Precommitment as a nudge for safer choices in repeated decisions about low-probability, high-magnitude losses

David J. Hardistya, Amir Sepehrib, and Poonam Arorac,

aUniversity of British Columbia, Sauder School of Business, Canada, david.hardisty@sauder.ubc.ca

bWestern University, Ivey School of Business, Canada, asepehri.phd@ivey.ca

cManhattan College, School of Business, United States, poonam.arora@manhattan.edu

Author note: This research was supported NSF grant SES-0820496 and by the Canadian Social Sciences and Humanities Research Council. Special thanks to Daniel Read for his thoughts on an earlier draft of this paper, and thanks to Kavita Dau and Tiffany Leung for their work and contributions on the project. Please direct correspondence to David J. Hardisty, david.hardisty@sauder.ubc.ca.

*Abstract*

Often, people face repeated decisions about whether to protect against a large loss that has a low probability of occurring, for example whether to invest in long-term insurance, or whether to wear a face mask to protect against coronavirus. The decision-maker may make choices one at a time, or may precommit their choices in advance. In a series of studies with both real and hypothetical consequences, we find that precommitment leads to safer choices. This happens because precommitment (including non-binding precommitment) works as a novel form of choice bracketing, increasing planning and the focus on cumulative outcomes (in addition to single-choice outcomes). Furthermore, we find that precommitment does *not* influence cumulative probability perceptions, and thus works independently of broad bracketing of probabilities. Finally, we show that precommitment (but not non-binding precommitment) improves cooperation in interdependent security situations, where one person’s risky decisions “spill over” and impact another person. In other words, precommitment offers a partial solution to stochastic prisoner’s dilemmas. Taken together, the results suggest that binding and non-binding precommitment should be considered as promising nudges in the toolkit to improve decisions about repeated, low-probability, large-magnitude losses.

Precommitment as a nudge for safer choices in repeated decisions about low-probability, high-magnitude losses

 People repeatedly face decisions about whether to protect against low-probability, high magnitude losses. For example, during the COVID-19 pandemic, people must repeatedly decide whether to maintain social distancing, wear a mask, and wash their hands. These actions require small, certain costs in time and comfort, and protect against the low probability, but highly negative impact of catching the disease. Other examples include decisions about whether to pay for insurance to protect against unlikely events, and decisions about whether to pay for a backup service to protect against computer data being lost. People may make these decisions one at a time, or may precommit many decisions in advance. For example, a data backup service may be paid monthly or annually. Some long-term flood insurance contracts run up to 10 years or more (Aerts & Botzen, 2011). These are examples of “binding” precommitments. In other cases, precommitments may be entirely psychological and non-binding. For example, a person may decide in advance whether to always (or never) wear a mask when going out to stores during the pandemic. How does this precommitment process influence their decision making and safety behavior?

 In this paper, we present evidence that precommitment leads to safer choices about low-probability (e.g., 4% chance), large magnitude losses. As such, organizational leaders, policy-makers, and other decision architects should consider precommitment of choices as a tool in the “nudge” toolkit (Thaler & Sunstein, 2008) to increase safety behavior in a non-coercive way. We find that the psychological process behind this effect is driven by an increased focus on planning and cumulative outcomes, and *not* by a change in probability perceptions. Thus, we contribute to research on choice bracketing (Read, Loewenstein, & Rabin, 1999), by distinguishing two distinct choice bracketing effects and processes. Finally, we test binding and non-binding precommitment in the context of an “interdependent security” social dilemma (Heal & Kunreuther, 2005), where the safety decisions and risks of each person “spill over” and influence the safety and risk profile of their counterpart.

 In the following sections, we review the relevant research on decision making under uncertainty, choice bracketing, and social dilemmas under uncertainty. We then introduce our theoretic framework, detail our hypotheses, and give an overview of the studies.

*Literature review*

*Decision making under uncertainty*

 The literature on decision-making uncertainty is vast (for a review, see Lipshitz & Strauss, 1997); here, we briefly summarize a few key findings that are relevant to current investigation.

Perhaps the most well-established theory of decision making under uncertainty is Prospect Theory (Kahneman & Tversky, 1979), and its further development in Cumulative Prospect Theory (Tversky & Kahneman, 1992). According to these theories, people generally prefer to take a risk of a loss, rather than accept a sure loss of equivalent value (said another way, the utility function is convex in the domain of losses). For example, people generally prefer to take a 50/50 gamble of losing $100, rather than accept a sure $50 loss. However, these theories also say that people overweight small probabilities, which could lead to overly cautious behavior for small probability losses. For example, consumers often buy flight insurance, even though the chance of disrupted travel is low, the expected value of the insurance is negative, and consumers can cover the losses on their own without insurance. In the current project, we mostly investigate losses with a 4% chance of occurrence (though see Study 6 and supplemental Study S2 for exploration of other probability levels), and where the expected value is slightly better for choosing the certain loss. Therefore, it is not clear what Prospect Theory would predict for our context, except that people will be more risk-taking in the domain of losses than in the domain of gains (a prediction we test and confirm in Supplemental Study S1). Prospect Theory does not make any predictions regarding precommitment.

 A second literature, which does study repeated choice, examines preferences when reading a *description* of risk (e.g., reading that that there is a 4% probability of loss) versus preferences when *experiencing* the risk (e.g., making a series of choices and receiving accurate feedback consistent with a 4% probability of loss). A consistent finding is the description-experience gap (Hertwig & Erev, 2009), whereby people tend to overweight descriptions of small probabilities, and underweight the experience of small probabilities (partly because rare events are rarely experienced). In our context, all participants receive both description and experience. However, the timing is different, in that when people precommit, they are basing their decision mainly or entirely on description, but when they play round-by-round, they base their decision on a combination of both. This suggests that people who precommit may over-weight the 4% probability of loss, and therefore be more likely to invest in protection.

 A nascent literature on risk preferences in intertemporal contexts has found that while people often prefer to take a risk to avoid an immediate loss (consistent with Prospect Theory), they are generally risk averse when considering losses and gains over time (Hardisty & Pfeffer, 2016). For example, someone might prefer a 50/50 risk of losing $100 to losing $50 for sure, yet also prefer an immediate $50 loss to a 50/50 chance of losing $100 in a month. This happens partly because people may prefer to “get it over with” and avoid anxiety and dread (Hardisty & Weber, 2020; Molouki, Hardisty, & Caruso, 2019; Sun et al., 2020). However, this is only true when the risky option enables people to avoid the loss altogether; when the risky option offers a narrow range of outcomes, it can actually increase the attractiveness of the option, due to excitement (Liu, Heath, & Onculer, 2020). In the current context, we study situations where the loss can be avoided entirely. Therefore, if precommitment changes the choice from an immediate choice to an intertemporal choice, this literature suggests that precommitment should lead to safer choices.

*Choice bracketing*

Choice bracketing refers to the fact that a decision-maker may consider a series of choices in isolation, as a series of one-off decisions (“narrow bracketing”), or together, as a set of connected choices (“broad bracketing”, Read et al., 1999), with a variety of behavioral consequences. Three effects of broad bracketing are: (i) a focus on aggregate outcomes, (ii) cumulative probability perceptions, and (iii) preferences for diversification.

Research on broad bracketing and aggregate outcomes began with the observation that people have different risk preferences when considering playing a gamble once than when considering playing the same gamble five times (Redelmeier & Tversky, 1992). When faced with the question “Imagine that you have the opportunity to play a gamble that offers a 50% chance to win $2,000 and a 50% chance to lose $500. Would you play the gamble?”, 43% of people answered yes. Subsequently, participants were asked “Now, suppose you have the opportunity to play the gamble five times, not just once. Would you play it five times?”, and 63% said yes. This shows that people are sensitive to the aggregated outcome of multiple risks. People are loss averse and want to avoid the chance of a loss in the single play, but when playing five times, the overall profile is quite positive, and people choose it more often. This was later extended to the idea of “myopic loss aversion”, whereby investors are overly risk averse due to a focus on short-term performance and fear of loss on an annual basis, even when investing for the long term (Benartzi & Thaler, 1995; Hardin & Looney, 2012). In the context of the current research (repeated decisions about low-probability, large-magnitude losses), we should expect that precommitment to multiple choices shift focus from an individual outcome to the cumulative distribution of outcomes, and should increase safe behavior if that cumulative distribution makes safety attractive.

