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Contextual deliberation and the choice-valuation preference reversal ☆

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Abstract

Revealed preferences between lotteries can be asymmetrically reversed across choice and valuation. The ongoing debate is whether the procedure-invariance principle is violated. This research presents a parsimonious theory to reconcile asymmetric preference reversals with procedure invariance. When risk attitude is ex ante imperfectly known, preference-eliciting procedures can endogenously influence revealed preferences through affecting the incentive for information retrieval/acquisition (i.e., deliberation). As predicted, when lottery pairing was known, experiment participants exhibited substantially less asymmetric reversals by stating mean-preserving and more dispersed valuations. Therefore, the endogeneity of asymmetric preference reversals can be substantiated.

JEL classification: C91; D01; D11; D83

Keywords: Choice; Deliberation; Preference reversal; Procedure invariance; Valuation

1. Introduction

Preferences are typically taken as primitive in decision theory and economic analysis. The basic belief is that preferences can be revealed by making inference from properties of ob-

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served responses (i.e., axioms) to incentive-compatible instruments. The canonical instrument is *choice* that captures preference relation between (normally two) alternatives. Another commonly used device is *valuation* that measures the monetary worth of individual alternatives. An implicit premise in the revealed-preference approach is the principle of procedure independence, i.e., same preferences should be derived from theoretically equivalent preference-eliciting procedures. For instance, although choice and valuation represent qualitatively different scales (ordinal versus cardinal), they should produce identical preference ranking between any two alternatives. This elementary assumption underlies classical economic models (e.g., expected utility theory and its many generalizations).

However, the procedure-independence principle is frequently violated in empirical tests. A prominent case is that preferences over monetary gambles can be reversed across choice and valuation (e.g., Lichtenstein and Slovic, 1971, 1973, Lindman, 1971, Grether and Plott, 1979; Seidl, 2002), which has been consistently replicated over the last half century. Experiments documenting the choice-valuation preference reversal (hereafter PR) normally center on a simple setting. Participants are asked to choose from pairs of lotteries, and separately state monetary valuation for each lottery. Each pair consists of a lottery that offers a relatively high chance of winning a modest amount of money (the P-bet), and another lottery that pays a larger prize at a smaller probability (the $-bet). An empirical regularity is that standard PR (i.e., the P-bet is chosen but valued lower relative to the $-bet) is significantly more frequent than nonstandard PR (i.e., the $-bet is chosen but the P-bet is preferred in valuation). What makes the PR phenomenon puzzling is not the reversal/variability *per se*, but the asymmetry in the direction of reversals. Put it differently, the asymmetric PR cannot be simply explained by stochastic preference or decision noise/error (Loomes, 2005). As a result, it not only poses direct compelling evidence against the procedure-independence principle, but also casts serious doubt on the validity of economic theories and applications that take the principle as presumption (e.g., consumer research, demand estimation, policy/welfare analysis).

It is therefore no surprise that many attempts have been made to account for the cause of the choice-valuation PR. The debate can be divided into two opposite streams. Economists tend to maintain the postulate of procedure independence but attribute reversals to violations of other axioms. Some interpret the PR phenomenon as evidence of preference intransitivity (e.g., Loomes et al., 1991). Others ascribe it to violation of the independence axiom or of the reduction axiom for compound lotteries (Holt, 1986; Karni and Safra, 1987; Segal, 1988). These researchers then suggest that the PR can be rationalized by generalizing the standard expected utility theory. Conversely, psychologists suggest that preferences are inherently procedure dependent. They propose that psychological hypotheses (e.g., attribute prominence, scale compatibility) may give rise to the asymmetric PR. Tversky et al. (1990) show that intransitivity had limited power in explaining the asymmetric PR phenomenon, which occurred under an ordinal payoff scheme that was designed to rule out accounts such as violations of the independence/reduction axioms. Subsequent studies seem converging to support the view of procedure-dependent preferences (e.g., Cubitt et al., 2004), which is not very appealing for mainstream economics.

My goal in present research is to reconcile different perspectives on the choice-valuation PR. I present a parsimonious theory of contextual deliberation that endogenizes the dependence of revealed preferences on elicitation procedure. The theory departs from standard models by assuming that a decision maker may not immediately recognize her true risk attitude when she faces a decision task (e.g., choice, valuation). Nevertheless, she can decide how much cognitive effort to invest in retrieving or acquiring preference-relevant information (i.e., deliberation). Conditional on the information collected from deliberation, she responds to the task as an expected-utility maximizer. The model's fundamental feature is that optimal deliberation varies endogenously with the elicitation procedure. Therefore, procedure-dependent preferences may emerge endogenously as well, even though the underlying preference/information structure is completely procedure-free.[1]

I spell out the necessary and sufficient conditions under which the asymmetric choice-valuation PR arises endogenously from contextual deliberation. The revealed preference order between lotteries may change systematically as deliberation enhances the dispersion in the posterior belief on risk attitude. As a result, a P-bet may be favored more in choice than in valuation, if and only if its stochastic preference order increases (declines) with deliberation and at the same time the incentive for deliberation decreases (rises) from choice to valuation. In addition, consistent with converging evidence from previous experiments (Berg et al., 2010), I present conditions under which participants generally prefer \$-bets but would deliberate more to increase P-bet choices.

Predictions of the theory are tested in a lab experiment. There are two novel ingredients on the experimental design. The first is the ordinal payoff scheme (Tversky et al., 1990). The subjects were asked to choose from and to value a series of lottery pairs, as in standard PR experiments. However, they were instructed that one lottery pair would be selected at random separately for each subject at the end of the experiment, and that another random device would determine whether to play the chosen lottery or the one with a higher valuation. This design feature ensures that intended randomization over a lottery pair can be achieved in two equal ways. It thus rules out the possibility to explain the asymmetric PR by generalized decision models that relax the independence/reduction axioms. The second ingredient of the design is to manipulate whether the subjects were explicitly informed of the pairing of lotteries in the ordinal payoff scheme. This leads to the unique prediction of contextual deliberation that unknown pairing should yield more asymmetric PR than known pairing.

The experiment results are remarkably consistent with predictions of contextual deliberation. First, when pairing was unknown, preferences for \$-bets were lower in choice than in valuation, and standard reversals were more frequent than nonstandard reversals. However, this behavioral pattern was substantially weakened when pairing information was available. Second, known pairing mitigated the asymmetry of reversals not by significantly changing the subjects' mean stated valuations: neither the P-bets were valued higher nor the \$-bets valued lower. Instead, known pairing gave rise to mean-preserving spread in the distribution of stated valuations, confirming the premise of contextual deliberation.

This paper is related to the literature on imprecise preferences (e.g., MacCrimmon and Smith, 1986; Butler and Loomes, 2007, Cubitt et al., 2015) and incomplete preferences (e.g., Aumann, 1962; Bewley, 2002). Preferences can be incomplete because of the lack of knowledge about the decision problem, e.g., subjective beliefs about the prospects are ambiguous/uncertain (Gilboa et al., 2010; Cerreia-Vioglio et al., 2011; Faro, 2015). Alternatively, people may simply be unable to decide between alternatives (e.g., Ok, 2002). Dubra et al. (2004) develop an expected multi-utility representation for incomplete preference over lotteries. Ok et al. (2012) consider incomplete preferences for uncertain acts by distinguishing between (and connecting) indecisiveness in beliefs and indecisiveness in the underlying tastes for outcomes. There are also models that characterize how people employ some conservative/pessimistic strategy to select among multiple beliefs

[1] Blavatskyy (2009) proposes a model of probabilistic choice and valuation that can yield the asymmetric PR phenomenon. The current research can be interpreted as offering a micro foundation for stochastic preferences that parsimoniously endogenizes the asymmetric PR.

or utility functions (Gilboa and Schmeidler, 1989; Gilboa et al., 2010). For instance, Cerreia-Vioglioy et al. (2015) consider a cautious expected utility model in which a decision maker with multiple utility functions evaluates each lottery by using the utility function that leads to the lowest certainty equivalent. Related to these studies, the model of contextual deliberation can be interpreted as one with multiple utility functions (in the spirit of a random parameter); nevertheless, the decision maker is an expected utility maximizer who integrates over the prior distribution over the utility functions and, more crucially, can engage in costly deliberation to improve information over the prior.

There is a growing literature on Bayesian cognition models (Gabaix, 2019) which posit that: 1) perceptions about the decision problem are imperfect, and 2) decisions are made based on Bayesian posteriors. For instance, Khaw et al. (2017) show that people may exhibit risk aversion when their perceptions about the monetary payoffs of lotteries are noisy. Gabaix and Laibson (2017) account for time discounting and intertemporal preference reversals by agents making Bayesian inference from noisy signals about future rewards. Similarly, Enke and Graeber (2019) demonstrate that the classical inverse S-shaped probability weighting function can arise from Bayesian cognition. They also propose cognitive uncertainty (i.e., subjective uncertainty about the optimal action) as an experimental measure to test predictions of their Bayesian cognition model. What is common between these models and that of contextual deliberation is the postulate that cognition is stochastic and imperfect. However, contextual deliberation is conceptually distinctive in that the decision maker may be uncertain about her preferences even when her perceptions about the parameters of the decision problem are perfect. More importantly, the decision maker can engage in costly activities to reduce her preference uncertainty prior to decision making.

This research is also related to an emerging literature that examines the implications of imperfect information acquisition (normally termed as rational inattention) for decision making (e.g., Sims, 2003; Woodford, 2009). Caplin and Dean (2015) and Matejka and McKay (2015) develop models on state-dependent stochastic choice data. They rationalize some seemingly abnormal choices by costly information acquisition. Bartos et al. (2016) show that discrimination against negatively stereotyped groups can arise endogenously from costly information acquisition prior to deciding whether to reject or accept an application. Their main insight is that prior beliefs and preferences, either positive or negative, can be magnified in screening decisions if ex ante information acquisition is endogenous. Another related research investigates the role of costly contemplation in characterizing preferences over menus (e.g., Ergin and Sarver, 2010). The theory of contextual deliberation shares the common premise that information about preference/utility can be acquired before preferences are revealed. Here I concentrate instead on how endogenous deliberation may rationalize apparently procedure-dependent preferences.

The rest of the paper is organized as follows. In next section the model of contextual deliberation is presented to explain the asymmetric PR phenomenon. The experimental design and procedure are described in detail in Section 3, and predictions from contextual deliberation and other accounts are discussed in Section 4. The experiment results are reported in Section 5. Summary and some further discussion are offered in Section 6.

2. Theory

In this section I present the model of contextual deliberation to account for endogenous procedure dependence in risk preferences under a general information structure. I will show that contextual deliberation can rationalize the asymmetric choice-valuation PR.

2.1. Model setup

The setup is essentially a random parameter model with endogenous deliberation. The decision maker (DM) is a Bayesian expected utility maximizer. Prior to responding to a preference-eliciting task, the DM has imperfect information about a preference parameter and so is unsure about her risk preference. The DM observes a signal on the preference parameter, and responds to the task based on the updated belief. Before receiving the signal, the DM can choose the level of costly deliberation that determines the informativeness of the signal (e.g., Ravid et al., 2019). Therefore, the DM's response to each task involves a two-stage sequential process: the selection of deliberation to improve preference information, and the optimal response to the task conditional on the information acquired from deliberation. Procedure-dependent preferences would arise, as the incentive for deliberation can vary endogenously across elicitation procedures.

The choice-valuation PR is typically demonstrated through within-subjects experiments with lottery pairs of dichotomous outcomes: the P-bet offers a relatively high probability of winning a modest sum of money and zero otherwise, and the \$-bet involves a relatively large winning payoff at a small probability and zero otherwise. Let the P-bet and the \$-bet be $A = (p_A, x_A; 1 - p_A, 0)$ and $B = (p_B, x_B; 1 - p_B, 0)$, respectively, where $x_A < x_B$ are the (positive) high-state outcomes, and $p_A > p_B$ are the corresponding probabilities. Under the standard experimental design (e.g., Tversky et al., 1990, Butler and Loomes, 2007; Loomes and Pogrebna, 2017), the P-bet has lower mean than the \$-bet, i.e., $p_A x_A < p_B x_B$.

I focus on the following parametric utility function that is defined on monetary payoffs:

$$u(x,\theta) = \begin{cases} 0, & \text{for } x = 0; \\ \theta + x, & \text{for } x > 0. \end{cases} \tag{1}$$

where $u(0,\theta) = 0$ reflects normalization, and $\theta \in [\underline{\theta}, \bar{\theta}]$ is a preference parameter capturing the utility difference of the winning payoffs (x_A and x_B) from that of the base payoff (zero). This parsimonious parameterization has the desirable feature that the preference ranking between the P-bet and the \$-bet can satisfy the single-crossing property with respect to θ for different elicitation procedures (Apesteguia et al., 2017, Apesteguia and Ballester, 2018). That is, when the P-bet is preferred over the \$-bet for some θ_1, the same order would be retained for any $\theta_2 > \theta_1$. Thus the parameter θ can be interpreted as capturing the level of risk aversion in current setting.

