants. The planned sample size was sufficient to achieve greater than 80% power to detect a medium main effect size. Unanticipated issues with online data collection and condition assignment meant that some additional participants were recruited. We used the data from these additional participants to replace individuals removed due to outliers or coding bugs (see the following).

Participants were excluded from analysis if their completion time for the test block was over 2.5 standard deviations above the mean completion time (no-time-pressure condition) or if they did not complete at least half of the risk decisions in the test block (time-pressure condition).

After data collection, a bug was discovered in the experimental code associated with the "stop movement" button. Fortunately, the experiment logged when this button was used, and fewer than 30 participants used it in either the practice or the test blocks. These participants were removed (and replaced where possible). This bug was fixed in the released code (Marusich and Bakdash 2022).

2.3 Participants

The final data set included $N = 172$ participants recruited from Amazon Mechanical Turk through the Volunteer Science platform (Radford et al. 2016); they were each compensated $5.00 for completing the task. Self-reported demographic information is summarized in Table 1.

Table 1 Participant demographics

Demographic	*n*	Percent %
Age		
18–24	8	4.65
25–34	80	46.51
35–44	49	28.49
45–54	23	13.37
55-64	8	4.65
65+	4	2.33
Gender		
Male	105	61.05
Female	67	38.95
Nonbinary/Other	0	0
Education		
Less than high school degree	0	0
High school degree or equivalent	25	14.53
Some college, no degree	20	11.63
Associate degree	20	11.63
Bachelor's degree	86	50.00
Graduate degree	21	12.21

2.4 Procedure

After providing consent, participants completed a tutorial designed to familiarize them with the layout of the different elements on the screen, the information and controls available to them, and the mechanics of the game. Because the task was conducted online without the benefit of an experimenter available to answer questions, the walkthrough was extremely thorough, using learning by successfully doing. Participants were required to perform each necessary task (clicking a unit, assigning it to a grid location, marking the relevant target as “captured,” etc.) before moving on to the next step.

After completing the tutorial, participants completed a practice block consisting of four target trials. Participants were not provided any guidance in this phase and were free to choose any combination of HVTs or LVTs. They then began the main experimental block consisting of 15 target trials.

When participants had finished the main block of experimental trials, they then completed 1) the NASA-Task Load Index (TLX; Hart and Staveland 1988), an assessment of workload with an item specifically assessing time pressure; 2) the Berlin Numeracy Test (BNT; Cokely et al. 2012), a measure of participants’ understanding of probability and risk; 3) a short demographics questionnaire; 4) a free-response item asking about strategies used in the task; 5) an understanding check asking participants to estimate the probability of capture for HVTs and

LVTs; and 6) another free-response item for any additional comments about the task.

3. Results

Code and data are available at https://osf.io/e3tdu/.

3.1 Manipulation Check

We first evaluated the impact of the time-pressure manipulation on participants' task performance and subjective experience. Figure 3 shows the number of choices (out of a possible 15) made by participants in the time-pressure condition and the no-time-pressure condition. In the no-time-pressure condition, the task only finished after completion of all 15 trials, so participants in this group all made the maximum 15 choices. In the time-pressure condition, only participants who made at least eight choices were included in the data set, so there are no values below 8.