Related research on broad bracketing of probabilities started with studies of seatbelt use: when the likelihood of being killed or injured during a single trip (~.00000025 probability of being killed, and .00001 of being injured) is communicated to individuals, it does not worry them much. However, when the lifetime risk of death (~.01) or injury (.33) is presented to individuals, they are more likely to use seatbelts (Slovic, Fischhoff, & Lichtenstein, 1978). Also, people are more likely to purchase insurance when they are presented with the cumulative risk compared to individual repeated risks (Chaudhry, Hand, & Kunreuther, 2020). More broadly, providing cumulative risk distributions appears to lead to more optimal risk preferences across all risk types, including negative EV and pure-loss gambles (Webb & Data, 2017). In summary, broad framing of probabilities (by the choice architect) leads to safer and smarter choices. However, in all of these cases, the objective cumulative probabilities have been explicitly provided to participants, and it is unclear whether precommitment affects subjective, implicit judgments of probability. It seems plausible that precommitment would increase the subjective probability of rare events (“its bound to happen sooner or later”) in a similar manner.

A third finding is that broad bracketing leads to a preference for choice diversification (Fox, Ratner, & Lieb, 2005; Read & Loewenstein, 1995). For example, when buying seven yogurts for the next week, someone might choose seven different flavors (strawberry, blackberry, key lime, etc.), yet when buying yogurt one day at a time, the same person might choose their favorite flavor (strawberry of course) all seven times. In financial decision making, this can manifest as an “equal allocation” or “1/*n*” heuristic, where people invest equal amounts in all portfolio options (Morrin, Inman, Broniarczyk, Nenkov, & Reuter, 2012). To the extent that precommitment induces broad bracketing and a diversification preference, it should move choice proportions toward 50%; if safe choices are rare (i.e., less than 50% at baseline), diversification tendencies should increase safe choices, and if safe choices are common (i.e., greater than 50% at baseline), diversification should decrease safe choices.

*Social dilemmas under uncertainty*

In social dilemmas (most famously, the “prisoners dilemma”), individuals are incentivized to put their (short-term) self-interest over the collective benefit and therefore act non-cooperatively. In the present research, we build on the literature on interdependent security (IDS) dilemmas, one specific type of social dilemma, which explores the effects of outcome uncertainty on cooperation (Heal & Kunreuther, 2005), particularly in cases of possible catastrophic loss. Real-life examples of IDS dilemmas include pandemics, computer security, fire protection, protection against bankruptcy, and theft protection. In each of these cases, cooperation is manifested through investing in protection measures, which have some spillover and reduce the chance that counterparts will experience a loss. Overall, uncertainty about losses lowers cooperation between individuals quite substantially. For example, while cooperation rates in a loss-framed, repeated prisoner's dilemma (PD) may hover around 60-75%, uncertainty lowers the cooperation rate to around 25-40% (Gong, Baron, & Kunreuther, 2009; Kunreuther, Silvasi, Bradlow, & Small, 2009). Thus, cooperation rates under uncertainty are up to three times lower. The present research investigates whether precommitment may be used as an effective nudge to increase cooperation under uncertainty.

Based on prior literature, the predicted effect of precommitment in IDS dilemmas is unclear. On the one hand, following the choice bracketing literature (described above), precommitment should lead to broad bracketing, a focus on aggregate outcomes and cumulative probability, and therefore lead to safer choices. However, precommitment also reduces the potential for interaction and feedback between players (e.g., reduces the opportunity for a “tit for tat” strategy), and thereby may *reduce* cooperation; people don’t want to be a sucker. Therefore, precommitment might have a positive effect or a negative effect in IDS situations.

*The current research*

 *Overview*

 In the current research, we examine the effect of precommitment on repeated choices concerning low-probability, high-magnitude losses, in both individual decision-making, and in interdependent (IDS) decision making. In the standard paradigm, participants make 80 choices, broken into 4 blocks of 20 choices each, and 1 block is paid out for real money (thus, each block is independent). For each choice, participants choose between -1,400Rp for sure, or a 4% chance of -40,000Rp. Thus, when considering a single choice, participants will most often earn more by taking the risk, but when considering multiple choices, the overall expected value is better from taking the certain loss (EV=-1,400) than the risky loss (EV=-1,600). In our studies, some participants make choices one round at a time, some precommit choices at the beginning of each block for all 20 rounds, and some make non-binding precommitments, where they indicate their choices for all 20 rounds, but have the opportunity to change their choices after each round.

What do we mean by “precommitment”? And why not use existing terms, such as “simultaneous choice” or simply “commitment”? The standard definition of “precommitment” is a commitment made in advance (https://www.merriam-webster.com/dictionary/precommitment). In our scenarios, participants play out multiple rounds over time, and in the precommitment conditions they may choices in advance, which may or may not be binding (depending on the experimental set-up). Thus, unlike simultaneous choice, which is an instant choice of multiple options, or a simple commitment, precommitment is an advance commitment to choices which may or may not be binding.

Non-binding precommitment, as a nudge in repeated decision making under uncertainty, has several appealing features. The first is that it is applicable across a wider range of situations; while binding precommitment is easy to do in the lab, often in the real world, people can back out of their commitments. The second is that it is non-coercive. It creates a self-set default, and in that way, is a form of adaptive default (Goldstein, Johnson, Herrmann, & Heitmann, 2008) that fits itself to the preferences of the user. The third is experimental cleanliness; when comparing standard sequential choice and non-binding precommitted choices, the timing of feedback and ability to use it is the same, which eliminates experimental confounds.

*Hypotheses*

The literatures on choice bracketing and decision making under uncertainty (described above) suggest that when making sequential choices one-at-a-time, people focus on individual outcomes. In a choice between a certain loss or a low-probability, larger loss, people will be most likely to avoid loss and achieve an acceptable outcome if they take the risk. However, precommitment may lead to broad bracketing of outcomes, greater subjective probability of the loss, and a preference to diversify choices, all of which should lead to safer behavior. Therefore, we hypothesized that:

**H1:** In the context of repeated decisions about low-probability, high-magnitude losses, precommitment increases the proportion of safe choices.

 While the above hypothesis was developed based on the literature and intuition, and prior to collecting data, the subsequent hypotheses we present below were developed after collecting data, and as such are “hypotheses about the world” rather than a report of our prior predictions.

 Turning to the psychological processes driving the precommitment effect, we test two distinct choice bracketing processes: broad bracketing of choices and outcomes, versus broad bracketing of probabilities. Based on self-report and experimental evidence, we find that precommitment leads people to plan ahead and consider both individual outcomes and overall outcomes. Put another way, it shifts people from the single goal of “do well on this choice” to have multiple goals of doing well on the individual choice and doing well overall. More formally, we now hypothesize that:

**H2:** The effect of precommitment on choices is mediated by an increase in planning and an increased focus on outcomes

In contrast, while it is intuitive that precommitment would lead to broad bracketing of probabilities and increase the subjective likelihood of the loss, this process was not supported by the data (neither by self-report, nor by experimental data). We did replicate the classic effect of explicit broad bracketing of probabilities on choice, but it did not influence the effect of precommitment. Therefore, we show that broad bracketing of choices and outcomes and broad bracketing of probabilities are distinct processes, and the effect of precommitment on choices is driven by the former and not the latter. More formally:

**H3:** The effect of precommitment on choices is *not* mediated by subjective, cumulative probability perceptions

 A simplified model to illustrate the hypothesized process is depicted in Figure 1, below. Many relevant factors, such as diversification motives, are not included in this simplified model. These studies shed a bit of light on diversification (see the General Discussion), but cannot definitively “rule it in” or “rule it out”, so it is not included in the simplified process model here.

*Figure 1. Simplified model showing the process by which precommitment influences repeated decisions about low-probability, high-magnitude losses.*



Turning to independent security situations (i.e., in social dilemmas under uncertainty), the impact of precommitment is unclear based on previous literature and logic. On the one hand, following H1 and H2 above, precommitment should increase cooperation in safety. However, given game dynamics and the potential for free-riding, non-binding precommitment could “fall apart” if participants observe that their counterpart is not investing in protection. Ultimately, we find that:

**H4:** In interdependent security situations, binding precommitment increases safe choices, but non-binding precommitment does not.

