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PRUDENT DISCOUNTING: EXPERIMENTAL EVIDENCE ON HIGHER ORDER TIME RISK PREFERENCES*

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We report results from an experiment that contrasts preferences toward the risk of *what* may happen (*outcome risk preferences*) with preferences toward the risk of *when* something may happen (*time or delay risk preferences*). Just as choices over monetary risks identify utility independently from discounting, choices over uncertain delays of a fixed reward identify discounting independently from utility. We replicate the widespread finding of outcome risk aversion, but—in a perfectly symmetric design—find substantial heterogeneity in delay risk aversion. Going beyond the second order of risk aversion, on the other hand, yields pervasive evidence for delay prudence and outcome prudence alike. This first empirical support for *prudent discounting* speaks to recent theoretical arguments that prudence may be a more important trait than previously realized.

1. INTRODUCTION

Although most studies on risk assume perfect knowledge about when risks materialize and that uncertainty only concerns how good or bad the outcome will be, this article looks at the dual case in which the outcome is certain but the time of its occurrence is not. In an experiment, we study preferences toward the risk of receiving a fixed monetary amount sooner or later; that is, although subjects are not confronted with any outcome risk, they are confronted with *delay* or *time risk*.¹ Unlike experimental designs that rely on eliciting choices over less money sooner versus more money later, the design proposed here allows for the identification of discounting independently from utility. Studying preferences toward the risk of *when* something may happen (instead of studying the risk of *what* may happen) thus provides a new angle to elicit properties of the discount function.²

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¹ Three articles have empirically studied time risk before: Chesson and Viscusi (2003), Onay and Öncüler (2007) and DeJarnette et al. (2020). We discuss these articles below.

² This article is about time discounting and not about the utility of time. The latter is studied by Noussair and Stoop (2015), among others, who study preferences over waiting time. In particular, the authors conduct experiments in which the outcome of subjects' decisions is waiting shorter or longer in a room without the possibility to do any-

In addition, *time risk preferences* are relevant in themselves as time risks are important to economics and beyond. Time risks describe events that are “only a matter of time:” They are certain to come about sooner or later, but the exact time of occurrence is uncertain. Since death is only a matter of time, although the amount to be received from life insurance or an inheritance may be certain, the time of receipt is not. In some search problems, the outcome is known but the date of availability is not. Known consequences of climate change are only a matter a time and will come with significant economic consequences.³ Monetary policy is another example. Oftentimes, there has been rather little uncertainty about a central bank raising interest rates eventually and what the consequences will be, but there is much uncertainty about when exactly it will do so. Finally, the development of a vaccine against coronavirus disease 2019 (COVID-19) constitutes a very recent example of an important matter of time.⁴

To empirically identify time risk preferences, we let subjects choose between two options that grant the *same* outcome but that differ in the (possibly random) delivery time of the outcome. For example, Option A could deliver the outcome in exactly two weeks, although Option B delivers, with equal probability, the outcome in either one or three weeks. A time-risk-averse individual would prefer the safe, former choice, whereas a time-risk-seeking individual would opt for the risky Option B. In the experiment, the certain outcome is a fixed monetary amount that is paid through a delayed bank transfer.

We go beyond risk aversion by studying preferences toward higher order risk properties such as skewness or kurtosis, which are determined by the preference traits of prudence (Kimball 1990) and temperance (Kimball 1993). In the case of outcome risks, beginning with an influential paper by Deck and Schlesinger (2010), these higher order risk preferences have received substantial attention in the recent empirical risk preference literature. Theoretical work has shown the importance of prudence and temperance for economic outcomes long before that. For example, prudence is necessary and sufficient for precautionary saving (Leland 1968; Sandmo 1970), and temperance is decisive for behavior under changing background risks (Eeckhoudt et al. 1996).⁵

In the atemporal expected utility model with smooth utility function u , prudence and temperance can be defined as $u''' \geq 0$ and $u'''' \leq 0$, respectively. However, equivalent and theory-free definitions, in terms of simple preferences over (outcome) lotteries, were put forward by Eeckhoudt and Schlesinger (2006). Prudence is a preference for disaggregating an unavoidable loss and a zero-mean risk across two equally likely states of nature, although temperance refers to a preference for disaggregating two unavoidable, independent zero-mean risks. In a theoretical paper, Ebert (2020) defines *prudent and temperate discounting* through similar lotteries that describe the apportionment of (fixed and risky) delays instead of outcomes, and studies the behavioral implications of those traits. Within the expected discounted utility (EDU) model with smooth discount function ρ , prudence is equivalent to $\rho''' \leq 0$, although temperance is equivalent to $\rho'''' \leq 0$. As shown in Ebert (2020), these traits are decisive for investment and saving behavior, health choices, and climate change abatement policies, among others.

thing. In that case, time is an *outcome*, and therefore, choices over risks in waiting time identify *utility* of “time.” The current article, on the other hand, is concerned with “the study of time as the duration that a person has to wait until she receives an outcome in intertemporal choice (discounting)” (Abdellaoui and Kemel 2014, p. 1844), with the special feature that this duration is risky. Recently, Abdellaoui et al. (2018) have conducted the first experiment that involves both types of “time.” The authors elicit preferences toward the (nonrisky) delay of (risky) outcome time.

³ In a regulatory document, Bolton et al. (2020) introduce the term “green swans” for climate change events. A major difference from “black swans” (unpredictable, rare, high-impact events; see Taleb 2007) is their foreseeable nature (see also NGFS 2019, p. 4). Although there is a high degree of certainty that green swans will materialize, there is “uncertainty regarding the timing” (Bolton et al. 2020, p. 3).

⁴ At the time of this writing, several vaccines have been developed, but their sufficient availability remains an important matter of time. Another argument for the relevance of time risk in light of COVID-19 can be made with reference to the uncertainty about a shutdown’s duration, see <https://berlin-econ.de/bse-sars-cov-2/weizsaecker-lotteries>.

⁵ Other applications of higher order risk preferences range from rent-seeking behavior (Treich, 2010) over health-care decisions (Courbage and Rey, 2012) to prevention efforts (Courbage et al., 2017), among many others.

The methodological contribution of the current article is to illustrate how the idea of time risk apportionment can be used to elicit old and new properties of individuals' discount functions. In an experiment, we employ these theory-free lottery definitions to elicit risk aversion, prudence, and temperance toward delay risk. We further test for risk aversion, prudence, and temperance toward outcome risk so that we can compare both types of risk preferences with one another. The risk apportionment approach benefits from consistent framing in the elicitation of the three traits in both the delay part and the outcome part of the experiment. Moreover, the framing is also consistent *between* these parts. This symmetry, and the fact that the experimental design systematically controls and tests for sequence effects (details below), makes outcome and delay risk preferences comparable within subjects.

The results of the experiment are as follows: First, we replicate and complement existing empirical evidence on risk aversion and higher order risk preferences (prudence and temperance) toward wealth as well as on time risk aversion and time-risk-seeking. Regarding risk preferences toward wealth, we find significant evidence for risk aversion and prudence and, to a lesser extent, temperance. In contrast, we find a tripartite pattern regarding risk aversion toward delay. Although a significant number of subjects is time-risk-averse, an even larger group of subjects is risk-seeking toward delay risk. A third group of subjects appears to be risk-neutral toward delay risk. Moreover, we find that risk aversion toward delay and risk aversion toward wealth correlate positively.

Second, we present the first evidence for delay prudence. There is strong evidence for prudence toward delay risk. That is, although delay and outcome risk preferences generally differ at the second order of risk aversion, they do not differ at the third order of prudence.

Third, the evidence for delay temperance is qualitatively similar to that of delay risk aversion. The evidence is divided into three sizable groups: temperate, intemperate, and temperate-neutral decision-makers (DMs).

Fourth, for outcome risk preferences, the stylized fact is that risk aversion decreases with the magnitude of delay (e.g., Shelley 1994; Ahlbrecht and Weber 1996; Abdellaoui et al. 2011). Within a between-subjects factorial design, we investigate whether there is an analogous observation for time risk preferences. In our experiment, risk aversion, prudence, and temperance neither increase nor decrease with the magnitude of the outcome that is paid at a random time.

Fifth, we observe some correlation between risk aversion toward delay and risk aversion toward wealth as well as between prudence toward delay and prudence toward wealth, and find that it is not due to carryover effect.⁶

The sixth and final finding of this article concerns the validity of recent theoretical predictions concerning the higher order risk preferences of risk averters and risk seekers (details later). This so-called *consistency heuristic*, proposed by Eeckhoudt et al. (2009), Tsetlin and Winkler (2009), and Crainich et al. (2013), has recently received empirical support by Deck and Schlesinger (2014), among others. We find rather strong support for the consistency of delay risk preferences.

Overall, due to its symmetry in the treatment of wealth and time risks, the experimental design proposed in this article allows for a first comparison of risk aversion toward wealth and toward delay as well as of their higher order counterparts. Experimental findings indicate differences, similarities, and relationships between these basic human traits.

2. RELATED LITERATURE

The current article elicits and compares time and outcome risk preferences through a perfectly symmetric experimental design that is based on risk apportionment. We go beyond the

⁶ As mentioned, the finding on risk aversion corroborates that of DeJarnette et al. (2020). In their study, risk aversion for delay (being the focus of the study) is always elicited before risk aversion for wealth, whereas in the current study, half of the subjects face choices eliciting risk aversion for wealth (respectively, delay) first. We find no evidence for the order to matter for results (no carryover effect).

second order of risk aversion and investigate whether the higher order risk preferences of prudence and temperance can be observed for time risk. Thereby, we contribute to the recent literature on higher order risk preferences (e.g., Deck and Schlesinger 2010, 2014, 2018; Ebert and Wiesen 2011, 2014; Maier and R uger 2011; Noussair et al. 2014; Haering et al. 2020; and Heinrich and Mayrhofer 2018; see Trautmann and van de Kuilen 2018 for a review). The major difference in the designs of these papers is that they identify higher order properties of a *utility* function, whereas this article is the first to identify higher order properties of the *discount* function. In particular, the current article is the first to investigate prudent and temperate discounting. Moreover, we compare higher order discounting with higher order outcome risk preferences within subjects, and show at what orders time and outcome risk preferences are similar and at what orders they are not. This article is also the first to study the consistency heuristic proposed by Eeckhoudt et al. (2009), Tsetlin and Winkler (2009), and Crainich et al. (2013) in the context of time risk.