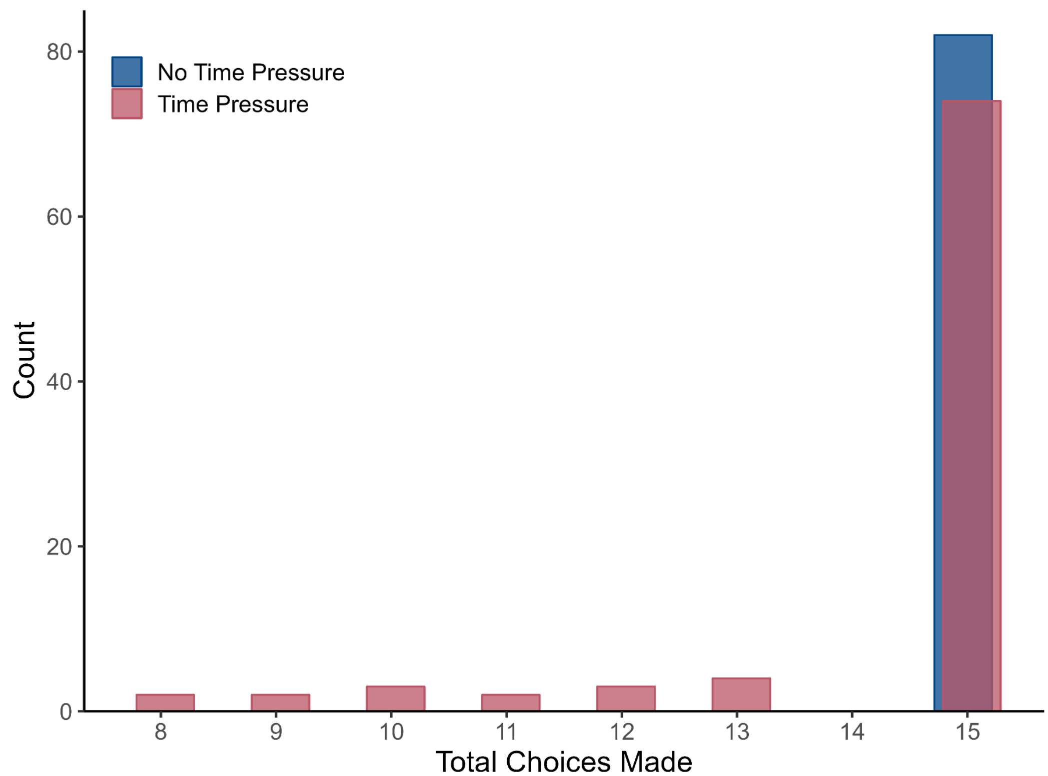

Fig. 3 Histogram of the number of risk choices made by participants in the two time-pressure conditions

We also compared responses on the NASA-TLX item specifically assessing time pressure ("How hurried or rushed was the pace of the task?"). The range of possible responses is 0–100, with higher numbers indicating more time pressure. An independent samples t-test showed that participants in the time-pressure condition rated this item significantly higher (M_{diff} = 7.47, confidence interval: [0.21, 14.72]) than participants in the no-time-pressure condition [$t(170) = 2.03$, $p = 0.04$, $d = 0.31$; Fig. 4].

These results indicate that participants did experience a greater level of time pressure in the time-pressure condition, but the effect was not large.

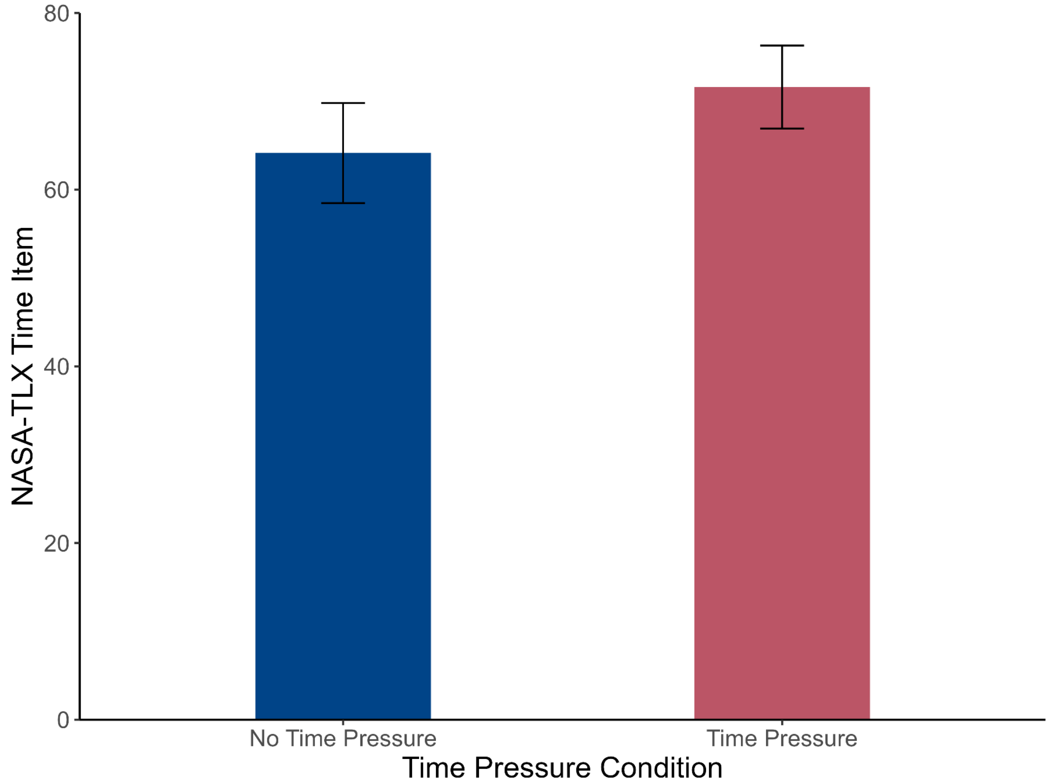

Fig. 4 Average rating on the NASA-TLX time pressure item for participants in the two time-pressure conditions. Higher ratings indicate more time pressure experienced.