It is assumed that the DM's true risk preference is not immediately accessible or *ex ante* perfectly known. In particular, the prior belief is that the cumulative distribution function (CDF) for θ is $F(\theta)$, with density $f(\theta)$, mean $\hat{\theta}$, and support on some interval $[\underline{\theta}, \bar{\theta}]$. Nevertheless, the DM can acquire a signal s about θ, which is generated from some joint distribution of θ and s. Conditional on the acquired signal, the posterior mean of θ is $\tilde{\theta} \equiv E[\theta|s]$. Given that the utility function is linear in θ (see (1)), it is without loss of generality to concentrate on $\tilde{\theta}$, which captures all relevant information in the signal. The posterior mean $\tilde{\theta}$ is a random variable from the ex ante perspective (prior to receiving the signal s). Let the CDF of $\tilde{\theta}$ be $H(\tilde{\theta}, \alpha)$, which is conditional on the level of deliberation $\alpha \in [0, 1]$. Let $H(\tilde{\theta}, \alpha)$ be continuous and differentiable in both $\tilde{\theta}$ and α.

The DM can choose deliberation α to determine the informativeness of the signal-generating process, as will be specified later. Deliberation can represent, for example, the recollection of past experiences in similar decisions, the contemplation over the willingness to accept risks, and/or the anticipation about the level of joy the DM may enjoy for a monetary outcome. The following assumptions about the deliberation cost $k(\alpha) \geq 0$ are made to ensure an interior solution for optimal deliberation: $k'(\cdot) > 0$ and $k''(\cdot) > 0$ for all α, $k'(0) \to 0$, and $k'(1) \to +\infty$.

The DM goes through a deliberation-then-response process for each incentive-based task (e.g., choice, certainty/probability equivalent) of a representative lottery pair (A, B) in a preference-eliciting experiment. Conditional on the posterior mean $\tilde{\theta}$ in the second stage, the DM's posterior expected utility for a lottery $L \in \{A, B\}$ is $u_L(\tilde{\theta}) = p_L u(x_L, \tilde{\theta})$. Denote the posterior expected utilities as $u(\tilde{\theta}) = (u_A(\tilde{\theta}), u_B(\tilde{\theta}))$. Let $U_E(d, u(\tilde{\theta}))$ be the objective function for a representative task under an elicitation procedure E, when the DM's response is d and the posterior expected utilities are given by $u(\tilde{\theta})$. The DM's second-stage problem is

$$max_d \; U_E(d, u(\tilde{\theta})). \tag{2}$$

This yields the optimal response d_E^* and the optimal interim utility $U_E(d_E^*, u(\tilde{\theta}))$. In anticipation of this, the DM determines the first-stage optimal deliberation by solving

$$max_\alpha \left\{ U_E(\alpha) \equiv \int_{\underline{\theta}}^{\bar{\theta}} U_E(d_E^*, u(\tilde{\theta}))\; h(\tilde{\theta}, \alpha) d\tilde{\theta} - k(\alpha) \right\}. \tag{3}$$

I now specify how the choice of deliberation α can determine the informativeness of the signal-generating process by influencing $H(\tilde{\theta}, \alpha)$. First, it follows from Bayesian updating that the mean of the posterior mean $\tilde{\theta}$ for any α is constant (equal to the prior mean $\hat{\theta}$), i.e., $\int_{\underline{\theta}}^{\bar{\theta}} \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta} = 0$. The limiting conditions for $H(\tilde{\theta}, \alpha)$ are that it would collapse to an atom at $\tilde{\theta} = \hat{\theta}$ as $\alpha \to 0$ and would approach the prior distribution $F(\cdot)$ as $\alpha \to 1$. Moreover, the rotation order introduced by Johnson and Myatt (2006) is adopted to specify how the informativeness of the preference signal may vary with intermediate levels of deliberation.

Assumption 1. (Rotation order): The family of distributions $H(\cdot, \alpha)$ are rotation ordered, i.e., there exists a rotation point $\theta^+ \in (\underline{\theta}, \bar{\theta})$ such that

$$\frac{\partial H(\tilde{\theta}, \alpha)}{\partial \alpha} > 0 \text{ if } \tilde{\theta} < \theta^+ \text{ and } \frac{\partial H(\tilde{\theta}, \alpha)}{\partial \alpha} < 0 \text{ if } \tilde{\theta} > \theta^+, \text{ for all } \alpha \in (0, 1).$$

Therefore, a higher α improves the informativeness of the signal by yielding a mean-preserving spread for $\tilde{\theta}$, i.e., $\int_{\underline{\theta}}^{z} \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta} > 0$ for all $z \in (\underline{\theta}, \bar{\theta})$. The rotation order encompasses some commonly known models of information acquisition as special case: Gaussian learning in which both the prior distribution $F(\cdot)$ and the marginal distribution for s are normal, and the "truth or noise" setup where s is equal to θ with probability α and is drawn from $F(\cdot)$ with probability $1 - \alpha$.

In standard theories of decision making, it is typically assumed that risk preferences are exogenous, deterministic, and perfectly known to the DM. However, many laboratory experiments demonstrate that participants frequently revise their decisions over time, contexts, and occasions, even for repeated trials of the same decision task (e.g., Hey and Orme, 1994, Ballinger and Wilcox, 1997, Loomes and Sugden, 1998; Hey, 2001). This suggests that risk preferences can be stochastic. Our assumption on preference uncertainty is consistent with this empirical regularity.[2]

[2] The timing to resolve the uncertainty about the realized monetary payoff is exogenously fixed, whereas the preference uncertainty about θ (i.e., risk attitude) can be partially resolved in the deliberation stage or after responding to the experiment tasks. That is, the current model can be interpreted as endogenizing the timing of resolving preference uncertainty, even though the preference domain cannot be simply defined as the space of temporal lotteries (Kreps and Porteus, 1978)

This model is an extension of the theory of contextual deliberation (e.g. Guo, 2016) to decision making under risk.[3] Its gist is that endogenous deliberation may generate the dependence of risk preferences on elicitation procedures. Put it differently, optimal deliberation may systematically vary with normatively equivalent elicitation procedures (i.e., α_E^*) and thus may give rise to procedure-dependent risk preferences, even when the primitives (i.e., the preference and information structures) are completely procedure-free.

2.2. Theoretical results

In this section I apply the theory of contextual deliberation to explain the PR between choice and valuation, two conventional preference-eliciting methods. A standard or predicted choice-valuation PR occurs when the DM chooses the P-bet (lottery A) over the \$-bet (lottery B) but states a higher certainty equivalent for the \$-bet. Conversely, a nonstandard or unpredicted PR is observed when the \$-bet is chosen but given a lower certainty equivalent than the P-bet. The puzzling empirical regularity is that the proportion of participants who exhibit the standard PR is significantly higher than that of the nonstandard PR. Let P_E be the probability that an experiment participant indicates a higher preference for the \$-bet over the P-bet under the elicitation method $E \in \{C, V\}$. With independence between choice and valuation, the proportion of participants who exhibit the standard or the nonstandard PR would be $(1 - P_C)P_V$ or $P_C(1 - P_V)$, respectively. It follows that the asymmetric choice-valuation PR phenomenon would occur if and only if $P_C < P_V$.

I now show that contextual deliberation can endogenously generate the asymmetric choice-valuation PR. Consider the binary choice first. The DM is asked to indicate the preferred lottery between A and B. It is straightforward that the optimal choice in the second stage is $d_C = B$ if and only if $u_A(\tilde{\theta}) < u_B(\tilde{\theta}) \iff \tilde{\theta} < \dot{\theta} \equiv \frac{p_B x_B - p_A x_A}{p_A - p_B}$. Lottery B is preferred to lottery A if and only if the DM perceives that she is not too risk averse. This implies that the probability that lottery B is chosen is $P_C = H(\dot{\theta}, \alpha_C)$, where α_C represents the level of deliberation in the choice task.

Consider then certainty equivalent valuations. Let the DM's stated certainty equivalent for lottery L be d_L. Most studies demonstrating the choice-valuation PR use the classical BDM mechanism (Becker et al., 1964) to elicit the minimum amount the DM is willing to accept in exchange for a lottery. Under this incentive scheme, the DM receives a sure amount of money equal to y if and only if $y \geq d_L$, and obtains the lottery L if otherwise, where y is drawn from a distribution $W(y)$ on $[\underline{y}, \bar{y}]$ with density $w(y)$. Typically $W(\cdot)$ is a uniform distribution. Following (2), the DM's second-stage problem to solve for the minimum certainty equivalent is

$$max_{d_L} \left\{ U_V(d_L, u_L(\tilde{\theta})) = \int_{\underline{y}}^{d_L} u_L(\tilde{\theta})\, w(y)dy + \int_{d_L}^{\bar{y}} (\tilde{\theta} + y)\, w(y)dy \right\}, L = A, B. \tag{4}$$

because the decision task is not intertemporal. On the one hand, there is an inherent or non-instrumental preference for delayed resolution: because of the cost of deliberation, the DM prefers later resolution if no decision were made following the uncertainty resolution. Despite this, the DM may prefer to reduce the preference uncertainty early because of the second, instrumental reason: the information gained from early resolution can guide the response to the experimental task. It is this instrumental and endogenous incentive that is highlighted in the model of contextual deliberation, and applied to explain the choice-valuation PR in this paper.

[3] See Blavatskyy and Kohler (2011) on empirical evidence for effortful deliberation about lottery valuation.

The first-order condition is $u_L(\tilde{\theta}) - (\tilde{\theta} + d_L) = 0$. It yields the optimal response to the certainty equivalent task: $d_L^* = (p_L - 1)\tilde{\theta} + p_L x_L$.[4] It is evident that d_L^* is decreasing in $\tilde{\theta}$. In addition, $d_A^* < d_B^*$ if and only if $\tilde{\theta} < \dot{\theta}$, i.e., the revealed preference between the P-bet and the \$-bet is still determined by the same cut-off point $\dot{\theta}$ as in the choice task. Therefore, the probability that the stated certainty equivalent of lottery B is higher than that of lottery A is $P_V = H(\dot{\theta}, \alpha_V)$, where α_V captures the deliberation level under the valuation task.

The following result obtains immediately from the definition of rotation order (Assumption 1).

Theorem 1. *$P_C < P_V$ if and only if one of the following conditions is satisfied: (i) $\dot{\theta} > \theta^+$ and $\alpha_C^* > \alpha_V^*$; or (ii) $\dot{\theta} < \theta^+$ and $\alpha_C^* < \alpha_V^*$.*

The necessary and sufficient conditions for the asymmetric choice-valuation PR, as presented in Theorem 1, are based on the comparison of the preference cut-off point (i.e., $\dot{\theta}$) with the deliberation rotation point (i.e., θ^+), and on the change of optimal deliberation across the elicitation methods. Intuitively, the asymmetric choice-valuation PR may arise, if optimal deliberation endogenously varies across the elicitation methods to change the distribution of posterior mean at the preference cut-off point $\dot{\theta}$ (in the manner of mean preserving spread/contraction). When the preference cut-off point is higher than the rotation point, the probability that lottery B is preferred would decrease with deliberation, i.e., $\frac{\partial H(\dot{\theta},\alpha)}{\partial \alpha} < 0$ for $\dot{\theta} > \theta^+$ according to Assumption 1. This means that, the probability that lottery B is chosen would be smaller than the probability that its valuation is higher than that of lottery A, if the choice leads to higher deliberation than the valuation does. In contrast, the coin needs to be flipped if the preference cut-off point is lower than the rotation point: because $\frac{\partial H(\dot{\theta},\alpha)}{\partial \alpha} > 0$ for $\dot{\theta} < \theta^+$, it would be necessary and sufficient that optimal deliberation is lower under choice than under valuation.

