



OPEN Brief mindfulness meditation increases risk-taking behavior

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Brief mindfulness-based meditation exerts a potent influence on social cognition. What is not yet understood, however, is whether and how it impacts an important facet of daily life—risk taking. Specifically, it is unclear the extent to which a single episode of mindfulness meditation shapes risk-taking behavior. Addressing this issue, here we examined the effects of mindfulness meditation on risk taking using two established experimental paradigms (i.e., Expt. 1: Balloon Analogue Risk Task; Expt. 2: Bomb Risk Elicitation Task), participants from different cultural milieus (i.e., Expt. 1: UK; Expt. 2: Singapore), and varied testing environments (i.e., Expt. 1: on-line; Expt. 2: in-person). A consistent pattern of results emerged across the experiments. Compared to both active and passive control conditions, brief mindfulness-based meditation increased risk-taking behavior. Of theoretical significance, additional computational analyses traced the origin of this effect to a reduction in loss aversion during decisional processing. The implications of these findings are considered.

Keywords Computational modeling, Decision-making, Loss aversion, Mindfulness, Risk taking

Mindfulness—the momentary observation and awareness of mental experiences without judgment or evaluation^{1–3}—not only improves mental health and well-being (e.g., depression, anxiety, stress management⁴, it also impacts core aspects of social cognition. Among novice practitioners, even brief (5–10 min) periods of mindfulness-based meditation are sufficient to generate a raft of benefits, including (but not limited to) enhanced mentalizing, diminished egocentrism, improved emotional understanding, and reduced self-prioritization^{5–11}. Crucially, however, despite repeated demonstrations of such effects, uncertainties remain. These primarily center on how exactly mindfulness shapes information processing and response generation, issues of longstanding theoretical interest^{12–17}. Put simply, with respect to the specific psychological process under investigation (e.g., mindreading, person construal, learning), what is the mechanism (or mechanisms) through which brief meditative experiences influence performance? In the context of risk-taking behavior, here we examined this matter.

Playing a fundamental role in various clinical disorders (e.g., attention-deficit/hyperactivity disorder, borderline personality disorder, addictive disorders) and comprising a common feature of everyday life (e.g., overtaking, investing, sexting), risk taking is an important arena for exploring the effects of mindfulness meditation. Supporting this observation, an extensive literature has suggested that mindfulness tempers people's tendency to engage in a range of risky activities, such as smoking, alcohol consumption, drug use, and dangerous driving^{18–24}. Broadly speaking, mindfulness is believed to reduce impulsivity and risk taking through a combination of heightened self-awareness and enhanced emotional regulation^{25–27}.

Notwithstanding the reported benefits of the practice, several issues merit consideration when reflecting on the effects of mindfulness meditation on risk taking. First, establishing a causal relationship between mindfulness and risk taking is problematic as, for the most part, correlational findings have been the norm². Second, rather than measuring actual risky behavior (e.g., sky diving, binge drinking, unprotected sex), risk taking has predominantly been probed only indirectly using self-report measures (e.g., questionnaires) that tap attitudes toward hypothetical risk-related choices or general risk-taking propensities^{28–30}. Third, research efforts have focused almost exclusively on the effects of extended (i.e., weeks or months) mindfulness interventions/training, thus overlooking the influence that brief mindfulness practices may exert on risk taking. Finally, no attempts have been made to identify the cognitive pathway(s) through which mindfulness meditation moderates risk-taking behavior. In other words, although the topic has attracted widespread scholarly interest and yielded noteworthy findings, critical matters persist.

Responding to these gaps in the knowledge base, the current investigation employed an experimental approach in conjunction with computational modeling to establish whether and how brief mindfulness-based meditation

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modulates risk-taking behavior. Handily, a range of tasks have been developed to explore risk taking in the laboratory, including the Balloon Analogue Risk Task (BART), the Iowa Gambling Task (IGT), the Columbia Card Task (CCT), and the Bomb Risk Elicitation Task (BRET)^{31–34}. In each case, these paradigms probe risk taking in uncertain environments, capturing how individuals juggle potential gains and losses through dynamic changes in their sensitivity to feedback and reward. Take, for example, the popular BART³⁴. During this task, participants are presented with balloons which must be inflated by means of a button press. With each successive press (i.e., pump) the balloon increases in size and a small monetary reward is received. If, however, the balloon is overinflated, it bursts and all the money accrued on the trial is lost (i.e., each pump of the balloon increases the risk of it popping). Critically, at any point in the trial, participants can choose to cash out (i.e., stop inflating the balloon) and collect their earnings. As such, risk taking in this paradigm is indexed by the average number of pumps undertaken on unexploded balloons (i.e., more pumps = greater risk taking). In this decision-making environment, performance is optimized when a balance is struck between risk taking and risk avoidance.

