Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Risk escalation is amplified by stakes, not by a sense of control

Hadeel Haj-Ali

hajali.hadeel5@gmail.com

University College London & The Max Planck UCL Centre https://orcid.org/0000-0002-5230-3906

Moshe Glickman

Bar-Ilan University

Bastien Blain

Panthéon-Sorbonne University

Tali Sharot

t.sharot@ucl.ac.uk

University College London, The Max Planck UCL Centre, & MIT

Research Article

Keywords: Financial risk, Rewards, Risk escalation, Agency, Sense of Control, Risk aversion

Posted Date: April 30th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9527851/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: The authors declare no competing interests.

Risk escalation is amplified by stakes, not by a sense of control

Hadeel Haj-Ali[1,2*], Moshe Glickman[1,2] , Bastien Blain[4], & Tali Sharot[1,2,3*]

[1] Department of Experimental Psychology, University College London, UK.

[2] The Max Planck UCL Centre for Computational Psychiatry and Ageing Research, University College London, UK.

[3] Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, USA.

[4] Sorbonne Economics Centre, Panthéon-Sorbonne University, Paris, France.

*Corresponding authors: hajali.hadeel5@gmail.com , t.sharot@ucl.ac.uk

Abstract

People are often faced with the same risky choices repeatedly: how much to invest, how much to drink, how fast to drive. These decisions are not made just once, but dozens of times. How does repetition *per se* alter risk-taking? Here, we isolate the effect of mere repetition from outcome learning to examine how risk attitude changes over time. Across three experiments, participants made repeated financial wagers on lotteries with positive expected value. Initially, participants wagered far below the optimal strategy of a risk-neutral agent. With repetition, however, risk-taking gradually escalated. Two factors boosted risk-taking, moving participants even closer to the 'rational' benchmark: stakes and agency. Participants wagered more when potential rewards were high and when they could select their own cue to wager on. Yet only stakes shaped the *trajectory* of escalation, with steeper escalation emerging exclusively at higher reward potential. These findings illuminate how repetition erodes risk aversion and suggest strategies for promoting adaptive risk-taking while curbing maladaptive risk-taking.

Keywords: Financial risk; Rewards; Risk escalation; Agency; Sense of Control; Risk aversion

In life, we are often faced with the same risky choice over and over again. Whether it is how much money to invest in the stock market, how much alcohol to consume or how fast to drive, these decisions are not made just once, but dozens of times. How does repetition per se alter risk-taking?

Most studies that examine *repeated* risky choice are concerned with learning from outcomes (Andrade & Iyer, 2009; Coval & Shumway, 2005; Dabney et al., 2020; Ert & Haruvy, 2017; Imas, 2016; Langer & Weber, 2008; Liu et al., 2010; Post et al., 2008; Rabin, 2000; Shiv et al., 2005; Thaler & Johnson, 1990). An agent makes a choice, observes an outcome and updates their prediction, which impacts their next choice. Often, however, outcomes are not visible before consecutive choices are made. Consider a venture capitalist investing in early-stage companies. Over months or years, she must repeatedly decide how much capital to commit with little along the way to guide her. Each investment is a risk taken in near-darkness. From doctors choosing treatments to policymakers whose choices unfold over years, repeated risky decisions with little to no feedback are the norm rather than the exception. Thus, it is important to understand how repetition *per se* influences choice.

The impact of repetition *per se* on financial decisions is unknown because the few studies that have attempted to isolate repetition from learning have yielded mixed results (Ert & Erev, 2013; Brooks & Zank, 2005; Erev et al., 2010). We speculate that the reason for this is the common use of binary decisions. Binary decisions on whether to take a risk may not be sensitive enough to pick up on gradual shifts in preferences. Here, we address this problem by examining temporal changes to decisions about *how much* risk to take, not simply on whether to engage in risk altogether. We do this using a continuous wagering scale that can capture even small shifts. The hypothesis is that with repetition people will gradually take more risks. The rationale is that taking a risk may make risk-taking feel a little more acceptable and a little less fear-inducing every time. Importantly, the drift will be gradual, with each step small enough to feel acceptable precisely because it departs only slightly from the last.

If financial risk-taking escalation is evident, two important questions arise. First, would escalation be dependent on what is at stake? Higher stakes, either due to larger potential gains or losses, may induce steeper escalation. The rationale is that when the stakes are higher, emotions are more intense (Knutson et al., 2005; Loewenstein et al., 2001) and thus habituation may be more pronounced, leading to faster risk-taking escalation.

Second, is escalation dependent on agency? It has been shown that active choice increases the amount people are willing to wager (Davis et al., 2000; Ladouceur & Mayrand, 1987). Participants bet more on the dice they throw themselves and on the chips they place on a roulette board than when someone else does so for them (Damen, 2019; Dunn & Wilson, 1990). This may reflect an illusion of control, whereby people believe that control can influence random outcomes (Langer, 1975; Langer & Roth, 1975). It has been shown that the pure act of making a choice inflates the subjective value of the chosen option and is intrinsically rewarding (Bobadilla-Suarez et al., 2017; Cockburn et al., 2014; Egan et al., 2010; Egan et al., 2007; Langer, 1975; Leotti & Delgado, 2011; Lieberman et al., 2001; Rao et al., 2008; Samejima et al., 2005; Sharot et al., 2009; Sharot et al., 2010b; Sharot et al., 2010; Studer et al., 2012), and/or because agency reduces stress and anxiety (Fielder et al., 2026; Liu et al., 2021; Meier et al., 2026) which may increase risk-taking (Horswill & McKenna, 1999). Both these mechanisms could impact not only how much people wager but also the temporal trajectory of

risk-taking. Higher perceived gain may boost escalation due to stakes seeming greater, while reduced negative emotions may temper it, as there are fewer emotions to habituate. Thus, perceived agency may either increase risk escalation, reduce it, or not impact it at all.

Understanding the conditions under which risk escalates is important for a complete understanding of human decision-making and for developing policies that can either facilitate risk escalation when risk is adaptive and reduce escalation when it is maladaptive.

To that end, we conducted three studies (total N = 195) where participants made repeated decisions on how much to wager with no outcome feedback. In all studies, agency was manipulated by having participants either select a cue to wager on themselves or have it assigned to them. In one experiment, the stakes were manipulated by varying the potential reward magnitude. Together, these studies allow us to investigate if financial risk escalated with repetition and whether this escalation is impacted by stakes and agency.

Results

To study the effect of repeated choice on financial risk-taking, participants (Experiment 1: N = 74; Experiment 2: N = 66) made 20 consecutive wagers. On each trial, they indicated how much they would like to wager (from 1 to 50 money bills) on one of two cues on a picker wheel. One cue would be the winning cue, and one would be the losing cue. The winning cue was determined randomly, thus the likelihood of winning was 50% regardless of the participant's choice. Participants were told that they would wager money on one of two cues of a picker wheel, after which the wheel would spin, and one winning cue would be chosen.

A win returned double the wagered amount, while a loss forfeited it. In other words, if a participant wagered 10 money bills and won, they would win 20 money bills and receive the 10 money bills they wagered back. If they lost, they lost the 10 bills they wagered. Thus, the expected value of wagers was always positive.