We also contribute to the scarce literature specifically concerned with time risks. Although there are hundreds of empirical studies on outcome risk preferences, there seem to be only three empirical studies concerned with human time risk preferences.⁷ In the first study on the topic, Chesson and Viscusi (2003) present survey evidence on time risk preferences. In particular, the authors find that about one-third of business owners is time-risk-averse. A second survey, by Onay and  nc ler (2007), finds that individuals are generally time-risk-averse over gains and time-risk-seeking over losses. Moreover, they find that time-risk-taking depends on the winning probability of the lotteries considered and is well explained by probability weighting. Although the main contribution of DeJarnette et al. (2020) is of a theoretical nature, this article also presents results from the first incentivized experiment on time risk preferences. The majority of subjects is time-risk-averse, and only very few subjects are consistently time-risk-seeking. The authors further report a positive correlation between time risk aversion and risk aversion toward wealth.⁸

The current article also contributes to the empirical literature on time preferences more generally. The standard approach in that literature is to elicit a subject's indifference between more of a desirable outcome later and less of it sooner (e.g., Andersen et al. 2008; Andreoni and Sprenger 2012; Abdellaoui et al. 2013), in which various experimental methods can be used to elicit the point of indifference (see Cheung 2016 for a discussion). Necessarily, any such trade-off is determined by both discounting and utility. Attema et al. (2016) identify discounting independently from utility through an ingenious approach that elicits choices over *riskless* streams of the same monetary reward (e.g.,  10 for four weeks starting in five weeks from now versus  10 for six weeks starting in 10 weeks from now). Although our time risk apportionment approach is conceptually very different from that of Attema et al. (2016), it shares its advantage of identifying discounting independently from utility. On a different matter, preferences regarding the timing of the resolution of outcome uncertainty (Kreps and Porteus 1978) and associated anticipatory emotions (Loewenstein 1987) were shown to be important in various studies (e.g., Chew and Ho 1994; Lovallo and Kahneman 2000; Noussair and Wu 2006; Kocher et al. 2014). In the experiment of the current article (just as in the other, aforementioned ones on time risk preferences), resolution of uncertainty is exogenous to experimental subjects and all risks (whether they concern outcome or delay) are resolved at the end of the experiment. The elicitation of preferences toward the resolution of time risk remains a topic for future research.

⁷ Interestingly, in the literature on zoology, outcome and delay risk preferences stand on equal ground. There are many empirical studies on outcome risk but also on delay risk. Kacelnik and Bateson (1996) review 59 studies on the risk preferences of animals, and find that their foraging behavior is largely consistent with time-risk-seeking. "We found that when risk is generated by variability in the amount of reward, animals are most frequently risk-averse [...]. In contrast, when variability is in delay to reward, animals are universally risk-prone" (Kacelnik and Bateson 1996, abstract).

⁸ Recently, Berman and Kirstein (2020) and Mu, Pomatto, Strack, and Tamuz (2021) propose further models of time risk preferences.

3. THEORETICAL BACKGROUND

This section describes the theoretical underpinnings of this article’s experimental method to elicit risk aversion, prudence, and temperance toward wealth and delay, respectively. The method is purely choice-based and, as such, not reliant on a given theory of preferences. Following Eeckhoudt and Schlesinger (2006) (for outcome, i.e., wealth, risks) and Ebert (2020) (for time, i.e., delay, risks), however, within the standard EDU model, these traits have implications for the signs of the derivatives of the utility and discount function, respectively. We follow these articles and define risk aversion, prudence, and temperance toward wealth and delay, respectively, through choices between two relatively simple lotteries. (The definitions of risk-seeking, imprudence, and intemperance are obtained by reversing the respective choice condition in each case.) We further present the EDU derivative characterization of each trait. In Section 6, we discuss relationships with other models of time risk preferences.

Throughout the article, let u denote a smooth and strictly increasing utility function that assigns monetary outcomes $x > 0$ to strictly positive utility levels $u(x)$. Let ρ denote a smooth and strictly decreasing discount function with $\rho(0) = 1$, mapping dates $t \geq 0$ to strictly positive discount factors $\rho(t)$. Within EDU, a nonnegative (possibly random) outcome \bar{x} that is paid at the nonnegative (possibly random) time $\bar{\tau}$ is evaluated as

$$(1) \quad U(\bar{\tau}, \bar{x}) := \mathbb{E}[\rho(\bar{\tau})u(\bar{x})].$$

In all the binary choices of the experiment, either outcomes or delays (but not both) are risky. All risks are resolved at the end of the experiment. Moreover, if the outcomes of a given choice are risky, then they are paid with the same nonrisky delay \bar{t} (in the experiment, 12 weeks). Therefore, such choices determine outcome risk preferences over payments delayed by a date \bar{t} in the future. Within EDU, the time- \bar{t} -delayed risky outcome \bar{x}_A is preferred over the time- \bar{t} -delayed risky outcome \bar{x}_B if

$$(2) \quad U(\bar{t}, \bar{x}_A) \geq U(\bar{t}, \bar{x}_B) \iff \mathbb{E}[u(\bar{x}_A)] \geq \mathbb{E}[u(\bar{x}_B)],$$

because the common constant factor $\rho(\bar{t})$ drops out of the inequality (1). Similarly, if $\bar{\tau}$ is risky, then both options of a choice concern the same nonrisky outcome \bar{x} (in the experiment, 11 euros). Therefore, such choices determine time risk preferences over delays referring to a fixed monetary amount \bar{x} . Within EDU, delaying \bar{x} by $\bar{\tau}_A$ is preferred over delaying it by $\bar{\tau}_B$ if

$$(3) \quad U(\bar{\tau}_A, \bar{x}) \geq U(\bar{\tau}_B, \bar{x}) \iff \mathbb{E}[\rho(\bar{\tau}_A)] \geq \mathbb{E}[\rho(\bar{\tau}_B)],$$

because, this time, the common constant factor $u(\bar{x})$ drops out of inequality (1). In summary, inequality (2) (inequality (3)) shows that random outcomes (random delays) with higher expected utility (higher expected discount) are desirable. This is what (Ebert, 2020) refers to as the time-outcome risk duality. It describes that—and how—choices over outcome risks with a fixed delay are determined solely by the utility function, whereas choices over the risky delay of a fixed outcome are determined solely by the discount function. In particular, adopting an empiricist’s viewpoint, choices over the risky delay of a fixed outcome allow for the identification of discounting independently from utility.

Next, we present the choice-based definitions of higher-order wealth risk preferences, based on Eeckhoudt and Schlesinger’s (2006) idea of risk apportionment. The only difference to Eeckhoudt and Schlesinger (2006) is that all payments are delayed by a fixed time \bar{t} , which, according to inequality (2), does not matter for choices. Let x be a wealth endowment and let $x_1 > 0$ and $x_2 > 0$ denote two fixed wealth reductions. All risks must be defined such that final outcomes (and later, also times) remain positive. The notation $[\cdot; \cdot]$ refers to a 50-50 risk so that, for example, $(\bar{t}, \bar{x}_A^{(2)}) := (\bar{t}, [x - x_1; x - x_2])$ refers to the lottery, which, at time \bar{t} , pays outcomes $x - x_1$ and $x - x_2$ with equal probability. An individual is called (wealth or

outcome) risk-averse if she prefers $(\bar{t}, \tilde{x}_A^{(2)})$ over $(\bar{t}, \tilde{x}_B^{(2)}) := (\bar{t}, [x - x_1 - x_2; x])$ for arbitrary parameter values \bar{t}, x, x_1 , and x_2 . Thus, risk aversion is characterized by the preference for disaggregating two unavoidable wealth reductions across states of nature. Note that (Eeckhoudt and Schlesinger, 2006) speak of “risk” apportionment, even though in this definition of risk aversion, the choice amounts to apportioning two fixed amounts (which can be seen, of course, as degenerate, negative-mean risks). Within EDU, this preference is equivalent to $u'' \leq 0$ (Eeckhoudt and Schlesinger 2006; see Ebert and Wiesen 2014 for an explicit proof) as well as to an aversion to mean-preserving spreads (Rothschild and Stiglitz 1970).

Wealth or outcome prudence (third-order risk aversion) is defined as the preference for disaggregating a certain reduction in wealth $-x_1$ and a nondegenerate zero-mean risk $\tilde{\epsilon}_2$. In other words, we simply replace x_2 by $\tilde{\epsilon}_2$ in the definition of risk aversion and call a DM prudent if and only if she prefers $(\bar{t}, \tilde{x}_A^{(3)}) := (\bar{t}, [x - x_1; x + \tilde{\epsilon}_2])$ over $(\bar{t}, \tilde{x}_B^{(3)}) := (\bar{t}, [x - x_1 + \tilde{\epsilon}_2; x])$ for all \bar{t}, x, x_1 , and $\tilde{\epsilon}_2$. The intuition is that a prudent DM prefers an unavoidable zero-mean risk in the state in which she is relatively wealthier. Eeckhoudt and Schlesinger (2006) show that this definition is equivalent to $u''' \geq 0$ in EDU. Therefore, prudence is also equivalent to downside risk aversion, as defined by Menezes et al. (1980).

Wealth or outcome temperance (fourth-order risk aversion) is defined as the preference for disaggregating two unavoidable, independent zero-mean risks across states of nature. In particular, an individual is temperate if and only if she prefers $(\bar{t}, \tilde{x}_A^{(4)}) := (\bar{t}, [x + \tilde{\epsilon}_1; x + \tilde{\epsilon}_2])$ over $(\bar{t}, \tilde{x}_B^{(4)}) := (\bar{t}, [x + \tilde{\epsilon}_1 + \tilde{\epsilon}_2; x])$ for all $\bar{t}, x, \tilde{\epsilon}_1$, and $\tilde{\epsilon}_2$. Within EDU, this preference is equivalent to $u'''' \leq 0$, which, in turn, is equivalent to outer risk aversion (“fat tails aversion”) as defined by Menezes and Wang (2005).