3.2 Primary Results

A 2 × 2 factorial analysis of variance was conducted to assess the effect of framing and time pressure on the proportion of high-risk choices (Fig. 5). There was no significant main effect of framing [$F(1, 168) = 2.34$, $p = 0.13$, $\eta_p^2 = 0.01$] or time pressure [$F(1, 168) = 0.34$, $p = 0.56$, $\eta_p^2 < 0.01$]. There was also no significant interaction effect [$F(1, 168) = 0.75$, $p = 0.39$, $\eta_p^2 < 0.01$].

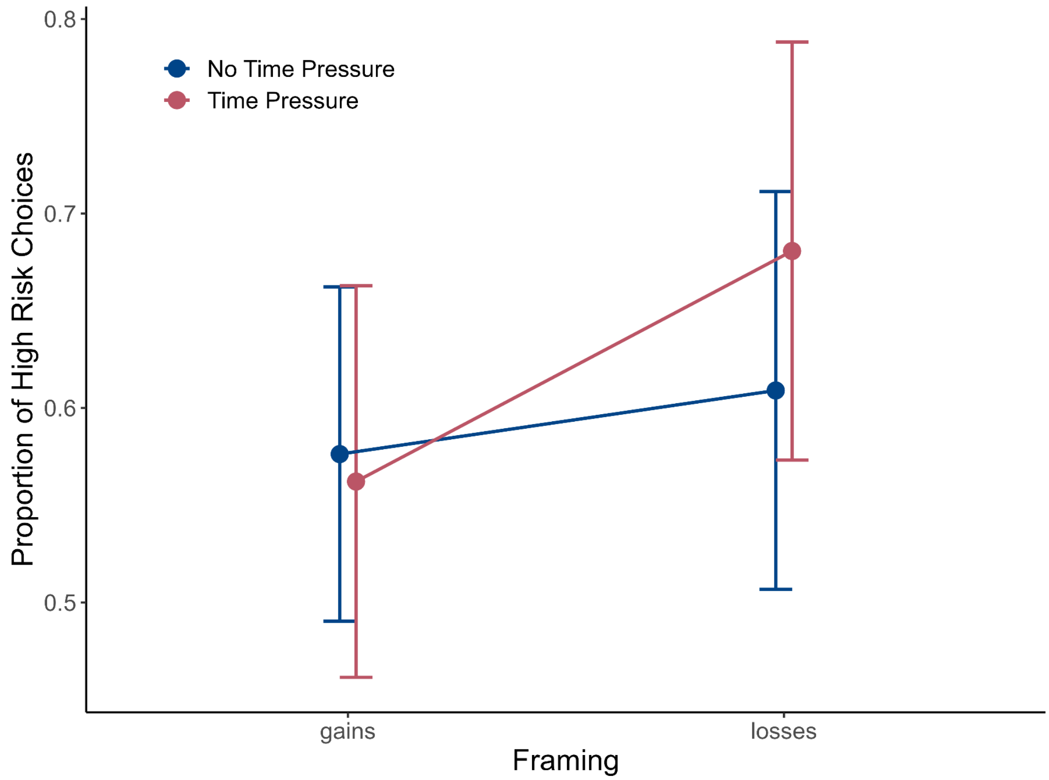

Fig. 5 Proportion of high-risk choices made in the two framing conditions (gains/losses) and the two time-pressure conditions (time pressure/no time pressure). Error bars represent 95% confidence intervals.

3.3 Exploratory Results

The findings were surprising, especially the lack of a framing effect, even in the no-time-pressure condition. We conducted additional exploratory analyses (not included in our preregistration) to investigate potential explanations. These are described in the following.