Cues could be two different coloured cards, two different diamonds, two dice, two chips, etc., and on each trial, the cues were completely new. The exact cues were meaningless; they did not carry any information. This was done to minimize any possible associations between cues and choices. No outcome feedback was provided, and the final bonus payment in addition to a fixed endowment (£9/hr), was determined based on one selected trial at the end of the experiment (see Fig. 1a-b). To manipulate a sense of agency, participants selected which cue to wager on half the trials. On the other half, a simulated confederate selected their cue first, leaving the participant to wager on the remaining cue.

In Experiment 3 (N = 55), participants completed an identical task to that described above, except that potential stakes were varied by altering the potential reward magnitude, which took one of five values (1.1X, 1.5X, 2.0X, 2.5X, or 2.9X, with X = the amount wagered). The potential loss was the same as in Experiments 1 and 2. Each reward magnitude appeared four times over the course of the experiment, with the sequence randomised for each participant (see Fig. 1c).

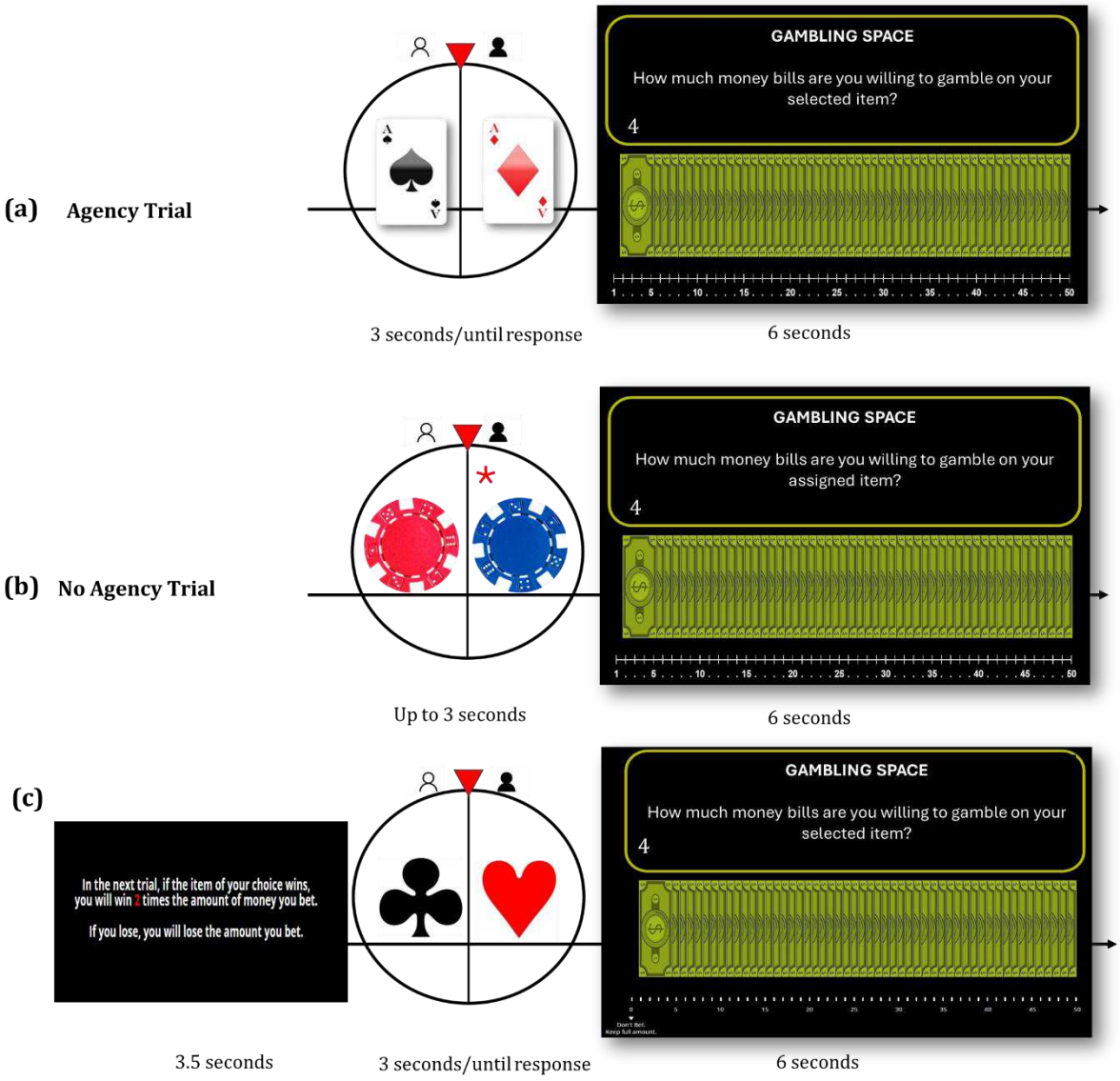


Fig. 1. Task. Participants took turns with a simulated player selecting a cue from a picker wheel to place their wager on. **(a)** In the agency condition, participants selected the cue, **(b)** while in the no-agency condition the cue was assigned to them by the other player whose choice was indicated by an asterisk. The cues were different on each trial and carried no information. In experiments 1 and 2, after selecting (or being assigned) a cue participants decided how much to wager on a scale from 1 to 50 money bills. **(c)** In Experiment 3 the task was the same as above except that the reward magnitude varied across trials and the wagering scale started at 0. Participants were informed of the potential reward multiplier at the start of each trial. On each trial, the amount of time remaining was displayed on screen.

Participants wagered substantially below the risk-neutral optimum

Since the expected value of the gamble was always positive, under risk neutrality, a rational agent should wager the maximum amount on every trial. Despite this, and consistent with the well-documented phenomenon of loss aversion and risk aversion (Kahneman & Tversky, 1979), participants wagered on average less than the optimal strategy of 50 bills.

In Experiment 1, they wagered on average 22.84 bills (SD = 11.55) and in Experiment 2, 29.23 bills (SD = 12.67); see Fig. 2a. In Experiment 3, wagers increased monotonically with reward magnitude, reflecting appropriate sensitivity to expected value. Nevertheless, the gap between

observed and optimal wagering remained large even at the highest multiplier. Specifically, at the lowest reward magnitude (×1.1) participants wagered on average only 12.6 bills (SD = 10.96); at ×1.5: M = 16.43, SD = 10.19; at ×2.0:M = 19.65, SD = 11.06; at ×2.5:M = 22.22, SD = 12.56. Even at the highest reward magnitude (×2.9), where the expected value advantage was most pronounced, participants wagered on average only 26.0 bills (SD = 14.09) - just over half the optimal amount (see Fig. 2b).