Next, we define higher order delay or time risk preferences (Ebert 2020).

The DM’s choices in the experiment are always between two delay risks that determine when the fixed amount \bar{x} is paid. As an example of a delay risk, let $\bar{x} = \text{€} 11$ and let wk denote the unit of a week. Then, $([1wk; 3wk], \text{€} 11)$ refers to the risk of receiving, with equal probability, the € 11 either in one week or in three weeks from now. Delay or time risk aversion (risk-averse discounting, second-order discounting) is defined as the preference $(\tilde{\tau}_A^{(2)}, \bar{x}) := ([t + d_1; t + d_2], \bar{x})$ over $(\tilde{\tau}_B^{(2)}, \bar{x}) := ([t + d_1 + d_2; t], \bar{x})$ for all \bar{x} , fixed “base (endowment) delays” t , and additional delays $d_1 > 0$ and $d_2 > 0$. Note that the positive delays d_1 and d_2 of a payment are undesirable just like the negative fixed amounts $-x_1$ and $-x_2$ were in the definition of risk aversion toward wealth. Delay risk aversion is characterized by a preference for disaggregating additional delays across states of nature. Within EDU, Ebert (2020) shows that delay risk aversion as defined is equivalent to $\rho'' \leq 0$. Note that the commonly used discount functions satisfy $\rho'' \geq 0$ and thus imply delay risk-seeking; we discuss the implications of this observation in more detail in Section 6.

Delay or time prudence (prudent discounting, third-order discounting) is defined as the preference $(\tilde{\tau}_A^{(3)}, \bar{x}) := ([t + d_1; t + \tilde{t}_2], \bar{x})$ over $(\tilde{\tau}_B^{(3)}, \bar{x}) := ([t + d_1 + \tilde{t}_2; t], \bar{x})$ for all \bar{x}, t, d_1 and zero-mean delay risks \tilde{t}_2 . Delay prudence thus implies that the DM wishes to disaggregate an additional fixed delay and a delay risk; that is, she prefers delay risk in the state in which delay is shorter. Note that this preference is defined regardless of whether the DM is risk-averse (so that delay risk is “bad”) or risk-seeking (so that delay risk is “good”). As in the case of wealth prudence, delay prudence is defined such that it is consistent with a preference for combining “good with bad” in each state of nature and, *also*, with a preference for combining “good with good” (Crainich et al. 2013). This argument is nontrivial and explained in detail in Appendix. Accepting it leads to the direction of preference in the definition and implies that, within EDU, prudence is equivalent to $\rho''' \leq 0$.⁹ Ultimately, the flip in sign compared to outcome prudence, $u''' \geq 0$, is a consequence of discount functions being decreasing,

⁹ Formally, from inequality (3), prudence is equivalent to

$$0.5\rho(t + d_1) + 0.5\rho(t + \tilde{t}_2) \geq 0.5\rho(t + d_1 + \tilde{t}_2) + 0.5\rho(t) \iff \frac{\rho(t+d_1)-\rho(t)}{d_1} \geq \frac{\rho(t+\tilde{t}_2+d_1)-\rho(t+\tilde{t}_2)}{d_1}.$$

whereas utility functions are usually assumed to be increasing. Ebert (2020) further shows that $\rho''' \leq 0$ induces precautionary behavior toward time risk, just as $u''' \geq 0$ does toward outcome risk (Kimball 1990). Precautionary behavior describes the undertaking of a costly action today to improve one’s constitution in the uncertain future. Moreover, prudence determines preferences over time risks that differ in their skewness (i.e., small-probability, high-impact risks); see Ebert (2020) for details.

Delay or time temperance (temperate discounting, fourth-order discounting) is defined as the preference $(\tilde{\tau}_A^{(4)}, \bar{x}) := ([t + \tilde{t}_1; t + \tilde{t}_2], \bar{x})$ over $(\tilde{\tau}_B^{(4)}, \bar{x}) := ([t + \tilde{t}_1 + \tilde{t}_2; t], \bar{x})$ for all \bar{x}, t , and independent zero-mean risks \tilde{t}_1 and \tilde{t}_2 . Delay temperance means that the DM prefers to disaggregate the delay risks across states of nature instead of face both of them in the same state, and can be shown to be equivalent to $\rho'''' \leq 0$ within EDU.¹⁰ Ebert (2020) shows that delay temperance induces preferences for platykurtic over leptokurtic time risks and may impact, for example, investment decisions with uncertain payout time.

4. EXPERIMENTAL DESIGN

The experiment took place at Tilburg University’s CentER Lab, on February 15 and 16, 2016. There were four sessions each day, and each session lasted for about 90 minutes. Ten Tilburg University students from various fields of study participated in each session; that is, the total number of participants was 80.

4.1. *Structure of the Experiment.* The experiment was structured into two parts. PART W elicited wealth risk preferences and was structured into three stages, RA-W, PR-W, and TE-W, which elicited risk aversion toward wealth, prudence toward wealth, and temperance toward wealth, respectively. Similarly, PART D elicited delay risk preferences and was structured into the three stages, RA-D, PR-D, and TE-D, which elicited risk aversion toward delay, prudence toward delay, and temperance toward delay, respectively. Subjects made seven choices in each stage and thus 21 choices in each part, which amounts to 42 choices in total. Table 1 summarizes the lottery preferences tested for in the experiment.

4.2. *Procedure.* Once arrived, subjects drew a card from a pile of cards numbered from 1 to 10, which determined their seat in the laboratory. Each place was prepared with a sheet and a blue pen. Pinned to the wall of each cubicle was a calendar with the current date circled (see document *CALENDAR* in the supplementary material). The sheets were stapled and contained a title page, instructions, control questions, the actual choice sheets, and a short questionnaire. In the following, we refer to the whole document as “the sheet” (for an example, see document *CHOICE SHEET* in the Supporting Information).

Each part was preceded by instructions that contained information specific to wealth or delay risks, respectively. All instructions were read aloud by the experimenter. Additional instructions preceded each stage. Control questions followed the instructions of each stage. The experimenter checked the answers to the control questions of each participant personally, which was feasible given the small session size.¹¹ After having received instructions and having answered the control questions for a stage, subjects made the seven choices for that stage. Once the choices in all six stages were made, subjects completed a short questionnaire.

Letting d_1 go to zero yields $\rho'(t) \geq \mathbb{E}[\rho'(t + \tilde{t}_2)]$ and the equivalence with $\rho''' \leq 0$ (i.e., ρ' concave) follows from Jensen’s inequality.

¹⁰ The proof is similar to that outlined in footnote . Instead of taking a derivative by letting d_1 go to zero, Jensen’s inequality is first applied to \tilde{t}_1 . Then, like in footnote , Jensen’s inequality is applied a second time, to \tilde{t}_2 .

¹¹ Participants could only proceed after having answered all comprehension questions correctly. Few subjects made mistakes, and those who made a mistake were able to find the correct answer with the second guess, after having gone back to the instructions. No personal explanations by the experimenter were given. No subject had to be excluded from the experiment due to comprehension issues.

TABLE 1
SUMMARY OF THE LOTTERY PAIRS IN THE EXPERIMENT

Risk Preferences for Wealth, PART W		
Trait	Preference Condition (Fixed Delay \bar{t})	EDU condition
Wealth risk aversion	$(\bar{t}, \bar{x}_A^{(2)}) = (\bar{t}, [x - x_1; x - x_2]) \succeq (\bar{t}, \bar{x}_B^{(2)}) = (\bar{t}, [x - x_1 - x_2; x])$	$u'' \leq 0$
Wealth prudence	$(\bar{t}, \bar{x}_A^{(3)}) = (\bar{t}, [x - x_1; x + \tilde{\epsilon}_2]) \succeq (\bar{t}, \bar{x}_B^{(3)}) = (\bar{t}, [x - x_1 + \tilde{\epsilon}_2; x])$	$u''' \geq 0$
Wealth temperance	$(\bar{t}, \bar{x}_A^{(4)}) = (\bar{t}, [x + \tilde{\epsilon}_1; x + \tilde{\epsilon}_2]) \succeq (\bar{t}, \bar{x}_B^{(4)}) = (\bar{t}, [x + \tilde{\epsilon}_1 + \tilde{\epsilon}_2; x])$	$u'''' \leq 0$
Risk Preferences for Delay, PART D		
Trait	Preference Condition (Fixed Amount \bar{x})	EDU condition
Delay risk aversion	$(\bar{t}_A^{(2)}, \bar{x}) = ([t + d_1; t + d_2], \bar{x}) \succeq (\bar{t}_B^{(2)}, \bar{x}) = ([t + d_1 + d_2; t], \bar{x})$	$\rho'' \leq 0$
Delay prudence	$(\bar{t}_A^{(3)}, \bar{x}) = ([t + d_1; t + \tilde{t}_2], \bar{x}) \succeq (\bar{t}_B^{(3)}, \bar{x}) = ([t + d_1 + \tilde{t}_2; t], \bar{x})$	$\rho''' \leq 0$
Delay temperance	$(\bar{t}_A^{(4)}, \bar{x}) = ([t + \tilde{t}_1; t + \tilde{t}_2], \bar{x}) \succeq (\bar{t}_B^{(4)}, \bar{x}) = ([t + \tilde{t}_1 + \tilde{t}_2; t], \bar{x})$	$\rho'''' \leq 0$

NOTES: This table summarizes the preference traits (column 1) tested for in PART W (top panel) and PART D (bottom panel) of the experiment. In PART W, subjects had to choose between two wealth risks and the resulting payoff is received with a fixed delay of $\bar{t} = 12$ weeks. x refers to a wealth endowment in euros, x_1 and x_2 are fixed wealth amounts, and $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ are independent zero-mean wealth risks. An example of a wealth prudence choice from the experiment is shown in Figure 1, and the parameters of all lotteries in the experiment are given in Table 2. In PART D, subjects had to choose between two delay risks about when to receive a pre-specified fixed amount of $\bar{x} = 11$ euros. t refers to a base delay (in weeks, wk), d_1 and d_2 are fixed increases in delay, and \tilde{t}_1 and \tilde{t}_2 are independent zero-mean delay risks. An example of a delay prudence choice from the experiment is shown in Figure 2, and the parameters of all 21 lottery pairs from PART D are given in Table 3.