3.3.1 Analysis of Practice Choices

We speculated that participants in our study might have been more likely to show standard framing effects early in the experiment before gaining extensive experience with the outcomes of their choices. The rationale was that classic framing effects are often shown in single-shot vignette-based studies where participants do not receive any feedback from the outcomes of their choices. To investigate this possibility, we conducted a similar analysis using only trials from the practice block (Fig. 6).

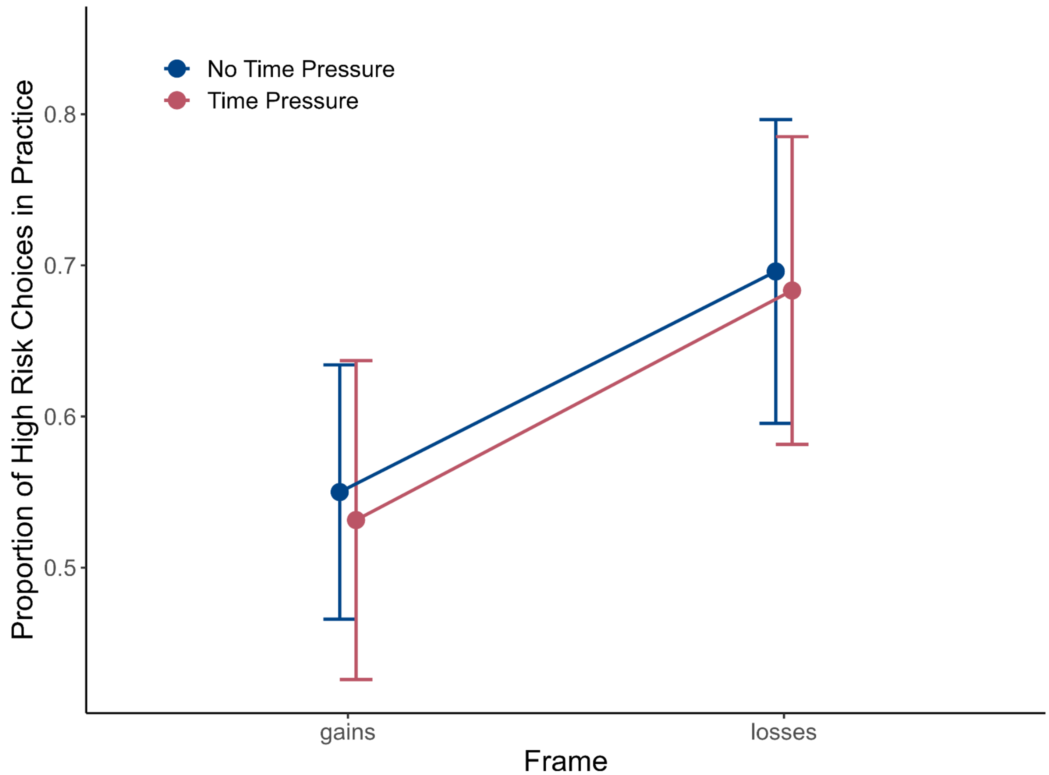

Fig. 6 Proportion of high-risk choices made out of the four possible practice trials in the two framing conditions (gains/losses) and the two time-pressure conditions (time pressure/no time pressure). Error bars represent 95% confidence intervals.

In this case, we did find a significant main effect of framing [$F(1, 168) = 9.25$, $p = 0.003$, $\eta_p^2 = 0.05$], with participants in the losses condition making more high-risk choices ($M = 0.69$) than those in the gains condition ($M = 0.54$). Note this exploratory effect size was at the upper end of the small range, lower than the typical magnitude of effects with framing. We found neither any statistically significant main effect of time pressure [$F(1, 168) = 0.10$, $p = 0.75$, $\eta_p^2 < 0.01$] nor any evidence that the framing effect was influenced by the time-pressure manipulation [$F(1, 168) = 0.004$, $p = 0.95$, $\eta_p^2 < 0.01$].

3.3.2 Influence of Risk Understanding

We also examined performance on the BNT, which assesses people's understanding of probability and risk. The total score on this instrument had a possible range of 0 to 4 with a total score of 1 representing chance performance. Fig. 7 shows the distribution of total scores among participants; 67 of the 172 participants (39%) scored at chance or below.