Then how can the level of optimal deliberation vary across the elicitation methods? This will help us determine which part of the conditions in Theorem 1 is more likely to account for extant experimental findings. Note that the choice-valuation PR experiments typically involve lower means for the P-bet than for the \$-bet (e.g., Tversky et al., 1990, Butler and Loomes, 2007; Loomes and Pogrebna, 2017), which implies that the preference cut-off point $\dot{\theta}$ is positive. So it is likely that $\dot{\theta}$ is higher than θ^+ (if the subjects are close to risk neutrality under the prior belief). This is strongly supported by Berg et al. (2010) in a comprehensive analysis of replication experiments along the original design of Lichtenstein and Slovic (1971). They compare the performance of task-dependent models under which preferences are directly dependent on the elicitation method (e.g., Tversky et al., 1990), with that of noisy maximization models under which the subjects have stable preferences but make random errors at task-dependent rates. They show that, based on 14 datasets that were generated with incentive-compatible instruments, a "two-error-rate" model can fit the observed behavior as well as any model possibly could, and significantly better than models of task-dependent preferences. Their parameter estimates indicate that the overall pattern from previous experiments is consistent with the subjects generally preferring the \$-bet but having a higher error rate for choices than for valuation tasks. These results conform to part (i) condition in Theorem 1: $\dot{\theta} > \theta^+$ and $\alpha_C^* > \alpha_V^*$.

[4] The second-order condition is satisfied at the optimal d_L^*: $[u_L(\tilde{\theta}) - (\tilde{\theta} + d)]w'(d) - w(d) = -w(d) < 0$.

Next, I investigate how optimal deliberation may be affected by the attribute values across the elicitation methods (Theorem 2 and 3), and present sufficient condition for $\alpha_C^* > \alpha_V^*$ (Theorem 4).

Theorem 2. *(i) A higher x_A or x_B first increases and then decreases α_C^*. (ii) A higher p_A increases α_C^* when p_A is relatively low such that $\dot{\theta} > \theta^+$, and decreases α_C^* when p_A is sufficiently high. (iii) A higher p_B increases α_C^* when p_B is sufficiently low, and decreases α_C^* when p_B is relatively high such that $\dot{\theta} > \theta^+$.*

This theorem suggests that changes in the lotteries' attribute values have non-monotonic impact on optimal deliberation under choice. The general pattern is that a sufficiently low attribute value can positively influence α_C^*, but may decrease it when the attribute value becomes sufficiently high. In particular, increasing a lottery's winning payoff (x_A or x_B) leads to an "inverted-U" influence on optimal deliberation. A higher winning probability for lottery A would necessarily increase the incentive for deliberation when p_A is relatively low such that $\dot{\theta} > \theta^+$, whereas the impact would become ambiguous when p_A is relatively high such that $\dot{\theta} < \theta^+$. Nevertheless, the impact of p_A on α_C^* would be negative when p_A becomes sufficiently high. Analogously, the impact of a higher winning probability for lottery B on optimal deliberation would be unambiguously negative when p_B is relatively high such that $\dot{\theta} > \theta^+$, would become ambiguous when p_B is relatively low such that $\dot{\theta} < \theta^+$, and would be positive for sufficiently low p_B.

These results are driven by two possible effects exerted by the attribute values on the information value of deliberation. First, the attribute values can affect the probability that the chosen lottery may actually be suboptimal (according to the true risk preference that is imperfectly known). Intuitively, as the lotteries become more similar to each other in the attribute space, choice would be less decisive and the DM would be increasingly unsure which lottery is truly optimal. This would then increase the incentive of acquiring more information to improve the choice. In particular, all else being equal, the marginal value of deliberation would be higher as changes in the attribute values move the preference cut-off point $\dot{\theta}$ closer to the rotation point θ^+. Second, the lotteries' winning probabilities can influence the size of expected utility loss in case a suboptimal choice is made. This is because the marginal impact of the preference parameter θ on a lottery's expected utility is proportional to its winning probability. As a result, the expected utility loss of choosing the "wrong" lottery would be higher as the difference between the lotteries' winning probabilities (i.e., $p_A - p_B$) becomes larger, thus prompting the DM to deliberate more.

Therefore, a lottery's winning payoff (x_A or x_B) would first increase and then decrease optimal deliberation, by making the lotteries more or less similar to each other, respectively. Similarly, a higher winning probability (p_A or p_B) can first increase and then decrease the incentive of deliberation by affecting the likelihood of suboptimal choice. However, this effect may not be in the same direction as the above-mentioned second effect on the expected utility loss (conditional on the chosen lottery being suboptimal), which is always positive for p_A and negative for p_B. As a result, the net impact of increasing a lottery's winning probability on α_C^* ceases to exhibit an "inverted-U" pattern, but may have an ambiguous sign. The ambiguity may arise if p_A is relatively high or p_B is relatively low (i.e., when $\dot{\theta} < \theta^+$). Nevertheless, when p_A becomes sufficiently high (or p_B becomes sufficiently low), the first force on the chance of making "mistaken" choice would become dominant to restore the negative effect of p_A (or the positive effect of p_B) on optimal deliberation.

Theorem 3. *A higher p_A or p_B decreases α_V^*.*

The impact of the attribute values on optimal deliberation under certainty equivalent valuations is qualitatively different from that under choice. This is because the information value of deliberation differs endogenously across the incentive schemes of the elicitation methods. The DM's response under the BDM mechanism does not directly influence how much to receive, but only determines the likelihood to obtain the presented lottery or a sure amount that is equal to the stated valuation d_L^* at the margin. As the lottery's winning probability (p_A or p_B) increases, the correlation between the expected utilities of these two options would be higher. In addition, the stated valuation d_L^* would be less sensitive to variations in the acquired preference signal (i.e., the posterior mean $\tilde{\theta}$). Therefore, as a lottery's winning probability increases, the value of information will be smaller and the DM will unequivocally deliberate less. This is the case for either the P-bet or the \$-bet, and irrespective of the preference cut-off point $\dot{\theta}$ or the structure of deliberation (e.g., the rotation point θ^+). This result contrasts strikingly with the case of binary choice, because the DM does not need to make a direct tradeoff between the bets under the valuation task.

Theorem 4. *$\alpha_C^* > \alpha_V^*$ if p_A is sufficiently high and $\dot{\theta}$ is sufficiently close to θ^+.*

This theorem gives a sufficient condition for optimal deliberation under choice to be higher than that under valuation. It features attribute values that tend to maximize the incentive of deliberation under choice (see Theorem 2): the winning probability for the P-bet is sufficiently high while at the same time the preference cut-off point $\dot{\theta}$ is sufficiently close to θ^+. In contrast, under these attribute values, the marginal impact of deliberation on the ex ante expected gross surplus for valuing lottery A converges to zero, and that for valuing lottery B is clearly lower than that for the choice task. The is because the optimal interim utility arising from valuing lottery B is a "less convex" function of $\tilde{\theta}$ than that for the choice problem. Intuitively, the potential utility loss in the case of making suboptimal decision is lower for continuous responses (e.g., valuation) than for discrete responses (e.g., choice). Therefore, the DM would desire to deliberate more to make better informed choice.

Note that the attribute values presented in Theorem 4 are highly consistent with those used in standard choice-valuation PR experiments (e.g., Tversky et al., 1990). This suggests that the contextual deliberation interpretation for the asymmetric choice-valuation PR is not merely a theoretical possibility. It does have face validity, and as explained above is compatible with the general pattern across many previous replication experiments (Berg et al., 2010). Moreover, as can be seen from the following corollary, contextual deliberation can generate ancillary predictions that conform to previous studies.

Corollary 1. *The variability of d_L^* is decreasing in p_L.*

This implies that d_A^* is less variable than d_B^*, which can account for a common empirical pattern in the literature. For instance, MacCrimmon and Smith (1986) and Butler and Loomes (2007) show that the interval of certainty equivalents for the P-bet is narrower than that for the corresponding \$-bet. Similarly, it is normally found that the standard deviations of certainty equivalents for P-bets are smaller than those for \$-bets (e.g., Tversky et al., 1990).

2.3. Discussions and extensions

I discuss several assumptions of the model and consider some extensions. Note that the DM has the same preference parameter θ (and posterior mean $\tilde{\theta}$) for both the P-bet and the \$-bet within a lottery pair. This guarantees monotonicity of monetary payoffs while permitting random preferences, i.e., the realized utility of x_A is always lower than that of x_B for all $x_A < x_B$. This assumption would hold even with sequential information processing and evaluation across the paired lotteries, as long as the belief on the initially processed lottery gets to be updated (from the signal acquired for the second lottery) before a final decision is made between them.

In addition, it is intentionally assumed that the deliberation structure is independent and identical across the choice and the valuations for a lottery pair. This essentially rules out any task-order effect (e.g., information spillover) as a potential account for the choice-valuation PR. It is also consistent with the design of standard experiments in the literature, where the choice tasks for all lottery pairs are temporally separated (with time break, additional instructions, or filler questions) from the valuation tasks (e.g., Grether and Plott, 1979). Nevertheless, as will be discussed subsequently in this paper, considering information spillover across valuation and choice can better organize the data of the paper.

Moreover, as a norm in the literature, responses across different lottery pairs are treated as independent. In the current setting this implies that the posterior means $\tilde{\theta}$ are distributed independently across lottery pairs. The motivation of the assumption is mainly for convenience. Nevertheless, it is not overly implausible, since the choice-valuation PR experiments typically involve substantially different attribute values across lottery pairs and task-order effects are normally controlled (through random trials or counterbalanced experimental design).[5]

Another implicit assumption is that the two paired bets are presented and valued simultaneously. This implies that, as in binary choice, the same posterior belief would be shared across the paired P-bet and \$-bet. The joint-valuation design is indeed adopted in some experiments (e.g., Wedell and Bockenholt, 1990). However, there are other studies where the subjects are shown and asked to value each lottery independently (e.g., Grether and Plott, 1979). Under the alternative separate-valuation design, the DM may generate disparate posterior beliefs for different lotteries within a pair, thus constituting another difference from the corresponding choice task. Nevertheless, the model of contextual deliberation can be readily applied to explain the asymmetric PR between choice and separate valuations. As shown in Appendix A, one sufficient condition for this to happen is basically similar to that for joint valuations (i.e., part (i) of Theorem 1, Theorem 4, and the prior mean $\hat{\theta}$ is higher than or not too much below the preference cut-off point $\dot{\theta}$).

Asymmetric PR can also arise between choice and probability equivalents. In a probability equivalent task, the DM is asked to state the minimum probability d_{RL} to receive a reference payoff x_R in exchange for the lottery $L \in \{A, B\}$, where $x_R > x_B > x_A$. As shown in the experiment of Butler and Loomes (2007), the proportion of participants who choose the \$-bet but state a higher probability certainty for the P-bet is significantly larger than the proportion of those who choose the P-bet but state a higher probability certainty for the \$-bet.[6] In addition, the in-

[5] Note that the utility specification in (1) can also represent imperfect perception about true attribute values (i.e., monetary payoffs). Under this alternative interpretation (as suggested by a reviewer), it would be easier to justify that preferences and beliefs are independent across lottery pairs with considerably varying attribute values.

[6] See also MacCrimmon and Smith (1986) and Cubitt et al. (2004) who find that, in an alternative setting with $x_B > x_R > x_A$, both kinds of reversals are roughly frequent.

terval widths and the variability of probability equivalents are larger for the P-bet than for the \$-bet. These phenomena are seldom studied in the literature, but they demonstrate stimulating patterns that are opposite to those for certainty equivalents. However, the underlying rationale has not been systematically examined in previous research, except the graphic illustration and empirical findings presented by MacCrimmon and Smith (1986) and Butler and Loomes (2007).

In Appendix A I apply the theory of contextual deliberation to account for asymmetric PR between choice and probability equivalents. It is shown that contextual deliberation can generate qualitatively different patterns for probability equivalents from those for certainty equivalents, as found in Butler and Loomes (2007). In particular, optimal deliberation for probability equivalent tasks is increasing in the lotteries' winnings probabilities (p_A or p_B) and decreasing in the winning payoffs (x_A or x_B). This implies that the marginal value of deliberation is higher for the P-bet than for the \$-bet. In addition, the interval widths and the variability of the stated probability equivalents are increasing in p_A or p_B and decreasing in x_A or x_B, and hence d^*_{RA} has wider interval and larger variability than d^*_{RB}. These results basically reverse those for certainty equivalents (e.g., Theorem 3, Corollary 1). Moreover, there exist conditions for the observed asymmetry between choice and probability equivalents: the DM may generally prefer the \$-bet but deliberate more to exhibit a higher tendency to report a larger probability equivalent for the P-bet. Therefore, the theory of contextual deliberation can accommodate not only the conventional asymmetric PR involving certainty equivalents, but also its mirror image involving probability equivalents.

3. Experimental design and procedure

A lab experiment was conducted to test some predictions of contextual deliberation and identify it from other potential explanations of the choice-valuation PR. The main ingredient of the experimental design is the ordinal payoff scheme. Its distinctive feature is that, although each lottery is measured on a monetary scale, what matters for a lottery pair is not their absolute valuations but their relative order: only the lottery with a higher stated valuation may be played out for real. Variants of this scheme have been employed in previous studies (Cox and Epstein, 1989; Tversky et al., 1990; Cubitt et al., 2004). The novelty of current experiment is a between-subjects design to manipulate whether the subjects were ex ante informed of the pairing of lotteries in the implementation of the ordinal payoff scheme. In particular, when responding to the valuation tasks, subjects in the *unknown pairing* (UP) group did not know how the lotteries had been paired by the experimenter, whereas those in the *known pairing* (KP) group did.