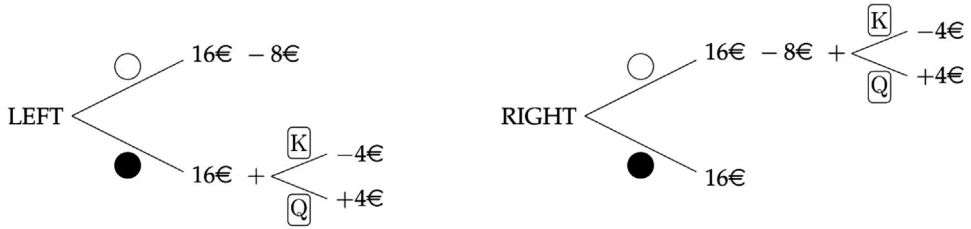
4.3. *Choices.* Figure 1 shows a choice from PART W of the experiment. Each choice is between a lottery LEFT and a lottery RIGHT. The framing of these lotteries is explained in detail in the notes to Figure 1. The participant makes her choice by checking one of the boxes beneath the respective lottery picture. The sentence above the two lottery pictures summarized the instructions for each choice. As discussed in more detail in Subsection 4.4, also in PART W, payments were delayed, which was implemented by a delayed bank transfer to participants' bank accounts. Therefore, there is no fundamental difference in potential trust issues regarding the receipt of payment in parts PART W and PART D. The important difference between the parts is that, in all of PART W, delay is constant. Depending on the session—see Subsection 4.6 for details—the delay was fixed to either 12 weeks (as seen in Figure 1) or one week. In all sessions, delays were communicated in both relative and absolute terms. The choice in Figure 1, for example, uses the expressions “in 12 weeks from now” as well as “on Monday, May 9.” Subjects could also consult the calendar pinned to their cubicle the whole time. All of this served to raise the awareness of the magnitude of delay.

The choice shown in Figure 1 is from stage PR-W. To imagine a choice from stage RA-W, simply replace the zero-mean risk in Figure 1 with another fixed amount, and to imagine a choice from stage TE-W, replace the -8€ with another zero-mean risk.

Figure 2 shows a choice from PART D stage PR-D of the experiment, and shows that the framing in PART D was very close to that of PART W.

4.4. *Payment.* At the beginning of the experiment, participants received written information regarding how their payment (amount and due date) would be determined. The experimenter asked the participant in seat 1 to draw a card from a pile of cards numbered from 1 to 42. (Participant 1 could check the pile of cards beforehand). This number indicated the choice relevant for payment (random incentive technique). Note that this choice could be different for each participant due to the randomization of choices. The experimenter put the card in an envelope, sealed it, and had the envelope signed by the participant in seat 1. At the end of the experiment, subjects had to put the blue pen they were given to indicate their choices on the ground so that they could no longer go back and make changes after the payoff-relevant choice was revealed. After opening the envelope and revealing the payoff-relevant choice, the experimenter marked each participant's decision in the payoff-relevant choice with a red pen. Afterward, all payoff-relevant uncertainties were resolved using three different

Choice 9. Please choose the option that determines the payment that will be transferred to your bank account in 12 weeks from now (on Monday, May 9):



I prefer Option LEFT.

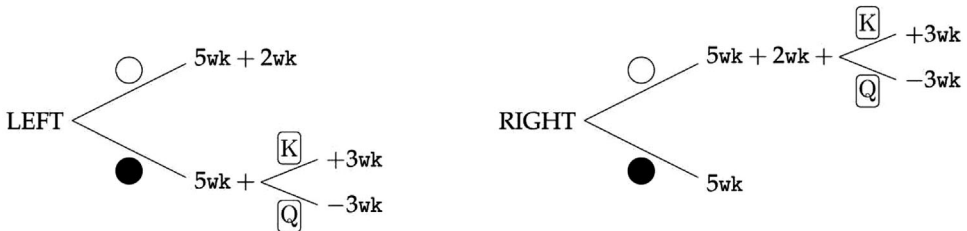
I prefer Option RIGHT.

NOTES: This figure shows a wealth prudence choice as shown to subjects in the experiment. The parameters are $x = 16$, $x_1 = 8$, and $\tilde{\epsilon}_2 = [-4; +4]$. Option LEFT depicts the prudent choice (i.e., $\tilde{x}_A^{(3)} = [x - x_1; x + \tilde{\epsilon}_2]$), and Option RIGHT depicts the corresponding imprudent choice (i.e., $\tilde{x}_B^{(3)} = [x - x_1 + \tilde{\epsilon}_2; x]$). The symbols \bigcirc and \bullet (\boxed{K} and \boxed{Q}) denote the possible draws from an urn that contains one white and one black ball (one King card and one Queen card), which were used to resolve the randomness of the risk $[\cdot; \cdot]$ (the zero-mean risk $\tilde{\epsilon}_2$). To imagine a risk aversion lottery choice, simply replace the zero-mean risk $\tilde{\epsilon}_2$ with another fixed reduction in wealth $-x_2$. To imagine a temperance lottery choice, replace the fixed reduction in wealth $-x_1$ with another symmetric zero-mean risk $\tilde{\epsilon}_1$. The randomness of the latter was resolved using a coin toss, which was illustrated using the symbols \textcircled{H} and \textcircled{T} , which stand for “heads” and “tails,” respectively.

FIGURE 1

EXAMPLE OF A WEALTH PRUDENCE CHOICE FROM THE EXPERIMENT

Choice 33. Please choose the option which determines when 11€ will be transferred to your bank account:



I prefer Option LEFT.

I prefer Option RIGHT.

NOTES: This figure shows a delay prudence choice as shown to subjects in the experiment. The parameters are $t = 5$, $d_1 = 2$, and $\tilde{t}_2 = [3; +3]$, and wk denotes the unit of a week. Option LEFT depicts the delay prudent choice (i.e., $\tilde{\tau}_A^{(3)} = [t - d_1; x + \tilde{t}_2]$), and Option RIGHT shows the corresponding imprudent choice (i.e., $\tilde{\tau}_B^{(3)} = [t - d_1 + \tilde{t}_2; t]$). The symbols \bigcirc and \bullet (\boxed{K} and \boxed{Q}) denote the possible draws from an urn that contains one white and one black ball (one King card and one Queen card), which were used to resolve the randomness of the risk $[\cdot; \cdot]$ (the zero-mean risk \tilde{t}_2). To imagine a delay risk aversion lottery choice, simply replace the zero-mean risk \tilde{t}_2 with a fixed delay d_2 . To imagine a delay temperance lottery choice, replace the fixed delay d_1 with another symmetric zero-mean risk \tilde{t}_1 . The randomness of the latter was resolved using a coin toss, which was illustrated using the symbols \textcircled{H} and \textcircled{T} , which stand for “heads” and “tails,” respectively.

FIGURE 2

EXAMPLE OF A DELAY PRUDENCE CHOICE FROM THE EXPERIMENT

randomization devices to emphasize statistical independence. These randomization devices (an urn with two balls, a deck with two cards, and a coin) were explained in the instructions and were shown to subjects at the time the instructions were read out loud. Afterward, each subject received a written confirmation signed by the experimenter that the payment would be transferred to her bank account, as determined by the payoff-relevant choice (see the *PAYMENT CONFIRMATION SHEET* in the supplementary material). In return, subjects had to sign a receipt of this receipt, which the experimenter required for reimbursement (see the *RECEIPT* in the Supporting Information).

4.5. *Randomization.* The choice sheets were coded using Lua to randomize the sequence of choices within each stage. Moreover, the position of the two lotteries (left or right), as well as their respective up or down states, were randomized individually for each subject. The order of PART W and PART D was varied systematically between subjects (see the next subsection). Within each part, a subject first made her choices for the risk aversion stage, then for the prudence stage, and, finally, for the temperance stage.¹²

4.6. *Factorial Design.* Eighty subjects participated in eight sessions to allow for a 2^3 factorial design with 10 subjects per factor combination (e.g., Montgomery 2005). In particular, we can test for the influence of three effects, with two levels each, on choice behavior. Factor A has meaning only for PART D and specifies whether the amount that is transferred with random delay is given by (a) € 11 or (A) € 17. That is, we test for a wealth effect on delay risk preferences. Factor B tests for a sequence effect of the two parts of the experiment and has levels (b) Wealth first (i.e., subjects first faced PART W and then PART D) and (B) Delay first (for those subjects, PART D of the experiment preceded PART W). One might think, for example, that subjects who first participate in PART W—for which one typically observes (higher order) risk-averse behavior—might be subject to a carryover effect that makes them more inclined to (higher order) risk-averse choice behavior in PART D. Factor C has meaning only for PART W and specifies whether the delay with which the uncertain amount is transferred to subjects' bank accounts is given by (c) 12wk or (C) 1wk. Factor C can be seen as “dual” to Factor A and investigates a not-yet-tested for effect of *constant* delay on the higher order risk preferences of prudence and temperance.¹³ The factor constellation for each session was determined randomly using a permutation drawn from MATLAB. For example, the first session took place on Monday, February 15, at 8:45 a.m. and featured factor combination aBc; that is, those subjects faced delay risk choices about the receipt of EUR 11 (a), they entered PART D first (B), and they faced wealth risk choices with payments made in 12wk (c).

