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## **Examining the role of risk in waiting preference and dynamic preference reversal**

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Examining the role of risk in waiting preference and dynamic preference reversal: an  
experience intertemporal choice study<sup>1</sup>

Abstract

Short waits are pervasive in modern life. This study addressed how risk impacts inter-temporal decisions that involve short waits (of 72 seconds or less) and how those decisions change while waiting. We used an experience time-discounting task sensitive to the impact of risk and which can measure intra-trial preference reversals. Three experiments showed that: 1) Adding uncertainty to outcomes does not change participants' preferences in waiting for a reward, but it reduces their willingness in waiting for a reduction of losses, 2) Adding uncertainty to outcomes increases participants' tendency to switch their decisions during the course of waiting, and 3) Participants showed no gain-loss asymmetry for risky intertemporal choices.

Keywords: Coin collection task, dynamic preference reversal, risky intertemporal choice, gain-loss asymmetry, experience time-discounting task.

Introduction

Many decision outcomes in real life are both delayed and risky. Therefore, it is not surprising that a growing number of studies examine decisions that involve both risk and delay (Andersen et al., 2008; Baucells & Heukamp, 2012; Keren & Roelofsma, 1995; Luckman et al., 2017; Luckman et al., 2020; Vanderveldt et al.,

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<sup>1</sup> Upon acceptance all our data and stimuli will be publicly made available on the Open Science Framework. To facilitate peer review, we provide a private read-only link to view our data and stimuli during the review process here [https://osf.io/z3kx5/?view\\_only=559bb93ba7a947e6906bc2afd96417e7](https://osf.io/z3kx5/?view_only=559bb93ba7a947e6906bc2afd96417e7)

2015). Among such studies, the question of how risk influences intertemporal preferences (e.g., tradeoffs between a larger-later reward and a smaller-sooner reward) and its change over time have attracted much attention (Anderson & Stafford, 2009; Hardisty & Pfeffer, 2017; Keren & Roelofsma, 1995; Öncüler, 2000; Sun & Li, 2010; Weber & Chapman, 2005a). Most of these studies have used a paradigm that describes choice options without the requirement for participants to actually experience delays. The topic of how risk impacts intertemporal decisions involving actual and short waiting experience is mostly neglected. Unlike a traditional descriptive task which allows for productive use of waiting time, online experiencing of delays prohibited a decision maker to make an alternative use of the waiting time. Therefore, the actual waiting experience could change subjective time perception and waiting preference (Xu et al., 2020). The present study addresses the effect of risk on waiting preference and its change over time with an online experiential time-discounting task (Xu et al., 2020) in which participants wait and receive rewards after they make their choices. Accordingly, we focused on intertemporal choices that involved short waiting periods of up to two minutes.

Traditional studies on risky intertemporal choices have mainly focused on rewards that involve long waiting periods spanning days to decades which are not actually experienced by participants in these studies. However, choices made over short waiting periods are also very important in the modern environment, as online shopping and e-business services become a part of our life. As a result, the waiting experience could have substantial consequences for both individuals and firms. For

example, a slow website may cost a business when a consumer gives up waiting (Janakiraman et al., 2011). It is no wonder companies have worked hard to ameliorate the aversion of waiting (Larson & Pinker, 2000; Lee et al., 2012). Therefore, extending our understanding of the effect of risk on intertemporal choices involving actual waiting for short periods is both practically useful and theoretically interesting.

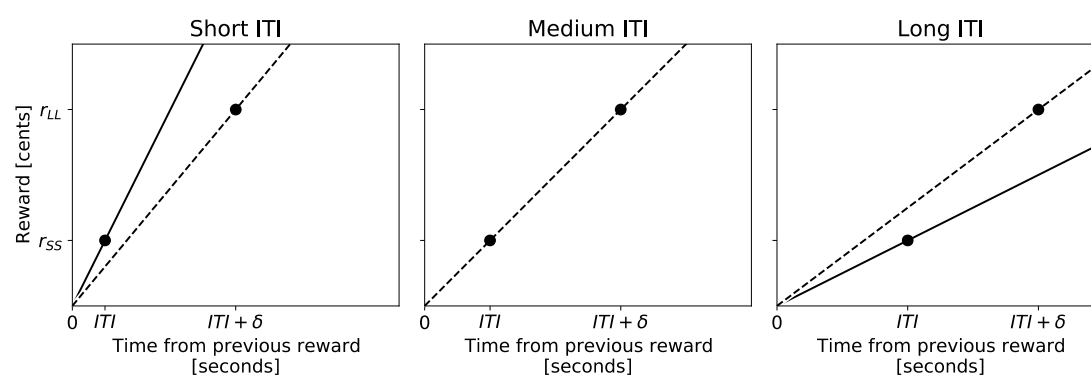
Short-term experience tasks for human beings were originally derived based on the operant paradigms used in non-human studies (Ainslie, 1975; Chung, 1965; Hayden, 2016; Wolfe, 1934). For animal studies, animals choose between a larger-later reward and a shorter-sooner reward, and the reward is usually a period of time with access to food. Because of this time variability, an adaptive inter-trial interval (ITI) is imposed between each trial to make sure the length of each trial is fixed and independent from choices (Rachlin & Green 1972; Mazur, 1991; Mazur, 1987). Earlier versions of experience tasks have not only required human subjects to experience the consequence of a decision before subsequent choices were made but also included an adaptive ITI (Flora & Pavlik, 1992; Hyten et al., 1994).

However, unlike animals who are insensitive to post-reinforcement waiting (Mazur, 1991; Mazur, 1987), humans are sensitive to ITI, which imposes a dilemma to the experience tasks. Including an adaptive ITI to hold constant the duration of each trial results in humans always choosing the larger-later reward (Flora & Pavlik, 1992; Hyten et al., 1994). Because the trade-off between reward and delay is broken, always choosing the larger-later reward corresponds to a rate (of reward) maximization strategy – the connection between rate maximization and delay

discounting has been discussed by Seinstra et al (2018).

Later paradigms remove fixed trial durations (via adaptive ITI's), to remove this drawback. But this alone still leaves the question of how to make the task one related to discounting, and not one of rate maximization. Figure 1 helps illustrate why. There is always *some* constant ITI simply because choices from one trial to the next cannot be chosen instantaneously – otherwise always choosing the smaller-sooner reward corresponds to an infinite rate of reward. If we consider smaller-sooner and larger-later rewards which have identical reward rates (Figure 1, middle), we can see that a shorter ITI would lead smaller-sooner to yield higher rewards per unit time (Figure 1, left) and a longer ITI would lead larger-later to yield higher rewards per unit time (Figure 1, right). If an experiment has a fixed duration, then rate maximizing choices are determined by the fixed ITI and no longer reflect discounting processes.

Therefore, some additional methodological changes are required.



*Figure 1.* Schematic demonstration of how short, medium, and long implicit fixed ITI's affect optimal decision making in experiments of fixed duration. Participants choose between a smaller-sooner reward available ITI seconds after receipt of the reward on the previous trial, and a larger-later reward available with a delay of  $ITI + \delta$  seconds. In the example with a medium ITI (middle) the smaller-sooner and larger-later rewards equate to the same rate of return (cents/second), as shown by the slope of the line. If the ITI is decreased (left) then the rate of return is maximized by choosing the smaller-sooner reward (solid line), but if the ITI is increased (right) then

the rate of return is maximized by choosing the larger-later reward (dashed-line).

Different experimental paradigms (as shown in Table 1) were proposed to deal with these methodological issues in different ways. Paradigms such as the experiential discounting task (EDT), quick discounting operant task (QDOT), and the coin collection task (Johnson, 2012; Reynolds & Schiffbauer, 2004; Xu et al., 2020) mainly differ in whether the experiment duration and or number of trials is held constant. The EDT task includes an inter-block interval to fix the length of the experiment. But it is unclear however if this fully solves the problem – participants may simply rate maximize within a block rather than in each trial. In fact, to avoid participants exclusively choosing the larger-later option, the larger-later option in the EDT task is probabilistic (35% chance of receiving the reward points). On the other hand, the coin collection task (Xu et al., 2020) fixed the number of trials and allows the length of experiment to be vary across participants. This maintains the reward/time trade-off – participants can opt for lower total rewards and a shorter experiment, higher total rewards and a longer experiment, or somewhere in between.