*Overview of studies*

 In all studies, we compare sequential choice with precommitment in a between-participants design. Across studies, we use a variety of online samples and student samples, and use both hypothetical scenarios and incentive-compatible designs. In Study 1, which was pre-registered, we show the basic precommitment effect, and use a think-aloud protocol to explore the process drivers of the effect (supporting H1 & H2). In Study 2, we test the typical broad-bracketing educational intervention of providing the cumulative probability to participants, and find that it is orthogonal to the precommitment effect (supporting H1 & H3). In Study 3, we vary the number of rounds in each block (to be either 5, 10, or 20), and find that it has no effect on choices (supporting H1 & H3). In Study 4, we introduce non-binding precommitment, and find that it has the roughly same effect as binding precommitment (supporting H1). In Study 5, which was also pre-registered, we collect self-report rating scales on decision process, which mediate the precommitment effect (supporting H1 & H2). In Study 6, we test precommitment in the interdependent security context (supporting H4). We also ran three additional studies (S1, S2, and S3), reported in the online supplement, which further support H1-H3 and rule out confounds, show an alternative manipulation of the process and effect, and explore variations in the experimental design (e.g., examining the gain domain, differences in expected value, and differences in probability levels).

*Study 1: Think-aloud protocol*

The first study tested the main effect of precommitment on decisions about low-probability, high-magnitude losses. We hypothesize that people who precommit their choices will choose the safer option more often than those who make their choices one at a time (H1). Participants were asked to voice their thoughts aloud throughout the study (i.e., a think-aloud protocol). Research assistants later transcribed and coded these thoughts for exploratory analysis to gain insight on the potential underlying mechanisms. We pre-registered the study design and choice analyses (which can be found here: https://aspredicted.org/blind.php?x=9d8gx3 ), but the thought coding categories were developed after data collection in an exploratory manner, as detailed below.

*Study 1: Design Overview*

 In a between-subjects design, participants played an economic game of decision making under uncertainty. Participants played 80 rounds, broken down into 4 blocks of 20. Participants were randomly assigned to either the precommitment condition or “repeated choice” control condition. One block was randomly selected and paid out for real money at the end of the study. Throughout the study, participants were asked to voice their thoughts out loud, to be recorded and transcribed for further use. We reminded the participants to think aloud at the beginning of each block. The complete experimental materials for this study and for all studies are provided in the online supplement.

*Study 1: Methods*

 104 participants, mainly students at a Canadian university, (59.6% female, Mage = 24.9) were recruited for an in-person study on Business Choices Under Uncertainty. Participants' compensation depended entirely on the outcome of the experiment, as described below. We used an experimental currency, the Indonesian Rupiah (Rp); this is done because larger numeric values have been found to motivate participants even if objective values remain unchanged (Furlong & Opfer, 2008). At the end of the study, Rp were converted to dollars at the rate of 13,632 Rp = 1 CAD, which was the actual exchange rate at the time the study was designed.

 Each participant was seated at a computer in a private room. Participants were instructed to say all of their thoughts aloud as they completed the study, even those that might seem silly or irrelevant. After the experimenter left the room, they listened briefly at the door, to be sure the participant was talking aloud. After agreeing to the consent form, participants read 5 pages of instructions. They learned that they would play a scenario in which their payment would depend on their choices as well as random chance. They were told to imagine they held a mining company in Indonesia. Each "month" (ie, game round), they would earn 8,500 Rp from their sales. They had the choice of investing in either the “Known” or “Unknown” regions.

The participants were informed that

“In the Known regions, the conditions are stable, and you will pay a fixed amount of 1,400 Rp for maintenance that month. In the Unknown regions, the conditions are uncertain. There is a 4% chance that you will pay 40,000 Rp for maintenance that month, otherwise you will pay nothing that month.”

Thus, participants learned they had the option each month to invest in the safe, though costly region, which would eliminate the risk of a big loss happening. Participants learned that they would play four blocks of 20-round sessions, one of which would be randomly selected and have all rounds paid out for real money (converted to dollars). Participants in the repeated (control) condition were told they would play one round at a time, while those in the precommitment condition learned that they would precommit their choices for all 20 rounds in a session.

 Participants were told that while average payments were around $10, it was theoretically possible (though unlikely) to finish with negative money, and if this happened they would have to stay after the study and complete additional surveys at the rate of 25 cents per minute to pay back their debt.

 After reading the instructions, participants saw a payoff matrix summarizing the contingencies (see Table 1).

Participants then took a 4-item comprehension test. If participants got any items on the test wrong, they had to re-read the instructions and take the test again. Every page of the experiment had a note at the bottom that said: "If you have questions at any time, please ask the experimenter." Participants did indeed ask questions, and the experimenter assisted as necessary.

*Table 1: Payoff matrix in Study 1.*

|  |  |
| --- | --- |
| **Known region** |  You definitely lose 1,400 Rp, and have a 0% chance of the large loss occurring. |
| **Unknown region**  |  You have a 4% chance of losing 40,000 Rp and a 96% chance of losing 0 Rp.  |

 Participants in the repeated condition made a choice between the known and unknown regions for the first round, and then got feedback for the first round. The feedback specified their choice, the randomly generated number, whether the big loss occurred, and the end result. Participants then made their choice for the second round, got feedback for the second round, and so-on, until they finished all 20 rounds, at which time they saw a summary of the results of all 20 rounds from the block. Participants in the precommitment condition first made choices for all 20 rounds at once (all on the same page). They then saw round by round feedback for each round, one at a time, and then the summary of all 20 rounds. Thus, the feedback seen in the precommitment condition and the repeated control condition were the same; only the timing was different, and by the beginning of block 2, both the repeated and precommitted conditions had seen all the same feedback (with variations only as a function of their choices and the random outcomes). Note that when participants made their choices, they could make a different choice for each round if they desired. For example, a participant could precommit to choosing the safe region for the first 15 rounds and unknown region in the last 5.

 At the beginning of each block, participants were reminded to continue thinking aloud, and were instructed to say the block number out loud (e.g., “starting block 1”), which aided in connecting the thoughts to individual parts of the study. After completing all 4 blocks, participants were asked a number of demographic questions. Finally, one block was randomly selected, and each participant was paid accordingly.

*Study 1: Results*

 Average investment rates were computed for each participant for each block of 20 rounds. Overall, participants in the repeated control condition chose the safe option 25% of the time, while participants in the precommitment condition chose the safe option 49% of the time. These means were compared with a repeated-measures ANOVA, confirming a main effect of condition, *F*(1,102)=17.08, *p*<.001. In this study, there were no significant differences from block to block, nor any interaction between block and precommitment condition. We report the statistics for the block effects (i.e., early blocks versus later blocks; as well as interactions with experimental condition) for all studies in the “Additional Analyses” section below, as the order effects are unreliable across studies and do not bear on our key hypotheses.

*Thought-coding:* All of the recorded thoughts that participants spoke out loud while they were going through the experiment (e.g., reading instructions, making decisions, etc.) were transcribed by a professional transcription software, and manually checked and corrected by a research assistant. Two trained coders were provided a spreadsheet with all transcribed thoughts. The coders were blind to our research hypotheses, and blind to the condition and response data for each participant. We first instructed the coders to list all recurring themes in the responses. The two coders generated their themes list independently. Then, two authors met with the two coders, and together they constructed a unique list of recurring themes and established a code book (provided in the online appendix). We broke down the transcripts into five different sections: General, block 1, block 2, block 3, and block 4. Both coders were instructed to code each text cell according to the code book. After an initial training set of 10 participants, the reliabilities were assessed, and the code book was revised to improve reliability. The final inter-rater reliabilities and correlations for each coded item are reported in the online supplement. We rejected any coding category with reliability below .70. For the remaining coding categories, in case of disagreement, continuous variables were averaged between the two coders, and categorical variables were resolved by discussion between the two coders.

Taking an exploratory approach, we examined every coding category with sufficient reliability as a candidate for explaining the precommitment effect, using mediation analysis. Almost all of the results were non-significant, as reported in the Online Supplement. The significant results, as well as other results that bear on our hypotheses (H2 and H3) are presented in Table 2. As seen in the table, participants who precommitted their choices were more likely to make a safe or mixed plan at the beginning, and more likely to mention (individual and/or cumulative) outcomes while they were planning. In turn, the safer planning and outcome focus predicted safer choices, and mediated the effect of precommitment on choice (supporting H2). Meanwhile, thoughts related to probability, chance, or luck did not vary between conditions, nor did they predict choices. These results are consistent with H3, but are not conclusive, due to the overall large number of non-significant thought coding results.