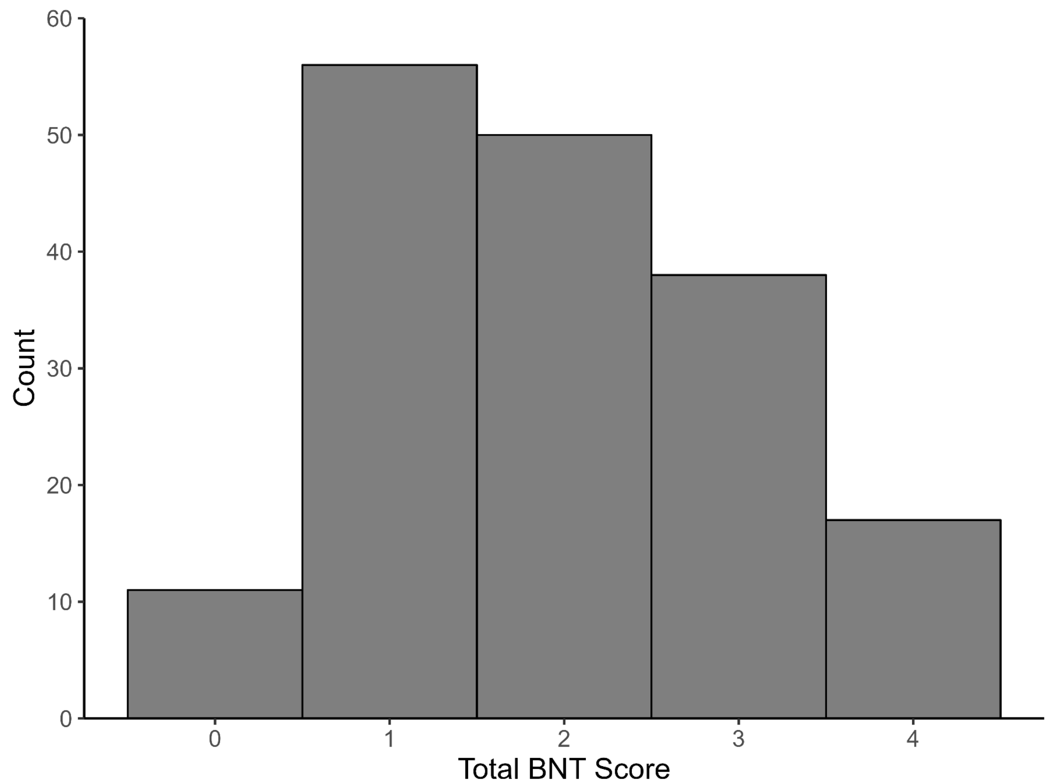

Fig. 7 Histogram of participants total scores on the BNT. Possible total scores ranged from 0 to 4, and a score of 1 represented chance performance.

As shown in Fig. 8, when only the participants who performed above chance on the BNT are included in the analysis, the results indicate a significant main effect of framing [$F(1, 101) = 7.25$, $p = 0.008$, $\eta_p^2 = 0.07$], with participants in the losses condition making more high-risk choices ($M = 0.68$) than those in the gains condition ($M = 0.52$). Again, we found neither any statistically significant main effect of time pressure [$F(1, 101) = 0.01$, $p = 0.916$, $\eta_p^2 < 0.01$)], nor any evidence that the framing effect was influenced by the time pressure manipulation [$F(1, 101) = 0.84$, $p = 0.36$, $\eta_p^2 < 0.01$].