Table 1

*Comparison of experiential discounting tasks.*

<b>Experiment</b>	<b>Experiment duration</b>	<b>No. of trials</b>	<b>Rewards</b>
EDT (Reynolds & Schiffbauer, 2004)	Fixed, by use of adaptive inter-block-intervals.	Variable.	Real money, delivered at end of experiment.
EDT variation (Voon et al., 2010)	Fixed, by use of adaptive inter-block-intervals.	Variable.	Probabilistically received. Real money, delivered each trial.
QDOT (Johnson,	Fixed, by adaptive	Fixed. 20 trials	Real money,

2012)	wait period after all 20 trials.		delivered each trial.
Coin Collection task (Xu et al., 2020, present study)	Variable, depending on choices made.	Fixed.	Real money, delivered at end of experiment.

With the above experience tasks, studies found that intertemporal choices that involve short waiting periods produce similar response patterns as those of traditional time-discounting tasks (Johnson, 2012; Reynolds & Schiffbauer, 2004; Xu et al., 2020). For example, Reynolds et al. (2004) showed that the hyperbolic discounting models can well describe a decision maker's responses in experience time-discounting tasks, and Xu et al. (2020) showed that even though participants are less likely to wait in the experience task, their responses follow the hyperbolic model and show a robust gain–loss asymmetry as that of traditional tasks.

In terms of addressing the effect of risk on people's waiting preference and its change over time, experience tasks have the following advantages relative to the traditional intertemporal choice tasks. First, while both the experience procedure and traditional tasks can assess the delay of gratification, researchers suggested that experience tasks concentrating on short timeframes might be more sensitive in detecting moment-to-moment variability in discounting (Johnson, 2012; Navarick, 2004; Reynolds & Schiffbauer, 2004). Supporting this, studies have demonstrated that experience tasks such as the EDT, but not traditional tasks, are affected by alcohol administration (Reynolds et al., 2006) and methylphenidate administration in children with attention-deficit/hyperactivity disorder (Shiels et al., 2009). Furthermore, even though studies have shown sleep-deprivation could increase effort discounting (Libedinsky et al. 2013; Massar et al, 2019), the detection of sleep-deprivation effect

on monetary discounting usually failed in descriptive tasks (Acheson et al., 2007; Libedinsky et al. 2013), but succeeded in a study with the EDT (Reynolds & Schiffbauer, 2004). Therefore, an experience task might be able to reflect affective fluctuations generated by risky choices (Loewenstein et al., 2001) better than a traditional task. Second, experience tasks monitor the full decision process and starts from the moment a choice is presented to the moment the decision outcomes are actually carried out, which provides the opportunity to track changes in preference over a continuous period of time. In particular, the coin collection task allows participants to reverse their choices while waiting; hence, a change of decision can be observed within a trial (Xu et al., 2020).

Experience tasks therefore hold some essential features of traditional tasks, and can measure moment-to-moment state changes and preference reversals over a continuous period of time (Reynolds & Schiffbauer, 2004; Reynolds et al., 2006; Xu et al., 2020); hence, they are a potentially unique and effective approach in examining the effect of risk, complementary to traditional tasks. Below, we review the existing literature on the effect of risk on intertemporal choices and its change over time, then present the experiments we conducted.

## **Background**

Intertemporal choices measure the preference of rewards that occur at different time points. The purpose is to assess how a decision maker's preference is influenced by time (i.e., delays). A robust finding is that people are usually impatient and willing to receive less to reduce delays, that is, a future reward is discounted by its time to



receive (Frederick et al., 2002). In addition, this devaluation process is time-inconsistent and accelerates as the reward approaches, a phenomenon well described by hyperbolic time discounting curves (Ainslie, 1975; Frederick et al., 2002; Green et al., 1994). Hyperbolic models could account for preference reversals from favoring a large-later reward over a small-sooner reward to favoring the smaller-sooner one over the larger-later one as the sooner one becomes immediately available (Ainslie, 1975). Hence, the discounting rate derived from hyperbolic models is considered as a measure of impulsivity. Consistently, a large number of studies have shown that people with impulsive behaviors entail higher discounting rates (i.e., they are more likely to change their preferences across time) than normal controls (Bickel et al., 1999; Cheng et al., 2012; Kirby et al., 1999; Madden et al., 1997). However, despite the large amount of literature on time preference and time-inconsistency, it remains unclear whether a risky outcome, compared to a certain outcome, makes people more impatient or inconsistent in their preferences over time.

**The effect of risk on intertemporal preferences.** Empirical studies have found inconsistent findings regarding the effect of risk on intertemporal preferences. Some studies have shown that risk increases impatience (Anderson & Stafford, 2009; Öncüler, 2000; Sun & Li, 2010). For example, Sun and Li (2010) found that adding risk to both larger-later and smaller-sooner options made the larger-later options less preferable, compared to certain choices. Öncüler (2000) found a similar result, showing that people discounted a delayed risky outcome more than a delayed certain outcome. Similarly, Anderson and Stafford (2009) found that participants became

more impatient in the presence of risk, regardless of whether risk was presented in the earlier or later reward, or both. However, the findings of some studies went in the opposite direction, showing that adding risk to both options increased the choice of the larger-later option (Keren & Roelofsma, 1995; Weber & Chapman, 2005a). Moreover, Hardisty and Pfeffer (2017) controlled the expected value between the risk and certain conditions, and demonstrated that adding risk to smaller–sooner outcomes decreased their participants’ impatience, adding risk to larger–later outcomes increased their impatience, and adding risk to both did not affect their preferences. Similar results were obtained by other researchers (Andreoni & Sprenger, 2012; Shavit et al., 2013). Findings have therefore been quite heterogeneous. Regarding experience tasks that use a small timeframe, we found no studies examined the effect of risk on waiting preference with human participants. However, for animals, risk is not taken as a unique concept; rather, trials without reinforcement in a risky condition are taken as additional waiting time for the subsequent reinforcement immediately following that trial (Mazur, 1991; Mazur, 1987). Hence, adding probability to an alternative essentially decreases preference for that option, regardless of whether the option is a sooner or later one (Mazur, 1991). This result agrees with those of Hardisty and Pfeffer (2017) and others.

**The effect of risk on dynamic preference reversals.** Dynamic preference reversals occur when a decision maker changes their decision while carrying out an original plan (Halevy, 2015). Dynamic preference reversals are studied across multiple disciplines, using different paradigms. For example, social psychologists use

the delay-of-gratification paradigm (e.g., the marshmallow task) to measure a person's capacity to maintain a choice by resisting other temptations (Mischel et al., 1989; Mischel et al., 1972). The marshmallow task requires children to wait for a large-delayed reward with the temptation of a smaller immediately available reward. The time a child spends waiting before they switch to the smaller reward has been taken as an index of capability on delay of gratification (Mischel et al., 1989). In the decision-making literature, dynamic preference reversals reflect unstable preferences over time (Halevy, 2015), which can be described by a time-inconsistent discounting curve (e.g., a hyperbolic curve), or by a shift of choice that occurs either when the same choice is made at two different time points (Sayman & Öncüler, 2009; Sprenger, 2015) or when the two choices differ only in time to the sooner reward but the inter-reward interval is held constant (Ahlbrecht & Weber, 1997; Keren & Roelofsma, 1995).

In the present work, dynamic preference reversals were measured by switches participants made during the course of online waiting in an experience task. As mentioned, in contrast to a traditional described time discounting task which allows participants productive use of waiting time, participants in an experienced task had to wait for idle for the larger-later option approaching as the sooner option remaining available. That is, participants could switch their decisions anytime during the continuous period of waiting time. In this sense, dynamic preference reversals examined by the present work are more similar to the construct studied by the delay-of-gratification paradigm. However, because social psychologists care more about the

impact from individual characteristics such as “willpower” (Baumeister et al., 2007; Mischel et al., 1989) rather than influences from choice features such as outcome magnitude, outcome domain, and outcome uncertainty as behavioral economists do (Frederick et al., 2002; Keren & Roelofsma, 1995), findings on the effect of risk on dynamic preference reversal have come mainly from the decision-making literature. Nevertheless, Both lines of literature have connected dynamic preference reversals with concepts such as self-control, impulsivity, and delay of gratification (Ainslie, 1975; Frederick et al., 2002; Mischel et al., 1972). In addition, some studies have demonstrated a strong correlation between delay-of-gratification tasks and time-discounting tasks (Göllner et al., 2018). Therefore, below we reviewed time discounting studies on the effect of risk on dynamic preference reversals, but readers should be reminded that our task is not the same as that of the traditional preference reversal task, as we discuss in more details in later sections.