The experimental stimuli were 18 distinct lottery pairs, each consisting of one P-bet and one \$-bet. A lottery was described as a probability to win a positive amount of money (and zero otherwise), and played out by rolling two 10-faced dice. As shown in Table 1, the 18 pairs were divided into 3 sets and no lottery appeared in more than one pair. The attribute values and the pairing of the lotteries were pre-determined and adapted from those in prior research. Note that each of the 18 P-bets had lower mean than the paired \$-bet.

The experiment was run on computers. The subjects were randomly allocated to either the UP or the KP group (59 participants in each group). Upon arriving at the lab, each subject was seated at a desktop computer and assigned a hard copy of the experiment instructions. The instructions were presented loudly by the experimenter through projected PowerPoint slides. At the beginning of the experiment, the subjects were presented an example of a lottery. They were told that the experiment would involve 18 lottery pairs and that, for each pair, they would complete two valuations and one choice in two separate parts, respectively. One example for each type of

Table 1
The lottery pairs.

Set	Pairs	1	2	3	4	5	6
I	P-Bet	(0.97, 40)	(0.81, 20)	(0.94, 30)	(0.89, 40)	(0.94, 25)	(0.92, 20)
	$-Bet	(0.31, 160)	(0.19, 90)	(0.50, 65)	(0.11, 400)	(0.39, 85)	(0.50, 50)
II	P-Bet	(0.97, 80)	(0.81, 40)	(0.94, 60)	(0.89, 80)	(0.94, 50)	(0.92, 40)
	$-Bet	(0.31, 320)	(0.19, 180)	(0.50, 130)	(0.11, 800)	(0.39, 170)	(0.50, 100)
III	P-Bet	(0.70, 120)	(0.80, 96)	(0.78, 100)	(0.94, 40)	(0.92, 105)	(0.89, 95)
	$-Bet	(0.30, 320)	(0.25, 400)	(0.08, 1000)	(0.03, 1500)	(0.06, 1650)	(0.08, 1200)

Note: Each lottery (P, X) denotes a bet that offers a probability P to win HK$X. The lotteries in Set I were adapted from Tversky et al. (1990), Set II was obtained by doubling all payoffs in Set I, Pairs III1-2 were adapted from Loomes and Pogrebna (2017), and Pairs III3-6 were adapted from Tversky et al. (1990). The following lotteries were used as examples in the experiment instructions: (0.67, 80), (0.96, 25), and (0.42, 70).

task was elaborated. In a valuation task the subjects would be asked to state the exact money amount (in natural number) such that they were indifferent between the amount of money and the presented lottery. In a choice task the subjects were asked to indicate the one they would prefer to play between a pair of lotteries, or to check the "Indifferent" option.

Next, the experimenter went through the details of the ordinal payoff scheme. The subjects were told that, at the end of the experiment, one of the 18 lottery pairs would be selected with equal probability, separately for each subject, by rolling two 6-faced dice. They would throw a 6-faced die again to determine whether they would play the preferred lottery from the valuation part or from the choice part. In case indifference was indicated, the computer would randomly select one of the two lotteries. A subject would be paid an amount according to the outcome of playing the drawn lottery, in addition to a HK$40 participation fee.

After the instructions were explained, the subjects were directed to respond to two quiz questions on their computer about each of two example lotteries. They were then prompted to ask questions before being given a passcode to start the experiment. Part I of the experiment included 36 valuation responses, which were followed by 18 choice tasks in Part II. A computer page was comprised of either two valuations or one choice, for one of the 18 lottery pairs. The lottery pairs were presented in random order for each subject within each part. After responding to all tasks, the subjects were asked to fill up a survey of demographic information. The payoff scheme was then executed based on the subjects' indicated preferences.

To implement the experiment manipulation, although the two valuations in a computer page were *always* from the same lottery pair (i.e., joint evaluation), the KP subjects were ex ante informed of this but the UP subjects were not. Subjects in the UP group were instructed that they would know how the 36 lotteries were paired once they proceeded from the valuation to the choice part of the experiment, whereas those in the KP group were told that the 36 lotteries were paired in the same way in either the valuation or the choice part. In addition, there were some minor differences in the stimuli of valuations across the two groups. For the UP group the two valuations within a computer page were presented as separate tasks, whereas for the KP group as two responses under one task (i.e., the display of both lotteries' attribute values was above the space to indicate both lotteries' valuations). Only subjects in the KP group were reminded, at the bottom of each valuation page, that they would play the lottery they valued higher if this particular task would be randomly selected at the end of the experiment. For both groups, the order of presenting the two lotteries within a computer page was random for either valuation or choice.

The subjects were recruited via a university system that sends weekly mass emails to the whole community. The only exclusion criterion was that nobody could participate more than once. The experiment consisted of 14 sessions. An experimental session lasted about 50 minutes. Average payment to each subject was about HK$117 (including HK$40 participation fee).

4. Predictions and alternative explanations

Many explanations have been proposed to potentially account for the asymmetric choice-valuation PR under the conventional incentive device (i.e., the BDM mechanism). However, contextual deliberation yields unique predictions for current experimental manipulation under the ordinal payoff scheme. This allows us to empirically identify contextual deliberation from other accounts, including two general classes of economic models and two psychological hypotheses.

The first prediction of contextual deliberation is that the proportion of standard PR relative to that of nonstandard PR is higher for the UP group than for the KP group. This is because the valuation problem can be influenced by the availability of information on lottery pairing. Under unknown pairing where the subjects value each bet without being informed about other paired bet, a valuation task amounts to stating a threshold number to determine whether the current bet or another ambiguous bet will be played. This can be interpreted as a modified BDM mechanism, obtained by replacing the randomly generated amount y in (4) with the expected payoff from an uncertain lottery.[7] Therefore, depending on whether the pairing of the lotteries is ex ante known or not, the valuation tasks under the ordinal payoff scheme can be logically akin to either binary choices or valuations under the traditional BDM mechanism, respectively. As a result, to the extent that the relative preference for the $-bet over the P-bet is lower in choice than in valuation tasks under the standard incentive scheme (Theorem 1), known pairing should yield less asymmetric PR than unknown pairing does.

H1a. The frequency of valuing the $-bet more highly over the paired P-bet is smaller for the KP group than for the UP group.

H1b. The frequency of standard reversals relative to that of nonstandard reversals is smaller for the KP group than for the UP group.

This prediction is consistent with results across previous experiments that adopted variants of the ordinal payoff scheme. Unknown pairing was used in Tversky et al. (1990) and Cubitt et al. (2004). They find that the reversal between choice and valuation was comparable, in direction and significance, with other studies in the literature. In contrast, when the pairing of lotteries was ex ante known, asymmetric PR was not observed (Cox and Epstein, 1989). Nevertheless, there were other notable discrepancies in the design/procedure of these experiments that may confound the

[7] Similarly, Alos-Ferrer et al. (2016) consider an ordinal payment scheme whereby a subject is asked to state the minimum selling price separately for each of a set of lotteries but only the induced ordering between two *randomly selected* lotteries matters. They show that this scheme generated standard and nonstandard reversals that were comparable to those under the BDM mechanism.

strikingly different results.[8] The current research is the first, using a randomized manipulation, to systematically investigate the effect of the pairing information on the asymmetric PR.

The second prediction is about how contextual deliberation may influence the distribution of posterior beliefs (i.e., mean-preserving spreads). To the extent that the asymmetric PR is caused by choices yielding higher deliberation than valuations (Theorem 1 and 4), the manipulation between known and unknown pairing can result in a similar impact on the valuation tasks of these two groups. That is, known pairing may lead to higher deliberation in the valuation tasks than unknown pairing does, implying the same mean in the posterior preference parameter $\tilde{\theta}$ across the two groups but higher dispersion for the KP group. This means that, if the same affine transformation (i.e., shift and scale) is applied by the subjects across the two groups, their stated valuations d_L (for either P-bet or \$-bet) would exhibit the same mean but higher dispersion for the KP group. Similarly, if the same scale transformation is used across groups and the same within-subjects shift transformation applied within a lottery pair, the mean of the difference in stated valuations $(d_B - d_A)$ should be invariant across groups while the dispersion would be higher for the KP group.

H2a. The mean of stated valuation (d_L) is preserved between the KP and the UP groups, but the variance is larger for the KP group than for the UP group.

H2b. The mean of the difference in stated valuations $(d_B - d_A)$ is preserved between the KP and the UP groups, but the variance is larger for the KP group than for the UP group.

Next, I discuss how other potential accounts for the asymmetric PR may lead to qualitatively different predictions from those of contextual deliberation. One class of economic models explain the asymmetric PR by relaxing the independence/reduction axioms of the expected utility theory while assuming procedure-independent deterministic preferences (e.g., Holt, 1986; Karni and Safra, 1987; Segal, 1988). They show that standard incentive schemes (e.g., the BDM mechanism, the random incentive system) may, by generating compound lotteries, bias stated preferences over simple lotteries. For instance, a subject who strictly prefers a mixture of lotteries A and B to either individual lottery may appear to exhibit reversed preferences by deliberately randomizing responses (Agranov and Ortoleva, 2017; Cerreia-Vioglioy et al., 2019). However, as argued by Tversky et al. (1990) and Cubitt et al. (2004), such preference for randomization can hardly account for the asymmetric PR under the ordinal payoff scheme. This is because the randomization can be realized in two equivalent ways: either choosing A and valuing B more highly, or choosing B and valuing A more highly. Put it differently, reversals due to deliberate randomization should be symmetric. Importantly, the randomization can be realized even without knowing how the lotteries are paired in the valuation tasks: irrespective of which lottery is valued more highly, the subject can subsequently choose the other lottery. As a result, this class of models would predict that there is no systematic difference between the UP and the KP groups in terms of either choice or valuation, and that the asymmetric PR cannot arise for either group.

Another stream of economic models assume exogenously stochastic preferences. As discussed in Loomes (2005), random preference models (e.g., Loomes and Sugden, 1995;

8 For example, joint valuation was used in Cox and Epstein (1989), but separate valuation considered in Tversky et al. (1990) and Cubitt et al. (2004). In addition, no incentive scheme was actually implemented for all subjects in Tversky et al. (1990), whereas the income effects were not controlled and the lottery payoffs were framed differently across the choice and valuation tasks in Cox and Epstein (1989).

Gul and Pesendorfer, 2006) can account for the asymmetric PR between choice and separate valuation. However, they cannot explain the asymmetric PR for joint valuation (Wedell and Bockenholt, 1990), because any preference relation that entails choosing the P-bet would necessarily lead to a lower valuation for the \$-bet, and vice versa. In addition, although the "strong utility" models (e.g., Hey and Orme, 1994; Loomes, 2005) can yield the systematic PR by making the ad hoc assumption that the error rate is greater for certainty equivalent valuation than for choice, their additive "utility+error" specification cannot accommodate the shift of preferences for the majority of experiment participants across the elicitation methods. Moreover, these stochastic-preference models predict no systematic impact of current manipulation where joint valuation was used across the UP and the KP groups.

Psychological hypotheses typically presume that preferences are procedure dependent, exogenously. Tversky et al. (1988) formulate the *prominence hypothesis* that some attribute is presupposedly important and weighs more heavily in choice than in matching tasks. This hypothesis can explain the asymmetric PR if the winning probability of lotteries is interpreted as the prominent attribute and monetary valuations as matching tasks (Tversky et al., 1990). Tversky et al. (1988) also propose the *scale compatibility hypothesis*, i.e., the relative weight for an attribute increases with its compatibility with the evaluation scale. They assert that the payoff attribute is compatible with the monetary valuation scale and thus weighs more heavily in valuation than in choice. This scale compatibility hypothesis has since become the prevalent explanation for the asymmetric choice-valuation PR.

Both psychological hypotheses predict the asymmetric PR for either unknown or known pairing. However, they would predict no systematic discrepancy between the responses of the two groups, in terms either of choices or of preference order or distribution of stated valuations.

5. Experiment results

The experiment results are reported in this section. A subject's responses to both the valuation and the choice tasks of a lottery pair were excluded, if a tied preference for either task was indicated.[9] This ensures unambiguous classification of behavioral pattern across the two elicitation methods.