Furthermore, each participants’ thoughts were coded automatically by the Linguistic Inquiry and Word Count (LIWC) program (Pennebaker, Boyd, Jordan, & Blackburn, 2015). LIWC uses dictionary-based text analysis to count words from text files and to provide percentage scores for several social (e.g., family, friends), psychological (e.g., positive emotions, sadness), or grammatical (e.g., question marks, exclamation marks) dimensions. LIWC’s coding results have been used and validated in several studies (for a review see Humphreys & Wang, 2018). The LIWC analysis revealed that participants in the precommitment condition were more likely to use insight words (e.g., think, know, consider) and that this use of insight words predicted safer choices, and mediated the effect of precommitment on choices.

*Table 2. Exploratory thought-listing coding results in Study 1. Variables shown are the cumulative total across the study (combining all four blocks).*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Item code | Coding instruction from codebook | Repeated | Precommitment | Correlation with DV | Indirect effect |
|  |  | Mean (SD) | Mean (SD) | r | 95% CI |
| Plan\_Safer | Do they make a safe or mixed plan at the beginning of each block? (Safe, Debt-avoiding, and Mixed strategies coded as 1; Unsafe and Random strategies coded as 0; total score is 0-4). | .47 (.83) | 1.34 (1.35) | .55\*\*\* | [.05,.18] |
| Prob | How many times do they mention probability, chance, or luck? | 3.47 (2.95) | 2.84 (2.75) | -0.05 | [-.02,.02] |
| Prob\_lucky | How often do they mention "getting lucky" or similar? Could be in the future or the past. | .76 (1.36) | .52 (.85) | 0.13 | [-.03,.01] |
| Prob\_unlucky | How often do they mention "getting unlucky" or similar? Could be in the future or the past. | .20 (.45) | .05 (.18) | 0.01 | [-.04,.01] |
| Insight | Insight words (e.g., think, know, consider); Generated by LIWC 2015 | 4.07 (1.70) | 4.93 (2.21) | .34\*\* | [.003,.08] |
|  |  | Count (%) | Count (%) | t-test value with DV | Indirect effect (Quasi-Bayesian CI) |
| Outcomes | Whether participants spoke about outcomes (individual or overall) while they were planning at the beginning of the study (mentioned =1, did not mention =0) | 6 (11.8%) | 19 (38%) | 3.88\*\*\* | [.003,.04] |
| *Notes:* \*\*\*: *p* < .001, \*\*: *p* < .01  |  |  |  |  |
|  |  |  |  |  |

*Study 1: Discussion*

 Study 1 demonstrates the main effect of precommitment: participants make safer choices (supporting H1). Study 1 also explored the process underlying this effect, with a think-aloud protocol. Participants who precommitted were more likely to make a safe (or mixed) plan, and were more focused on outcomes, both of which correlated with choices and mediated the results (supporting H2). However, these thought-coding results were quite exploratory and subject to family-wise error and researcher biases. Therefore, we follow up this open-ended process study with a more controlled, pre-registered process study in Study 5, as well as experimental tests of process, such as supplemental Study S3 which manipulates planning and outcome focus directly through an explicit prompt.

 Study 1 also casts a bit of doubt on subjective “broad bracketing of probability” as an explanation of the precommitment effect (H3), as no results were found to support it. Likewise, in other studies, we asked several self-report measures of probability (e.g., “How likely is it that the big loss will occur at least once”?), and never found significant results. However, null results are difficult to interpret. Therefore, we designed Studies 2 and 3 as direct, experimental tests of H3.

*Study 2: Probability education*

 The goal of study 2 is to examine the effect of probability education (i.e., explicit broad bracketing of probabilities) on the precommitment effect, testing H3. If precommitment works by subjective broad bracketing of probability, then explicitly presenting the cumulative probability should have the same effect, and should wipe out the effect of precommitment. On the other hand, if precommitment does not work via subjective broad bracketing of probability, then explicitly presenting the cumulative probability should have no effect.

*Study 2: Methods*

 280 participants (55% female, Mage = 35.2) were recruited from Prolific Academic in exchange for a fixed monetary compensation. Participants played the same game as Study 1 in a 2 (choice structure: precommitted choice versus repeated choice control) by 2 (Probability education: control versus education) between-subject design. The procedure was identical across the probability education factor with the only difference being an extra sentence educating participants about the probability of the big loss happening at least once over 20 rounds. Specifically, wherever participants read in the instructions about the 4% chance of losing 40,000 Rp., they also read that this translates into “a 56% probability of losing 40,000 at least once over 20 months”.

*Study 2: Results*

 As seen in Figure 2, participants made safer choices more often when they precommitted (supporting H1) and made safer choices more often when they were given the cumulative probability. However, these two effects were independent; the provision of cumulative probability did not influence the size of the precommitment effect (consistent with H3). A 2 (choice structure) by 2 (probability education) by 4 repeated (blocks) ANOVA with investment proportion in each block as the DV found a main effect of precommitment (*M*rep = .35 vs *M*pre = .54, *F*(1,276) = 29.62, *p* < .001), and a marginally significant effect of probability education (*Mcontrol* = .41 vs *Meducation* = .48, *F*(1,276) = 3.58, *p* =.06). The interaction of probability education and choice structure was not significant (*F*(1,276) = .11 , *p* = .74). As seen in Figure 2, precommitment is equally effective regardless of whether participants received the probability education or not.

*Figure 2. Overall proportion of safe choices in Study 2, as a function of precommitment (or control) and probability education (or control). Error bars indicate +/- one standard error.*

*Study 2: Discussion*

 The effect of precommitment was replicated such that individuals who precommitted their choices chose the safer option more often than those who made their choices round-by-round (supporting H1). Educating participants about the probability of the big loss happening at least one over the 20 rounds had a similar effect, increasing the choice of safe option. However, it did not influence the precommitment effect (supporting H3).

 This study shows that precommitment and broad bracketing of probability are separate, additive tools for nudging, and suggests that they involve separate mental processes. Thus, any choice architect aiming to increase safety behaviour would be wise to consider using both interventions together, rather than just one or the other.

 In Study 3, we examine the same issue of whether precommitment is driven by probability perception or not, using a different experimental paradigm.

*Study 3: Varying the number of rounds*

 The goal of study 3 is to test the extent to which precommitment varies as a function of the number of choices precommitted to (i.e., the number of rounds in the block). In previous studies, the game always involved 4 blocks of 20 rounds, but in the current study, the block length is varied to be 5 rounds, 10 rounds, or 20 rounds. The overall length of the study is correspondingly affected, to be 20 rounds in total (across all 4 blocks), 40 rounds in total, or 80 rounds in total (as in previous studies).

If the precommit effect is driven by a shift from a single-round focus to planning and a focus on both the individual round outcome and the cumulative outcome (H2), this should be true regardless of the block length. However, if the precommitment effect is driven by cumulative probability perceptions, the effect should be weakest in the 5 round version, as the cumulative chance that the loss will occur at least once in five rounds is somewhat low, and at any rate is noticeably lower than the chance that the loss would happen at least once in 20 rounds.

*Study 3: Methods*

 422 participants (48.3% female, Mage = 35.1) were recruited from Prolific Academic participant pool in exchange for a fixed monetary compensation. Participants played the same game as previous studies in a 2 (choice structure: precommitted versus repeated) by 3 (number of rounds: 20 versus 10 versus 5) between-subject design. The procedure was identical across the number of rounds factor with the only difference being the number of rounds participants played the game in each block.

*Study 3: Results*

 As seen in Figure 3, participants in the precommitment conditions chose the safe option more often (supporting H1). Furthermore, the effect of precommitment was roughly equally strong across different block lengths (consistent with H2 & H3). A 2 (choice structure: precommitted or repeated) by 3 (number of rounds: 20, 10, or 5) by 4 repeated (blocks) ANOVA with investment proportion in each block as the DV found a main effect of precommitment (*M*rep = .32 vs *M*pre = .47, F(1,416)= 24.13, *p* < .001), but no effect of number of rounds (*M20* = .41 vs *M10* = .42 vs *M5* = .36, F(2,416)= 1.64, *p* =.2). The interaction of number of rounds and choice structure was also not significant (*F*(2,416) = .08 , *p* = .93). As seen in Figure 3, precommitment is equally effective regardless of the number of rounds participants played in each block.