Current findings on the effect of risk on dynamic preference reversals are somewhat mixed. Blackburn and El-Deredy (2013) found that the hyperbolic discounting parameter of a certain outcome does not differ from that of a risky outcome, indicating that risk did not affect time-inconsistency. Similarly, Ahlbrecht and Weber (1997) observed no time-inconsistency for both certain outcomes and risky outcomes in the choice task. Sun and Li (2010) adapted the indifference point task to the cross-sectional design and compared the preference reversal between certain and risky intertemporal choices. They found that preference reversals were more common for risky outcomes but did not reach statistical significance. On the contrary, Keren

and Roelofsma (1995) observed that preference reversals disappeared when risk was added to both options, demonstrating that risk removed participants' preference reversals. Later, Weber and Chapman (2005a) failed to replicate the same results when they repeated the study by Keren et al. (1995); however, by using the indifference point task, they replicated the same results, showing that risk removes preference reversals. Therefore, there is scope to further understand how risk impacts time inconsistent preferences.

While empirical studies have produced varied evidence on the effect of risk on time preference and time inconsistency, various theories and models have been developed to account for preference reversals (Loewenstein et al., 2001; Metcalfe & Mischel, 1999; Read et al., 2017; Trope & Liberman, 2000). Among these, the affective approach has discussed the impact of feelings of risk on preference reversals (Loewenstein et al., 2001). According to this approach, preference reversals occurs because emotions such as fear have a strong temporal effect and increase dramatically with the approaching of the related event. A decision maker who is initially concerned about the cognitive aspects of an event might be disproportionately driven by emotions as these become intensified by the approaching event. Risky decisions are more affect-laden than riskless decisions (Bechara, 1997; Loewenstein et al., 2001; Loomes & Sugden, 1982; Lopes, 1987; Mellers et al., 1999; Peters & Slovic, 1996; Rottenstreich & Hsee, 2001); thus, the former is more vulnerable to change. However, impulses evoked by specific emotions differs from each other. For example, fear elicits avoidance while happiness approaches (Frijda et al., 1989, 2014). Additionally,

risk could elicit various emotions such as anxiety, worry, fear, pleasure, excitement, and hope (Anselme & Robinson, 2013; Wilson et al., 2005), depending on factors such as the magnitude of outcomes and their probabilities (Weber & Chapman, 2005b). Therefore, the influence of risk on time-inconsistency could be different for large-stake and small-stake gambles, and of large-probability and small-probability gambles.

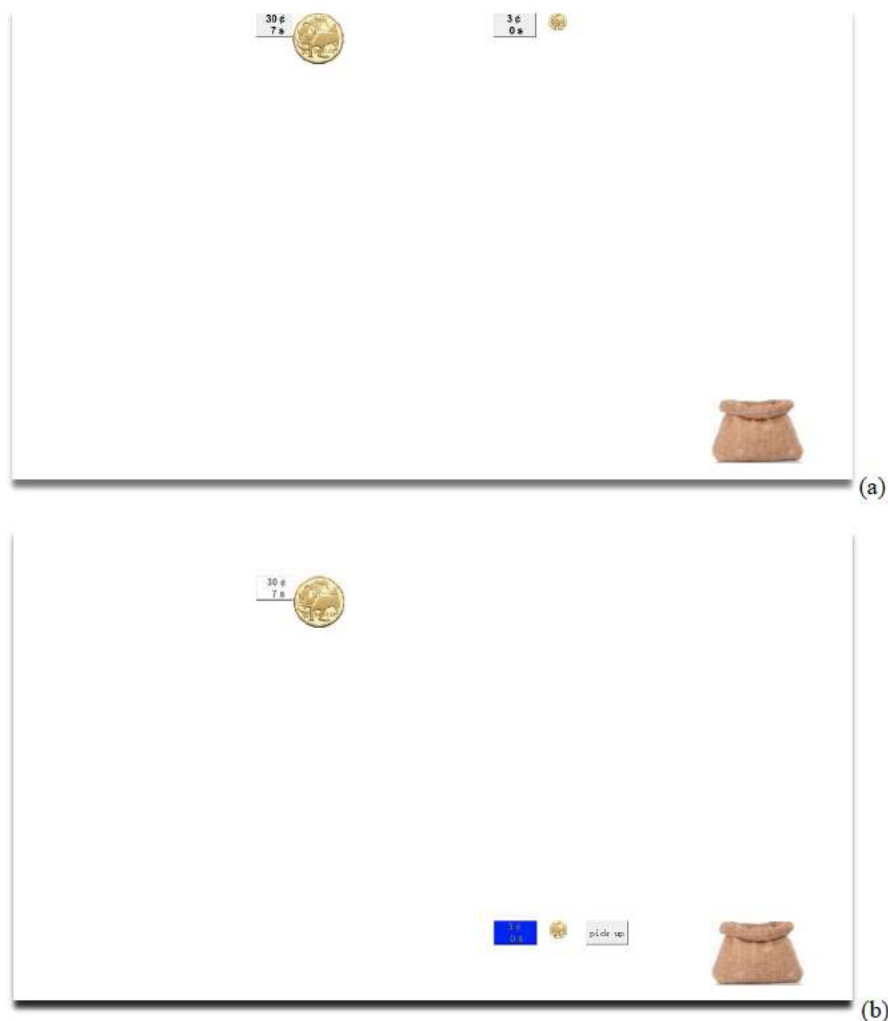
In summary, the effect of risk on intertemporal preferences and its change over time remains unclear. More studies are needed to clarify this topic. The present study focused on this point but differed from previous studies in that we used an experience time-discounting task. Below, we describe the experience task we used.

### **The present study**

**The coin collection task.** The coin collection task of Xu et al. (2020) presents participants with a fixed number of choices between a large–later coin and a small–sooner coin in a computerized experiment. For each trial, participants have to wait for a period of time as described by the option they select. Hence, the task renders participants to make a tradeoff between either waiting for a longer period of time to acquire the larger coin or waiting for a shorter period of time to acquire the smaller coin. The task also allows participants to change their decisions while waiting.

More specifically, participants see two labeled coins and select one from these (Figure 1, panel a). Once participants chose a coin, both coins fall toward the bottom of the screen with a constant speed that matches the labeled delay. In the present context, the smaller coin arrives at the bottom of the screen instantly. At that point of

time, a pickup button appears next to the smaller coin immediately (Figure 1, panel b), and participants may choose to pick up the small coin or wait for the arrival of the larger one. If participants click the pickup button, the small coin is collected into the bag at the lower righthand corner of the screen, and a new trial starts. If participants choose to wait, they can pick up the large coin upon its arrival. Note that a smaller coin is always available to be picked up while participants wait for the larger coin. However, in any case, participants could only pick up one coin. Like other online experience tasks, the coin collection task deprives participants of productive use of the waiting time, which distinguishes from traditional tasks. In this sense, the coin collection task is analogous to the delay-of-gratification task that has multiple trials (Mischel et al., 1989).



*Figure 2.* Online waiting intertemporal choice experiment. Rewards and delays are described in labels at the start of a trial (a). After a choice is made by participants by clicking on one of the buttons, the immediate reward appears at the bottom of the screen, while the delayed reward falls slowly to the bottom of the screen (b). Either reward is available for pickup when it is at the bottom of the screen, allowing participants the possibility of a preference reversal during the waiting process. Adapted from “Waiting in intertemporal choice tasks affects discounting and subjective time perception” by Xu, P., González-Vallejo, C., & Vincent, B. T., 2020, *Journal of Experimental Psychology: General*, 149(12), 2289–2313. Copyright 2020 by the American Psychological Association.