I start with investigating the behavior of the UP group. For each lottery pair and each elicitation method, the proportion of strictly preferring a \$-bet over the corresponding P-bet is presented in Table 2. The null hypothesis is tested, separately for each of the 18 lottery pairs, that the proportion of instances with a relatively higher rank for the \$-bet was the same across choice and valuation. In each case, the alternative hypothesis is overwhelmingly favored that the UP subjects were less likely to prefer the \$-bet in choice compared with valuation, using a two-tailed paired-samples Student's t-test and a significance level of less than 0.01 (less than 0.001 for 15 cases). Similar striking results can be obtained if the Wilcoxon signed-rank (hereafter WSR) tests are conducted instead. Pooling across all lottery pairs, a \$-bet was preferred in only 40 percent of choices but in 83 percent of valuations, a significant difference at less than

[9] The number of removed observations at the subject-lottery pair level are 153 (14 percent) and 108 (10 percent) for the UP and the KP group, respectively. If these observations were included, standard reversals would have been increased more than nonstandard ones, and the asymmetric PR pattern would have been stronger for the UP than for the KP group, irrespective of whether the tied responses were classified in favor of the P-bets or the \$-bets. Moreover, the other results are robust to the inclusion of the tied responses. Therefore, including these observations would strengthen, ranter than weaken, the main results in support of predictions of contextual deliberation.

Table 2
Comparing proportions of preferring $-bets between choice and valuation.

Lottery Pair		UP Group					KP Group				
		n	Choice	Valuation	Paired-Samples t	Wilcoxon Signed-Rank z	n	Choice	Valuation	Paired-Samples t	Wilcoxon Signed-Rank z
I	1	53	0.51	0.87	−4.996 (<0.001)	−4.146 (<0.001)	54	0.39	0.63	−3.233 (0.002)	−2.982 (0.003)
	2	43	0.49	0.81	−3.313 (0.002)	−2.985 (0.003)	44	0.57	0.64	−0.903 (0.372)	−0.905 (0.366)
	3	46	0.52	0.85	−3.696 (0.001)	−3.273 (0.001)	52	0.60	0.73	−1.849 (0.070)	−1.807 (0.071)
	4	50	0.40	0.84	−5.088 (<0.001)	−4.158 (<0.001)	53	0.43	0.60	−2.020 (0.049)	−1.964 (0.050)
	5	48	0.65	0.94	−4.013 (<0.001)	−3.500 (<0.001)	52	0.65	0.71	−1.000 (0.322)	−1.000 (0.317)
	6	47	0.66	0.94	−3.808 (<0.001)	−3.357 (0.001)	48	0.71	0.79	−1.159 (0.252)	−1.155 (0.248)
II	1	56	0.36	0.88	−7.189 (<0.001)	−5.209 (<0.001)	55	0.33	0.60	−3.614 (0.001)	−3.273 (0.001)
	2	44	0.48	0.95	−5.364 (<0.001)	−4.200 (<0.001)	50	0.36	0.54	−2.436 (0.019)	−2.324 (0.020)
	3	52	0.42	0.87	−5.915 (<0.001)	−4.600 (<0.001)	53	0.43	0.60	−2.133 (0.038)	−2.065 (0.039)
	4	57	0.23	0.79	−7.921 (<0.001)	−5.488 (<0.001)	57	0.37	0.46	−1.150 (0.255)	−1.147 (0.251)
	5	52	0.52	0.88	−4.201 (<0.001)	−3.657 (<0.001)	56	0.46	0.71	−3.416 (0.001)	−3.130 (0.002)
	6	47	0.62	0.94	−3.936 (<0.001)	−3.441 (0.001)	53	0.64	0.77	−1.995 (0.051)	−1.941 (0.052)
III	1	49	0.41	0.71	−3.136 (0.003)	−2.887 (0.004)	52	0.35	0.52	−2.431 (0.019)	−2.324 (0.020)
	2	49	0.24	0.76	−5.246 (<0.001)	−4.226 (<0.001)	55	0.33	0.51	−2.839 (0.006)	−2.673 (0.008)
	3	53	0.11	0.72	−8.273 (<0.001)	−5.488 (<0.001)	55	0.31	0.47	−2.425 (0.019)	−2.324 (0.020)
	4	54	0.31	0.80	−6.546 (<0.001)	−4.914 (<0.001)	53	0.28	0.62	−4.473 (<0.001)	−3.838 (<0.001)
	5	55	0.16	0.69	−7.250 (<0.001)	−5.209 (<0.001)	55	0.25	0.40	−2.058 (0.044)	−2.000 (0.046)
	6	54	0.24	0.78	−7.315 (<0.001)	−5.209 (<0.001)	57	0.26	0.46	−3.038 (0.004)	−2.840 (0.005)

Note: Tests of the equality, between choice and valuation, of the proportions of strictly preferring a $-bet over the corresponding P-bet, for each lottery pair and each group (UP: unknown pairing; KP: known pairing). Responses with tied preferences are excluded. Two-tailed tests for paired-samples Student's t tests. P values in the parenthesis.

0.001 for either the Student's t or the WSR test. Fig. 1 displays the average percentage of lottery pairs per subject for which a $-bet was preferred over the paired P-bet, separately for choice and valuation. It is evident that the UP subjects chose a $-bet for sweepingly less lottery pairs than they valued it more highly (average 40 percent versus 82 percent, significant at less than 0.001 for either type of test).

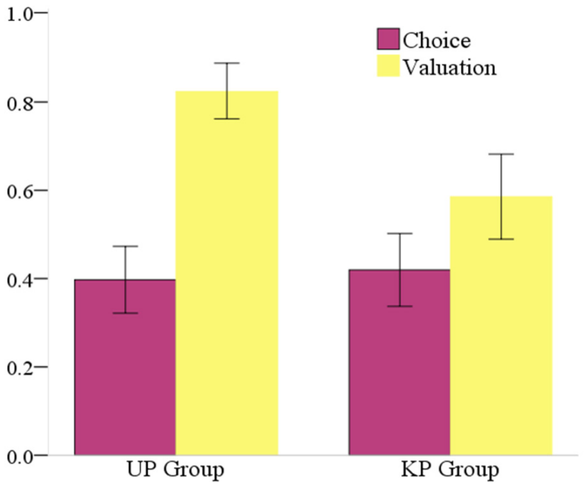

Fig. 1. Average proportions of preferring $-bets. Note: Subject-level proportions (across lottery pairs). Error bars for 95% confidence interval.

Table 3
Frequencies of response types.

Lottery Pair	UP Group					KP Group				
	n	Consistent (P-bet)	Nonstandard PR	Standard PR	Consistent ($-bet)	n	Consistent (P-bet)	Nonstandard PR	Standard PR	Consistent ($-bet)
I 1	53	6	1	20	26	54	17	3	16	18
2	43	4	4	18	17	44	12	4	7	21
3	46	4	3	18	21	52	10	4	11	27
4	50	5	3	25	17	53	15	6	15	17
5	48	2	1	15	30	52	12	3	6	31
6	47	2	1	14	30	48	6	4	8	30
II 1	56	6	1	30	19	55	19	3	18	15
2	44	0	2	23	19	50	20	3	12	15
3	52	6	1	24	21	53	16	5	14	18
4	57	11	1	33	12	57	24	7	12	14
5	52	2	4	23	23	56	13	3	17	23
6	47	1	2	17	27	53	9	3	10	31
III 1	49	8	6	21	14	52	22	3	12	15
2	49	7	5	30	7	55	25	2	12	16
3	53	14	1	33	5	55	26	3	12	14
4	54	10	1	27	16	53	18	2	20	13
5	55	16	1	30	8	55	29	4	12	10
6	54	11	1	30	12	57	29	2	13	13

Note: Frequencies of different types of responses across the choice and valuation tasks, for each lottery pair and each group (UP: unknown pairing; KP: known pairing). Responses with tied preferences are excluded.

For any given lottery pair, a subject's responses across the choice and valuation tasks can be classified into one of four types: consistent preference for P-bet, nonstandard PR, standard PR, and consistent preference for $-bet. The frequency of each type of behavior is reported in Table 3, for each lottery pair. It is apparent that standard PRs were overwhelmingly more frequent

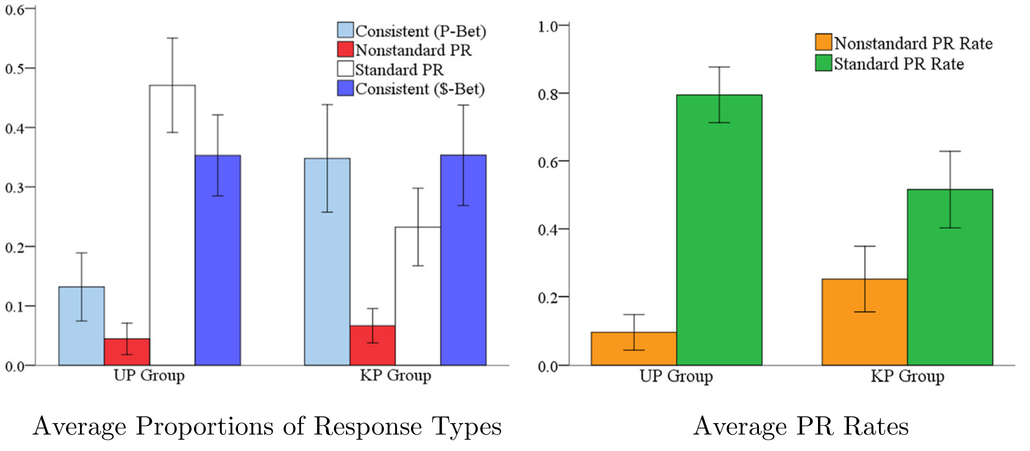

Fig. 2. Average proportions of response types and PR rates. Note: Subject-level proportions/rates (across lottery pairs). Error bars for 95% confidence interval.

than nonstandard PRs for the UP subjects. Overall, of the 909 response pairs, 470 (52 percent) involved reversals: 431 (47 percent) were standard and only 39 (4 percent) were nonstandard. Fig. 2 (left panel) provides a visual summary of the average proportion of lottery pairs per subject that are classified as a particular response type. For average UP subjects, the proportion of lottery pairs was obviously higher for standard than for nonstandard reversals (47 percent versus 4 percent, significant at less than 0.001 for either the Student's t or the WSR test).

Following the literature (e.g., Grether and Plott, 1979), conditional reversal rates are also examined. The standard (nonstandard) PR rate is defined as the number of standard (nonstandard) reversals divided by the number of P-bet ($-bet) choices. The comparison between these conditional measures allows us to take into consideration the impact of uneven preference across the bets on the asymmetric PR phenomenon. According to stochastic-preference models, for example, if the likelihood of choosing P-bets was basically larger than that of $-bets, the number of standard reversals could be higher than that of nonstandard ones, even though inherent preferences were invariant across elicitation methods. Aggregating across lottery pairs, the PR rates were 0.79 and 0.11 for the standard and the nonstandard reversals of the UP subjects, respectively, indicating a substantially larger disparity than that implied by the unconditional reversal measures (0.47 and 0.04). Alternatively, the PR rates can be computed across lottery pairs for each subject. Fig. 2 (right panel) displays the average PR rates per subject. The standard PR rates were significantly higher than the nonstandard ones for the UP group (average 0.79 versus 0.09; two-tailed paired-samples Student's t-test, n=49, t=12.785, $p < 0.001$; WSR test, n=49, z=-5.876, $p < 0.001$).

Result 1. For the UP group, the $-bet was significantly less likely to be preferred over the paired P-bet in choice than in valuation, and the frequency/rate of standard PR was significantly lower than that of nonstandard PR.

Next, I test the hypotheses by comparing the KP and the UP groups. How did the treatment on pairing information influence behavior? Table 2 reveals that, compared to the UP group, it becomes easier to accept the null hypothesis that the proportion of strictly preferring a $-bet was the same across choice and valuation for the KP group. The null of equal proportion cannot be

Table 4
Comparing proportions of preferring \$-bets between KP and UP groups.