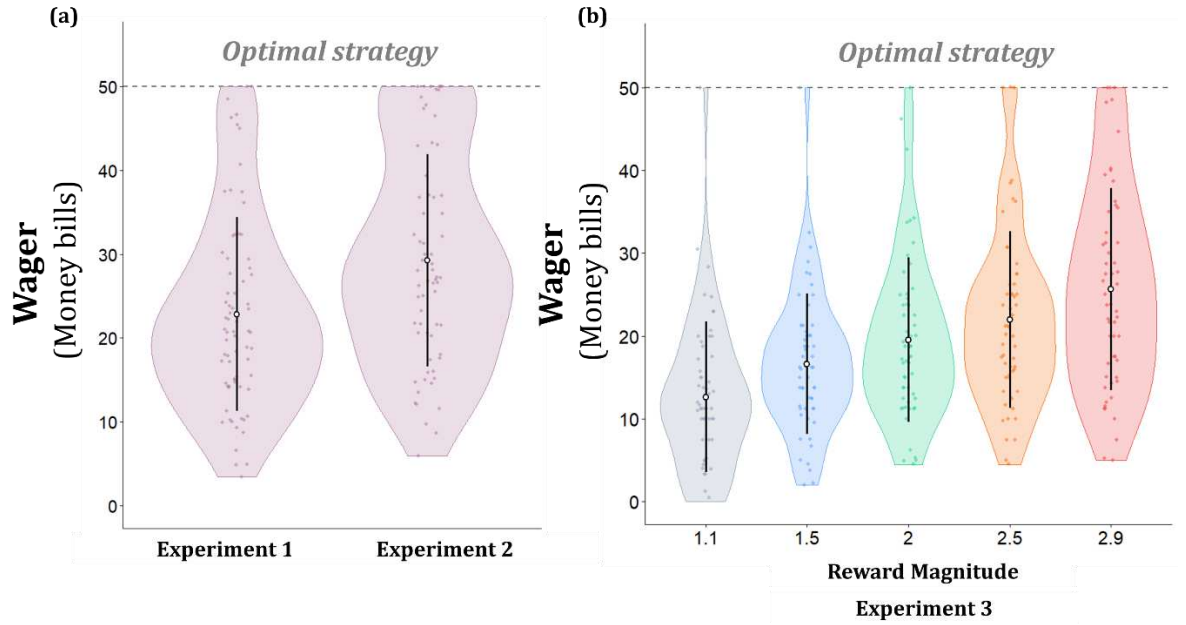


Fig. 2. Participants are risk-averse. The dashed horizontal line at 50 bills represents the strategy of a risk-neutral agent maximising expected value. **(a)** Participants wagered less than the "optimal" amount in both the in-person Experiment (Exp 1: M = 22.84, SD = 11.55) and online replication (Exp 2: M = 29.23, SD = 12.67). **(b)** In Experiment 3, participants wagered significantly below the optimal strategy across all five reward magnitudes, with mean wagers ranging from 12.6 bills at the lowest multiplier (×1.1) to 26.0 bills at the highest (×2.9). Individual dots represent the mean wagering magnitude for each participant; central points and error bars reflect the group mean ± 1 SD.

Risk-taking escalates with repetition

Thus far, the results reveal that in a task where the expected value of a gamble is positive, and a risk-neutral agent should wager the maximum amount, participants wager significantly lower amounts. Next, we investigated whether participants were less likely to do so with repeated opportunities to take risks. To examine the impact of repetition per se on risk-taking, it is crucial to isolate its influence from that of learning. To do so, we ensured participants did not observe the outcomes of their decisions.

To test for the effect of repetition, we conducted a linear mixed model for each experiment predicting wager from trial number. Across all three experiments we found that participants wagered more over time (Experiment 1: b = 0.21, t (72.92) = 4.5, $p < .001$; Experiment 2: b = 0.15, t (65.74) = 3.68, $p < .001$; Experiment 3: b = 0.26, t (52.49) = 5.15, $p < .001$; see Fig. 3a-c). The results show that financial risk-taking escalates with repetition even when there is no opportunity to learn from outcomes.

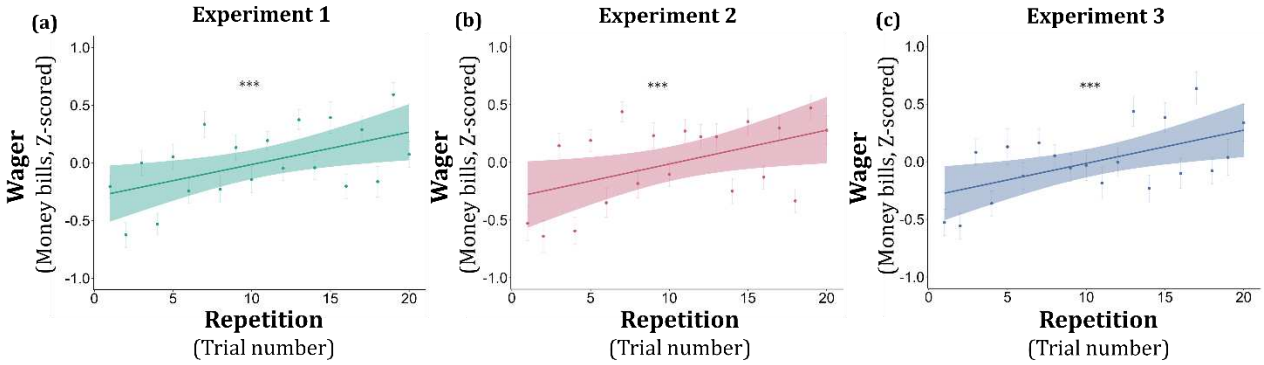


Fig. 3. Risk-taking escalates with repetition in the absence of outcome feedback. A main effect of repetition on risk-taking was observed across all three experiments: **(a)** Experiment 1, **(b)** Experiment 2 (online replication), and **(c)** Experiment 3 (averaged across all reward magnitudes). Bold lines represent linear model predictions collapsed across both agency conditions; shaded areas correspond to 95% confidence intervals. Each dot represents the mean wager across all participants for that trial. Error bars indicate the standard error of the mean. For visual purposes, wagers were standardized within each participant. ***$p < .001$. (Note, that as detailed later and apparent below in Figure 6 the deviations from linearity observed here are due to agency, as participants took turns in selecting the cue to bid on.)

Risk-taking escalation is modulated by potential stakes

Thus far we have found that people take more and more risk over time. Next, we ask whether this escalation is sensitive to potential stakes. To test this, in Experiment 3 we varied the reward magnitude from x1.1 the amount wagered to x2.9 the amount wagered. We varied only the reward multiplier as we wanted to ensure that in all cases the expected value remained positive, such that risk is adaptive - consistent with Experiments 1 & 2. We note, however, that it would be interesting to vary the stakes differently in future studies.

We used five reward magnitudes, each presented four times throughout the study. We then predicted the amount wagered from reward multiplier (1.1, 1.5, 2, 2.5, 2.9), repetition of the reward multiplier (1,2,3,4), and the interaction of the two, using a linear mixed model with random slopes and intercepts by participant.

Critically, a significant interaction emerged between repetition and reward multiplier (b = 1.14, t (53.65) = 3.1, p = .003), indicating that escalation rate was not uniform but dependent on potential stakes. As expected, the model also revealed a significant main effect of reward magnitude (b = 6.87, t (54.34) = 7.86, p < .001). The effect of repetition was also positive and significant (b = 1.21, t (54.24) = 4.79, p < .001).