*Figure 3. Proportion of safe choices in Study 3, as a function of whether choices were precommitted or not, and whether the block had 20 rounds, 10 rounds, or 5 rounds. Error bars show +/- one standard error.*

*Study 3: Discussion*

 The effect of precommitment was replicated such that individuals who precommitted their choices chose the safer option more often than those who made their choices round-by-round (supporting H1). Moreover, decreasing the number of rounds did not have any effect on the choice of safe option or on the effect of precommitment on the choice of safe option. This is consistent with the idea that precommitment leads to planning and multiple goals (both single round outcome and cumulative outcome), but inconsistent with the theory that precommitment leads to higher cumulative probability perceptions. Furthermore, the observed pattern of results demonstrates the robustness of the precommitment effect, showing that it is effective, even when the timeframe is somewhat short.

*Study 4: Binding vs non-binding precommitment*

 In this study, we introduce the “non-binding” precommitment nudge, and compare it with “binding” precommitment (which was used in previous studies), as well as repeated-choice control. The purpose of this study is two-fold. First, it addresses (real-world motivated) situations in which participants may change their choices after initial commitment. Second, it further sharpens our understanding of the process underlying the precommitment effect, by testing whether it is driven mainly by the fact of being forced to consider all choices in advance, or driven by the fact that once committed, choices cannot be changed and therefore the participant cannot respond to round-by-round feedback.

*Study 4: Methods*

 We used a one-factor (Choice structure: Repeated vs. Precommitted vs. Non-binding precommitted) between-participants design. Participants were 210 (48.6% female, Mage = 36.8) users of Amazon’s mechanical Turk who received a fixed monetary compensation for their participation.

 The repeated and binding precommitment conditions were the same as previous studies. In the non-binding precommitment condition, the participants learned that they would precommit their choices, and also that they would return to the choice page after each round and have the opportunity to change their current and future choices if they wished. Indeed, participants had the opportunity to change their current and future choices after each round. Thus, the feedback timing was identical in the repeated condition and non-binding pre-commitment condition; in both cases, participants received feedback after every round and had the opportunity to make a different choice in the next round. After the game, the participants completed demographic questions.

*Study 4: Results*

 As seen in Figure 4, participants made safer choices when they precommitted their choices (supporting H1), regardless of whether that precommitment was binding or non-binding. Although the effect of non-binding precommitment looks a bit weaker, the difference between binding and non-binding precommitment is not significant. Nonetheless, it seems plausible that non-binding precommitment would be weaker, and we suspect that a significant difference would emerge with adequate power.

A 3 (choice structure: Repeated vs. Binding-precommitted vs. Non-binding precommitted) by 4 (blocks) repeated-measures ANOVA revealed a significant omnibus effect of choice structure (F(2,207)= 5.80, *p*= .004). A follow-up LSD post-hoc test indicated that investment in the safer option in the non-binding precommitment condition (*Mnon*= .43, *SE*= .04) was roughly as high as in the standard precommitment condition (*Mpre* = .48, *SE*= .04, *p* = .37). Investment rates in the repeated condition (*Mrep*= .30, *SE*= .04) were significantly less than those in the precommitment condition (*p* = .001) and the non-binding precommitment condition (*p* = .02).

*Figure 4. Proportion of safe choices in Study 4, as a function of whether choices were simple repeated choices, binding-precommitted choices, or non-binding precommitted choices. Error bars show +/- one standard error.*

*Study 4: Discussion*

 Study 4 replicated the effect of precommitment on preference for the safer option, even when the commitment was non-binding. This adds to the real-world applicability of the precommitment effect: choice architects often may not be able to force people to follow through on their commitments (or may not want to force people to do so, for ethical reasons). Nonetheless, having people precommit their choices in a non-binding way can still lead to safer choices. The non-binding precommitted condition was equally flexible as the repeated condition (in that participants could make individual decisions at any given month), yet the mere fact that participants in the former condition precommitted their choices increased safe choices, perhaps due to planning and the consideration of multiple outcomes. Thus, this study clarifies that it is the “forward-looking” nature of precommitment, rather than the inflexibility or differential timing of feedback, which drives the observed effect.

*Study 5: Process data & mediation*

 The goal of study 5 was to verify the self-report of psychological processes underlying the precommitment effect. Based on the findings of the think-aloud study (Study 1) as well as those of the other studies, we created 7 measures to examine the potential processes. The full text for these 7 measures can be found in Table 5. The methods, predictions, and analyses of this study were pre-registered, and can be found at https://aspredicted.org/blind.php?x=9pg5eu . We predicted that precommitment would lead to greater planning, which would lead to greater use of math (to improve cumulative outcomes) and greater preference for diversification, leading to safer choices. While this was not significant, the highly similar process of precommitment leading to greater planning, leading to math being judged as useful, leading to safer choices was significant (though not predicted in advance).

*Study 5: Methods*

 800 participants (60% female[[1]](#footnote-1), Mage = 34.8) were recruited from the Prolific Academic participant pool in exchange for a fixed monetary compensation. Participants played the same game as in previous studies, using a between-subjects design (choice structure: non-binding precommitment versus repeated control). The only difference from previous studies (e.g., Study 1) was in that the precommitment of choices was non-binding. After playing the game for two blocks, the participants were asked to answer the seven process questions (listed in Table 5). Once the participants provided their answers for these questions, they played the remaining two blocks of the game and the experiment concluded with demographic questions.

*Study 5: Results*

 As seen in Figure 5, non-binding precommitment increased the proportion of safe choices. A 2 (choice structure) by 4 (blocks) repeated-measures ANOVA with investment proportion in each block as the DV found a main effect of precommitment (*M*rep = .29 vs *M*pre = .46, *F*(1,791) = 77.35, *p* < .001). Moreover, we found a significant linear contrast for blocks and blocks × choice structure effects (stats reported in Table 5). The interaction is shown in Figure 5.

*Figure 5. Proportion investing in the repeated and non-binding precommitted conditions in each block in Study 5. Error bars show +/- 1 SE.*

*Process measures (pre-registered analyses):* We examined whether each of the measured variables mediate the effect of precommitment on choices. The indirect effects through each of the seven process measures is reported in Table 3. As can be seen in the table, only the indirect effects for items 5, 6, and 7 is significant on a 95% bootstrapped confidence interval.

Moreover, we had pre-registered the following *serial* mediation analyses to further probe into the mechanisms underlying precommitment effect: a) Precommitment -> Follow plan? -> Used math? -> Investment proportion, and b) Precommitment -> Follow plan? -> Same or diversify? -> Investment proportion. The results for both of these, however, turned out non-significant (Table 4).

*Process measures (exploratory analyses):* We tested other, non-pre-registered serial mediation analyses, as exploratory analyses. Specifically, we tested the following serial effects: a) Precommitment -> Follow plan? -> Is math useful? -> Investment proportion, and b) Precommitment -> Used math? -> Is math useful? -> Investment proportion. The results for these two analyses are summarized in Table 4. As illustrated there, both serial indirect effects are significant using the 95% confidence intervals. Still, these results should be interpreted with caution, as they are post-hoc.

Table 3. Pre-registered simple mediation analyses in Study 5. Significant mediation effects are bolded.

|  |  |  |  |
| --- | --- | --- | --- |
| Item text | Repeated | Non-binding Precommitment | Indirect effect |
|  | Mean (SD) | Mean (SD) | 95% CI |
| 1. How complicated is this decision task? | 1.82 (1.13) | 1.97 (1.17) | [-.005, .001] |
| 2. How difficult is it to decide which region to mine?  | 2.35 (1.26) | 2.47 (1.27) | [-.006, .001] |
| 3. How much information do you need to consider to make your decision? | 3.32 (1.17) | 3.43 (1.24) | [-.003, .002] |
| 4. Do you prefer to mine in the same region each time, or diversify the regions that you mine in? | 3.56 (1.97) | 3.61 (1.93) | [-.002, .003] |
| 5. Do you think it is useful to use math or calculations to make your decision in the task?  | 3.84 (1.99) | 4.24 (1.93) | **[.002, .014]** |
| 6. Did you actually do math or calculations to help you make your decision?  | 1.80 (0.88) | 2.12 (0.86) | **[.0002, .0157]** |
| 7. How much do you agree with the following statement: “I set out a plan at the beginning of the block, and I follow it.”  | 4.56 (1.91) | 5.04 (1.81) | **[.001, .012]** |

Table 4. Pre-registered and exploratory serial mediation analyses in Study 5. Significant mediation effects are bolded.