Lottery Pair		Choice				Valuation			
		Independent Samples t	P Value	Mann-Whitney-U z	P Value	Independent Samples t	P Value	Mann-Whitney-U z	P Value
I	1	−1.251	0.214	−1.248	0.212	−2.932	0.004	−2.824	0.005
	2	0.739	0.462	−0.741	0.459	−1.873	0.065	−1.842	0.065
	3	0.734	0.464	−0.737	0.461	−1.427	0.157	−1.402	0.161
	4	0.346	0.730	−0.348	0.728	−2.757	0.007	−2.651	0.008
	5	0.083	0.934	−0.084	0.933	−3.112	0.003	−2.924	0.003
	6	0.506	0.614	−0.508	0.611	−2.084	0.040	−2.038	0.042
II	1	−0.329	0.743	−0.330	0.741	−3.429	0.001	−3.282	0.001
	2	−1.144	0.256	−1.145	0.252	−5.317	<0.001	−4.515	<0.001
	3	0.112	0.911	−0.112	0.911	−3.153	0.002	−3.016	0.003
	4	1.643	0.103	−1.631	0.103	−3.875	<0.001	−3.655	<0.001
	5	−0.566	0.572	−0.568	0.570	−2.254	0.026	−2.186	0.029
	6	0.250	0.803	−0.252	0.801	−2.380	0.020	−2.261	0.024
III	1	−0.637	0.525	−0.640	0.522	−2.040	0.044	−2.002	0.045
	2	0.925	0.357	−0.921	0.357	−2.671	0.009	−2.574	0.010
	3	2.553	0.012	−2.474	0.013	−2.646	0.009	−2.571	0.010
	4	−0.356	0.722	−0.357	0.721	−1.995	0.049	−1.971	0.049
	5	1.169	0.245	−1.167	0.243	−3.174	0.002	−3.050	0.002
	6	0.270	0.788	−0.271	0.787	−3.668	<0.001	−3.461	0.001

Note: Tests of the equality, between KP and UP groups, of the proportions of subjects who strictly preferred a \$-bet over the corresponding P-bet, for each lottery pair and each elicitation method. Responses with tied preferences are excluded. Two-tailed tests (assuming unequal variances) for independent-samples Student's t tests.

rejected for 12 (7) lottery pairs at the significance level of 0.01 (0.05), under either the paired-samples Student's t or the WSR test. The magnitude of the preference difference between choice and valuation of the KP group was clearly smaller for any lottery pair.

Formal tests to compare between the groups the proportions of subjects who strictly preferred a \$-bet over the paired P-bet are presented in Table 4. Except for one lottery pair, choice behavior was not significantly different between the groups at 0.05, according to either the two-tailed independent-samples Student's t (assuming unequal variances) or the Mann-Whitney-U (hereafter MWU) test. However, except for two lottery pairs, the null can be rejected in favor of the alternative that the KP subjects were less likely to value the \$-bet more highly than the UP subjects, using either of the two tests. Similar results can be obtained at the aggregate level across lottery pairs: the proportions of choosing \$-bets were 42 percent and 40 percent (Student's t=1.104, p=0.270; MWU z=-1.104, p=0.270), while the proportions of valuing \$-bets more highly were 60 percent and 83 percent (Student's t=-11.647, $p < 0.001$; MWU z=-11.181, $p < 0.001$), for the KP and the UP subjects, respectively. These results are also confirmed by comparing subject-level percentages of preferring the \$-bets that are computed across lottery pairs (Fig. 1). The percentages of lottery pairs with \$-bet choices were close between the KP and the UP groups (average 42 versus 40; Student's t=0.401, p=0.689; MWU z=-0.353, p=0.724), but the KP subjects valued \$-bets more highly for less lottery pairs (average 59 percent versus 82 percent; Student's t=-4.163, $p < 0.001$; MWU z=-3.358, p=0.001). As summarized in the following result, Hypothesis H1a is not rejected.

Result 2. The frequency of choosing the $-bet over the paired P-bet was not significantly different between the KP and the UP groups, but the frequency of valuing the $-bet more highly over the paired P-bet was significantly smaller for the KP group than for the UP group.

The differential impact of pairing information on choices versus valuations was reflected on the PR measures. The general pattern is that the asymmetric PR phenomenon was weaker for the KP group. This can be observed from Table 3: standard PR was less frequent and nonstandard PR was generally more frequent for the KP than for the UP group. Pooling across lottery pairs, even though the percentage of consistently preferring $-bets was invariantly 36, the percentage of inconsistent behavior was reduced from that in the UP group (31 versus 52). More importantly, the percentage of standard PR was lower (24 versus 47; Student's t=-10.955, $p < 0.001$; MWU z=-10.659, $p < 0.001$), and that of nonstandard PR was higher (7 versus 4; Student's t=2.296, p=0.022; MWU z=-2.282, p=0.022), for the KP than for the UP subjects. Regarding subject-level measures in left panel of Fig. 2, even though the percentages of lottery pairs for nonstandard reversals were not significantly different between the groups (average 7 versus 4; Student's t=1.120, p=0.265; MWU z=-1.359, p=0.174), those for standard reversals were significantly lower for the KP group (average 23 versus 47; Student's t=-4.648, $p < 0.001$; MWU z=-4.362, $p < 0.001$).

The difference between standard and nonstandard PR rates was substantially weaker for the KP group as well. Aggregating across lottery pairs, the availability of pairing information made the standard PR rate shrink considerably from 0.79 to 0.41 and the nonstandard PR rate increase slightly from 0.11 to 0.16. This means a remarkable contraction in the asymmetric PR phenomenon. Similarly, as illustrated in right panel of Fig. 2, the subject-level standard PR rates were lower (average 0.48 versus 0.79; Student's t=-4.710, $p < 0.001$; MWU z=-4.169, $p < 0.001$), and the subject-level nonstandard PR rates were higher (average 0.23 versus 0.10; Student's t=2.364, p=0.020; MWU z=-1.850, p=0.064), for the KP than for the UP group. These findings demonstrate that the reversal asymmetry was notably weakened by the experimental treatment (Hypothesis H1b).

Result 3. The frequency/rate of standard reversals relative to that of nonstandard reversals was significantly smaller for the KP group than for the UP group.

Then what could cause the mitigated asymmetry between the reversals? Put it differently, what might yield lower preference orders for $-bets in valuation tasks for the KP than for the UP group? Was it that the KP subjects stated higher valuations for the P-bets, lower valuations for the $-bets, or both? The groups' mean stated valuations are presented in Table 5, for each pair of lotteries (d_A and d_B) and their difference ($d_B - d_A$). The null hypothesis is tested, separately for each case, that the mean valuation was the same between the groups, using a two-tailed independent-samples Student's t-test (assuming unequal variances). It appears that in general the KP subjects had a higher mean P-bet valuation than the UP subjects. But the standard error was large such that the difference was not significant at 0.05 for 14 out of 18 cases. Likewise, the difference in mean $-bet valuation between the groups was insignificant for all cases. In addition, except for one pair, the groups did not differ significantly in the mean of the valuation difference ($d_B - d_A$). These results can be seen at the aggregate level for the P-bets (mean 105 versus 48; t=1.358, p=0.175), the $-bets (mean 204 versus 154; t=1.329, p=0.184), as well as the paired lotteries' differences (mean 98 versus 106; t=-0.339, p=0.735). Similar pattern emerges when the group averages of subject-level mean valuations are compared. As can be observed from Fig. 3,

Table 5
Comparing stated valuations between KP and UP groups.

Lottery Pair		d_A			d_B			d_B-d_A		
		KP	UP	t	KP	UP	t	KP	UP	t
I	1	44	39	0.626 (0.533)	71	75	−0.375 (0.708)	26	36	−0.932 (0.354)
	2	20	15	1.848 (0.070)	33	45	−1.202 (0.234)	13	30	−1.679 (0.098)
	3	30	32	−0.220 (0.826)	42	38	1.079 (0.283)	12	6	0.866 (0.390)
	4	38	30	2.427 (0.017)	168	126	0.548 (0.586)	131	96	0.445 (0.658)
	5	26	22	1.237 (0.219)	44	44	0.014 (0.989)	18	22	−0.729 (0.468)
	6	21	18	0.984 (0.328)	34	32	0.624 (0.534)	14	14	−0.188 (0.852)
II	1	86	68	1.157 (0.252)	140	136	0.171 (0.864)	54	68	−0.744 (0.458)
	2	40	27	2.229 (0.030)	62	83	−1.702 (0.092)	22	56	−2.963 (0.004)
	3	58	48	2.253 (0.026)	72	72	−0.051 (0.959)	14	24	−1.615 (0.110)
	4	70	60	2.073 (0.041)	216	214	0.043 (0.966)	146	154	−0.143 (0.887)
	5	55	42	1.641 (0.105)	79	87	−0.831 (0.408)	24	50	−1.744 (0.084)
	6	39	34	1.296 (0.198)	59	57	0.353 (0.725)	20	23	−0.499 (0.619)
III	1	96	85	0.942 (0.349)	146	138	0.313 (0.755)	50	52	−0.101 (0.920)
	2	82	75	0.746 (0.458)	140	141	−0.032 (0.975)	58	66	−0.349 (0.728)
	3	74	66	1.339 (0.184)	435	252	0.969 (0.336)	362	186	0.934 (0.354)
	4	154	33	1.051 (0.298)	444	289	1.102 (0.274)	291	256	0.378 (0.706)
	5	818	82	1.014 (0.315)	889	496	0.710 (0.480)	71	414	−1.523 (0.132)
	6	102	69	1.598 (0.115)	486	330	0.828 (0.410)	384	261	0.656 (0.514)

Note: Tests of the equality, between KP and UP groups, of the stated valuations for each P-bet (d_A), \$-bet (d_B) and their difference (d_B-d_A). Responses with tied preferences are excluded. Two-tailed independent-samples Student's t tests (assuming unequal variances). P values in the parenthesis.

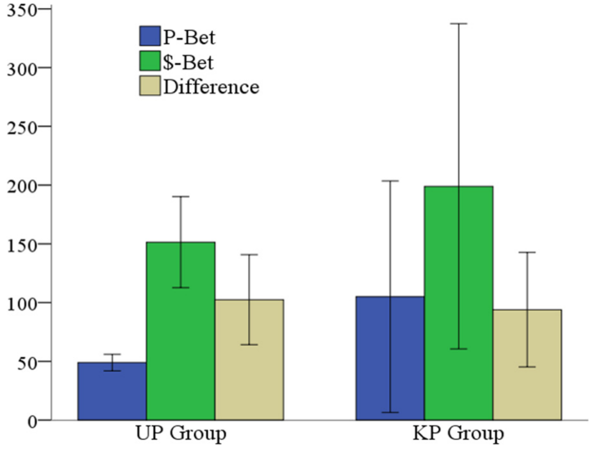

Fig. 3. Average valuations. Note: Subject-level mean valuations (across lotteries). Error bars for 95% confidence interval.

the KP subjects seemed to have higher mean valuations for either the P-bets (group average 105 versus 49; t=1.136, p=0.261) or the \$-bets (group average 199 versus 151; t=0.663, p=0.510), but the standard errors were too large to generate statistical significance. Moreover, the group averages of subject-level mean valuation differences were clearly not different (94 versus 102; t=-0.274, p=0.784).

Therefore, known pairing reduced the subjects' propensity to value a \$-bet higher than the paired P-bet (see Table 4, Fig. 1 and Result 2), without significantly changing their absolute valuations. In other words, the distributions of the stated valuations were affected in the predicted direction, but their means were not, by the pairing information. To further examine the impact of known pairing, the variances of the groups' stated valuations are compared by using Levene's F tests. For the aggregate data, the standard deviations for the KP group were higher than those for the UP group: d_A (1,309 versus 38; F(1, 1861)=3.325, p=0.068), d_B (1,124 versus 287; F(1, 1861)=7.511, p=0.006), and $d_B - d_A$ (629 and 281, F(1, 1861)=3.394, p=0.066). This suggests that known pairing led to mean-preserving spreads in the distributions of stated valuations, for either the P-bets, the \$-bets, or their differences (Hypotheses H2a, H2b).

Result 4. The means of stated valuations (d_A and d_B) and those of valuation differences ($d_B - d_A$) were not significantly different between the KP and the UP groups, but the variances were significantly larger for the KP group than for the UP group.

Note that the subjects' stated valuations should not be literally interpreted as capturing their true valuations for the lotteries. Under the ordinal payoff scheme, what matters is not the absolute values of the subjects' responses, but the comparisons of responses within each lottery pair. As a result, it is not surprising that the stated valuations can be (substantially) higher than the lotteries' winning payoffs. This can be seen from Table 5, especially for the KP group's P-bet valuations. In this regard, what is more relevant for testing the mean-preserving-spread property of contextual deliberation across the groups should be the valuation differences ($d_B - d_A$).

Nevertheless, it happened that the subjects' stated valuations were not completely uninformative in reflecting their true valuations across the lotteries. This can be readily observed from Table 5 by comparing each of the 12 lotteries in Set I with the corresponding lottery in Set II for each group, where the winning probability is the same and the winning payoff is doubled for the analogous lottery in Set II (Table 1). In all but one (the I/II4 \$-bets for the KP group) of the 24 comparisons, the stated valuations in Set II were higher than (roughly twice) those in Set I at a significance level of at least 0.05, based on either the parametric Student's t or the non-parametric MWU test. In addition, regression analyses reveal that the stated valuations were positively related to the lotteries' mean values $p_L x_L$ for either the P-bets or the \$-bets and for either the KP group ($p < 0.05$) or the UP group ($p < 0.001$). It seems that the subjects shifted/scaled up the responses in stating their valuations, but the extent to which they did so was similar across the board for the lotteries and for both groups. This may be why mean-preserving spreads are also predictedly observed for the individual lotteries' stated valuations.