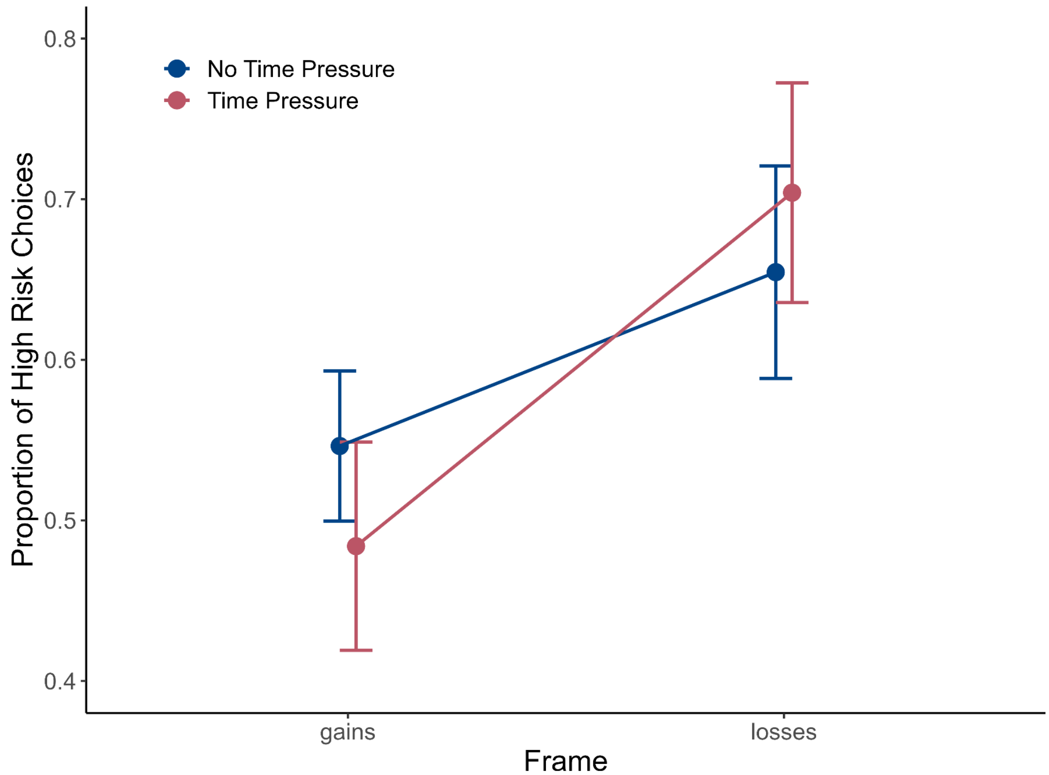

Fig. 8 In the subset of participants who scored above chance on the BNT, the proportion of high-risk choices made out of the 15 possible test trials in the two framing conditions (gains/losses) and the two time-pressure conditions (time pressure/no time pressure). Error bars represent 95% confidence intervals.

3.3.3 Analysis of Choice Sequences

We also conducted exploratory analysis of choice sequences over time using the TraMineR package (Gabadinho et al. 2011). We examined only the first eight choices in the test block of trials, as all sequences, even those in the time pressure condition, were at least this long. Sequences of different length can be difficult to compare.

Fig. 9 suggests some distinct clusters of choice patterns for gains versus losses despite the lack of a statistically significant difference on the mean proportions of choices for framing. Although the majority of participants make both high and low choices at different points in the sequence, there is a subset of participants in each condition that exclusively choose either the high-risk or the low-risk option. These are represented by the solid bands at the bottom of each plot. The number of people who exclusively choose the high-risk option appears to be higher in the loss framing condition.

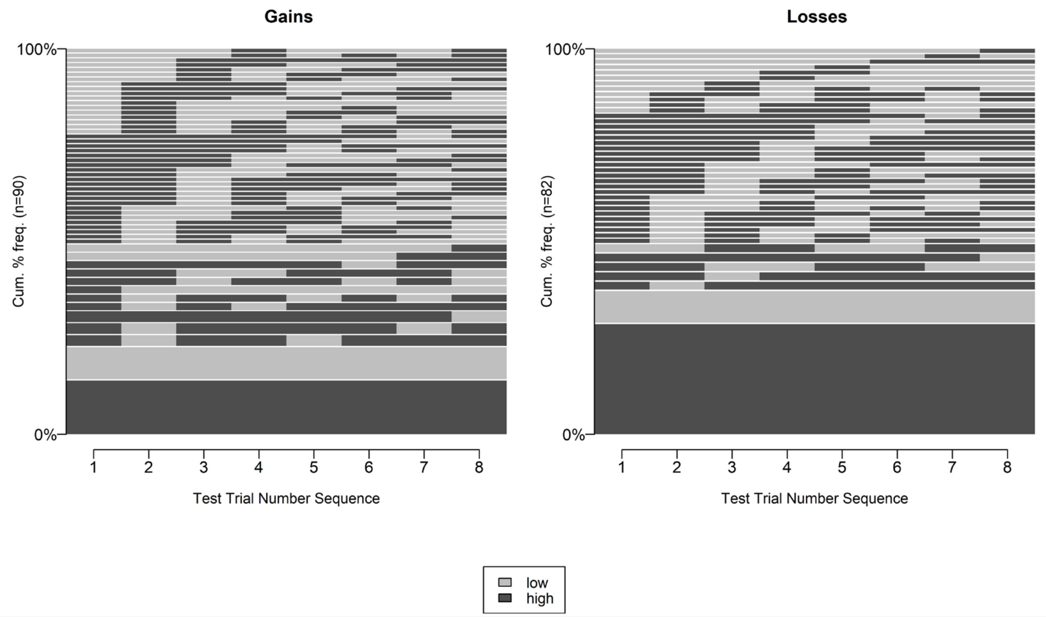

Fig. 9 The x-axis is the temporal sequence of the first eight choices at test, and the y-axis is the cumulative number of participants as a percentage. Dark gray depicts choosing an HVT, and light gray depicts choosing an LVT.