To decompose the interaction between repetition and stakes, we estimated simple slopes at each reward level using Bonferroni-adjusted Wald t-tests. At the two lowest reward multipliers, no escalation was observed (×1.1: b = 0.18, t (53.5) = 0.46, p = 1.0; ×1.5: b = 0.65, t (53.5) = 2.1, p = 0.2). Escalation only emerged when the potential reward was double the amount invested (b = 1.21, t (53.8) = 4.79, p < .001) and became numerically larger thereafter [×2.5: b = 1.78, t (53.6) = 5.59, p < .001; ×2.9: b = 2.24, t (53.5) = 5.27, p < .001; see Fig. 4). Pairwise comparisons of individual escalation slopes, estimated per participant per multiplier by regressing wager on presentation number, then compared using paired t-tests with Bonferroni correction revealed that the steepest escalation, observed at ×2.9, was significantly greater than one of the lowest multipliers (compared to ×1.5: t(54) = -3.32, p = .016) and marginally significant compared to ×1.1: t(54) = -2.89, p = .056; BF_{01} = 0.16), and did not differ significantly from ×2.0 or ×2.5 . No other pairwise comparisons reached significance after

Bonferroni correction. The selectivity of escalation suggests that stakes matter, with higher potential gain leading to faster escalation.

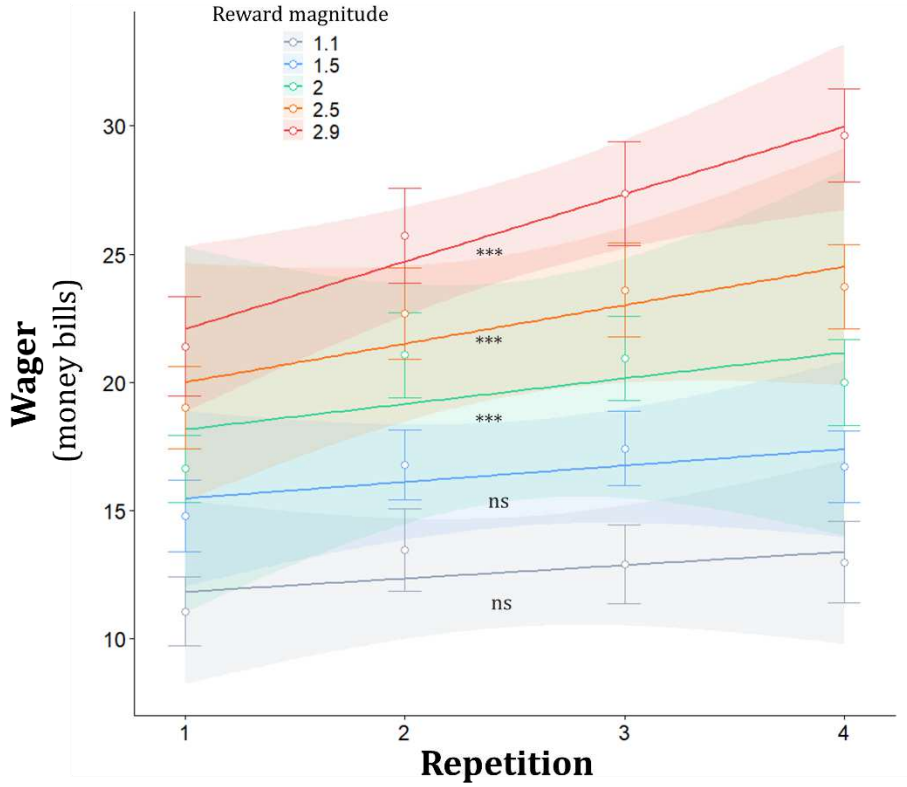


Fig. 4. Risk-taking escalation is sensitive to stakes. The amount wagered increased with repetition when the potential reward was ×2.0 or higher; the amount invested remained stable at lower reward magnitudes (×1.1 and ×1.5). Bold lines represent linear model predictions; shaded areas correspond to 95% confidence intervals. Each dot represents the mean wager across all participants for that presentation. Error bars indicate the standard error of the mean. *** $p < .001$; ns, not significant. The x-axis represents the number of times the participants encountered that reward magnitude. Each reward magnitude was presented 4 times.

A sense of control boosts risk-taking, but not its escalation

Thus far, we have shown that participants wager less than optimal under risk-neutrality and that this suboptimality is reduced with repetition. Moreover, escalation is pronounced when potential rewards are high. Next, we asked whether the amounts wagered were dependent on whether participants were granted agency in the task. To that end, on half the trials participants selected the cue they wagered on and in the other half they were assigned it.

Results revealed that participants wagered more on trials where they selected their own cue than on trials where the cue was randomly assigned to them. This is despite the fact that the probability of winning was identical across both conditions and choice conferred no objective advantage over the outcome.

In Experiment 1, participants wagered on average 24.3 bills (SD = 11.4) on self-chosen cues compared to 21.4 bills (SD = 12.2) on assigned cues (LMM predicting wager from agency with random slopes and intercepts: $b = 2.83$, $t(73.17) = 4.9$, $p < .001$; see Fig. 5a). This effect replicated in Experiment 2, where participants wagered 30.7 bills (SD = 12.8) on self-chosen cues versus 27.7 bills (SD = 13.0) on assigned cues ($b = 3.02$, $t(65.2) = 4.93$, $p < .001$; see Fig. 5b). The agency effect was also evident in Experiment 3 such that participants wagered on

average 20.46 bills (SD = 12.72) on self-chosen cues, compared to 18.34 bills (SD = 12.79) on the assigned cues (LMM predicting wager from agency condition, controlling for reward multiplier, with random slopes and intercepts, b = 2.0, t (55.49) = 4.24, p < .001; see Fig. 5c).

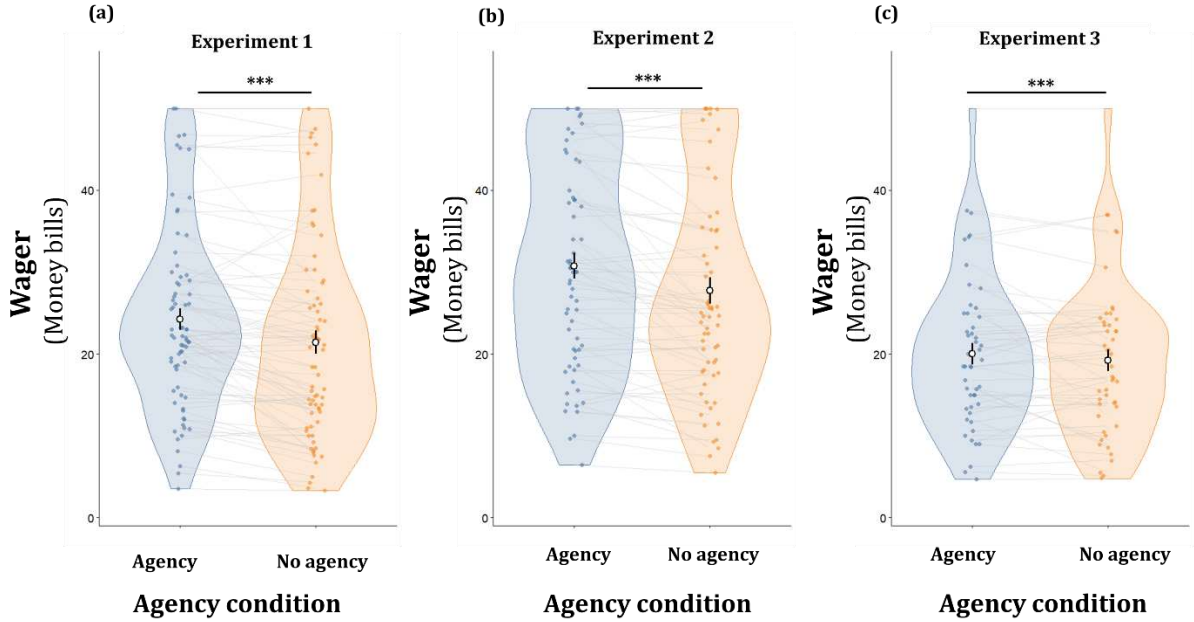


Fig. 5. A sense of control boosts risk-taking. Participants wagered more when they selected which cue to wager on (Agency condition) relative to when the cue was assigned to them (No Agency condition). Results are shown for **(a)** Experiment 1 (In-person), **(b)** Experiment 2 (Online Replication) and **(c)** Experiment 3 (online). Individual dots represent mean wagers for each participant; central points and error bars reflect the group mean ± 1 SD. *** p < .001.