To summarize, reversed preferences across choice and valuation were markedly asymmetric, which were nevertheless mitigated by the provision of pairing information. The UP subjects' predominant preferences were for P-bets in choices, but for \$-bets in valuations. As a result, the frequency/rate of standard reversals was plainly higher than that of nonstandard ones (Result 1). The magnitude of the asymmetric PR is comparable to those in prior research with similar design as the UP setting (Tversky et al., 1990; Cubitt et al., 2004). However, the preponderance to value \$-bets more highly was substantially undermined for the KP group, resulting in remarkable contraction in the asymmetric PR phenomenon (Results 2-3). Critically, the mitigation of asymmetric reversals was accompanied by mean-preserving spreads in the KP group's stated valuations (Result 4). These results are extraordinarily consistent with the predictions of contextual deliberation, and can readily remove the other potential explanations (i.e., preference for randomization, stochastic preference models, psychological hypotheses) as contenders.[10]

Nevertheless, it would be delusive not to mention that known pairing considerably decreased, but did not fully eliminate, the asymmetry in reversals. For some lottery pairs, the KP group's preference for $-bet was still lower in choice than in valuation (Table 2), and the proportion/rate of standard PR remained higher than that of nonstandard PR (Table 3). This cannot be explained by the current model of static deliberation acting alone. What could account for this particular data feature? One possibility is that not all subjects fully comprehended or attended to the experiment instructions (e.g., the ordinal payoff scheme): some subjects might literally interpreted the valuation tasks. This might then open up the opportunity for the other explanations (e.g., preference for randomization, the prominence or the scale compatibility hypothesis) to take a hold.[11] Another possibility is due to information spillover. That is, preference information acquired in a valuation task could carry over to the subsequent choice task.[12] This implies that, even though valuation and choice under the ordinal payoff scheme are logically equivalent for the KP group and hence should entail similar incentive for deliberation, the amount of preference information could nevertheless be higher in choice than in valuation because of sequential spillover. As a result, asymmetric reversals might still arise even under known pairing, analogous to the mechanism of contextual deliberation under unknown pairing. This is consistent with the task order effect observed by Alos-Ferrer et al. (2016): asymmetric reversals become significantly less frequent when choice precedes valuation.

Therefore, there are two possible strategies to better organize the data through accommodating the residual asymmetric PR for the KP group. The first one is to propose a hybrid theory combining contextual deliberation with some other explanations. Alternatively, a dynamic deliberation model can be developed to incorporate information spillover. The second approach has the desirable features of parsimony and theoretical coherence.

6. Summary and discussion

The asymmetric choice-valuation PR for lotteries is a robust finding. Its interpretation has been the subject of a half-century debate. One stream of researchers attempted to attribute it to insufficient control of conventional experimental confounders, or to violations of axioms such as transitivity or independence. Another family of researchers interpret it as a sheer violation of the fundamental procedure-invariance principle. The current stance of the literature seems to settle down to the latter perspective, as many experiments have been conducted to rule out standard accounts of the former school. However, this apparently converging view poses more problem than it solves. As put by Tversky et al. (1990, p. 215):

> Because (procedure) invariance—unlike independence or even transitivity—is normatively unassailable and descriptively incorrect, it does not seem possible to construct a theory of choice that is both normatively acceptable and descriptively adequate.

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[10] As shown in Appendix A, the response time data provides preliminary evidence for contextual deliberation.

[11] To the extent that manipulation was randomized across the KP and the UP groups, misconception of experiment instructions or the other explanations could not account for the main findings of the paper (Results 1-4).

[12] The learning/experience effect for repeatedly presented lotteries is documented in the literature, i.e., decisions made in preceding trials can systematically influence responses to subsequent tasks (e.g., Hey and Orme, 1994, Ballinger and Wilcox, 1997, Loomes and Sugden, 1998).

My objective in present research is to address this challenge by offering a parsimonious theory of contextual deliberation to rationalize the asymmetric PR. Its primitives (i.e., utility and information) are completely procedure independent, and the decision maker always seeks to maximize expected utility/surplus whenever possible. Nevertheless, observed behavior may appear to be procedure dependent because of the endogeneity of deliberation about preference information. Therefore, the model is able to reconcile the empirical puzzle within a normative framework.

This paper reports an experiment that was designed to test predictions of contextual deliberation. The experiment manipulated the availability of lottery-pairing information in the ordinal payoff scheme. The main findings are: (i) standard PRs were overwhelmingly more frequent than nonstandard PRs when pairing was unknown; (ii) known pairing substantially reduced asymmetric reversals by increasing the dispersion but not the mean of stated valuations. These results demonstrate that the proposed model is not only normatively appealing, but also has descriptive power to represent the observed behavior.

The model provides guidance about how the asymmetric PR can be moderated. When the cost/need of deliberation becomes either sufficiently low or extremely high, procedure-dependent reversals would be mitigated. This means that proxies of deliberation cost/need (e.g., cognitive skills, time constraint, preference articulation) can have predictive impact on the asymmetric PR.

Contextual deliberation can be extended to account for other nonstandard preferences. It is an promising research agenda to develop the theory of contextual deliberation as a parsimonious tool to explain seemingly disparate phenomena of preference construction. For instance, it can rationalize context-dependent preferences such as the compromise effect and choice overload (Guo, 2016, 2020a). It can also reconcile the dependence of stated valuations on arbitrarily generated numbers, i.e., the anchoring effect (Guo, 2020b). More generally, I hope that contextual deliberation can provide a coherent framework to bridge different schools of research on decision making.

Appendix A

Proof of Theorem 2. The DM's interim utility, arising from solving the second-stage choice problem, is $U_C(d_C^*, u(\tilde{\theta})) = \max\{u_A(\tilde{\theta}), u_B(\tilde{\theta})\}$. The ex ante expected surplus is then $U_C(\alpha) = \int_{\underline{\theta}}^{\dot{\theta}} u_B(\tilde{\theta})\ h(\tilde{\theta},\alpha)d\tilde{\theta} + \int_{\dot{\theta}}^{\bar{\theta}} u_A(\tilde{\theta})\ h(\tilde{\theta},\alpha)d\tilde{\theta} - k(\alpha) = u_A(\hat{\theta}) + \int_{\underline{\theta}}^{\dot{\theta}} [(p_B - p_A)\tilde{\theta} + p_B x_B - p_A x_A]\ h(\tilde{\theta},\alpha)d\tilde{\theta} - k(\alpha)$, where $\dot{\theta} \equiv \frac{p_B x_B - p_A x_A}{p_A - p_B} > 0$. Integrating by parts leads to $U_C(\alpha) = u_A(\hat{\theta}) + \int_{\underline{\theta}}^{\dot{\theta}} (p_A - p_B)\ H(\tilde{\theta},\alpha)d\tilde{\theta} - k(\alpha)$. It follows that the first-order condition for the deliberation problem is

$$\frac{\partial U_C(\alpha)}{\partial \alpha} = \int_{\underline{\theta}}^{\dot{\theta}} (p_A - p_B)\ \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta} - k'(\alpha).$$

Optimal deliberation α_C^* increases as the first-part of the above first-order condition becomes higher. By the rotation order, $\int_{\underline{\theta}}^{\dot{\theta}} \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta}$ increases with $\dot{\theta}$ if $\dot{\theta} < \theta^+$, and decreases with $\dot{\theta}$ if $\dot{\theta} > \theta^+$. Note that the preference cut-off point $\dot{\theta}$ is decreasing in p_A and x_A, and increasing in p_B and x_B.

Therefore, optimal deliberation α_C^* first increases (when $\dot{\theta} > \theta^+$) and then decreases (when $\dot{\theta} < \theta^+$) with x_A. Similarly, when p_A is not high such that $\dot{\theta} > \theta^+$, its impact on α_C^* is positive.

However, when p_A becomes higher such that $\dot{\theta} < \theta^+$, its impact on α_C^* becomes ambiguous. Nevertheless, when p_A becomes sufficiently high such that $\dot{\theta} \to \underline{\theta}$, its impact on α_C^* would be negative as $\int_{\underline{\theta}}^{\dot{\theta}} \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta}$ would converge to zero.

Analogously, optimal deliberation α_C^* first increases (when $\dot{\theta} < \theta^+$) and then decreases (when $\dot{\theta} > \theta^+$) with x_B. When p_B is high such that $\dot{\theta} > \theta^+$, its impact on α_C^* is negative. However, when p_B becomes lower such that $\dot{\theta} < \theta^+$, its impact on α_C^* becomes ambiguous. Nevertheless, when p_B becomes sufficiently low such that $\dot{\theta} \to \underline{\theta}$, its impact on α_C^* would be positive as $\int_{\underline{\theta}}^{\dot{\theta}} \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta}$ would converge to zero.

Proof of Theorem 3. Consider the lottery $L \in \{A, B\}$. The interim utility obtained from solving (4) is $U_L(\tilde{\theta}) = \int_{\underline{y}}^{d_L^*} u_L(\tilde{\theta})\ w(y)dy + \int_{d_L^*}^{\bar{y}} (\tilde{\theta} + y)\ w(y)dy$, where $d_L^* = (p_L - 1)\tilde{\theta} + p_L x_L$. The first-order derivative with respect to $\tilde{\theta}$ is $U_L'(\tilde{\theta}) = p_L W(d_L^*) + 1 - W(d_L^*)$. The second-order derivative with respect to $\tilde{\theta}$ is $U_L''(\tilde{\theta}) = (1 - p_L)^2 w(d_L^*) > 0$, which is decreasing in p_L given that $W(\cdot)$ is uniform. The ex ante expected gross surplus is $U_L(\alpha) = \int_{\underline{\theta}}^{\bar{\theta}} U_L(\tilde{\theta})\ h(\tilde{\theta}, \alpha)d\tilde{\theta} = U_L(\bar{\theta}) - U_L'(\bar{\theta}) \int_{\underline{\theta}}^{\bar{\theta}} H(\tilde{\theta}, \alpha)d\tilde{\theta} + \int_{\underline{\theta}}^{\bar{\theta}} U_L''(\tilde{\theta}) \int_{\underline{\theta}}^{\tilde{\theta}} H(z, \alpha)dzd\tilde{\theta}$, where the second equality is obtained by integrating by parts twice. The marginal impact of deliberation on the ex ante expected gross surplus of the lottery L is

$$\frac{\partial U_L(\alpha)}{\partial \alpha} = \int_{\underline{\theta}}^{\bar{\theta}} U_L''(\tilde{\theta}) \int_{\underline{\theta}}^{\tilde{\theta}} \frac{\partial H(z, \alpha)}{\partial \alpha} dzd\tilde{\theta}.$$

Therefore, $\frac{\partial U_L(\alpha)}{\partial \alpha}$ is decreasing in p_L, given that $\int_{\underline{\theta}}^{\tilde{\theta}} \frac{\partial H(z,\alpha)}{\partial \alpha} dz > 0$ for all $\tilde{\theta} \in (\underline{\theta}, \bar{\theta})$. Note that the total ex ante expected surplus is $U_V(\alpha) = U_A(\alpha) + U_B(\alpha) - k(\alpha)$. This implies that $\frac{\partial U_V(\alpha)}{\partial \alpha}$ is decreasing in p_L, and so is α_V^*.

Proof of Theorem 4. Using the notation in the proof of Theorem 3, the optimal interim utility arising for valuing lottery $L \in \{A, B\}$ is $U_L(\tilde{\theta})$. As has been shown there, as p_A converges to 1, we would have $U_A''(\tilde{\theta}) \to 0$ and hence $\frac{\partial U_A(\alpha)}{\partial \alpha} \to 0$. This implies that optimal deliberation for valuation is driven mainly by the marginal impact of deliberation on lottery B: $\frac{\partial U_V(\alpha)}{\partial \alpha} = \frac{\partial U_B(\alpha)}{\partial \alpha} - k'(\alpha)$. Note also that $U_B'(\tilde{\theta}) = p_B W(d_B^*) + 1 - W(d_B^*) \in (p_B, 1)$.