5. RESULTS

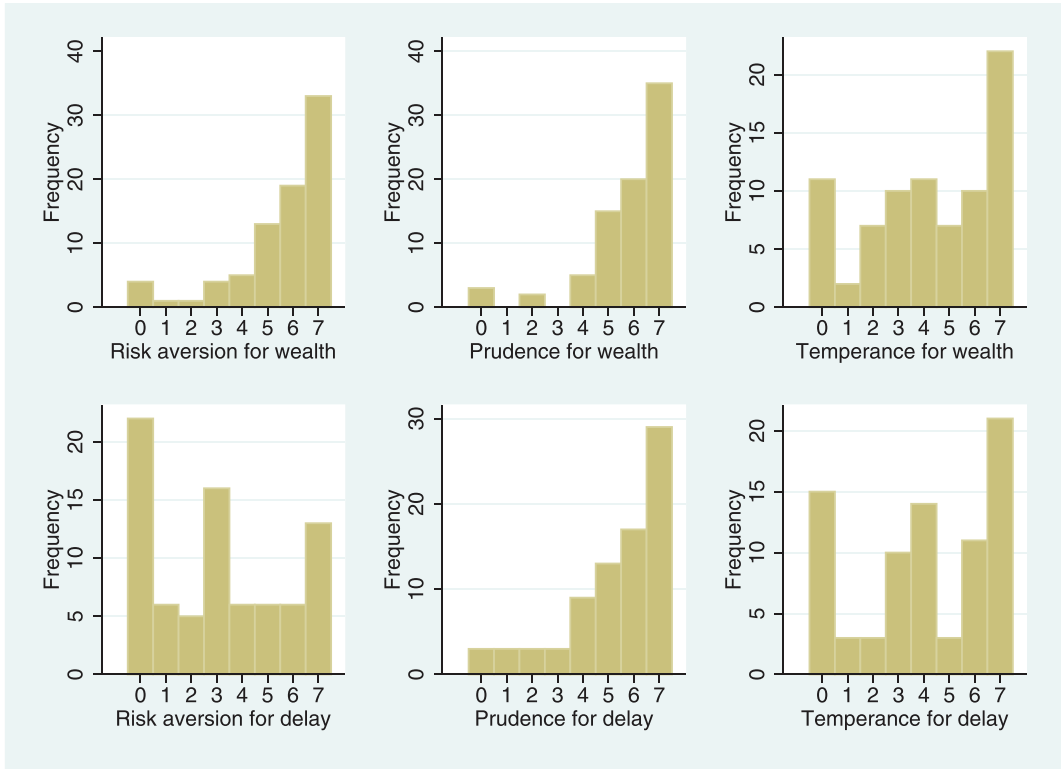
5.1. Aggregate Results.

5.1.1. *Overview and main results.* Figure 3 shows the distribution of choices made by the 80 subjects in each of the six stages in the experiment. For example, the upper-left histogram indicates that 33 subjects made seven out of seven wealth risk-averse choices, 19 subjects made six out of seven wealth risk-averse choices, and so forth.¹⁴ The top row of Figure 3 provides evidence on higher order risk preferences for wealth, which is very much in line with

¹² This order of increasing the complexity of choices with each stage has become the standard in the higher order experimental literature for outcome risk preferences; for example, Noussair et al. (2014). Ebert and Wiesen (2014) varied the order of stages to test for sequence effects and found no significant effects on choice behavior.

¹³ Ebert and van de Kuilen (2016) have tested for differences in higher order risk preferences when payments are made in cash today as opposed to when they are made by bank transfer later.

¹⁴ The distributions of subjects' choices over (higher order) wealth and time risks, respectively, are very different from random choice. This is evident from the histograms and confirmed through Pearson's χ^2 -test against a binomial distribution with $n = 7$ trials and probability parameter $p = 0.5$, which indicate $p < 0.01$ for each of the six stages in the experiment.



NOTES: This figure shows the distribution of choices made by the 80 subjects in each of the six stages in the experiment. Each stage consisted of seven choices. Column (1) (2, 3) shows the data for the stage that tested for risk aversion (prudence, temperance) in PART W (risk preferences for wealth, top row), and PART D (risk preferences for delay, bottom row), respectively. For example, the upper-left histogram indicates that 33 subjects made seven out of seven risk-averse choices, 19 subjects made six out of seven risk-averse choices, and so forth.

FIGURE 3

CHOICES IN THE EXPERIMENT

earlier experiments such as Deck and Schlesinger (2010) and Ebert and Wiesen (2011). Table 4 shows the mean number of risk-averse, prudent, and temperate choices in each stage of the experiment. The data from PART W show that there is strong evidence for risk aversion and prudence toward wealth. Further in line with most earlier experiments, the evidence for temperance is less pronounced. This replication of earlier experiments provides confidence in the experimental method and its implementation, by showing that the higher order risk preferences toward wealth observed in the current experiment are no different from those observed in earlier experiments. Most importantly, the replication of risk preferences toward wealth will allow us to analyze differences in preferences toward wealth and toward delay within subjects.

The distributions of risk preferences toward delay of the same 80 subjects are shown in the bottom row of Figure 3. It is immediately seen that the distribution of delay risk-averse choices is very different from that for wealth, whereas the distributions of prudence and temperance, respectively, look more similar. These first impressions are consistent with statistical tests.¹⁵ The bottom panel of Table 4 collects, for PART D, the mean number of risk-averse,

¹⁵ A two-sample Wilcoxon signed-rank test rejects the null hypothesis that the difference in risk-averse choices for wealth and risk-averse choices for delay is obtained from a symmetric distribution with mean zero ($p < 0.01$). For prudence, there is weak evidence of a difference ($p = 0.08$), and for temperance the difference is insignificant. Two-sample Kolmogorov-Smirnov tests only detect a difference for risk aversion ($p < 0.01$) and find no significant difference for prudence and temperance.

TABLE 2
EXPERIMENTAL PARAMETER CHOICES IN PART W OF THE EXPERIMENT

Parameter/Lottery No.	1	2	3	4	5	6	7
Wealth Risk Aversion (RA-W)							
x (in €)	18	20	20	24	24	26	26
$-x_1$ (in €)	-6	-6	-2	-10	-8	-8	-4
$-x_2$ (in €)	-6	-10	-14	-10	-8	-12	-16
Wealth Prudence (PR-W)							
x (in €)	14	16	18	18	18	20	22
$-x_1$ (in €)	-4	-8	-12	-8	-4	-8	-12
$\tilde{\epsilon}_2$ (in €)	± 6	± 4	± 2	± 6	± 6	± 4	± 2
Wealth Temperance (TE-W)							
x (in €)	12	12	12	14	16	16	16
$\tilde{\epsilon}_1$ (in €)	± 2	± 2	± 4	± 4	± 2	± 2	± 4
$\tilde{\epsilon}_2$ (in €)	± 4	± 6	± 4	± 6	± 6	± 8	± 6

This table shows the parameters used in the construction of the 21 lottery pairs in PART W of the experiment. PART W consisted of three stages RA-W, PR-W, and TE-W, with seven choices each. The general format of the lottery pairs in each stage was summarized in the top panel of Table 1. x refers to the wealth endowment, $-x_1$ and $-x_2$ are fixed reductions in wealth, and $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ are independent 50-50 zero-mean wealth risks.

TABLE 3
EXPERIMENTAL PARAMETER CHOICES IN PART D OF THE EXPERIMENT

Parameter/Lottery No.	1	2	3	4	5	6	7
Delay Risk Aversion (RA-D)							
t (in €)	5	4	4	3	2	1	1
d_1 (in €)	3	3	1	5	4	4	2
d_2 (in €)	3	5	7	5	4	6	8
Delay Prudence (PR-D)							
t (in €)	7	6	5	5	5	4	3
d_1 (in €)	2	4	6	4	2	4	6
\tilde{t}_2 (in €)	± 3	± 2	± 1	± 3	± 3	± 2	± 1
Delay Temperance (TE-D)							
t (in €)	8	8	8	7	6	6	6
\tilde{t}_1 (in €)	± 1	± 1	± 2	± 2	± 1	± 1	± 2
\tilde{t}_2 (in €)	± 2	± 3	± 2	± 3	± 3	± 4	± 3

NOTES: This table shows the parameters used in the construction of the 21 lottery pairs in PART D of the experiment. PART D consisted of three stages RA-D, PR-D, and TE-D, with seven choices each. The general format of the lottery pairs in each stage was summarized in the top panel of Table 1. t refers to the base delay, d_1 and d_2 are fixed increases in delay, and \tilde{t}_1 and \tilde{t}_2 are independent 50-50 zero-mean delay risks.

prudent, and temperate choices, together with statistical tests against the mean being equal to 3.5, as would be observed for random choice. Further analysis shows that the percentage of delay risk-averse choices does not vary systematically over the seven lotteries shown in Table 3; same with prudence and temperance.¹⁶ Now we discuss the evidence on (higher order) delay risk preferences in more detail and compare them to the evidence on risk preferences toward wealth.

5.1.2. Delay risk aversion. On average, subjects answered three out of seven questions in a time-risk-averse manner. The majority (22) answered all seven questions in a time-risk-seeking manner. At the same time, a second and significant subgroup of 13 subjects made

¹⁶ For example, in the case of delay risk aversion, the fraction of risk-averse responses in Choice 1 is not significantly different from that of any of the other six choices concerning risk aversion for delay, according to two-sided paired t -tests. There is also no significant evidence of a certainty effect in delay risk aversion (i.e., that there are more risk-averse responses when the risk-averse option implies a certain time of receipt, as in Choices 1, 4, and 5 in Table 3); $p = 0.11$, one-sided paired t -test. This nonresult corroborates that of DeJarnette et al. (2020) and speaks against the possibility that delay risk aversion could be driven by probability distortion.