To date, work exploring the effects of brief mindfulness-based meditation on risk-taking behavior has been scant and generated only suggestive results. Although failing to demonstrate a direct effect of a transitory meditative experience on risk-taking behavior, mindfulness has been shown to be positively correlated with performance on the BART (i.e., increased mindfulness was associated with greater risk taking³⁵). At first glance, the idea that mindfulness promotes risk taking may appear counterintuitive. Neuroimaging research offers a different perspective, however. At least for experienced meditators, mindfulness practices dampen activity in subcortical (i.e., striatum) and pre-frontal areas involved in reward-related processing and valuation^{36–38}. In essence, mindfulness appears to diminish the salience/impact of reward-related prediction errors, a finding with direct implications for decision-making under conditions of uncertainty, such as during the BART³⁴. For instance, if brief mindfulness meditation reduces sensitivity to anticipated gains and losses—particularly losses (i.e., exploding balloons)—this could lead to increased risk-taking behavior³⁹.

In our first experiment, utilizing the BART^{34,35}, a straightforward question was addressed. Does risk-taking behavior increase or decrease following a brief period of mindfulness-based (vs. control) meditation^{7–9,40}? Moving beyond an analytical approach focused only on the number of balloon pumps/bursts during the task³⁵, here we also employed computational modeling to explicate how mindfulness meditation influences the cognitive subprocesses underpinning decision-making^{41–44}. Based on recent developments, the Experimental-Weight Mean-Variance (EWMV) model was adopted^{44,45}. Outperforming other computational approaches, the EWMV model is useful as it captures the key parameters underlying decision-making during the BART: namely, risk preference, sensitivity to losses (i.e., loss aversion), prior beliefs about the probability of bursts, rate of belief updating (i.e., learning), and decisional consistency^{45,46}. In so doing, it has the capacity to provide a formal account of the mechanism(s) through which mindfulness meditation influences decisional processing^{8,17,40,47,48}, thereby advancing theoretical understanding of risk taking under conditions of uncertainty.

Experiment 1: bursting balloons

Methods

Participants and design

Three hundred participants (201 female, $M_{age} = 24.21$, $SD_{age} = 7.61$; 100% UK nationals), with normal or corrected-to-normal visual acuity, took part in the research. Data collection was conducted online using Prolific Academic (www.prolific.co), with each participant compensated at the rate of £10 (~\$13) per hour. A total of 23 participants (6 female) were excluded from the study for failing to follow the instructions. Informed consent was obtained from participants prior to the commencement of the experiment, and the protocol was reviewed and approved by the Ethics Committee at the School of Psychology, University of Aberdeen, Scotland, UK. The experiment was conducted in accordance with the principles outlined in the Declaration of Helsinki. The experiment had single factor (Condition: mindfulness or control or puzzle) between-participants design. To detect a significant effect with a medium effect size ($d = 0.5$), a sample of 270 participants afforded 92% power (PANGEA, $v = 0.0.2$).

Stimulus materials and procedure

The experiment was conducted online using Inquisit software, with participants recruited from within the UK. Having accessed the experiment via a weblink, participants were randomly assigned to one of the treatment conditions. In the mindfulness condition, participants listened to a 5-minute audio recording until a bell chimed to signal the end of the activity⁹. During this exercise, participants were instructed to focus attention on the sensation of their breathing. If, however, distractions arose they were told to perceive the episodes as fleeting experiences and to return attention to the sensation of their breathing. This mindfulness induction has previously been shown to exert a reliable effect on a range of social-cognitive processes^{7–9,40}. Participants in the control condition heard audio instructions that were identical in length and style. Contrasting the mindfulness treatment, however, they were instructed to attend to each thought, emotion, or memory that occurred and to be totally immersed in the experience⁴⁹. Finally, participants in the baseline (i.e., no guided thinking) condition performed a 5-minute Chinese puzzle (i.e., Tangram) in which they had to construct shapes using polygons^{8,40}.