Pre-registered analyses

|  |  |  |  |
| --- | --- | --- | --- |
|  | Precommitment -> Follow plan? -> Used math? -> Investment proportion |  | Precommitment -> Follow plan? -> Same or diversify? -> Investment proportion |
|  | Effect | SE | LLCI | ULCI |  | Effect | SE | LLCI | ULCI |
| TOTAL effect | 0.0098 | 0.0044 | 0.002 | 0.0192 |  | 0.0072 | 0.0033 | 0.0016 | 0.0145 |
| Indirect effect through 1st med | 0.0045 | 0.0031 | -0.0005 | 0.0111 |  | 0.0068 | 0.0032 | 0.0016 | 0.0138 |
| Indirect effect through 2nd med | 0.0041 | 0.0032 | -0.0016 | 0.0109 |  | 0.0015 | 0.0016 | -0.0009 | 0.0055 |
| Serial mediation effect | 0.0012 | 0.0009 | -0.0005 | 0.0032 |  | -0.0011 | 0.0008 | -0.003 | 0.0003 |

Exploratory analyses

|  |  |  |  |
| --- | --- | --- | --- |
|  | Precommitment -> Used math? -> Is math useful? -> Investment proportion |  | Precommitment -> Follow plan? -> Is math useful? -> Investment proportion |
|  | Effect | SE | LLCI | ULCI |  | Effect | SE | LLCI | ULCI |
| TOTAL effect | 0.0076 | 0.0046 | -0.0007 | 0.0173 |  | 0.0096 | 0.0042 | 0.0026 | 0.0186 |
| Indirect effect through 1st med | 0.0011 | 0.0044 | -0.0079 | 0.0104 |  | 0.0035 | 0.0029 | -0.0015 | 0.0102 |
| Indirect effect through 2nd med | 0.0003 | 0.002 | -0.0038 | 0.0046 |  | 0.0038 | 0.0025 | -0.0001 | 0.0097 |
| Serial mediation effect | 0.0062 | 0.0028 | **0.0014** | **0.0124** |  | 0.0022 | 0.0011 | **0.0005** | **0.0048** |

*Study 5: Discussion*

 In this study, precommitment again led to safer choices (supporting H1). As we predicted, the effect of precommitment on safety choices was mediated by planning (supporting H2). We also predicted serial mediation, of precommitment leading to planning, leading to self-reported use of math, leading to safer choices. The thinking here is that a greater focus on cumulative outcomes should lead to greater usage of math. While this was not significant, the (unpredicted but similar) serial mediation of planning, leading to perceived usefulness of math, leading to safer choices was significant. Overall, these results partially support H2.

 Finally, in Study 6 we examine influences choices in the context of independent security dilemmas.

*Study 6: Precommitment in Social Dilemmas*

The goal of study 6 was to test the application of the precommitment nudge in the context of social dilemmas. Specifically, we examine and compare the effects of non-binding versus binding precommitment in a social dilemma setting. We used a stochastic prisoners’ dilemma (i.e., interdependent security) whereby game outcomes were a function of the participant’s choices, their counterpart’s choices, and random factors.

*Study 6: Design overview*

In a between-subjects design, participants played one of three versions of a social dilemma game (with incentive-compatible outcomes): a stochastic prisoner's dilemma with repeated choices, a stochastic prisoner's dilemma with binding precommitted choices, or a stochastic prisoner's dilemma with non-binding precommitted choices. Participants played 3 blocks of 20 rounds each. In this study, we used 3 blocks rather than 4 for brevity, to be sure the study would finish within a 30-minute timeslot. Counterparts for each block were anonymous, participants were randomly assigned a counterpart for each block (with replacement), and one block was randomly selected and paid out for real money at the end of the study.

*Study 6: Methods*

 160 participants (70% female, Mage = 22.8) were recruited for a study on Interdependent Security Games. Participants' compensation depended entirely on the outcome of the experiment, as described below.

 The study materials, were modeled after Kunreuther et al. (2009) and Gong et al. (2009). Similar to previous studies, we used the Indonesian Rupiah (Rp) as our experimental currency.

 Each participant was seated at a computer and instructed not to communicate with any of the other participants. After agreeing to the consent form, participants read 5 pages of instructions. They learned that they would play a scenario in which their payment would depend on their choices as well as those of a counterpart. They were told to imagine they held a shared risky venture in Indonesia. Each "month" (ie, game round), they would earn 8,500 Rp from their investments. However, there was a small chance (4%) of a big financial loss, also affecting their counterpart.

 Participants learned they had the option each year to invest in a protective measure for 1400 Rp which would protect them against the big loss. However, the loss was only completely eliminated if both counterparts invested. Participants learned that they would play a 20-year session with one anonymous counterpart, after which they would again be randomly paired with a new counterpart and play another session. They would play 3 sessions in total, one of which would be randomly selected and have all rounds paid out for real money (converted to dollars).

 After reading the instructions, participants saw a payoff matrix summarizing the contingencies (see Table 5). Similar to the previous studies, there was a comprehension test on the rules of the game.

*Table 5. Payoff matrix shown to participants in Study 6.*

|  |  |
| --- | --- |
|  | Your Counterpart |
| INVEST | NOT INVEST |
| You | INVEST | - You definitely lose **1,400 Rp**, and have a 0% chance of the large loss occurring.- Your counterpart definitely loses **1,400 Rp**, and has a 0% chance of the large loss occurring. | - You definitely lose **1,400 Rp** and have a 1% chance of losing an additional **40,000 Rp**.- Your counterpart has a 3% chance of losing **40,000 Rp** and a 97% chance of losing **0 Rp**. |
| NOT INVEST | - You have a 3% chance of losing **40,000 Rp** and a 97% chance of losing **0 Rp**.- Your counterpart definitely loses **1,400 Rp** and has a 1% chance of losing an additional **40,000 Rp**. | - You have a 4% chance of losing **40,000 Rp** and a 96% chance of losing **0 Rp**.- Your counterpart has a 4% chance of losing **40,000 Rp** and a 96% chance of losing **0 Rp**. |

 Participants had to wait until all participants present had completed the knowledge test, and were then randomly paired with a counterpart for the first block of 20 rounds. Subsequently, participants were again presented with the appropriate payoff matrix, and were asked to choose whether to invest in the protective measure or not.

 Participants in the repeated condition and non-binding precommitment condition made a choice for the first round, and then got feedback for the first round. The feedback specified their choice, the choice of their counterpart, the randomly generated number, and the end result. Participants then made their choice for the second round, got feedback for the second round, and so-on, until they finished all 20 rounds, at which time they saw a summary of the results of all 20 rounds. Participants in the precommitment condition first made choices for all 20 rounds at once. They then saw round by round feedback for all 20 rounds, and then the summary of all 20 rounds.

 After the summary, participants were again randomly paired with a counterpart (with replacement) and played another block. After completing all 3 blocks, one block was randomly selected, and each participant was paid accordingly.

*Study 6: Results*

 As seen in Figure 6, binding precommitment increased safe choices, but non-binding precommitment did not (supporting H4). Average investment rates were computed for each participant in each block of 20 rounds and compared with a repeated-measures ANOVA. This revealed an omnibus main effect of condition, *F*(2,157)=6.51, *p*=.002. A follow-up LSD post-hoc test indicated that investment rates in the precommitment condition (M= .49) were higher than the non-binding precommitment (M= .32, *p*= .003) and repeated conditions (M= .31, *p*= .002) while the latter two were not statistically different (*p*= .87).

*Figure 6. Proportion of safe choices in Study 6 as a function of whether choices were repeated, binding precommitted, or non-binding precommitted. Error bars show +/- one standard error.*

*Study 6: Discussion*

 As in previous studies of interdependent security (Gong et al., 2009), the overall proportion of cooperation in safety behavior was low, around 30-35%. Binding precommitment increased the proportion of safe cooperation, but non-binding pre-commitment had basically no effect (supporting H4). The reason for the difference between binding and non-binding precommitment in this study is unclear, but certainly relates to the dynamics of playing with a counterpart. One possibility is that cooperation in safety is fragile in this situation, and if one person sees that the other is not paying for safety, then they are not likely to pay for safety either. This dynamic can only emerge in non-binding precommitment; in binding precommitment there is not opportunity to react to one’s counterpart, until the next block of choices, when one is randomly paired with a (potentially new) counterpart again. An empirical investigation of the process driving the difference vs non-binding precommitment in social dilemmas remains a topic for future research.