For each trial, the task records the coins participants initially select and finally pick up. Therefore, the task could measure switches from the later coin to the sooner coin (which we abbreviate as L→S), and switches from the sooner coin to the later coin (which we abbreviate as S→L).

**Risky version of the coin collection task.** As well as the standard risk-free coin



collection task, we used a risky version of the coin collection task. The task was similar to that of the standard coin collection task except that the two coins were replaced with two red envelopes that represented two gambles. Participants were told that there is a 50% chance of the sooner envelope containing a coin, and a 50% chance of the later envelope containing a coin. The coin in the later envelope was larger than the coin in the sooner envelope, but the former required a longer time to arrive at the bottom of the screen. Once the choice was made, both envelopes fell toward the bottom of the screen. Immediately after the sooner envelope reached the bottom of the screen, an “open” button appeared nearby. Participants were free to either open the sooner envelope or wait for the later envelope. In any case, participants could only open one of the two envelopes. When participants clicked the open button, the program displayed whether there was a coin in the envelope (randomized with a chance of 50%). A new trial started after participants clicked the next trial button that appeared together with the results of the envelope.

We compared participants’ responses between the two risk conditions in terms of 1) the tendency they chose to wait, 2) the tendency they actually waited, 3) the likelihood of L→S reversal, and 4) the likelihood of S→L reversal.

**Our contributions.** Experiment 1 compared risk choices and riskless choices in the gain domain with a between-subject design. Experiment 2 also used a between-subject design, but compared risky choices and riskless choices in the loss domain. We studied losses because gain/loss moderates both intertemporal and risky preferences. That is, people are more patient waiting for a deduction of loss than for

the same amount of reward (Frederick et al., 2002; Xu et al., 2020), and are more risk-seeking for losses than for gains (Kahneman & Tversky, 1979). Therefore, the effect of risk might vary between the gain and loss domains. In addition, previous studies on the effect of risk on intertemporal preferences have mainly focused on the gain domain, with only a few exceptions concerning losses (Ahlbrecht & Weber, 1997; Hardisty & Pfeffer, 2017). Therefore, Experiment 2 addressed the same topic but was focused on losses. In Experiment 3, we used only the risky version of the coin collection task, and compared risky intertemporal choices between the gain and loss domains. We tested the gain–loss asymmetry for risky intertemporal choices. The rationale for conducting Experiment 3 is outlined in more detail in the corresponding section.

## Experiment 1

### **Method**

**Participants.** A total of 57 undergraduate students (female: 53, male: 4) from a large public university participated in this experiment. All participants were between 18 to 24 years old. Participants were recruited using an advertising poster that indicated that the experiment would last around 40 minutes, with a cash incentive ranging between 25 to 35 Chinese Yuan. Each participant read and signed an informed consent form prior to the start of the experiment. None of the participants had ever participated in a similar experiment. The study was approved by the ethics committee of the university with which the first author was affiliated. Our sample size was based

on a large effect size of .8, according to a pilot study we had conducted.

**Stimuli.** In the present study, the smaller–sooner option was always immediate. Since the experiment rendered real tradeoffs between actual waiting and real money, we paid special attention to avoid a floor or ceiling effect. First, to attenuate the effect of tiredness and excessive motivation, the stimuli were set such that the experiment would last within 40 minutes and the incentives participants would achieve would range between 25 to 35 Yuan. Second, we adopted a non-dynamic staircase indifference point procedure. More specifically, the expected value of the larger coin was always fixed at 40 cents, and delays of the larger coin had six levels: 7 seconds (s), 15s, 29s, 56s, 63s, and 72s, with each corresponding to one block. The delays were set to minimize possible inter-block comparisons. For each block, the amount of the immediate coin was adjusted from trial to trial, with a fixed interval, as shown in Table 2. Notably, the amount of smaller coins for long delays (e.g., 72s) was slightly lower than those for the short-delay blocks (e.g., 7s)<sup>2</sup>. The reason for such treatment was that a pilot study had shown that for trials with long delays and large immediate values (e.g., [40 cents, 72s] vs. [39 cents, 0 s]), participants would exclusively choose the smaller coin, while for trials with short delays and small immediate amounts (e.g., [40 cents, 7s] vs. [1 cent, 0 s]), participants would exclusively choose the larger coin. Therefore, we deliberately excluded such non-informative stimuli. The block of 72s included 7 trials; the block of 7s included 5 trials; all other blocks included 6 trials, which made a total of 36 trials. Importantly, except that outcomes were 50% to 50%

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<sup>2</sup> The full set of stimuli can be found at [https://osf.io/z3kx5/?view\\_only=559bb93ba7a947e6906bc2afd96417e7](https://osf.io/z3kx5/?view_only=559bb93ba7a947e6906bc2afd96417e7)

gambles, the stimuli in the risk condition were exactly the same. All participants used the same block order which was randomly generated. Within each block, the adjusting amount of the sooner option increased from trial to trial.

Table 2

*Stimuli for the 72s block for the risk-free and risky conditions (Experiment 1)*

Risk-free condition			Risky condition		
Delayed coin		Immed. coin	Delayed envelope		Immed. envelope
Amount <sup>1</sup>	Delay <sup>2</sup>	Amount	Amount <sup>3</sup>	Delay	Amount
40	72	1	(.5, 80; 0)	72	(.5, 2; 0)
40	72	4	(.5, 80; 0)	72	(.5, 8; 0)
40	72	9	(.5, 80; 0)	72	(.5, 18; 0)
40	72	14	(.5, 80; 0)	72	(.5, 28; 0)
40	72	19	(.5, 80; 0)	72	(.5, 38; 0)
40	72	24	(.5, 80; 0)	72	(.5, 48; 0)
40	72	29	(.5, 80; 0)	72	(.5, 58; 0)

*Note.* <sup>1</sup> The units of amounts are cent; <sup>2</sup> the units of delays are second. <sup>3</sup>( $p, R; 0$ ) represents that there is a  $p\%$  chance that the envelope contains an  $R$ -cent coin or nothing. Immed. = Immediate

**Incentives.** Participants were paid a show-up incentive of 15 Yuan and performance-based bonuses. We randomly selected 97% of 36 trials (35 trials)<sup>3</sup>, and the coins participants collected in these trials were their bonuses. The same incentive rules were applied for both conditions.

**Procedure.** The participants were led to a computer lab individually. Cellphones, watches, and other belongs were placed separately. After they read and signed the consent forms, participants were told they needed to participate in 36 trials of choices

<sup>3</sup> In the present study, participants did not receive academic credit hour as those in Xu et al.'s study (2020). Therefore, we increased the percentage of payment trials to 97% (compared to 10% in Xu et al.'s study). However, considering that paying all decisions might increase the possibility of cross-task contamination (Charness, et al., 2016), we maintained the randomization procedure by excluding one random trial from the bonus calculation.

about time and money. Each participant would earn a 15 Yuan show-up incentive and a bonus determined by their selections regarding the choices they would be given in the trials. Then, participants read a written version of the instructions. The instructions for the two conditions were kept as similar as possible. The instructions stated that people often face situations that require a tradeoff between rewards and time, for example, waiting for a long time at a sit-down restaurant to eat a more desirable meal vs. waiting for a short time at a fast-food restaurant to eat a less desirable meal. The participants' task was to play a coin-machine game in which one machine gave out larger-valued coins (or envelopes) slowly, while the other gave out smaller-valued coins (or envelopes) quickly. The instructions gave a detailed procedure on how to complete the task with illustrations of Figure 2.

The participants were randomly assigned to either a "risk-free" condition or a "risky" condition. To ensure that the participants completely understood the task, an experimenter demonstrated the procedure to the participants through a practice trial. During the demonstration, the experimenter emphasized that even though the initial choices the participants would make for each trial did not influence the coin (or envelope) they would finally pick up, every selection they would make in the experiment would be important to the research; therefore, they were asked to treat each choice seriously. After the demonstration, the participants were left alone in the lab to complete the task. They were debriefed and paid at the end of the experiment.