Thus far we find that agency increases risk-taking, we next asked whether it also impacted risk escalation. To test this, we ran three linear mixed models predicting wager from agency, trial, and their interaction with random slopes and intercepts. The analysis did not reveal an interaction effect between the two (Experiment 1: b = −0.01, t (1250.6) = −0.19, p = .849, BF_{01} = 5.96; Experiment 2: b = 0.03, t (1113.25) = 0.58, p = .557, BF_{01} = 4.83; Experiment 3: LMM predicting wager from agency, trial, and their interaction, controlling for reward multiplier with random slopes and intercepts: b = 0.08, t (859.78) = 1.13, p = 0.258; BF_{01} = 1.50; see Fig. 6a–c). Note that when trying to add random effects interaction slopes to the model, it did not converge, removing those meant the model did converge, but inflated degrees of freedom. This would have made an effect more likely to emerge if it was present. The fact that we still see null effects even with inflated degrees of freedom supports the BF indication that these null effects are reliable. The results suggest that agency affects the magnitude of risk-taking but leaves the temporal dynamics through which risk escalates over time unchanged.

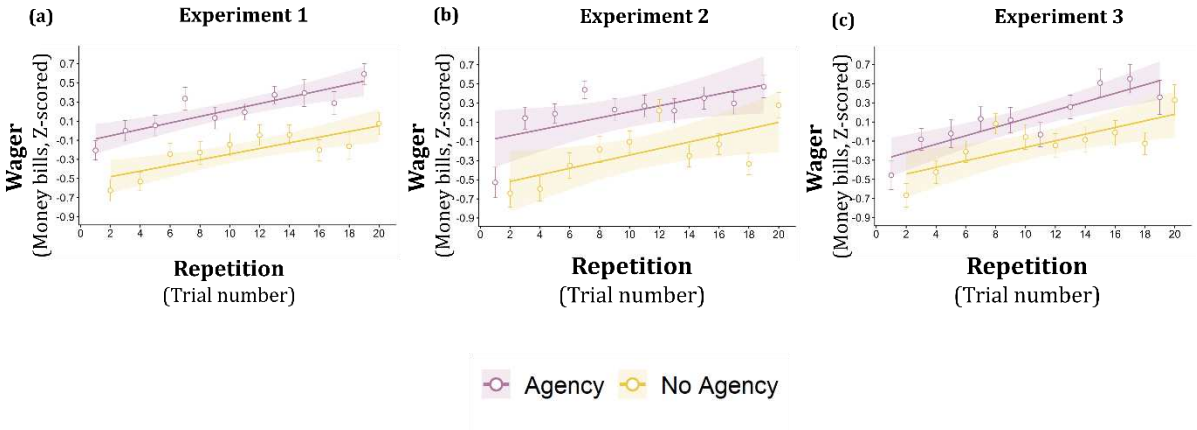


Fig. 6. Risk-taking escalates gradually with repetition independent of agency. Risk-taking, measured as the amount wagered per trial, increased significantly across repetitions in **(a)** Experiment 1 (N =74), **(b)** Experiment 2 (N = 66), and **(c)** Experiment 3 (N = 55) regardless of whether participants chose the cue to wager on (agency condition) or were assigned it (no agency condition) . In all three experiments, agency elevated the overall level of wagering but did not modulate the rate of escalation. Bold lines represent linear model predictions separately for each agency condition; shaded areas correspond to 95% confidence intervals. Each dot represents the mean wager across all participants for that trial. Error bars indicate the standard error of the mean.

Taken together, the three experiments show that risk-taking escalates with repetition even when learning from outcomes is controlled for. While both the amount of reward at stake and agency increase the amount people are willing to risk, only the former impacts the escalation of risk-taking.

Discussion

People often decide how much risk to take with little to no feedback to guide them. The venture capitalist must pick how much money to invest in a company and returns to that commitment again and again before profits or losses become apparent; a teenager decides whether to smoke another cigarette before the impact on their lungs is evident. Much like participants in our task selecting which cue to place their bet on, individuals often decide not only how much to risk, but also what to 'wager' on – which company to invest in, which cigarette to smoke.

Across three experiments, we show that risk-taking escalated as a consequence of mere repetition in the absence of feedback, with escalation becoming steeper as the potential rewards increased. Perceived agency, meanwhile, boosted the baseline from which this escalation began, but did not alter its trajectory. In particular, participants wagered more on chosen cues than assigned ones, even though cue choice could not affect outcomes.

Thus, repetition, stakes, and agency all led to greater risk-taking. In our task, these effects were adaptive because the expected value of the gamble was always positive. Thus, the optimal strategy under risk neutrality was to wager the maximum amount on every trial. Escalation, stakes, and agency all moved participants closer to the rational benchmark. However, whether increased risk-taking due to agency and/or repetition will be adaptive in other contexts depends on the incentive structure of the environment. In contexts where the risky option carries a negative expected value, the same processes could lead to harmful outcomes (Adams et al., 2009; Blaszczynski & Nower, 2002; Fergusson et al., 2003; Florenthal & Shoham, 2000; Millstein & Halpern-Felsher, 2002).

While our task did not include gambles in which the expected value is negative, we did alter the stakes by altering the positive expected outcome. In particular, in Experiment 3 we varied the magnitude of the potential reward from 1.1 times the wagered amount to 2.9 times the wagered amount, while holding the potential loss constant. Critically, we found that the effect of repetition on risk-taking only emerged when the potential reward was at least double the amount wagered. In other words, as risk became more beneficial, escalation was more likely.

The current results provide new insights regarding the factors that impact risky choice. First, we show that repetition *per se* leads to risk escalation. Previous studies that attempted to examine the impact of repetition on financial risk-taking while controlling for learning utilized binary choices that may not have been sensitive enough to capture gradual changes. Consequently, these studies produced mixed results (Brooks & Zank, 2005; Erev et al., 2010; Ert & Erev, 2013). The continuous wagering scale introduced here matters both for detecting subtle dynamics and for ecological validity, as most consequential financial decisions involve choosing how much to commit, not simply whether to commit. Our results may be interpreted in light of previous theoretical suggestions that risk escalation occurs via emotional habituation (Sharot & Sunstein, 2024). Indeed, it has been shown that as people repeatedly engage in simulated physical risk both their anxiety and excitement subside, and the steeper the habituation the faster their risk escalates (Haj-Ali et al., 2025). Alternatively, escalation may reflect a form of task learning. For example, growing familiarity with the task structure may lead participants to realize higher wagers are optimal. Further, while outcomes are not presented participants may mentally simulate them (Kappes & Morewedge, 2016), learning from these simulations (Charness & Chemaya, 2023).