TABLE 4
AVERAGE NUMBER OF RISK-AVERSE, PRUDENT AND TEMPERATE CHOICES

Risk Preferences for Wealth, PART W				
Stage	Trait	Mean	<i>p</i> (<i>t</i> -Test)	<i>p</i> (Sign-Rank)
RA-W	Wealth risk aversion	5.56	<0.01	<0.01
PR-W	Wealth prudence	5.80	<0.01	<0.01
TE-W	Wealth temperance	4.24	0.01	0.01
Risk Preferences for Delay, PART D				
Stage	Trait	Mean	<i>p</i> (<i>t</i> -Test)	<i>p</i> (Sign-Rank)
RA-D	Delay risk aversion	3.06	0.13	0.11
PR-D	Delay prudence	5.30	<0.01	<0.01
TE-D	Delay temperance	4.04	0.07	0.08

NOTES: This table summarizes for each stage of the experiment (column 1) and corresponding preference trait (column 2) the mean amount of choices per subject (column 3) that are consistent with each trait. Since each stage consisted of seven choices, random choice would result in a mean of 3.5. Column 4 reports the results of *t*-tests of the null hypothesis that the mean is 3.5 in the respective stages, and column 4 reports the results of Wilcoxon signed-rank tests of the null hypothesis that the median is 3.5.

risk-averse choices throughout. A third peak in the lower-left histogram of Figure 3 indicates that 16 subjects made three out of seven risk-averse choices, and the remainder of subjects distributes almost equally among the other categories. This third group of subjects seems quite indifferent toward delay risk.¹⁷ Overall, therefore, and in contrast to the evidence on wealth risk preferences, there is substantial heterogeneity in preferences toward delay risk. There are risk-seeking, risk-averse, and risk-neutral subjects.

5.1.3. *Delay prudence.* Interestingly, unlike the case for second-order risk, the evidence for delay prudence (third-order delay risk aversion) is qualitatively not different from that of wealth prudence. As mentioned above, Kolmogorov–Smirnov and Wilcoxon signed-rank tests fail to reject a significant difference at the 5% level. There is broad evidence for prudence.

5.1.4. *Delay temperance.* The evidence for delay temperance is qualitatively similar to that for delay risk aversion. As in the latter case, the choice distribution is three-peaked, which indicates significant heterogeneity in preferences. Fifteen subjects are decisively intemperate, 24 subjects chose three or four out of seven times temperately, which indicates indifference, and 21 subjects are decisively temperate. On the aggregate, there is mild evidence for temperance, as indicated by the tests in the last row of Table 4.

5.1.5. *Summary: Comparison of risk preferences toward wealth and toward delay.* There is heterogeneity regarding second-order risk aversion in PART D, which is different from PART W. On the other hand, there is strong evidence for prudence and weak evidence for temperance in PART D, which is similar to PART W.

5.2. *Correlations between Wealth and Delay Risk Preferences.* Spearman rank correlations between the number of choices from different parts of the experiment are shown in Table 5. Delay risk aversion correlates significantly with risk aversion and prudence toward wealth, respectively. Delay prudence correlates with wealth prudence.¹⁸ The positive relationships between risk aversion and prudence, respectively, seem intuitive if one believes that these traits

¹⁷ In fact, one subject indicated on the choice sheet: “I don’t care...”

¹⁸ Since some of the reported correlations have no particular theoretical underpinning, one may argue for the adjustment of *p*-values for multiple hypothesis testing. Depending on the exact method of adjustment, the reported significance levels vanish. On the other hand, given the earlier finding of DeJarnette et al. (2020) that risk aversion toward delay correlates with risk aversion toward wealth, and that this result is predicted by their model, one may conjecture to find a positive relationship in the current experiment as well (and, maybe, also for prudence and temperance). Moreover, in that case, one may argue for the use of one-sided tests, strengthening the results. We leave

TABLE 5
SPEARMAN STAGE CORRELATIONS BETWEEN PART D AND PART W OF THE EXPERIMENT

	RA-W	PR-W	TE-W
RA-D	0.26**	0.24**	0.14
PR-D	-0.13	0.25**	0.07
TE-D	0.09	0.02	0.12

NOTES: This table shows Spearman rank correlations between the number of choices for the stages in the two parts of the experiment. *** (**, *) indicates a significant difference from zero at the 1% (5%, 10%) level of significance (two-sided *t*-tests).

do not change from one type of risk (outcome risk) to another (time risk). The EDU model, however, due its multiplicative separability into a discount and a utility function, does not speak to this relationship.

Correlations between the number of choices from within a given part of the experiment (in particular, the correlations between risk aversion, prudence, and temperance toward delay, respectively) are discussed in the next subsection.

5.3. Consistency of Delay Risk Preferences. In this subsection, we relate the previous results to the theory of “consistent” risk preferences (sometimes also called the good-with-bad heuristic). We explain and summarize the intuition behind the good-with-bad heuristic in Appendix, but reading it is not necessary to understand its behavioral predictions: Consistency predicts that risk averters and risk seekers are both prudent, but risk averters are temperate, whereas risk seekers are intemperate.

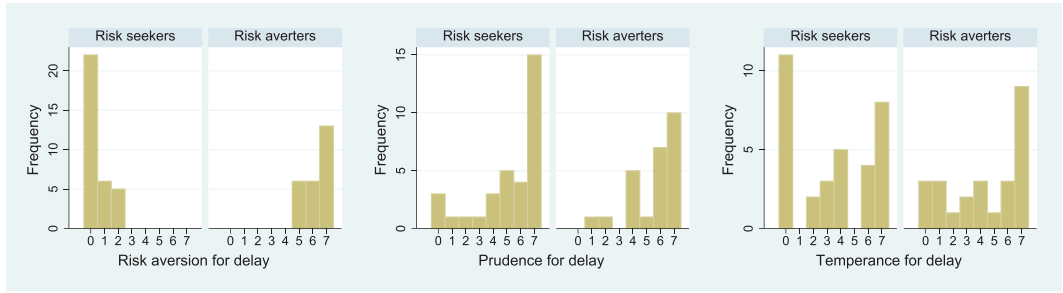
Although there is some support for the consistency of outcome risk preferences (Deck and Schlesinger 2014; Ebert and Wiesen 2014; Ebert and van de Kuilen 2016), the evidence is often constrained by the small number of risk seekers relative to risk averters in these studies. Typically—just as in the current experiment—the number of wealth risk seekers is small, and the decisions of risk seekers are relatively more plagued by noise.¹⁹ In line with this observation, there is quite comforting support for the consistency of risk averters, but the evidence for risk seekers is less clear-cut. As shown above, a significant number of individuals is delay risk-seeking. Therefore, choices over delay risk provide an excellent opportunity to test the consistency heuristic. Apart from examining the consistency of delay risk preferences for the first time, the second contribution of this subsection is thus to provide new evidence on the consistency heuristic through a reliable sample of risk seekers.

Figure 4 shows the distribution of choices made in PART D of the experiment, separately for risk seekers (defined as making zero, one, or two risk-averse choices) and risk averters (defined as making five, six, or seven risk-averse choices).²⁰ Applying the same categorization to choices in PART W gives only six risk seekers for wealth, exemplifying the small data issue described before, and thus, the analysis presented in this paragraph is conducted for delay risk preferences only. The left two histograms in Figure 4 illustrate this categorization, which leads to 33 delay risk seekers and 25 delay risk averters. The middle two histograms clearly show that the majority of risk seekers is prudent, as predicted by the consistency heuristic. Also the delay risk averters are mostly prudent, as predicted by the consistency heuristic. Statistical test results from Table 6 confirm this visual impression. Regarding the fourth order of delay risk preferences, the good-with-bad heuristic predicts intemperance for the risk seekers and temperance for the risk averters. There seems to be some evidence for this prediction from the

judgment about these trade-offs to the reader and take the results reported in Table 5 as mild evidence for positive relationships between risk aversion and prudence, respectively.

¹⁹ As noted by Ebert and van de Kuilen (2016), a subject choosing randomly is equally likely to be falsely coded as a risk seeker or a risk averter. A few of these false positives will not impair the inference made from a sample of about 70 risk averters much. However, they will severely dilute the inference made from about 10 risk seekers.

²⁰ The results of the subsequent analysis are very similar when changing the categorizations by plus/minus one.



NOTES: This figure shows the distribution of choices made in PART D of the experiment separately for risk seekers (defined as making zero, one, or two risk-averse choices) and risk averters (defined as making five, six, or seven risk-averse choices). This separation of the data is also shown in the first panel. The second and third panels show the distributions of prudent and temperate choices of these 33 risk seekers and 25 risk averters, respectively.

FIGURE 4

CHOICES IN PART D OF THE EXPERIMENT FOR RISK AVERTERS AND RISK SEEKERS SEPARATELY

TABLE 6
DELAY RISK PREFERENCES FOR RISK AVERTERS AND RISK SEEKERS SEPARATELY

	RA-D	PR-D	TE-D
Mean (Delay risk seekers)	0.48***	5.21***	3.42
Mean (Delay risk averters)	6.28***	5.60***	4.36*

NOTES: Rows 2 and 3 of this table show, for 33 delay risk seekers and 25 delay risk averters, respectively, the mean number of choices per subject that are consistent with delay risk aversion (column 2), delay prudence (column 3), and delay temperance (column 4). Risk seekers are defined as making zero, one, or two risk-averse choices, and risk averters are defined as making five, six, or seven risk-averse choices. *** (**, *) indicates a significant difference from 3.5 at the 1% (5%, 10%) level of the null hypothesis suggested by the consistency heuristic (one-sided Wilcoxon signed-rank tests; *t*-tests yield the same results).

TABLE 7
SPEARMAN STAGE CORRELATIONS WITHIN THE TWO PARTS OF THE EXPERIMENT

	RA-W	PR-W
PR-W	0.12	
TE-W	0.52***	0.23**
	RA-D	PR-D
PR-D	0.01	
TE-D	0.18*	-0.04

NOTES: This table shows Spearman rank correlations between the number of choices in the stages of PART W (left) and PART D (right), respectively. *** (**, *) indicates a significant difference from zero at the 1% (5%, 10%) level of significance using one-sided tests of the null hypothesis that the correlation is negative.

right two histograms in Figure 4. In particular, there are 10 risk seekers who made zero temperate choices and nine risk averters who chose intemperately all seven times. Unlike for prudence, however, on the aggregate, we find no significance for risk averters being temperate and only weak significance for risk seekers being intemperate.