## Result

We included all participants in the following analysis<sup>4</sup>. For each participant, we counted the number of trials in which the delayed option was selected as their first choice (Later-initial), the number of trials in which the delayed option was picked up (Later-final), the number of L→S reversals, i.e., intra-trial switches from the delayed option to the immediate option, and the number of S→L reversals, i.e., intra-trial switches from the immediate option to the delayed option. We then calculated the rate of L→S by dividing it with the number of trials in which the later option was originally chosen, and the rate of S→L by dividing it with the number of trials in which the sooner option was originally chosen. The descriptive statistics for each condition are shown in Table 3.

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<sup>4</sup> Three participants from the risk-free condition always chose the smaller options. Removing these three participants from the analysis did not change the result as those reported in the text.

Table 3.

*Descriptive statistics for the risk-free and risky conditions in the gain domain (Experiment 1).*

Risk	N	Later-initial	Later-final	L→S	S→L	L→S rate	S→L rate
Risk-free	30	16.73 (10.15)	16.0 (10.53)	.93 (1.46)	.20 (.48)	.13 (.26)	.01 (.03)
Risky	27	19.33 (7.23)	17.04 (7.94)	3.56 (2.89)	1.26 (1.43)	.22 (.20)	.09 (.12)

*Note.* M (SD). Later-initial = the number of trials in which the later option was originally chosen. Later-final = the number of trials in which the later option was finally picked up. L→S rate: the ratio between L→S and Later-initial. S→L rate: the ratio between S→L and the number of trials in which the sooner option was originally chosen.

**Differences in waiting preference.** To compare the waiting tendency between the risk-free and risky conditions, we calculated the indifference point of each delay for each participant. A larger indifference point value meant a higher preference for waiting for the delayed option. Calculations were based on the coin that was picked up at the end of each trial. To find the indifference points, adjacent trials between which participants made inter-trial switches were identified; the middle point of the immediate of the two adjacent trials was taken as the indifference points. For delays that showed more than one inter-trial switch point, the average of all the adjacent amounts over more than two trials was used to compute the indifference points. For the risky condition, we obtained the expected value of the indifference points. Figure 3 shows the group-level mean indifference points for the risk-free and risky conditions, respectively.

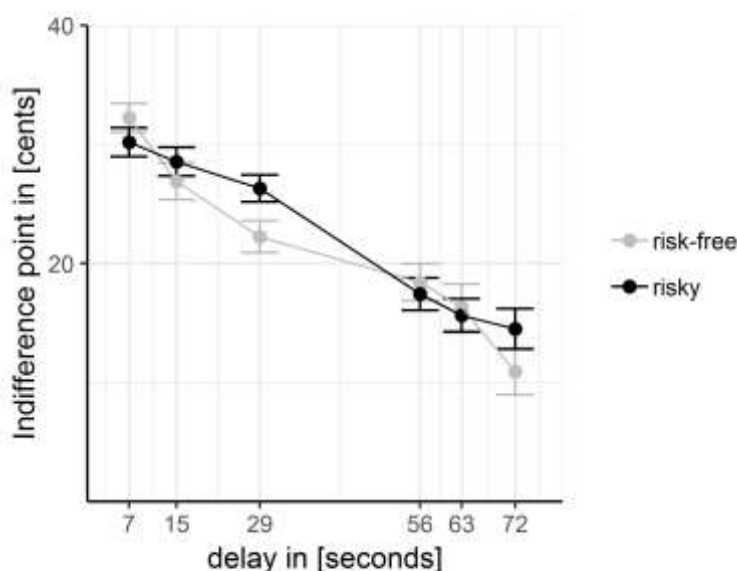


Figure 3. Group-level mean indifferent points for the risk-free and risky conditions



(Experiment 1). Delays are 7 seconds, 15s, 29s, 56s, 63s, and 72s, respectively. Grey dots refer to the risk-free condition; black dots refer to the risky condition. Calculations were based on the participants' final choices. The error bars refer to standard error of the mean.

A repeated measures ANOVA with delay as a within-subject factor and risk condition as a between-subject factor revealed that there was a main effect of delay,  $F(5, 275) = 99.01, p < .001, \eta^2 = .63$ , and an interaction between risk and delay,  $F(5, 275) = 3.08, p = .01, \eta^2 = .02$ . A simple effect analysis revealed that there was a significant difference between the risk-free and risky conditions only for the 29s block,  $F(1, 275) = 5.30, p = .03$ , and not for the other blocks. For the 29s block, participants waited for the delayed coin more frequently in the risky condition than in the risk-free condition. The main effect of risk was not significant,  $F(1, 55) = .4, p = .58$ .

**Differences in dynamic preference reversals.** Given that the distributions of the intra-trial switch rates were not symmetric, we conducted non-parametric tests to test for differences in dynamic preference reversals. Unpaired two-sample Wilcoxon tests on the proportion of reversals revealed that compared to the risk-free condition, participants in the risky condition conducted L→S switches more frequently,  $w = 213, p < .001$ , and this was also true for switches from the delayed coin to the immediate coin,  $w = 170.5, p < .001$ . Therefore, Experiment 1 demonstrated that in the gain domain, introducing risk into waiting outcomes increased the likelihoods of both L→S and S→L reversals.

## Experiment 2

In a traditional task, discounting a loss means a person prefers to pay more to postpone the payment. Many studies showed that losses are less discounted than gains (Frederick et al., 2002; Loewenstein, 1988; Thaler, 1981), meaning people are less willing to incur a cost to postpone a payment than to accelerate a gain. Indeed, a substantial number of participants in many studies preferred to incur a loss immediately rather than being postponed (for a review see Frederick et al., 2002). In a study conducted by Hardisty et al. (2013), participants were willing to pay more for an immediate loss than a delayed loss when the amount was small (e.g., \$10). As mentioned, waiting time in an experience task was qualitatively different from that of a traditional task which allows participants productive use of waiting time. In other words, waiting a loss for idle in an experience task is aversive rather than beneficial to a decision maker. Therefore, while tradeoffs in a traditional task are typically between a larger–later loss vs. a smaller–sooner loss, tradeoffs in the present study are between a larger–sooner loss vs. a smaller–later loss, similar to the setting of this study (Xu et al., 2020), which detected a gain–loss asymmetry in participants’ waiting preference using the same coin collection task. Consequently, Experiment 2 compared the risk-free and risk conditions with outcomes as losses so that waiting would lead to a reduced loss.

### Method

**Participants.** Our sample size was based on an effect size of .75 on the proportion of reversals, as estimated from Experiment 1; a power level of 80%; and

an alpha level of 0.05. A total of 67 undergraduate students (female: 61, male: 6) from a large public university participated in Experiment 2. Participants were recruited using the same poster as in Experiment 1. All participants were between 18 to 24 years old. Each participant signed individual informed consent forms. None of the participants had ever participated in a similar experiment. The study was approved by the ethics committee of the university with which the first author was affiliated.

**Stimuli.** In Experiment 2, choices were set such that losses would be less if the participants chose to wait, i.e., the choices were between paying out a larger immediate coin vs. a smaller delayed coin. Table 4 shows the stimuli of a sample block. Similar to Experiment 1, six blocks were created to correspond to six delays: 7s, 15s, 29s, 56s, 63, and 72s. Unproductive trials were removed as in Experiment 1. However, slightly differing from Experiment 1, the block orders were randomized across participants. In addition, the number of trials for each block were all 6, yielding a total of 36 trials. Within each block, the adjusting value of the sooner option increased from trial to trial.

Table 4

*Stimuli of the 72s block for the risk-free and risky conditions (Experiment 2)*

Risk-free condition			Risky condition		
Immed. coin	Delayed coin		Immed. envelope	Delayed envelop	
Amount <sup>1</sup>	Delay <sup>2</sup>	Amount	Amount <sup>3</sup>	Delay	Amount
-40	72	-1	(.5, -80; 0)	72	(.5, -2; 0)
-40	72	-4	(.5, -80; 0)	72	(.5, -8; 0)
-40	72	-9	(.5, -80; 0)	72	(.5, -18; 0)
-40	72	-14	(.5, -80; 0)	72	(.5, -28; 0)
-40	72	-19	(.5, -80; 0)	72	(.5, -38; 0)
-40	72	-24	(.5, -80; 0)	72	(.5, -48; 0)

Note. <sup>1</sup> The units of amounts are cent; <sup>2</sup> the units of delays are second. <sup>3</sup>( $p, R; 0$ )

represents that there is a  $p\%$  chance that the envelope contains an  $R$ -cent coin or nothing. Immed. = Immediate.