Second, we reveal that risk escalation only emerges when the stakes reach a certain threshold. This may be because higher stakes trigger an emotional response that can gradually dampen with repetition. Third, we show that agency does boost risk-taking but does not alter its trajectory. The finding that agency increases risk-taking is consistent with past studies (Damen, 2019; Dixon, 2000; Dunn & Wilson, 1990). The novel finding is that agency does not impact risk escalation. This could be because agency simultaneously influences mechanisms that would boost escalation and dampen it, which cancel each other out. On the one hand agency may increase the subjective value of the options (Langer, 1975; Langer & Roth, 1975) and we show that higher potential reward is associated with greater escalation. On the other hand, agency reduces baseline anxiety (e.g., Liu et al., 2021) and less anxiety may mean less habituation and thus less escalation. These speculations would be interesting to test in the future. Note that while participants select which cue to wager on, on average their choice had no bearing on outcomes because the likelihood of each cue leading to a win was 50%. Whether the same pattern of results will hold when choice is skill-based remains to be tested.

Our findings have implications for how risk preferences are formally modelled. Classical frameworks characterise risk preferences as stable parameters, a fixed trade-off between potential gains and losses recovered by fitting utility functions to data aggregated across choices(Barberis, 2013; Benartzi & Thaler, 1995; Kahneman & Tversky, 1979; Kahneman & Tversky, 1982; O'Donoghue & Somerville, 2018; Rabin, 2000). The present results suggest that risk preferences can drift systematically with repetition even when the decision environment is held constant. Thus, models should accommodate this temporal evolution of risk preferences.

Together, the results suggest that repetition erodes risk aversion when the potential reward is high enough, while agency amplifies the baseline level from which escalation departs. These findings could inform strategies designed to both increase risk-taking when it is advantageous

and curb it when it is dangerous. For instance, by increasing/reducing the sense of agency over choice, or by encouraging/limiting repeated choice.

Materials and methods

Participants

Participants were recruited from the UCL SONA recruitment system (Experiment 1) and Prolific platform (Experiment 2 & Experiment 3). Experiment 1 was conducted in person at University College London. Experiment 2 (replication) and Experiment 3 were conducted online with Prolific participants. All participants provided written consent before the experiment and were paid £9/hr for their participation. The study was approved by the UCL Psychology Ethics Committee [ID: EP_2023_009]. The sample size was estimated based on pilot data (N=20) with a moderate effect size and a power of 80%, with alpha of 0.05 in linear regression test. Eleven participants in Experiment 3 were excluded from the analysis following failure to respond on more than five trials within the allocated time. No exclusions occurred in Experiment 1 which took place in person, and its online replication (Experiment 2). Final sample: Experiment 1: N = 74 (mean age = 22.6, SD=3.35; 56 women, 18 men); Experiment 2: N = 66 (mean age = 27.7, SD = 4.3; 32 women, 33 men, 1 missing); Experiment 3 : N = 55 (mean age = 27.2, SD=5.88 ; 28 women, 27 men).

Gambling task

Experiments 1-2

Participants completed a simplified roulette task in which they wagered money on one of two cues displayed on a picker wheel. Across 20 trials, participants and a simulated agent alternated in selecting one of two cues to wager on, with participants selecting first. Cues were images of diamonds, roulette chips, etc. The image carried no information as each cue had a 50% chance of being the winning cue. Participants were told that they will wager money on one of two cues of a picker wheel, after which the wheel will spin and one winning cue will be chosen. All cues appeared only once. We verified that the agency effect was not driven by the novelty of initiating the task by rerunning all agency analyses excluding the first trial. Results remained unchanged (see **Supplementary Materials**).

Participants were told they were playing alongside another participant. This participant was in fact a simulated agent that selected cues randomly. The agent's choice was indicated by an asterisk with the unchosen cue assigned to the participant to wager on.

On their turn, participants had up to 3 seconds to select a cue and then 6 seconds to wager a bet between 1 and 50 bills. They kept any amount they chose not to bid. If the wheel landed on their cue, participants won double their wager in addition to receiving what they wagered back; otherwise, they would lose the wager.

One trial was selected at the end of the experiment and determined the final bonus. This design eliminates wealth effects, ensuring that each wager reflected an independent risk preference uncontaminated by prior trial outcomes. Additionally, participants were not told the monetary value of each money bill, only that it would range from $0.01 to $1.0 and change on each trial. (Fig. 1a-b).

Experiment 3

Experiment 3 was identical to Experiments 1 and 2 except:

(i) Potential stakes were varied by manipulating the reward multiplier – that is the potential amount gained per unit wagered - across trials, which took one of five values (x1.1, x1.5, x2.0, x2.5, x2.9). The multiplier was displayed at the start of each trial. The potential loss was held constant. For example, at a multiplier of 1.5, a winning wager of 10 returned 15 in profit *plus* the original wager of 10 (so a total of 25), while a loss forfeited only the amount wagered (e.g., 10). Each reward multiplier appeared four times over the course of the experiment, yielding 20 trials in total. The sequence of reward multipliers was randomised independently for each participant and then repeated across the four cycles, ensuring that all participants encountered the same reward multiplier equally often while controlling for order effects.

(ii) Participants could wager between 0 and 50 money bills, allowing them to opt out of gambling entirely.

Procedure

After providing informed consent, participants completed a demographics questionnaire (age, sex, education level, and income) and read the task instructions (for instructions, see **Supplementary Materials**). They then completed a comprehension test to verify their understanding of the task rules. Following successful completion of the comprehension test, participants were told they were paired with another player and completed 20 trials of the gambling task. In each trial, the amount of time remaining to select was displayed on screen.

Statistical analyses

All analyses were conducted in R using RStudio (Posit Team, 2025). Mixed-effects models were estimated using the *afex* package (Singmann et al., 2018) with the Kenward-Roger method, and *lme4* package in R (REML estimation) using the bobyqa optimizer with an increased maximum number of function evaluations (maxfun = 200,000) to aid convergence. For models with interaction fixed effects, continuous predictors were mean-centered prior to analysis to facilitate interpretation of main effects in the presence of interactions.

For null interaction effects, Bayes Factors (BF_{01}) were computed using Bayesian mixed-effects models estimated via the brms package (Bürkner, 2017) with default priors, run for 10,000 iterations (2,000 warmup) across 4 chains. Marginal likelihoods were estimated using bridge sampling (Gronau et al., 2017) via the bridgesampling package, and BF_{01} was obtained by dividing 1 by the ratio of the marginal likelihood of the full model (including the interaction) to that of the null model (excluding the interaction).