We proceed with presenting within-subjects evidence for the good-with-bad heuristic. To this end, Table 7 shows the correlations between choices in the three stages within PART W and PART D, respectively. Under the good-with-bad heuristic, both risk averters and risk seekers should be prudent (so that no positive correlation between risk aversion and prudence is expected), but risk averters should be temperate, whereas risk seekers should be intemperate (predicting a positive correlation between risk aversion and temperance). Consistent with this prediction, we observe a positive and significant correlation between risk

TABLE 8
ENDOWMENT AND SEQUENCE EFFECTS (FACTORIAL DESIGN ANALYSIS)

Factor (level)		RA-W	PR-W	TE-W	RA-D	PR-D	TE-D
a ($\bar{x} = \text{€ } 11$)	Mean				3.23	5.38	4.01
A ($\bar{x} = \text{€ } 17$)	Mean				2.90	5.22	4.00
	<i>p</i>				0.60	0.94	0.94
b (PART W first)	Mean	5.53	5.60	4.72	2.63	5.45	3.67
B (PART D first)	Mean	5.60	6.00	3.75	3.50	5.15	4.40
	<i>p</i>	0.38	0.75	0.09	0.09	0.43	0.27
c ($\bar{t} = 12$ wk)	Mean	6.03	5.78	4.72			
C ($\bar{t} = 1$ wk)	Mean	5.10	5.83	3.75			
	<i>p</i>	0.04	0.56	0.08			

NOTES: This table shows the influence of the three factors A, B, and C on the choices in the six stages of the experiment. FACTOR A manipulated, in PART D of the experiment, the amount \bar{x} to be transferred to each subject's bank account. FACTOR A took the levels (a) € 11 and (A) € 17. FACTOR B determined whether subjects made first their choices in (b) PART W or (B) PART D. FACTOR C manipulated, in PART W of the experiment, the fixed delay \bar{t} that determined when payments would be transferred to subjects' bank accounts. FACTOR C took the levels (c) 12wk and (C) 1wk. For each factor and its corresponding two levels, the table shows the mean number of choices observed in three (FACTOR A and FACTOR C) or six (FACTOR B) tasks of the experiment. Moreover, for each of those tasks it shows *p*-values of Mann-Whitney-Wilcoxon rank sum tests of the null hypothesis that the choice distributions under the two factor levels differ.

aversion and temperance toward wealth (52%). With weak significance ($p = 0.0524$), we also observe a positive correlation between risk aversion and temperance toward delay (18%).

Overall, the evidence for consistency within higher order delay risk preferences is rather strong. There is strong evidence that both risk averters and risk seekers are prudent, consistent with a heuristic of combining good with bad. Also consistent with this heuristic is that delay prudence is uncorrelated with delay risk aversion and delay temperance, and that delay risk aversion and delay temperance correlate positively (although only with weak statistical significance).

5.4. Endowment and Sequence Effects (Factorial Design Analysis). In this subsection, we investigate three possible influences on risky choice behavior as described in Subsection 4.6. Table 8 reports the results of the data analysis.

As indicated by the *p*-values of Mann-Whitney-U tests, there is almost no evidence that the considered factors impact choice behavior in the six stages of the experiment in a systematic way. (This is even without adjusting for multiple hypothesis testing.) In particular, there is no significant evidence that delay risk preferences are influenced by the size of the amount that is transferred to subjects' bank accounts (FACTOR A, top panel of Table 8). This is interesting as, for outcome risk preferences, the stylized fact is that risk tolerance increases with the magnitude of delay (e.g., Shelley 1994; Ahlbrecht and Weber 1996; Abdellaoui et al. 2011). In the current experiment, there is no analogous evidence for tolerance toward delay risk; that is, there is no evidence for time risk tolerance to increase (or decrease) with the magnitude of outcomes.

There is also no significant evidence of a sequence effect of subjects making choices in PART W or in PART D first (FACTOR A, middle panel of Table 8). In particular, having seen that the distribution of delay risk-averse choices is very different from that of wealth risk-averse choices, there is no significant evidence of a carryover effect from the first part of the experiment to the second part.

Finally, there is some evidence of more risk-seeking behavior toward wealth risks that come with less delay (FACTOR C, bottom panel of Table 8). As mentioned before, this observation is at odds with the stylized fact that outcome risk tolerance increases with delay.²¹ Overall,

²¹ There is reason to believe that the opposing result in the current article is a spurious significance, and that one should be cautious about interpreting it as counterevidence to the stylized fact that risk tolerance increases with

the factor analysis does not suggest that the experimental design and its main results are sensitive to sequence effects as well as to the parameter choices of base wealth and base delay. It is difficult, however, to argue that the individual effect sizes reported in Table 8 are small (i.e., close to zero), because, rather, the experiment may have been underpowered for this specific analysis. A sufficiently powered new experiment could shed light on this matter.

6. DISCUSSION

In this section, we discuss some further implications of our results for the descriptive modeling of time risk preferences as well as further aspects of the experimental design.

6.1. Time Risk Preferences and the Assumption of EDU. Section 3 presented choice-based definitions of higher order time risk preferences and characterizations thereof within the EDU model. These characterizations have important implications for behavior (e.g., prudence implies precautionary behavior). It should be kept in mind, however, that the assumption of EDU is not an innocuous one. First, previous research has highlighted that delay risk aversion, as is also observed for a sizable number of subjects in the current experiment, is difficult to explain within EDU. Delay risk aversion requires a concave discount function, which appears unnatural (not only, but also because it cannot be defined on the whole positive half-line without turning negative). Several non-EDU models have successfully addressed this issue; see the next subsection.

Second, other and potentially more fundamental limitations of the discounted utility model (i.e., in the absence of time risk; see, e.g., Loewenstein and Prelec 1992) carry over to EDU (the case with time risk). We discuss some of these limitations in a later subsection.

Third, one may wonder whether there is a link between time-(in)consistency and the higher order time risk preferences that were elicited in this article. Ebert (2020) observes that the discount functions that are most commonly used in the literature (including the exponential and the relevant generalized hyperbolic discount functions of Loewenstein and Prelec 1992) are decreasing with derivatives that alternate in sign. Therefore, although the former induce time consistency and the latter do not, both imply risk-seeking, prudence, and intemperance.

6.2. Time Risk Preferences Outside EDU. In this subsection, we discuss (higher order) time risk preferences when EDU does not hold. Note that, because the definitions of risk aversion, prudence, and temperance toward time risk are purely choice-based, they are essentially theory-free. For example, prudence—as documented in our experiment—constitutes evidence for a preference for negatively over positively skewed delay risks, regardless of the assumption of a behavioral model. Although such preferences toward skewness are interesting in their own right, characterizations within a given model (such as delay risk aversion being equivalent to a concave discount function within EDU) allow for tests of that model as well as, potentially, more specific behavioral predictions (e.g., prudence inducing a precautionary motive).

Chesson and Viscusi (2003) and Onay and Öncüler (2007) have illustrated how probability weighting can explain delay risk aversion more naturally, and DeJarnette et al. (2020) have

delay. In particular, note that Abdellaoui et al.'s (2011) evidence is found within subjects, whereas Table 8 reports results from a between-subjects analysis. It turns out that from the 40 subjects who participated in one of the sessions in which FACTOR C was at its low level ($\bar{t} = 12$ wk), four subjects made zero out of the seven possible choices in a wealth risk-averse manner. On the other hand, none of the 40 subjects who participated in one of the sessions in which FACTOR C was at its high level ($\bar{t} = 1$ wk) was such an extreme risk seeker. If we drop those four extreme risk seekers from the factorial analysis, FACTOR C becomes insignificant in all stages. We thus believe that the influence of FACTOR C on risk aversion over wealth is the consequence of all four extreme risk seekers happening to be allocated to experimental sessions with large base delay.

further proposed two models that can. Their generalized EDU (GEDU) model, which is similar to Kihlstrom and Mirman (1974) when applied to time, evaluates a time risk $(\bar{\tau}, \bar{x})$ as

$$(4) \quad \mathbb{E}[\phi(\beta^{\bar{\tau}}u(\bar{x}))],$$

where u is as above, ϕ is strictly increasing, and $\beta \in (0, 1)$. GEDU features delay risk aversion if ϕ is a concave transformation of the log function. Intuitively, then, the concavity of ϕ overcompensates the convexity of the exponentiation of the discount factor β . Note that, because ϕ applies simultaneously to the utility function u , the model can also accommodate the positive association between delay risk aversion and outcome risk aversion that is also observed in the current experiment.

Characterizations of delay prudence and delay temperance (instead of delay risk aversion) in theories other than EDU have—to the best of our knowledge—not been studied yet. Even for outcome risk preferences, which have been around for much longer, there are relatively few results on higher order risk preferences and characterizations of prudence and temperance outside the expected utility model; exceptions include Eeckhoudt et al. (2020) and Ebert and Karehnke (2019). Higher order time risk preferences and associated behavior—within EDU and beyond—likewise constitute a rich domain for future theoretical research. Obtaining such results will likely not be easy and is beyond the scope of this article.