**Incentives.** Participants received a show-up incentive of 15 Yuan and performance-based bonuses. Participants were provided with a savings account with a balance of 22.31 Yuan. Then, 97% of 36 trials (35 trials) were randomly selected; the amount participants selected to pay in these trials was deducted from their accounts. The balance left was the bonuses participants received. The open balance was set as 22.31 Yuan so that for participants who always chose the immediate coin, their bonus would be the same as their counterparts in the gain condition of Experiment 1. The same incentive rules were applied for the two conditions.

**Procedure.** The procedure used for Experiment 2 was similar to that of Experiment 1, except that the choices were framed as losses. Participants were randomly assigned to either a risk-free or a risky condition. To ensure that participants fully understood the task, participants first read a written version of the instructions, then an experimenter provided explanations with demonstrations. The experimenter emphasized that every selection they would make was important to the study; therefore, they were asked to treat each selection seriously. After the demonstration, the participants were left alone in the lab to complete the task. They were debriefed and paid at the end of the experiment.

## Result

One participant was interrupted during the course of the experiment, and another two (one from each condition) treated their first choices carelessly, reflected by always choosing the delayed option initially but switching to pick up the immediate

option for many trials. These three participants were excluded from our analyses<sup>5</sup>. As in Experiment 1, for each participant, we counted the number of trials in which the delayed option for the original choice was chosen (Later-initial), the number of trials in which the delayed option in the final choice was picked up (Later-final), the number of L→S reversals, i.e., intra-trial switches from the delayed option to the immediate option, and the number of S→L reversals, i.e., intra-trial switches from the immediate option to the delayed option. Note that in the loss domain, the later option has a small coin to pay, while the sooner option has a large coin to pay. As in Experiment 1, we calculated the rates of L→S and S→L. The descriptive statistics for each condition are shown in Table 5.

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<sup>5</sup> Including the two careless participants in the analysis neither changed the results regarding waiting preference nor the results regarding dynamic preference reversal.

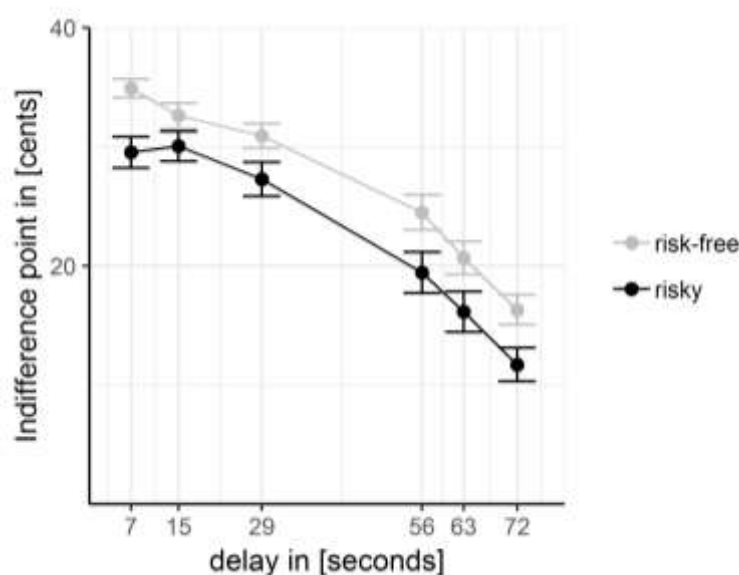
Table 5

*Descriptive statistics for the risk-free and risky conditions in the loss domain (Experiment 2).*

Risk	N	Later-initial	Later-final	L→S	S→L	L→S rate	S→L rate
Risk-free	36	25.17 (7.65)	25.50 (8.04)	1.83 (2.91)	1.17 (1.61)	.09 (.14)	.12 (.16)
Risky	28	18.57 (9.17)	18.32 (9.14)	2.96 (2.92)	2.71 (3.58)	.20 (.19)	.22 (.28)

*Note.* M (SD). Later-initial = the number of trials in which the delayed option was originally chosen. Later-final = the number of trials in which the delayed option was finally picked up. L→S rate: the ratio between L→S and Later-initial. S→L rate: the ratio between S→L and the number of trials in which the sooner option was originally chosen.

**Differences in waiting preference.** Following the same procedure as Experiment 1, we calculated the indifference point of each delay for each participant based on their final choices. Group-level mean indifference points for the two conditions are shown in Figure 4.



*Figure 4.* Group-level mean indifference points for the risk-free and the risky conditions in the loss domain (Experiment 2). Delays are 7 seconds, 15s, 29s, 56s, 63s, and 72s, respectively. Grey dots refer to the risk-free condition; black dots refer to the risky condition. Calculations were based on the participants' final choices. The error bars refer to standard error of the mean.

A repeated measures ANOVA with delay as a within-subject factor and risk condition as a between-subject factor revealed that there was a main effect of delay,  $F(5, 305) = 117.11, p < .001, \eta^2 = .66$ , and a main effect of risk,  $F(1, 61) = 8.57, p < .01, \eta^2 = .12$ . Participants chose to wait in the risk-free condition more frequently than in the risky condition. The interaction between delay and condition was not significant,  $F(5, 305) = .58, p = .71$ . Therefore, in contrast to the gain domain, adding risk to both options reduced the preference for the delayed coin in the loss domain.

**Differences in dynamic preference reversals.** Similarly, we used non-

parametric tests to examine differences in dynamic preference reversals. Unpaired two-sample Wilcoxon tests on the proportion of reversals revealed that participants were more likely to show L→S reversals in the risky condition than in the risk-free condition,  $w = 324$ ,  $p = .01$ , but the effect did not reach significance for S→L reversals,  $w = 354.5$ ,  $p = .12$ .

## Discussion

Experiment 2 revealed that adding risk decreased the participants' waiting preference for a smaller payment. This result differed from Experiment 1, which found that adding risk did not affect waiting preference in the gain domain. Regarding intra-trial switches, both Experiments 1 and 2 showed that the likelihood of L→S reversal increased when risk was introduced. However, Experiment 1 showed that risk also increased the likelihood of S→L reversal. Experiment 2 showed a similar tendency of S→L reversal, but did not reach statistical significance.

## Experiment 3

Using an experience inter-temporal choice task, Experiments 1 and 2 showed that risk affected the participants' waiting preference differently for the gain and loss domains. Specifically, adding risk reduced preference for waiting in the loss domain, but not for the gain domain. The asymmetric effect of risk on waiting gains and losses implies that risk might attenuate or remove the sign effect when people need to experience the waiting course online as in an experience task. Experiment 3 examined this possibility by comparing waiting choices in the risky gain and risky loss



conditions. We also expected to obtain relatively similar dynamic preference reversal rates to partially test the robustness of the findings of Experiments 1 and 2.

## Method

**Participants.** Based on an effect size of 0.75, with a power of 80% and an alpha level of 0.05, we recruited 53 undergraduate students (female: 50, male: 3) from a large public university. The participants were recruited using the same poster as in Experiment 1. All participants were between 18 to 24 years old and signed individual informed consent forms. None of the participants had ever participated in a similar experiment. The study was approved by the ethics committee of the university with which the first author was affiliated.

**Stimuli.** The loss condition in Experiment 3 used the same stimuli as those in the risk condition of Experiment 2. These same stimuli were converted to positive values in the gain condition. Hence, the delayed envelope was the larger one in the gain condition and the smaller one in the loss condition. The stimuli of a sample block are shown in Table 6.