Indeed, as shown in the mosaic plot in Fig. 10, the distribution of the three basic patterns of choices is different for gains framing versus loss framing [$\chi^2(2) = 7.20$, $p = 0.03$], with more people in the loss condition exclusively choosing the high-risk option.

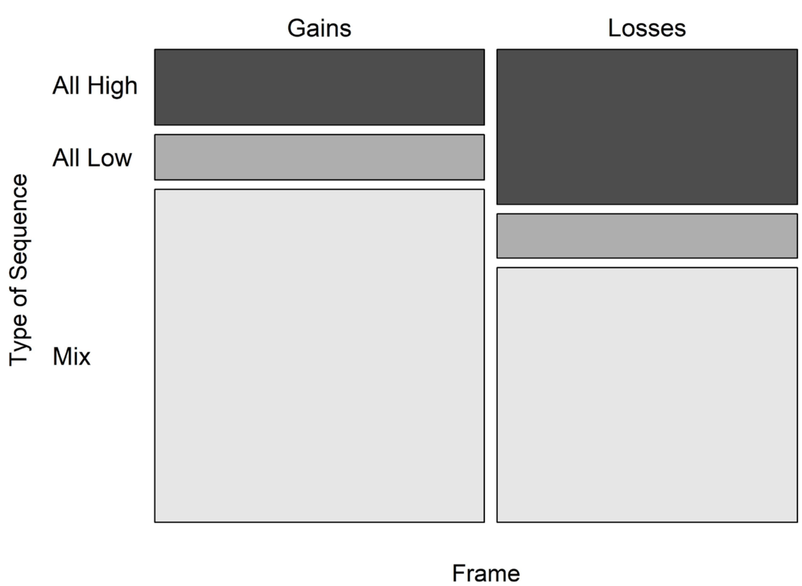

Fig. 10 Mosaic plot of choice patterns for the first eight test trials. "All High" refers to people who exclusively made high-risk choices, while "All Low" is people who exclusively made low-risk choices. "Mix" refers to people who made any combination of high- and low-risk choices.

4. Discussion

We manipulated risk framing and time pressure in a behavior-based, military-relevant decision-making task. We did not find evidence supporting our principal hypothesis that risk preferences would reverse under time pressure, as reported by Saqib and Chan (2015).

Further, our primary analysis also failed to show any statistically significant framing effects at all, even in the no-time-pressure condition. As previously mentioned, this second finding was especially surprising given the decades of replication (Steiger and Kühberger 2018; Ruggeri et al. 2020) of the classic framing effects predicted by Prospect Theory (Kahneman and Tversky 1979).

Our exploratory analyses attempted to probe specifically the small framing effects obtained in our study, providing some compelling potential explanations. First, the majority of work in this field relies on one-shot vignette-based tasks where participants receive no feedback on the outcomes of their choices. We consider the experiential nature of our task, which does provide outcome feedback, to be an advantage in terms of external validity; however, this difference may offer a partial explanation into our reduced framing effects.

This tentative explanation is supported by the finding that when limiting the analysis to the practice block, comprising only the first four trials of the experiment, we do obtain substantial framing effects: more high-risk choices in the loss condition and more low-risk choices in the gains condition. Thus, the repeated exposure to choice–outcome feedback may diminish the magnitude of the classic framing effects in this military-relevant behavioral task.

Another interesting exploratory finding is that when looking at the number of people who persist in the same choice across multiple trials, more people in the loss condition exclusively make high-risk choices than exclusively make low-risk choices. In the gains condition, the number of people making exclusively high-risk versus exclusively low-risk choices is more even. The implication is that there is a subset of participants in this task who “exploit” a single strategy as opposed to those who “explore” various strategies throughout the experiment. Among these single-strategy participants, high-risk strategies were more common in the loss condition than the gain condition. This exploratory finding aligns with typical framing effects described by Prospect Theory, albeit with a limited effect size.