*Additional Studies*

 We conducted three supplemental studies, S1-S3, reported in the online supplement, which we briefly summarize here. In Study S1, we systematically varied the display of choices to “aggregated”, all on one page, or “segregated” across multiple pages, and crossed that with precommitment. Thus, a person might precommit their choices with each choice on a separate page, or do repeated choice with all choices shown on a single page. The display of choices in aggregated vs segregated format made not difference, and did not change the effect of precommitment, thus ruling out a potential confound. Study S1 also examined gain outcomes versus loss outcomes, with somewhat ambiguous results in the gain domain.

 In Study S2, we examined different probability levels for the big loss (4%, 20%, or 50%), while holding expected value constant. This showed that when the risk of loss was high (50%), most participants preferred the safe option even in the repeated condition, and precommitment had little effect. This demonstrates a boundary condition; when the safe option is already attractive in one-off repeated choices, precommitment does not change or further enhance the preference for safety.

 In Study S3, we “manipulated the mediator” of the precommitment effect. Participants in the “planning” conditions were given instructions at the beginning to think about all 20 rounds, what strategy would serve them best, and how many rounds they think they should invest. This “planning” intervention increased safe choices in the repeated condition, but had no effect in the precommitted condition. Study S3 also examined the situation where the risky loss has superior expected value, finding that precommitment still increased safe choices but was reduced, and that the effect of the “planning” intervention was reduced.

*Additional Results & Analyses*

 There are two sets of results and analyses that are easier to interpret when presented together (looking at all nine studies in the same table) rather than presented separately across studies: block effects, and differences from chance.

 Across studies, we often saw an effect of block number, as shown in Table 6. These significant block effects indicate a gradual decrease in safe choices over time, across all conditions. This could be related to the “description” versus “experience” of risk (Hertwig & Erev, 2009), wherein most people do not experience the big loss, most of the time, and so gradually lose their sensitivity to it.

 Also seen in Table 6, there were two studies with a significant interaction of block number and the precommitment effect. Figures illustrating those interactions are already presented in those two studies (Study 5 and Study S2). As seen in those two figures, the effect of precommitment gets a bit weaker across the blocks. Again, this could be related to the “experience” of risk versus the description. However, this interaction effect is small, and is not reliable across studies; it is only seen in two of the nine studies.

*Table 6. Block main effects and blocks by precommitment interaction effects, in all studies:*

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  | F-values for linear contrasts |
| Study No. | Name | df1,df2 | Blocks | Blocks\*RepPre |
| 1 | **Think-aloud protocol** | (1,102) | 0.47 | 0.85 |
| 2 | **Probability education** | (1,278) | 8.99\*\* | 0.31 |
| 3 | **Varying the number of rounds** | (1,420) | 40.79\*\*\* | 1.43 |
| 4 | **Binding vs non-binding precommitment (Pre vs. Rep)** | (1,141) | 8.32\*\* | 0.57 |
| 4 | **Binding vs non-binding precommitment (Non-Pre vs. Rep)** | (1,133) | 0.34 | 1.15 |
| 5 | **Process data and mediation** | (1,791) | 19.54\*\*\* | 4.37\* |
| 6 | **Precommitment in Social dilemmas (Pre vs. Rep)** | (1,104) | 8.28\*\* | 0.56 |
| 6 | **Precommitment in Social dilemmas (Non-Pre vs. Rep)** | (1,106) | 3.55† | 0.17 |
| S1 | **Separated vs Aggregated Displays and Gains vs Losses** | (1,350) | 8.26\*\* | 0.77 |
| S2 | **Probability levels** | (1,413) | 1.89 | 3.93\* |
| S3 | **Alternate manipulation of time horizon & changing EV** | (1,565) | 26.41\*\*\* | 1.06 |

*Note: †: <.10, \*: <.05, \*\*: <.01, \*\*\*: <.001*

Finally, we examine an alternative process account of the precommitment effect: that it drives the decision maker towards choosing safety 50% of the time. This could happen because precommitment presents an overwhelming number of choices, leading to difficulty, confusion, and random responding. Or it could happen because precommitment induces a preference for diversity in choices (similar to the diversification bias seen in previous research on choice bracketing), which would lead towards 50% as well. Indeed, looking at the data the baseline in the repeated condition is nearly always below 50%, and precommitment generally increases the proportion of safe choices, often moving the proportion closer to .50. Therefore, we examine this systematically in Table 7, which shows the proportion of safe choices in the precommitment conditions in all 9 studies, and tests whether the observed proportion is statistically different from .50, using a one-sample t-test. As seen there, the precommitment condition is often near .50, but also sometimes pushes significantly past .50, to .60 or more, as seen in Studies 2, 3, S1, and S2. Overall, these results cannot rule out decision difficulty and diversification as drivers of the effect, but also show that they are not the *only* thing driving the effect.

*Table 7. Summary of investment proportion in the precommitment condition of every study, and whether the proportion is significantly different from .50 using a one-sample t-test.*

|  |  |  |
| --- | --- | --- |
|  |  | Blocks |
| Study | Name | 1 | 2 | 3 | 4 |
| 1 | **Think-aloud protocol** | 0.51 | 0.51 | 0.45 | 0.48 |
| 2 | **Probability Education (Control)** | 0.54 | 0.49 | 0.52 | 0.5 |
| 2 | **Probability Education (Education)** | 0.65\*\*\* | 0.56 | 0.53 | 0.54 |
| 3 | **Varying the number of rounds (20 rounds)** | 0.59\* | 0.5 | 0.42† | 0.41\* |
| 3 | **Varying the number of rounds (10 rounds)** | 0.59\* | 0.51 | 0.45 | 0.49 |
| 3 | **Varying the number of rounds (5 rounds)** | 0.48 | 0.39\* | 0.44 | 0.43 |
| 4 | **Binding vs non-binding precommitment (Precommitment)** | 0.54 | 0.49 | 0.43 | 0.47 |
| 4 | **Binding vs non-binding precommitment (Non-binding Precommitment)** | 0.45 | 0.39\* | 0.46 | 0.44 |
| 5 | **Process data and mediation (Non-binding Precommitment)** | 0.51 | 0.46\* | 0.46\* | 0.43\*\*\* |
| 6 | **Precommitment in Social dilemmas (Precommitment)** | 0.56 | 0.47 | 0.45 | - |
| 6 | **Precommitment in Social dilemmas (Non-binding Precommitment)** | 0.34\*\*\* | 0.32\*\*\* | 0.3\*\*\* | - |
| S1 | **Loss &Gain study (Loss/Separate display)** | 0.6† | 0.55 | 0.53 | 0.51 |
| S1 | **Loss & Gain study (Loss/Aggregate display)** | 0.64\*\* | 0.53 | 0.52 | 0.49 |
| S1 | **Loss & Gain study (Gain/Separate display)** | 0.67\*\*\* | 0.67\*\*\* | 0.67\*\*\* | 0.67\*\*\* |
| S1 | **Loss & Gain study (Gain/Aggregate display)** | 0.6† | 0.63\* | 0.63\* | 0.58 |
| S2 | **Probability levels (4% condition)** | 0.5 | 0.52 | 0.49 | 0.49 |
| S2 | **Probability levels (20% condition)** | 0.63\*\* | 0.51 | 0.53 | 0.56 |
| S2 | **Probability levels (50% condition)** | 0.69\*\*\* | 0.63\*\* | 0.67\*\*\* | 0.6† |
| S3 | **Choice Focus study (40K/control)** | 0.57† | 0.49 | 0.46 | 0.51 |
| S3 | **Choice Focus study (40K/all20rounds)** | 0.58† | 0.54 | 0.48 | 0.49 |
| S3 | **Choice Focus study (30K/control)** | 0.57 | 0.43 | 0.46 | 0.45 |
| S3 | **Choice Focus study (30K/all20rounds)** | 0.49 | 0.44 | 0.41 | 0.43 |
| *Note: †: <.10, \*: <.05, \*\*: <.01, \*\*\*: <.00* |

*General Discussion*

 Across six studies and three supplemental studies, we found that precommitment increases safety behavior regarding low-probability, large magnitude losses, strongly supporting H1. We found evidence that this happens because precommitment increases planning and a focus on outcomes, as seen in Study 1, Study 5, and Study S3, supporting H2. Furthermore, we found evidence (especially in Studies 2 and 3) that precommitment is *not* driven by an increase in subjective probability, suggesting that broad bracketing of choices and broad bracketing of probabilities are distinct and additive processes. Finally, we tested precommitment in the context of a stochastic “interdependent security” social dilemma, and found that while binding precommitment increased cooperation rates, non-binding precommitment did not.