Risk escalation. To test whether wagering increased over trials, we fitted a linear mixed-effects model (LMM) for each experiment predicting wager from trial number as a fixed effect with random intercepts and random slopes for all fixed effects:

$$Wager \sim Trial + (1 + Trial \mid Participant)$$

Effect of reward magnitude on risk escalation. To test how reward magnitude modulated risk escalation in Experiment 3, we fitted an LMM predicting wager from repetition (1 to 4), reward magnitude (1.1, 1.5, 2.0, 2.5, 2.9), and their interaction, with random intercepts and random slopes for presentation number and reward magnitude by participant:

$$Wager \sim Repetition + reward\ magnitude + Repetition * reward\ magnitude + (1 + Repetition + reward\ magnitude + Repetition * reward\ magnitude \mid Participant)$$

To decompose the reward magnitude interaction, simple slopes of presentation number were estimated at each of the five reward magnitude levels and tested against zero using Bonferroni-adjusted Wald *t*-tests (five comparisons). To examine differences in escalation across reward multipliers, we first estimated individual escalation slopes for each participant at each multiplier by regressing wager on presentation number. These participant-specific slopes were then compared across multiplier levels using paired-samples *t*-tests with Bonferroni correction for multiple comparisons.

Effect of agency on wagering. To test whether agency elevated overall wagering, we fitted an LMM predicting wager from agency condition and trial number as fixed effects, with random intercepts and random slopes for both trial number and agency by participant:

Experiments 1 and 2:

$$Wager \sim Agency + (1 + Agency \mid Participant)$$

Experiment 3:

$$Wager \sim Agency + reward\ multiplier + (1 + Agency + reward\ multiplier \mid Participant)$$

To test whether agency modulated the *rate* of escalation, we extended the above models by including the Trial × Agency interaction term:

Experiments 1 and 2:

$$Wager \sim Trial + Agency + Trial * Agency + (1 + Trial + Agency \mid Participant)$$

Experiment 3:

$$Wager \sim Trial + Agency + Trial * Agency + reward\ multiplier + (1 + Trial + Agency + reward\ multiplier \mid Participant)$$

Competing interests

The authors declare no competing interests.

Data Availability Statement

Data is available online via GitHub at: https://github.com/Hadil0520/RiskEscalation.git

Author Contributions

H.H.A was involved in conceptualization, design synthesis, data curation and analysis, data collection, results interpretation, and drafting, editing, and reviewing the manuscript. M.G. was involved in conceptualization, design synthesis, results interpretation, and editing and reviewing the manuscript. B.B was involved in design conceptualization, analyses, and discussions. T.S. was involved in conceptualization, design synthesis, data curation and

analysis, results interpretation, drafting, editing, and reviewing the manuscript, and funding acquisition.

Acknowledgments

H.H.A is funded by the Economic and Social Research Council (Reference No. ES/P000592/1). T.S is funded by a Wellcome Trust Senior Research Fellowship (214268/Z/18/Z) and a Wellcome Trust Discovery Award (554452/Z/25/Z). The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript. We would like to thank India Pinhorn, Denis Lan, Eva Lash, Tal Nahari, Refael Tikochinski, and Amber Düttmann for discussion and manuscript review.

References

Adams, P. J., Raeburn, J., & de Silva, K. (2009). A question of balance: prioritizing public health responses to harm from gambling. *Addiction*, *104*(5), 688–691. https://doi.org/10.1111/j.1360-0443.2008.02414.x

Andrade, E. B., & Iyer, G. (2009). Planned Versus Actual Betting in Sequential Gambles. *Journal of Marketing Research*, *46*(3), 372–383.

Barberis, N. C. (2013). Thirty Years of Prospect Theory in Economics: A Review and Assessment. *Journal of Economic Perspectives*, *27*(1), 173–195. https://doi.org/10.1257/jep.27.1.173

Benartzi, S., & Thaler, R. H. (1995). Myopic Loss Aversion and the Equity Premium Puzzle. *Quarterly Journal of Economics*, *110*(1), 73–92.

Blaszczynski, A., & Nower, L. (2002). A pathways model of problem and pathological gambling. *Addiction*, *97*(5), 487–499.

Bobadilla-Suarez, S., Sunstein, C. R., & Sharot, T. (2017). The intrinsic value of choice: The propensity to under-delegate in the face of potential gains and losses. *Journal of Risk and Uncertainty*, *54*(3), 187–202. https://doi.org/10.1007/s11166-017-9259-x

Brooks, P., & Zank, H. (2005). Loss averse behavior. *Journal of Risk and Uncertainty*, *31*(3), 301–325.

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of statistical software*, *80*, 1–28.

Charness, G., & Chemaya, N. (2023). Repeated experience and consistent risk preferences. *Economics Letters*, *233*. https://doi.org/10.1016/j.econlet.2023.111375

Cockburn, J., Collins, A. G. E., & Frank, M. J. (2014). A Reinforcement Learning Mechanism Responsible for the Valuation of Free Choice. *Neuron*, *83*(3), 551–557. https://doi.org/10.1016/j.neuron.2014.06.035

Coval, J. D., & Shumway, T. (2005). Do behavioral biases affect prices? *Journal of Finance*, *60*(1), 1–34.

Dabney, W., Kurth-Nelson, Z., Uchida, N., Starkweather, C. K., Hassabis, D., Munos, R., & Botvinick, M. (2020). A distributional code for value in dopamine-based reinforcement learning. *Nature*, *577(7792), 671–675. https://doi.org/10.1038/s41586-019-1924-6*

Damen, T. G. (2019). Sense of agency as a predictor of risk-taking. *Acta psychologica*, *197*, 10–15.

Davis, D., Sundahl, I., & Lesbo, M. (2000). Illusory personal control as a determinant of bet size and type in casino craps games. *Journal of Applied Social Psychology*, *30*(6), 1224–1242.

Dixon, M. R. (2000). Manipulating the illusion of control: Variations in gambling as a function of perceived control over chance outcomes. *The Psychological Record*, *50*(4), 705–719.

Dunn, D. S., & Wilson, T. D. (1990). When the stakes are high: A limit to the illusion-of-control effect. *Social cognition*, *8*(3), 305–323.

Egan, L. C., Bloom, P., & Santos, L. R. (2010). Choice-induced preferences in the absence of choice: Evidence from a blind two choice paradigm with young children and capuchin monkeys. *Journal of Experimental Social Psychology*, *46*(1), 204–207. https://doi.org/10.1016/j.jesp.2009.08.014

Egan, L. C., Santos, L. R., & Bloom, P. (2007). The origins of cognitive dissonance - Evidence from children and monkeys. *Psychological science*, *18*(11), 978–983.

Erev, I., Ert, E., Roth, A. E., Haruvy, E., Herzog, S. M., Hau, R., Hertwig, R., Stewart, T., West, R., & Lebiere, C. (2010). A choice prediction competition: Choices from experience and from description. *Journal of Behavioral Decision Making*, *23*(1), 15–47.

Ert, E., & Erev, I. (2013). On the descriptive value of loss aversion in decisions under risk: Six clarifications. *Judgment and Decision Making*, *8*(3), 214–235.