Finally, it may be the case that people with lower risk-literacy/-numeracy skills have a poorer understanding of the task as a whole. When we limit the analysis to only participants who scored above chance on the BNT, we again find classic framing effects.

We do find support in the literature for these interpretations of our findings. Although the effect of time pressure in behavior-based, risky decision-making tasks has not been explored in depth previously, there is work showing an effect of experience-based (as opposed to vignette-based) tasks on decision-making outcomes more broadly. This difference in outcomes is known as the description–experience gap (Hertwig et al. 2004; Hertwig and Erev, 2009). A description–experience gap for framing effects has been reported in a handful of studies, although there is inconsistency about whether this gap reflects a reduction of typical framing effects, a complete disappearance, or even a reversal (see Kühberger 2021).

Regarding the absence of a time-pressure effect in our study, while Saqib and Chan (2015) found that time pressure reversed framing effects, this result is not universal. Other studies have demonstrated an overall increase in risk-seeking choices under time pressure (Young et al. 2012; Guo et al. 2017), or even an amplification, rather than a reversal of framing effects (Roberts et al. 2022). Another recent study shows, similar to our findings, no effect of time pressure manipulations on risk choices (Banerjee and Das 2021). Importantly, there are again many methodological differences among these studies, making it difficult to interpret the contradictory findings.

For future studies incorporating time pressure, it will be important to re-examine the amount of time pressure applied. Our participants' self-reported levels of temporal workload indicated that our time-pressure manipulation could have been substantially stronger. However, in the current design of our task, more time pressure potentially means the loss of more data due to participants being unable to complete all trials in the time limit.

We also plan to conduct future work exploring the nature of the description–experience gap for risk framing. Experiential tasks differ from description-based tasks in more than just a single way. Differences include 1) single-shot versus repeated trials, 2) probability information given up-front versus learned from experience, and 3) participants receive no outcome information about their decision versus participants do receive outcome information. Planned studies will attempt to disentangle which differences are driving the decision–experience gap and to what extent. The results of these studies will inform the design of future work examining the impact of information presentation and visualization on the framing effect for military-relevant decision-making. The proposed research has the potential to inform how information is represented and visualized in adaptive displays to improve tactical and strategic decision-making under uncertainty.

5. Conclusion

In summary, our confirmatory analyses neither supported support a risk-reversal under time pressure, nor did we find evidence for typical framing effects. These findings may be partially explained by our use of an experiential military-relevant decision-making task rather than a one-shot vignette task—an example of the description–experience gap. This explanation was supported by exploratory analyses, which showed typical framing effects with limited experience with the task, in participants with greater-than-chance numeracy performance, and among participants who made consistent choices throughout the task rather than alternating between different options. Future work should manipulate in isolation each of the multiple differences among vignette and behavioral tasks to investigate specific factors that may influence framing effects and their potential reversal under time pressure.

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List of Symbols, Abbreviations, and Acronyms

BNT	Berlin Numeracy Test
HVT	high-value target
LVT	low-value target
NASA-TLX	NASA-Task Load Index

1 (PDF)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA
1 (PDF)	DEVCOM ARL FCDD RLD DCI TECH LIB
1 (PDF)	DEVCOM ARL FCDD RLH B T DAVIS BLDG 5400 RM C242 REDSTONE ARSENAL AL 35898-7290
1 (PDF)	DEVCOM ARL FCDD HSI J THOMAS 6662 GUNNER CIRCLE ABERDEEN PROVING GROUND MD 21005-5201
1 (PDF)	USN ONR ONR CODE 341 J TANGNEY 875 N RANDOLPH STREET BLDG 87 ARLINGTON VA 22203-1986
1 (PDF)	USA NSRDEC RDNS D D TAMILIO 10 GENERAL GREENE AVE NATICK MA 01760-2642
1 (PDF)	OSD OUSD ATL HPT&B B PETRO 4800 MARK CENTER DRIVE SUITE 17E08 ALEXANDRIA VA 22350

<u>ABERDEEN PROVING GROUND</u>

15 (PDF)	DEVCOM ARL FCDD RLH J LANE Y-S CHEN P FRANASZCZUK K MCDOWELL FCDD RLH F J GASTON K OIE FCDD RLH FA AW EVANS G BOYKIN FCDD RLH FB J GARCIA (A) H ROY FCDD RLH FC J TOURYAN (A) T ROHALY FCDD RLH FD A MARATHE FCDD RLH FE L COOPER J BAKDASH