The present research makes several contributions to theory and practice. First, it introduces non-binding precommitment as a novel nudge for use in repeated decisions about low-probability, large-magnitude losses. This is both practically useful as a new tool in the toolkit for choice architects, and also makes a conceptual contribution to the default literature as a form of adaptive, self-set default. Second, the present research finds that broad bracketing of choices & outcomes, and broad bracketing of probabilities are distinct decision processes. These two flavors of choice bracketing have both been previously studied in the literature, but not empirically compared within the same framework. The finding that they are distinct and complementary, with additive effects (Study 2) has implications for the theory and practice of choice bracketing. Third, this research is the first to examine precommitment in social dilemmas, and reveals a critical difference between binding versus non-binding precommitment in this context.

 We found that non-binding precommitment is *not* effective in anonymous, interdependent situations, and in real life people can easily renege on interdependent commitments. While this may often result in lower investment rates in IDS situations, there are reasons to believe that precommitment could still be an effective tool, perhaps through public declarations and non-anonymous interactions between interdependent people. In other cases, legal contracts and social pressure may be needed enforce commitments in many social dilemma situations.

 The current research has many limitations. One is that we studied precommitment in a fairly narrow and sterile decision context. While it is tempting to generalize and directly apply our results to real-world decisions of interest (such as decisions about protecting against COVID-19), there are many important differences between contexts, and it is likely that our controlled, experimental context overestimates the strength of the precommitment effect. Therefore, while the results presented here suggest that precommitment is a promising nudge, it should be tested in other, real-world contexts and samples. A second limitation of the current research is theoretic. While we have focused on establishing the basic effect and distinguishing between two decision processes (supporting the one and ruling out the other), there are many “loose ends” that remain as topics for future research. For example, why does planning and a focus on cumulative outcomes lead to safer choices? It seems intuitive enough, but looking into the details of supplemental studies S1-S3 reveal important complexities. We suspect that when people are planning and focused on cumulative outcomes, they are motivated both to maximize their expected value (EV), and to safely satisfice at some target level. In some contexts, such as when safe behavior is EV maximizing, these lead in the same direction. In other cases, when risky behavior is EV maximizing, these motivations are in opposition, and may change the effect of precommitment accordingly. Another loose end concerns the divergence between binding and non-binding precommitment in social dilemmas. How and why does non-binding precommitment unravel? And how might this be avoided? Perhaps we decision science researchers should commit to answering these important questions in future research.

**References**

Aerts, J. C., & Botzen, W. W. (2011). Climate change impacts on pricing long-term flood insurance: A comprehensive study for the Netherlands. *Global Environmental Change, 21*(3), 1045-1060.

Benartzi, S., & Thaler, R. H. (1995). Myopic loss aversion and the equity premium puzzle. *The quarterly journal of Economics, 110*(1), 73-92.

Chaudhry, S., Hand, M., & Kunreuther, H. (2020). Broad bracketing for low probability events. *NBER Working Paper*(w27319).

Fox, C. R., Ratner, R. K., & Lieb, D. S. (2005). How subjective grouping of options influences choice and allocation: diversification bias and the phenomenon of partition dependence. *Journal of Experimental Psychology: General, 134*(4), 538.

Furlong, E. E., & Opfer, J. E. (2008). Cognitive Constraints on How Economic Rewards Affect Cooperation. *Psychological Science, 20*(1), 11-16.

Goldstein, D. G., Johnson, E. J., Herrmann, A., & Heitmann, M. (2008). Nudge your customers toward better choices. *Harvard Business Review, 86*(12), 99-105.

Gong, M., Baron, J., & Kunreuther, H. C. (2009). Group cooperation under uncertainty. *Journal of Risk & Uncertainty, 39*, 251-270. doi:10.1007/s11166-009-9080-2

Hardin, A. M., & Looney, C. A. (2012). Myopic loss aversion: Demystifying the key factors influencing decision problem framing. *Organizational Behavior & Human Decision Processes, 117*, 311-331.

Hardisty, D. J., & Pfeffer, J. (2016). Intertemporal Uncertainty Avoidance: When the Future Is Uncertain, People Prefer the Present, and When the Present Is Uncertain, People Prefer the Future. *Management Science*.

Hardisty, D. J., & Weber, E. U. (2020). Impatience and Savoring vs. Dread: Asymmetries in Anticipation Explain Consumer Time Preferences for Positive vs. Negative Events. *Journal of Consumer Psychology*.

Heal, G., & Kunreuther, H. C. (2005). IDS Models of Airline Security. *Journal of Conflict Resolution, 49*(2), 201-217. doi:10.1177/0022002704272833

Hertwig, R., & Erev, I. (2009). The description–experience gap in risky choice. *Trends in cognitive sciences, 13*(12), 517-523.

Humphreys, A., & Wang, R. J.-H. (2018). Automated text analysis for consumer research. *Journal of Consumer Research, 44*(6), 1274-1306.

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica, 47*(2), 263-292.

Kunreuther, H. C., Silvasi, G., Bradlow, E. T., & Small, D. (2009). Bayesian analysis of deterministic and stochastic prisoner's dilemma games. *Judgment and Decision Making, 4*(5), 363-384.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational behavior and human decision processes, 69*(2), 149-163.

Liu, Y., Heath, T. B., & Onculer, A. (2020). The Future Ambiguity Effect: How Narrow Payoff Ranges Increase Future Payoff Appeal. *Management Science*.

Molouki, S., Hardisty, D. J., & Caruso, E. M. (2019). The sign effect in past and future discounting. *Psychological science, 30*(12), 1674-1695.

Morrin, M., Inman, J. J., Broniarczyk, S. M., Nenkov, G. Y., & Reuter, J. (2012). Investing for retirement: The moderating effect of fund assortment size on the 1/n heuristic. *Journal of Marketing Research, 49*(4), 537-550.

Pennebaker, J. W., Boyd, R. L., Jordan, K., & Blackburn, K. (2015). *The development and psychometric properties of LIWC2015*. Retrieved from

Read, D., & Loewenstein, G. (1995). Diversification bias: Explaining the discrepancy in variety seeking between combined and separated choices. *Journal of Experimental Psychology: Applied, 1*(1), 34.

Read, D., Loewenstein, G., & Rabin, M. (1999). Choice Bracketing. *Journal of Risk and Uncertainty, 19*, 171-197.

Redelmeier, D. A., & Tversky, A. (1992). On the Framing of Multiple Prospects. *Psychological Science, 3*(3), 191-193. doi:10.1111/j.1467-9280.1992.tb00025.x

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1978). Accident probabilities and seat belt usage: A psychological perspective.

Sun, H.-L., Li, A.-M., Shen, S.-C., Xiong, G.-X., Rao, L.-L., Zheng, R., . . . Li, S. (2020). Early Departure, Early Revival: A" Free From Care" Account of Negative Temporal Discounting. *Advances in Cognitive Psychology, 16*(2).

Thaler, R., & Sunstein, C. R. (2008). *Nudge: improving decisions about health, wealth, and happiness*: Yale University Press.

Tversky, A., & Kahneman, D. (1992). ADVANCES IN PROSPECT-THEORY - CUMULATIVE REPRESENTATION OF UNCERTAINTY. *Journal of Risk & Uncertainty, 5*, 297-323. doi:10.1007/bf00122574

Webb, E. C., & Data, S. B. S. (2017). Is broad bracketing always better? How broad decision framing leads to more optimal preferences over repeated gambles. *Judgment and Decision Making, 12*(4), 382.

1. Due to a technical error in the study scripting, some individual-level data were lost. The demographic data reported here is based on the data before the error (n= 548). [↑](#footnote-ref-1)