Nonetheless, in the remainder of this subsection, we make two early observations on higher order time risk preferences outside EDU. First, for a suitable transformation of the GEDU model in Equation (4), delay prudence can be shown to relate to the sign of ϕ''' , that is, to the third derivative of the aggregator function ϕ .²² Second, Mu, Pomatto, Strack, and Tamuz (2021) axiomatize monotone stationary time risk preferences. A time risk-seeking evaluation of a time risk $(\bar{\tau}, \bar{x})$ that is consistent with these preferences is given by the aforementioned EDU evaluation $\mathbb{E}[e^{-r\bar{\tau}}u(\bar{x})]$ with $r > 0$. A time risk-averse evaluation is given by

$$\frac{u(\bar{x})}{\mathbb{E}[e^{r\bar{\tau}}]}.$$

Note that the latter is not an EDU evaluation. (The expectation operator is in the denominator.) Nonetheless, it is similarly tractable, because, also under this specification, for time risks $(\bar{\tau}_A, \bar{x})$ and $(\bar{\tau}_B, \bar{x})$, it holds that

$$(\bar{\tau}_A, \bar{x}) \succeq (\bar{\tau}_B, \bar{x}) \iff \mathbb{E}[\rho(\bar{\tau}_A)] \geq \mathbb{E}[\rho(\bar{\tau}_B)],$$

for $\rho(t) = -\exp(rt)$. This function has negative derivatives of all orders, and therefore, implies prudent risk apportionment (Ebert 2020). So does the aforementioned time risk-seeking EDU model, because also the exponential discount function has a negative third derivative. In conclusion, in either case, the DM is prudent. It follows that the model of Mu, Pomatto, Strack, and Tamuz (2021) can accommodate the heterogeneity in our experiment regarding the second order of risk aversion and, at the same time, is specific as concerns the prediction of prudence (which we observe for risk averters and risk seekers alike).

6.3. *Binary Choice, Time Risk Premia, and Further Aspects of the Experimental Design.* On the experimental side, Loewenstein and Prelec (1992) and Benzion et al. (1989), among others, have convincingly pointed to the sensitivity of time preference measurements to the experimental technique and parameter choices. The binary choice design of the current experiment has its advantages in regard to simplicity, comparability to existing work on higher order risk preferences, or in the symmetry of the time and outcome risk preference measurement. There are, however, other approaches that deserve investigation. First, instead of binary

²² The author is thankful to Daniel Gottlieb for pointing him to this result.

choices, one could elicit time risk premia; that is, risk premia for time risks. Such time risk premia could be defined in terms of delay or in terms of the outcome that is only a matter of time. Either approach would bring us closer to the experimental techniques used in the measurement of discounting in the absence of time risk, such as techniques based on front-end delays. Moreover, the elicitation of time risk premia is interesting in its own right. As mentioned, the relatively large number of subjects who chose neither consistently risk-averse nor risk-seeking toward delay (similarly with temperance and intemperance) may point to the fact that preferences toward time risk are rather “weak.” This weakness of preference might reflect in a low willingness to pay (likewise, a low willingness to delay) for avoiding (respectively, gaining) time risk. Broadly speaking, such quantitative measurements could provide insight into the empirical importance of time risk.

Second, with the seminal study of Benzion et al. (1989) in mind, such time risk premia could be different depending on whether the receipt has to be postponed or expedited and on whether the outcome under consideration concerns a payment instead of a receipt. Moreover, measurements could not only depend on the sign but also on the size of the outcome that is only a matter of time. Within the factorial design of the present experiment, there was no effect of the magnitude of the outcome (€ 11 vs. € 17) on time risk preferences, but Benzion et al. (1989) considered much larger (hypothetical) outcomes varying from \$40 to \$5,000. Given that the current study is only the second incentivized experiment on time risk preferences, many other design features (be they theoretically or operationally motivated) deserve investigation.

7. CONCLUSION

The current article proposes and implements an experimental design to elicit discounting independently from utility, and utility independently from discounting, in a symmetric way. The idea behind the experimental design is based on risk apportionment (Eeckhoudt and Schlesinger 2006), applied to monetary risks (as usual), and then, in an analogous way, to *time risks* (Chesson and Viscusi 2003). The experimental data evidence risk aversion toward monetary risks, as expected. Although a large number of subjects is also risk-averse toward time risk, an even larger group of subjects is risk-seeking toward time risk, and a significant fraction appears risk-neutral or indifferent toward time risks. This heterogeneity is broadly consistent with the scarce empirical evidence on time risk aversion to date, even though the studies by Onay and Öncüler (2007) and DeJarnette et al. (2020) found more evidence for time risk aversion than time-risk-seeking.

The risk apportionment-based experimental design allows for the study of time risk preferences beyond the second order of risk aversion. The most interesting finding is the following: Given the differences in time and outcome risk aversion, one might expect similar differences in time and outcome risk preferences at the higher orders, and at the third order of prudence in particular. This is not the case. There is strong evidence for time and outcome prudence alike. Crainich et al. (2013) and Deck and Schlesinger (2014) have hypothesized that prudence could be a more important trait than previously realized, the reason being that prudence is a trait to be expected for risk averters and risk seekers. Consequently, the third-order trait of prudence could be even more prevalent than the second-order trait of risk aversion. A limitation of previous studies has been that a large and reliable sample of risk seekers is usually hard to come by, which is also evidenced by our data on risk aversion for wealth. The current sample on time risk preferences, on the other hand, even features a majority of risk seekers. Exploiting this natural heterogeneity in risk aversion/risk seeking toward time risk, we obtain direct support for the mechanism underlying the prevalence of prudence, as described in Crainich et al. (2013): Both risk seekers and risk averters are prudent.

APPENDIX A: CONSISTENCY EXPLAINED

In this appendix, we explain the intuition behind consistency (also called the preference for combining good with bad, or the good-with-bad heuristic) in time-risk-taking behavior (Ebert 2020). This discussion further offers intuition into the definitions of delay prudence and temperance. In particular, it clarifies the directions of preference in the respective definitions, and consequently, the signs of the derivatives of the discount function that they characterize.

Recall from Table 1 that delay risk aversion is characterized by a preference for disaggregating two harmful increases in delay, d_1 and d_2 , across the two equally likely states of nature, instead of having to face both delays in the same state, as follows:

$$(\tilde{\tau}_A^{(2)}, \bar{x}) := ([t + 0 + d_1; t + 0 + d_2], \bar{x}) \succeq (\tilde{\tau}_B^{(2)}, \bar{x}) = ([t + d_1 + d_2; t + 0 + 0], \bar{x}).$$

Note that we have added some zeros, and further note that, relative to those zero delays, strictly positive delays (like d_1 or d_2) are bad. In this sense, the risk-averse lottery choice $(\tilde{\tau}_A^{(2)}, \bar{x})$ combines, in each state of nature, a good zero delay with a bad strictly positive delay. The risk-seeking lottery choice $(\tilde{\tau}_B^{(2)}, \bar{x})$, on the other hand, combines bad with bad in one state and good with good in the other state. Therefore, risk aversion follows from a preference for combining good with bad, whereas risk-seeking follows from a preference for combining good with good (bad with bad, respectively). From now on, as is common in the literature, in the latter case, we omit the bad with bad part for sake of brevity.

Let us now consider a DM who likes to combine good with bad, and analyze whether this preference for combining good with bad will make her prudent (or not, or whether we cannot say). Let us write the risk apportionment definition of delay prudence (cf. Table 1), as follows:

$$(\tilde{\tau}_A^{(3)}, \bar{x}) = ([t + 0 + d_1; t + 0 + \tilde{t}_2], \bar{x}) \succeq (\tilde{\tau}_B^{(3)}, \bar{x}) = ([t + d_1 + \tilde{t}_2; t + 0 + 0], \bar{x}).$$

We have already shown that an individual who likes to combine good with bad is risk-averse. For a risk averter, the zero-mean delay risk \tilde{t}_2 is bad. The prudent lottery choice $(\tilde{\tau}_A^{(3)}, \bar{x})$, then, combines the good zero with a bad delay d_1 in one state and a good zero with a bad zero-mean risk in the other state, whereas $(\tilde{\tau}_B^{(3)}, \bar{x})$ gathers both goods and both bads in the same state, respectively. Thus prudence follows from a preference for combining good with bad, in a similar way as risk aversion did.

Next, consider an individual who, instead, has the preference to consistently combine good with good. As shown above, such an individual is delay risk-seeking. What follows is the crucial observation. For a risk seeker, a zero-mean risk is good instead of bad. Consequently, an individual who likes to combine good with good *also* prefers $(\tilde{\tau}_A^{(3)}, \bar{x})$ over $(\tilde{\tau}_B^{(3)}, \bar{x})$, as it combines both goods in one state—the state with $t + 0 + \tilde{t}_2$, in which zero is good relative to d_1 and in which \tilde{t}_2 is good relative to the other zero. It is easy to check that, from the perspective of risk seeker, $(\tilde{\tau}_B^{(3)}, \bar{x})$ is consistent with a preference for combining good with bad, and thus not preferred. Therefore, risk seekers who like to combine good with good are also prudent.²³

Finally, the lottery preference characterizing delay temperance can be written as (cf. Table 1)

$$(\tilde{\tau}_A^{(4)}, \bar{x}) = ([t + 0 + \tilde{t}_1; t + \tilde{t}_2 + 0], \bar{x}) \succeq (\tilde{\tau}_B^{(4)}, \bar{x}) = ([t + \tilde{t}_1 + \tilde{t}_2; t + 0 + 0], \bar{x}).$$

²³ In fact, Ebert (2020) chose the definition of discount prudence such that it is consistent with a preference for combining good with bad and with a preference to combining good with good. This is analogous to the case of utility prudence (Eeckhoudt et al. 2009; Crainich et al. 2013). Then, prudence is equivalent to $\rho''' \leq 0$ within EDU, and this is also the property that ensures a precautionary waiting motive (Ebert 2020).

Consequently, a risk averter (who prefers combining good with bad and thus dislikes zero-mean risks relative to no delay) is temperate, choosing $(\bar{\tau}_A^{(4)}, \bar{x})$, whereas a risk seeker (who prefers combining good with good and thus likes zero-mean risks relative to no delay) is intemperate, choosing $(\bar{\tau}_B^{(4)}, \bar{x})$.

A DM is called *consistent* if she either consistently combines good with bad (and thus is risk-averse, prudent, and temperate) or if she consistently likes to combine good with good (and thus is risk-seeking, prudent, and intemperate). To test for consistency, one may thus separate the sample into risk averters and risk seekers. Then, one checks whether, first, risk seekers and risk averters agree on the third order of prudence and, second, whether they disagree on the fourth order of temperance.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

SuppMat S1

SuppMat S2

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