Ert, E., & Haruvy, E. (2017). Revisiting risk aversion: Can risk preferences change with experience? *Economics Letters*, *151*, 91–95. https://doi.org/10.1016/j.econlet.2016.12.008

Fergusson, D., Swain-Campbell, N., & Horwood, J. (2003). Risky driving behaviour in young people: prevalence, personal characteristics and traffic accidents. *Aust N Z J Public Health*, *27*(3), 337–342. https://doi.org/10.1111/j.1467-842x.2003.tb00404.x

Fielder, J. C., Shi, J., McGlade, D., Huys, Q. J., & Steinbeis, N. (2026). Sense of control buffers against stress. *Elife, 14*, RP105025. *https://doi.org/10.7554/eLife.105025*

Florenthal, B., & Shoham, A. (2000). Value differences between risky sports participants and nonparticipants. *Sport Marketing Quarterly*, *9*(1), 26–33.

Gronau, Q. F., Sarafoglou, A., Matzke, D., Ly, A., Boehm, U., Marsman, M., Leslie, D. S., Forster, J. J., Wagenmakers, E.-J., & Steingroever, H. (2017). A tutorial on bridge sampling. *Journal of mathematical psychology*, *81*, 80–97.

Haj-Ali, H., Glickman, M., & Sharot, T. (2025). Escalating risk-taking is linked to emotional habituation. *Communications Psychology*, *3*(1). https://doi.org/10.1038/s44271-025-00319-1

Horswill, M. S., & McKenna, F. P. (1999). The effect of perceived control on risk taking 1. *Journal of Applied Social Psychology*, *29*(2), 377–391.

Imas, A. (2016). The realization effect: Risk-taking after realized versus paper losses. *American Economic Review*, *106*(8), 2086–2109.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 47*(2), 263–292.

Kahneman, D., & Tversky, A. (1982). The Psychology of Preferences. *Scientific american*, *246*(1), 160-173.

Kappes, H. B., & Morewedge, C. K. (2016). Mental Simulation as Substitute for Experience. *Social and Personality Psychology Compass*, *10*(7), 405–420. https://doi.org/10.1111/spc3.12257

Knutson, B., Taylor, J., Kaufman, M., Peterson, R., & Glover, G. (2005). Distributed neural representation of expected value. *Journal of Neuroscience*, *25*(19), 4806–4812. https://doi.org/10.1523/Jneurosci.0642-05.2005

Ladouceur, R., & Mayrand, M. (1987). The Level of Involvement and the Timing of Betting in Roulette. *Journal of Psychology*, *121*(2), 169–176.

Langer, E. J. (1975). The illusion of control. *Journal of personality and social psychology*, *32*(2), 311.

Langer, E. J., & Roth, J. (1975). Heads I win, tails it's chance: The illusion of control as a function of the sequence of outcomes in a purely chance task. *Journal of personality and social psychology*, *32*(6), 951.

Langer, T., & Weber, M. (2008). Does commitment or feedback influence myopic loss aversion? An experimental analysis. *Journal of Economic Behavior & Organization*, *67*(3-4), 810–819. https://doi.org/10.1016/j.jebo.2006.05.019

Leotti, L. A., & Delgado, M. R. (2011). The inherent reward of choice. *Psychological science*, *22*(10), 1310–1318.

Lieberman, M. D., Ochsner, K. N., Gilbert, D. T., & Schacter, D. L. (2001). Do amnesics exhibit cognitive dissonance reduction? The role of explicit memory and attention in attitude change. *Psychological science*, *12*(2), 135–140.

Liu, Q., Wu, J., Zhang, L., Sun, X., Guan, Q., & Yao, Z. (2021). The relationship between perceived control and hypothalamic–pituitary–adrenal axis reactivity to the trier social stress test in healthy young adults. *Frontiers in Psychology*, *12*, 683914.

Liu, Y. J., Tsai, C. L., Wang, M. C., & Zhu, N. (2010). Prior Consequences and Subsequent Risk Taking: New Field Evidence from the Taiwan Futures Exchange. *Management science*, *56*(4), 606–620. https://doi.org/10.1287/mnsc.1090.1131

Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin*, *127*(2), 267–286. https://doi.org/10.1037//0033-2909.127.2.267

Meier, J., Kollmann, B., Meine, L. E., Meyer, B., Yuen, K., Stork, M., Tüscher, O., & Wessa, M. (2026). Perceived control as a resilience factor: associations with neural, physiological and affective stress responses and mental health. *Translational Psychiatry*, *16*(1), 39. https://doi.org/10.1038/s41398-025-03786-6

Millstein, S. G., & Halpern-Felsher, B. L. (2002). Judgments about risk and perceived invulnerability in adolescents and young adults. *Journal of Research on Adolescence*, *12*(4), 399–422.

O'Donoghue, T., & Somerville, J. (2018). Modeling Risk Aversion in Economics. *Journal of Economic Perspectives*, *32*(2), 91–114. https://doi.org/10.1257/jep.32.2.91

Posit Team. *RStudio: Integrated Development Environment for R* (Posit Software, PBC, 2025).

Post, T., Van den Assem, M. J., Baltussen, G., & Thaler, R. H. (2008). Deal or no deal? decision making under risk in a large-payoff game show. *American Economic Review*, *98*(1), 38–71.

Rabin, M. (2000). Risk aversion and expected-utility theory: A calibration theorem. *Econometrica*, *68*(5), 1281–1292.

Rao, H., Korczykowski, M., Pluta, J., Hoang, A., & Detre, J. A. (2008). Neural correlates of voluntary and involuntary risk taking in the human brain: An fMRI Study of the Balloon Analog Risk Task (BART). *Neuroimage*, *42*(2), 902–910. https://doi.org/10.1016/j.neuroimage.2008.05.046

Samejima, K., Ueda, Y., Doya, K., & Kimura, M. (2005). Representation of action-specific reward values in the striatum. *Science*, *310*(5752), 1337–1340. https://doi.org/10.1126/science.1115270

Sharot, T., De Martino, B., & Dolan, R. J. (2009). How choice reveals and shapes expected hedonic outcome. *Journal of Neuroscience*, *29*(12), 3760–3765.

Sharot, T., Shiner, T., & Dolan, R. J. (2010b). Experience and Choice Shape Expected Aversive Outcomes. *Journal of Neuroscience*, *30*(27), 9209–9215. https://doi.org/10.1523/Jneurosci.4770-09.2010

Sharot, T. & Sunstein, C. R. *Look Again: The Power of Noticing What was Always There* (Little, Brown Book Group, 2024).

Sharot, T., Velasquez, C. M., & Dolan, R. J. (2010). Do decisions shape preference? Evidence from blind choice. *Psychological science*, *21*(9), 1231–1235.

Shiv, B., Loewenstein, G., Bechara, A., Damasio, H., & Damasio, A. R. (2005). Investment behavior and the negative side of emotion. *Psychological science*, *16*(6), 435–439.

Singmann, H., Bolker, B., Westfall, J., Aust, F., & Ben-Shachar, M. (2018). afex: Analysis of Factorial Experiments.[R package].

Studer, B., Apergis-Schoute, A. M., Robbins, T. W., & Clark, L. (2012). What are the Odds? The Neural Correlates of Active Choice during Gambling. *Front Neurosci*, *6*, 46. https://doi.org/10.3389/fnins.2012.00046

Thaler, R. H., & Johnson, E. J. (1990). Gambling with the house money and trying to break even: The effects of prior outcomes on risky choice. *Management science*, *36*(6), 643–660.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SOP.docx