Table 6

*Stimuli of the 72s block in the gain and loss domains for risky intertemporal choices*

*(Experiment 3)*

Gain			Loss		
Delayed envelope Amount <sup>1</sup>	Delay <sup>2</sup>	Immed. envelope Amount <sup>3</sup>	Immed. envelope Amount <sup>3</sup>	Delayed envelope Delay	Amount <sup>3</sup>
(.5, 80; 0)	72	(.5, 2; 0)	(.5, -80; 0)	72	(.5, -2; 0)
(.5, 80; 0)	72	(.5, 8; 0)	(.5, -80; 0)	72	(.5, -8; 0)
(.5, 80; 0)	72	(.5, 18; 0)	(.5, -80; 0)	72	(.5, -18; 0)
(.5, 80; 0)	72	(.5, 28; 0)	(.5, -80; 0)	72	(.5, -28; 0)

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(.5, 80; 0)	72	(.5, 38; 0)	(.5, -80; 0)	72	(.5, -38; 0)
(.5, 80; 0)	72	(.5, 48; 0)	(.5, -80; 0)	72	(.5, -48; 0)

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*Note.* <sup>1</sup> The units of amounts are cent; <sup>2</sup> the units of delays are second. <sup>3</sup>  $(p, R; 0)$  represents that there is a  $p\%$  chance that the envelope contains an  $R$ -cent coin or nothing. Immed. = Immediate.

**Incentives.** The incentive in this experiment was the same as those in Experiments 1 and 2, including the 15 yuan show-up incentive and performance-based bonuses. For the gain condition, the bonus was the amount participants collected in 35 randomly selected trials (97%). For the loss condition, the bonus was the balance of the savings account after deducting the payments of 35 trials (randomly selected) from 22.31 yuan.

**Procedure.** The procedure for the two conditions was the same as that for the gain–risky condition in Experiment 1 and the loss–risky condition in Experiment 2.

## Result

As in Experiment 1, we counted the number of trials in which the delayed coin for the original choice was chosen (Later-initial), the number of trials in which the delayed coin was picked up (Later-final), the number of L→S reversals (switch from the later option to the sooner option), and the number of S→L reversals (switch from the sooner option to the later option). Note that the later option in the gain condition represented a chance of receiving the larger coin, while the later option in the loss condition meant a chance of paying the smaller coin. We then calculated the rates of L→S and S→L. The descriptive statistics for each condition are shown in Table 7.

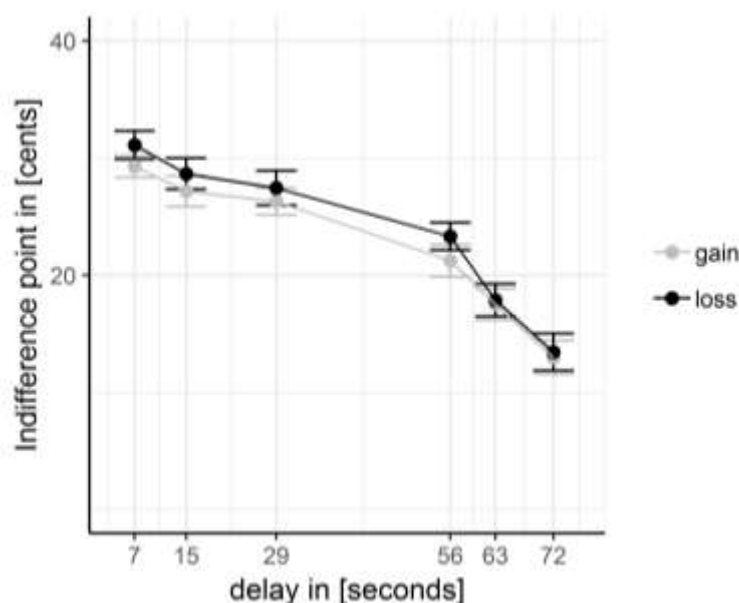
Table 7

*Descriptive statistics of risky intertemporal choice for the gain and loss domains (Experiment 3).*

Condition	N	Later-initial	Later-final	L→S	S→L	L→S rate	S→L rate
Gain	27	19.59 (6.70)	17.85 (6.99)	2.78 (3.14)	1.04 (1.09)	.16 (.18)	.08 (.11)
Loss	26	20.27 (7.15)	20.08 (8.26)	3.50 (3.85)	3.31 (3.13)	.21 (.23)	.21 (.23)

*Note.* M (SD). Later-initial = the number of trials in which the delayed envelope was originally chosen. Later-final = the number of trials in which the delayed envelope was finally picked up. L→S rate: the ratio between L→S and Later-initial. S→L rate: the ratio between S→L and the number of trials in which the immediate envelope was originally chosen.

**Differences in waiting preference.** As in Experiments 1 and 2, we calculated the indifference points of each delay and participant according to the participants' final choices, following exactly the same procedure. The group-level mean indifference points for both domains appear in Figure 5.



*Figure 5.* Group-level mean indifferent points for the risky intertemporal choices in the gain and loss domains (Experiment 3). Delays are 7 seconds (s), 15s, 29s, 56s, 63s, and 72s, respectively. Grey dots refer to the gain domain; black dots refer to the loss domain. Calculations were based on the participants' final choices. The error bars refer to standard error of the mean.

A repeated measures ANOVA with delay as a within-subject factor and domain as a between-subject factor revealed that there was a main effect of delay,  $F(5, 245) = 70.27, p < .001, \eta^2 = .59$ . There was neither a main effect of domain nor an interaction between domain and delay,  $F(1, 49) = 1.97, p = .20$ , and  $F(5, 245) = .29, p = .92$ , respectively.

**Differences in dynamic preference reversal.** Given that the distributions of both types of dynamic preference reversal rates were not symmetric, we conducted non-parametric tests to examine differences. Unpaired two-sample Wilcoxon tests on the

proportion of reversals revealed that participants were more likely to make S→L reversals in the loss domain than in the gain domain,  $w = 204.5$ ,  $p = .01$ , but there was no difference in the likelihood of L→S reversal,  $w = 317.5$ ,  $p = .55$ .

### General discussion

The present study investigated the effect of risk on intertemporal preference and its change over time. We used an experience time-discounting task that allowed for intra-trial switches. We found that adding risk to both larger–later and smaller–sooner options did not affect the participants’ waiting preference for the gain domain (Experiment 1), but decreased their waiting preference for the loss domain (Experiment 2). Both Experiments 1 and 2 showed that adding risk increased intra-trial switches, regardless of whether the outcomes were gains or losses. Experiment 3 observed no gain–loss asymmetry when the outcomes of intertemporal choices were risky. To the best of our knowledge, the present study is the first to use an experience time-discounting task to examine the effect of risk on intertemporal preference and intra-trial switches. Below, we discuss the implications of these findings in relation to previous literature.

#### **The effect of risk on intertemporal preference**

The finding that risk has no impact on waiting preference for gain outcomes converges with findings from some previous studies, i.e., Andreoni & Sprenger, 2012 and Hardisty & Pfeffer, 2017. Both these studies used traditional question-based tasks that involved relatively long delays, and found that when risk was added to both

options, participants did not change their waiting preferences. Our findings add that this is true even for choices that involve very short waiting periods and when delays are actually experienced. However, this finding diverges from other studies that showed that there is either an increased risk of impatience (Öncüler, 2000; Sun & Li, 2010) or decreased impatience (Keren & Roelofsma, 1995; Weber & Chapman, 2005). We explain that these conflicts might be attributed to factors such as whether probability was presented in one or both options, and whether the expected values of the risk and risk-free conditions were matched. For example, both studies conducted by Öncüler (2000) and Sun and Li (2010) used the same value for risky and riskless prospects; hence, the expected value in their risk conditions was smaller than that in their riskless conditions. Because people typically discount small magnitudes more than large magnitudes (Frederick et al., 2002), the heavier discounting in the risk condition than that in the riskless condition might have been due to the magnitude effect.

For the loss domain, we found that adding risk reduced the participants' preference for waiting. Previous studies have yielded varying findings in connection to this point. One study showed that risk increases the discount of a loss (Blackburn & El-Deredy, 2013). Another study showed that risk decreases the discount of a loss (Ahlbrecht & Weber 1997), but only for a matching task. Furthermore, other studies have shown no impact on choices (Ahlbrecht & Weber, 1997; Hardisty & Pfeffer, 2017). While these differences might be related to the heterogeneous methods used in these studies, a detailed examination on this point is beyond the scope of our study.