The ex ante expected gross surplus for lottery B is $U_B(\alpha) = \int_{\underline{\theta}}^{\bar{\theta}} U_B(\tilde{\theta})\ h(\tilde{\theta}, \alpha)d\tilde{\theta} = U_B(\bar{\theta}) - \int_{\underline{\theta}}^{\bar{\theta}} U_B'(\tilde{\theta})H(\tilde{\theta}, \alpha)d\tilde{\theta}$, where the second equality is obtained by integrating by parts. Similarly, the ex ante expected surplus for the choice task is $U_C(\alpha) = \int_{\underline{\theta}}^{\bar{\theta}} U_C(\tilde{\theta})\ h(\tilde{\theta}, \alpha)d\tilde{\theta} - k(\alpha) = U_C(\bar{\theta}) - \int_{\underline{\theta}}^{\dot{\theta}} U_C'(\tilde{\theta})H(\tilde{\theta}, \alpha)d\tilde{\theta} - \int_{\dot{\theta}}^{\bar{\theta}} U_C'(\tilde{\theta})H(\tilde{\theta}, \alpha)d\tilde{\theta} - k(\alpha)$, where $U_C(\tilde{\theta}) = \max\{u_A(\tilde{\theta}), u_B(\tilde{\theta})\}$ is the optimal interim utility under the choice problem. As $p_A \to 1$, comparing the marginal impacts of deliberation on the ex ante expected surpluses across the elicitation methods leads to:

$$\frac{\partial U_C(\alpha)}{\partial \alpha} - \frac{\partial U_V(\alpha)}{\partial \alpha} = \int_{\underline{\theta}}^{\dot{\theta}} [U_B'(\tilde{\theta}) - U_C'(\tilde{\theta})] \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta} + \int_{\dot{\theta}}^{\bar{\theta}} [U_B'(\tilde{\theta}) - U_C'(\tilde{\theta})] \frac{\partial H(\tilde{\theta},\alpha)}{\partial \alpha} d\tilde{\theta}.$$

Therefore, $\frac{\partial U_C(\alpha)}{\partial\alpha} - \frac{\partial U_V(\alpha)}{\partial\alpha} > 0$ as $p_A \to 1$ and $\dot{\theta} \to \theta^+$. This is because $U'_B(\tilde{\theta}) > U'_C(\tilde{\theta}) = p_B$ for $\tilde{\theta} \in (\underline{\theta}, \dot{\theta})$, $U'_B(\tilde{\theta}) < U'_C(\tilde{\theta}) = p_A$ for $\tilde{\theta} \in (\dot{\theta}, \bar{\theta})$ and $p_A \to 1$, $\frac{\partial H(\tilde{\theta},\alpha)}{\partial\alpha} > 0$ for $\tilde{\theta} \in (\underline{\theta}, \theta^+)$, and $\frac{\partial H(\tilde{\theta},\alpha)}{\partial\alpha} < 0$ for $\tilde{\theta} \in (\theta^+, \bar{\theta})$. It follows that $\alpha^*_C > \alpha^*_V$ as $p_A \to 1$ and $\dot{\theta} \to \theta^+$.

The asymmetric PR between choice and separate valuations:

Let α_L be the deliberation level when the certainty equivalent for lottery $L \in \{A, B\}$ is elicited. Consider the conditions given in Theorem 4. When p_A converges to one, the marginal value of deliberation for lottery A would approach zero and hence $\alpha^*_A \to 0$. Meanwhile, optimal deliberation for the choice task would be similarly higher than that for the task of valuing lottery B, i.e., $\alpha^*_C > \alpha^*_B$. Moreover, the stated certainty equivalents would be $d^*_L = (p_L - 1)\tilde{\theta}_L + p_L x_L$, where $\tilde{\theta}_L$ captures the posterior belief under the valuation task for lottery $L \in \{A, B\}$. It is evident that the condition for $d^*_A < d^*_B$ is $\tilde{\theta}_B < \vec{\theta} \equiv \frac{p_B x_B - p_A x_A + (1-p_A)\hat{\theta}}{1-p_B}$, given that $\tilde{\theta}_A$ collapses to a single point at the prior mean $\hat{\theta}$ (as $\alpha^*_A \to 0$). This gives rise to the probability that the stated certainty equivalent of lottery B is higher than that of lottery A under separate valuations: $P_V = H(\vec{\theta}, \alpha^*_B)$. Therefore, if $\vec{\theta} \geq \dot{\theta} > \theta^+$, we would have $P_C = H(\dot{\theta}, \alpha^*_C) \leq H(\vec{\theta}, \alpha^*_C) < H(\vec{\theta}, \alpha^*_B) = P_V$, where the second inequality is because $\alpha^*_C > \alpha^*_B$ (and $\vec{\theta} > \theta^+$). Note that the condition $\vec{\theta} \geq \dot{\theta}$ is equivalent to $\hat{\theta} \geq \dot{\theta}$, and the condition $\dot{\theta} > \theta^+$ is that in part (i) of Theorem 1. This presents one sufficient condition for the emergence of the asymmetric PR between choice and separate valuations. Note also that, even when $\vec{\theta}$ is a little below $\dot{\theta}$ (or $\hat{\theta} < \dot{\theta}$), the asymmetric PR between choice and separate valuations can still arise if α^*_C is sufficiently higher than α^*_B.

The asymmetric PR between choice and probability equivalents:

Consider the probability equivalent task for $L \in \{A, B\}$. Similar to (4) for the certainty equivalent, the DM's second-stage problem is

$$max_{d_{RL}} \left\{ U_P(d_{RL}, u_L(\tilde{\theta})) = \int_{\underline{y}}^{d_{RL}} u_L(\tilde{\theta})\, w(y)dy + \int_{d_{RL}}^{\bar{y}} y(\tilde{\theta} + x_R)\, w(y)dy \right\}, L = A, B.$$

The first-order condition yields $d^*_{RL} = \frac{p_L(\tilde{\theta}+x_L)}{\tilde{\theta}+x_R}$, and the second-order condition is satisfied at d^*_{RL}. It is evident that d^*_{RL} is increasing in $\tilde{\theta}$.

The interim utility from the above problem is $U_{PL}(\tilde{\theta}) = \int_{\underline{y}}^{d^*_{RL}} u_L(\tilde{\theta})\, w(y)dy + \int_{d^*_{RL}}^{\bar{y}} y(\tilde{\theta} + x_R)\, w(y)dy$. The first-order derivative with respect to $\tilde{\theta}$ is $U'_{PL}(\tilde{\theta}) = p_L W(d^*_L) + \int_{d^*_{RL}}^{\bar{y}} y\, w(y)dy$. The second-order derivative with respect to $\tilde{\theta}$ is $U''_{PL}(\tilde{\theta}) = (p_L - d^*_{RL})w(d^*_{RL})\frac{\partial d^*_{RL}}{\partial\tilde{\theta}} = \frac{p_L^2(x_R-x_L)^2}{(\tilde{\theta}+x_R)^3} w(d^*_{RL}) > 0$, which is increasing in p_L and decreasing in x_L. Therefore, the marginal impact of deliberation on the ex ante expected gross surplus of the lottery L, $\frac{\partial U_{PL}(\alpha)}{\partial\alpha}$, is increasing in p_L and decreasing in x_L. This implies that optimal deliberation under either joint or separate evaluation (α^*_P or α^*_{PL}) is increasing in p_L and decreasing in x_L. Moreover, $U''_{PA}(\tilde{\theta}) > U''_{PB}(\tilde{\theta})$ for all $\tilde{\theta}$, because $p_A(x_R - x_A) > p_B(x_R - x_B)$. This implies that the marginal impact of deliberation on the ex ante expected gross surplus of lottery A is higher than that for lottery B, and so $\alpha^*_{PA} > \alpha^*_{PB}$.

It is evident that, under joint evaluation, the interval of d^*_{RL} is increasing in p_L and decreasing in x_L. In addition, the stated probability equivalent can be rewritten as $d^*_{RL} = p_L - p_L(x_R -$

$x_L)/(\tilde{\theta} + x_R)$, which implies that the variability of d^*_{RL} is increasing in p_L and decreasing in x_L as well. It follows that d^*_{RA} has a wider interval and larger variability than d^*_{RB}. These results also hold for separate evaluation, given $\alpha^*_{PA} > \alpha^*_{PB}$.

Next, consider the ex ante probability that the \$-bet is preferred over the P-bet, P_C and P_P, for the choice and the probability equivalent tasks, respectively. Let us focus on joint evaluation for probability equivalents. Note that $d^*_{RA} < d^*_{RB}$ if and only if $\tilde{\theta} < \dot{\theta}$, which implies $P_P = H(\dot{\theta}, \alpha^*_P)$. Similar to part (i) of Theorem 1, we would have $P_C > P_P$ if $\dot{\theta} > \theta^+$ and $\alpha^*_C < \alpha^*_P$. One sufficient condition for this to happen is that x_A converges to zero and/or p_B is not too small, such that $\dot{\theta}$ would converge to the upper bound $\bar{\theta}$ to yield $\alpha^*_C \to 0$ while α^*_P would be increased.

Process data:

I examine the process data to further explore the role of deliberation in the decision making process. The software Qualtrics automatically recorded the response time (RT) for each computer page, i.e., the length of elapsed time between when the page was loaded and when the response(s) on that page were confirmed. This measure can be readily collected without contaminating the decision making process. It has been increasingly used in the literature to uncover the cognitive process underlying decision making (e.g., Rubinstein, 2007; Guo, 2020a). Nevertheless, one challenge for the current study is that RT variations across elicitation methods and/or subjects may originate from non-deliberation differences. For example, inputting valuation responses on the keyboard would take inherently more time than using the mouse to indicate the chosen lottery, even though optimal deliberation was higher for the latter decision. In addition, the subjects can differ in the speed of comprehending the experiment stimuli and/or inputting their responses. This implies that RT variations along these two dimensions may contain limited information about deliberation.

To circumvent these issues, I make use of within-subjects, across-lottery-pair RT variations. Subject-level mean RT values are computed, separately for valuation (RTV) or choice (RTC) responses that involved a higher preference order for either the P-bet or the \$-bet. The null hypothesis is tested, for each type of task and each group, that the mean RT values when the P-bets were preferred were the same as those when the \$-bets were preferred, using two-tailed paired-samples Student's t and WSR tests. For the UP group, the mean RTVs were not different between P-bet and \$-bet responses (group average 24.78 versus 23.31, n=32; Student's t=0.657, p=0.516; WSR z=-0.411, p=0.681). However, the mean RTCs for P-bet choices were significantly higher than those for \$-bet choices (group average 10.63 versus 8.68, n=49; Student's t=2.073, p=0.044; WSR z=-2.164, p=0.030). This pattern is remarkably consistent with the behavioral data: the subjects were induced to deliberate more in choice than in valuation, thus substantially increasing their likelihood to favor P-bet choices relative to that in valuation tasks. In contrast, for the KP group the comparison between P-bet and \$-bet responses did not yield significant difference for either RTV (group average 24.35 versus 23.71, n=37; Student's t=0.233, p=0.817; WSR z=-0.068, p=0.946) or RTC (group average 7.65 versus 8.91, n=46; Student's t=-0.940, p=0.352; WSR z=-0.224, p=0.823). The differential associations between RT and preferences across the groups seem compatible with the findings on how the pairing information mitigated the asymmetric PR for the KP group.

How can deliberation differ across the subjects' response types? If the incentive for deliberation was relatively high, a subject would have a tendency to raise deliberation even in valuation and thus to exhibit consistent preference for the P-bet across valuation and choice. If the deliberation incentive was lukewarm, the subject would be inclined to do it in choice rather than in valuation, thus fostering the emergence of standard reversal. With relatively low deliberation incentive, however, the subject would be disposed to maintain the predominant preference for the $-bet without deliberating much for either valuation or choice. Put it differently, the elicitation method may modulate heterogeneous incentives for deliberation. Therefore, RTV is expected to be higher for responses exhibiting consistent preference over the P-bet than for responses with consistent preference over the $-bet, and standard reversals may involve higher RTC than consistent $-bet responses.

These implications are tested on subject-level mean RTs computed for each response type. For the UP group, consistent P-bet responses were indeed associated with larger mean RTVs than consistent $-bet responses (group average 24.77 versus 19.52, n=22; Student's t=1.965, p=0.063; WSR z=-1.672, p=0.095), and the mean RTCs were higher for standard reversals than for consistent $-bet responses (group average 11.64 versus 8.56, n=46; Student's t=2.355, p=0.023; WSR z=-2.890, p=0.004). Similar pattern is observed for the KP group's mean RTVs at lower statistical significance (group average 22.65 versus 19.89, n=30; Student's t=1.246, p=0.223; WSR z=-1.759, p=0.079), but not for the mean RTCs (group average 8.73 versus 9.30, n=40; Student's t=-0.264, p=0.793; WSR z=-1.438, p=0.150). Overall, it seems that the modulation of the elicitation method on heterogeneous deliberation incentives was stronger for the UP than for the KP group. This is expected in light of the theoretical equivalence between valuation and choice for the latter group.

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jet.2021.105285.

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