However, we note that waiting for a loss in the aforementioned studies was beneficial because it postponed a payment, while it was aversive in the present context (Xu et al., 2020). Therefore, the two are not directly comparable. In the present context, we propose that the increase in impatience on waiting for a smaller risky loss might be because adding risk destroyed the extra effort that participants would exert to treat sure loss outcomes. That is, for certain outcomes, Xu et al. (2020) demonstrated that participants are more patient waiting for a reduction of loss than waiting for the same amount of reward, using the same coin collection task. In contrast, for risky outcomes, this gain–loss asymmetry disappeared in Experiment 3. A possible explanation is that feelings elicited by the gambling procedure might interact with the fear of loss; hence, muddle the extra effort participants would exert waiting for sure losses (Frederick et al., 2002). In this sense, our finding was congruent with the previous finding that risk increases the discount of a loss (Blackburn & El-Deredy, 2013). However, future research, for instance, comparing both risk vs. risk-less, and gain vs. loss outcomes simultaneously is needed to verify this effect and its explanation.

### **Dynamic preference reversals over time**

The present study found that risk increases intra-trial switches. We advocate that cautiousness should be paid in the interpretation of this finding.

First, the L→S reversals observed in the coin collection task was more analogous to that reflected in the delay-of-gratification paradigm (Mischel et al., 1972). It differs from reversals in time-inconsistency studies in at least two aspects: 1) the sooner option remains stable across decisions in the delay-of-gratification paradigm, while its

delay varies among two decisions when examining time-inconsistency. Accordingly, reversals in time inconsistency are attributed as a result of a faster increase of subjective utility of the sooner outcome than the later outcome, as both approach availability (Frederick et al., 2002), but not the intra-trial switches in the coin collection task; and 2) dynamic preference reversals in the coin collection task could occur during a continuous period of time that lasts from the original decision until the time point the final (second decision) decision is made, while in the time inconsistency paradigms, dynamic preference reversals are generated between two decisions made at two disparate time points. In short, even though the two may be connected (Göllner et al., 2018), and both are considered as a measure of impulsivity (Ainslie, 1975; Frederick et al., 2002; Mischel et al., 1972; Xu et al., 2020), the two might measure different dimensions of the impulsivity construct (Duckworth & Kern, 2011; Reynolds et al., 2008). This partly explains the divergence that risk increased intra-trial switches in the present study, but showed no impact on time-inconsistency (Ahlbrecht & Weber, 1997; Blackburn & El-Deredy, 2013; Sun & Li, 2010), or reduced time-inconsistency (Keren & Roelofsma, 1995; Weber & Chapman, 2005a) in previous studies. However, the present study also used very small outcomes and short delays. It has been well established that risk aversion is more pronounced for large outcomes than for small ones (Weber & Chapman, 2005b). Compared to large-stake gambles, low-stake gambles are more likely to induce emotions such as excitement over emotions such as fear and disappointment (Haisley et al., 2008; van Winden et al., 2011; Weber & Chapman, 2005b). Given that emotions are strong



motivators (Frijda et al., 1989; Loewenstein, 1996), it is possible that the effect of risk on decision switches depends on the outcome's magnitude.

Second, the findings might be explained in several ways. Foremost, our finding echoed with the well-established finding that risky choices are time-variant (Rieskamp, 2008). This line of literature has shown that when an identical risky choice is repeatedly presented, a decision maker frequently switches his/her choice (Hey, 2001). In a review of literature, Rieskamp et al. (2008) concluded that people's decisions differed for approximately 25% of cases when encountering the same set of choices twice. In fact, the probabilistic nature of risk decisions has been so widely accepted that most decision theories have abandoned the deterministic characteristic and take a probabilistic approach (González-Vallejo, 2002; Rieskamp, 2008; Rieskamp et al., 2006). A probabilistic representation of a decision indicates both preference direction and decision strength, so that the decision strength is stronger for a 90% chance of choosing A vs. a 60% chance of choosing A (Busemeyer & Townsend, 1993; González-Vallejo, 2002). According to this framework, risk might attenuate the decision strength of the initial decisions (i.e., being less decisive), which in turn makes decisions more likely to be changed.

A related question worthy to delve into is whether participants in the risk condition were less decisive about their initial choices or simply made more errors because of inattention or calculation errors. This is because the initial choices in the task had no impact on the final results and the money participants obtained; the participants may have made their initial choices quickly to reduce the overall length

of the experiment. Because the risky choices were slightly more information-laden than the risk-free choices, the risky choices may have led to more errors, which were corrected after further deliberations. We admit that the observed dynamic preference reversal was contingent upon participants' authentic treatments for both choices. However, we are confident that the differences in dynamic preference reversal were unlikely to have been fully caused by inattention or calculation errors. As described in the procedure section, effort was taken to have participants treat each decision of theirs carefully. In addition, the following additional analyses support the indecisiveness account<sup>6</sup>. First, in all three experiments, L→S reversal was more frequent for trials near indifference points that were supposed to be harder to decide, converging with the previous finding that people are more indecisive and show more inter-option waving flips in the mouse trajectory for choices near indifference points (Dshemuchadse et al., 2013). Second, we analyzed inter-trial switches based on the coin the participants picked up. Experiment 1 showed significantly more inter-trial switches in the risk condition than in the risk-free condition. Experiment 2 yielded the same tendency, but did not reach the significance level. Because these calculations were based on the participants' final choices, for which they had enough time to deliberate and had experienced the consequences, we advocate these inter-trial switches confirm that participants were more indecisive in the risk condition.

Aside from the decision strength account, an alternative explanation is the affective approach, which has been proposed by both social psychologists (Metcalfe

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<sup>6</sup> Details of the analysis can be found in supplementary material at [https://osf.io/z3kx5/?view\\_only=559bb93ba7a947e6906bc2afd96417e7](https://osf.io/z3kx5/?view_only=559bb93ba7a947e6906bc2afd96417e7)

& Mischel, 1999) and behavioral economists (Loewenstein et al., 2001; Loewenstein, 1996; McClure et al., 2004). From this perspective, waiting for risky outcomes elicits more affective fluctuations than waiting for certain outcomes. In particular, people frequently experience excitement when taking gambles, especially gambles with small stakes (Haisley et al., 2008; van Winden et al., 2011). Hence, these state fluctuations in the risky condition might increase intra-trial switches. However, the present study also observed an increase in the tendency of S→L reversal (although slightly less pronounced than L→S reversal), implying the involvement of mechanism(s) free from directional prediction (e.g., the decision strength account). We advocate that future studies that include affective measures are needed to verify the mechanism underlying the risk effect on decision switches.

## Conclusions

In interpreting the present findings, a few limitations need to be kept in mind. First, the participants were mainly females due to the unbalanced sex ratio in the campus where the experiments were conducted. Second, the study adopted a staircase indifference point task in which the SS options were always immediately available and its order within block was not randomized. Future studies could address these issues and use choices in which the sooner options are shortly delayed so that the procedure is more analogous to traditional tasks on time-inconsistency. Fourth, is that the coin collection task, as with other experience tasks (Flora & Pavlik, 1992; Reynolds & Schiffbauer, 2004; Smits et al., 2009), uses in-game points in each trial before they were converted to real money at the end of the experiments. Hyten et al.

(1994) showed that both delays to in-game points (i.e., delays occurring in each trial) and delays to the exchange (i.e., time interval between the moment receiving in-game points and the moment when in-game points being converted to real money) can affect behavior. However, in their study (Hyten et al., 1994), delay to exchange was on the timescales on days-weeks, as opposed to our timescales of seconds-minutes. We speculate that results from the study (Hyten et al., 1994) may not generalize to our context of very short timescales where the participants do not have an opportunity to spend any of their rewards. That being said, from a modelling perspective, using in-game points can be seen as an additional source of uncertainty about cashing the in-game points, future studies could manipulate and model the difference on waiting preference between using in-game points and real cash.

By using an experience-based time discounting task, the present study showed that for real and short online waits, the uncertainty aspect of an outcome does not affect people's willingness in waiting for a reward, but it reduces people's willingness in waiting for a reduction of losses. Furthermore, the uncertainty aspect of an outcome increases people's tendency to switch their decisions, with the reasons underlying the switches remaining to be investigated for future studies.

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