Next, participants completed the computer-based BART³⁴, with the goal of accruing as much money as possible. During the task, participants were presented with 30 individual balloons which they had to inflate. On each trial, every time the 'spacebar' (i.e., pump) was pressed, the balloon increased slightly in size and an accumulating monetary reward (i.e., £0.05) was earned. Across the task, balloons exploded after a random number of inflations, ranging from 1 to 128 pumps. When this happened, all earnings associated with the trial were lost. At any point in the trial, however, pressing the 'escape' key (i.e., collect) enabled participants to cash out and collect their earnings. For each balloon, the first pump had a 1/128 probability of bursting and a potential gain of £0.05. The second pump had a 1/127 probability of exploding and a potential gain of £0.10,

and so on until the 128th pump which had a 1/1 probability of bursting and a potential gain of 0. Based on this algorithm, the average bursting point was 64 pumps. Participants were provided with no information about the maximum number of possible pumps for each balloon or the likelihood of explosions (i.e., the explosion point varied across the balloons). Instead, they were informed it was up to them how much they inflated each balloon. On completion of the task, participants were thanked and debriefed.

Results and discussion

After exclusions, there were ninety-four participants in the mindfulness condition (75 female; $M_{age} = 22.67$, $SD_{age} = 10.03$), ninety-two in the control condition (72 female; $M_{age} = 23.18$, $SD_{age} = 8.00$), and ninety-four in the puzzle condition (53 female; $M_{age} = 26.21$, $SD_{age} = 3.39$). To investigate risk taking during the BART, adjusted pumps (i.e., average number of successful pumps excluding balloons that exploded) were analyzed using a linear mixed model (LMM) with Condition (mindfulness acting as reference), Trial (mean-centered), Previous Outcome (t-1: popped vs. collect), and Gender as fixed effects. Participants were included as a random effect with a random slope for Trial. Trial (mean-centered) was included to capture learning-related drift across the task and was allowed to vary by participant to accommodate individual differences in learning. Previous Outcome (t-1: popped vs. collect) was entered to capture the well-documented post-explosion adjustment that occurs (i.e., fewer pumps immediately after a burst), thereby reducing residual autocorrelation. Gender was included as a fixed covariate to control for potential demographic differences in baseline pump counts (with few category levels, a fixed-effect treatment improves precision). REML was used to fit the model, with Satterthwaite-adjusted degrees-of-freedom (optimizer = *bobyqa*).

The analysis revealed that, compared to mindfulness-based meditation, pump counts were lower in both the control ($b = -5.70$, $SE = 2.36$, $t = -2.41$, $p = .017$) and puzzle ($b = -8.07$, $SE = 2.38$, $t = -3.40$, $p < .001$) conditions. As indicated by the estimated marginal means, pumps in the mindfulness ($M = 31.5$, $SE = 3.99$, 95% CI [23.7, 39.3]) condition exceeded both the control ($M = 25.8$, $SE = 3.84$, 95% CI [18.3, 33.3]) and puzzle ($M = 23.4$, $SE = 3.80$, 95% CI [16.0, 30.9]) conditions (see Fig. 1). An additional comparison between the control and puzzle conditions revealed no reliable difference in adjusted pump counts ($b = 2.38$, $SE = 2.42$, $t = 0.98$, $p = .589$), indicating equivalent levels of risk-taking behavior. Across the duration of the task, pump counts increased with Trial ($b = 0.24$, $SE = 0.08$, $t = 3.05$, $p = .003$), indicating gradual learning. Choices were strongly sensitive to the outcome of the previous trial, with fewer pumps following an explosion ($b = -4.77$, $SE = 0.38$, $t = -12.42$, $p < .001$). Neither the Condition X Trial interaction ($|t| \leq 0.92$, $ps \geq 0.36$) nor the Gender covariate were significant ($|t| \leq 1.56$, $ps \geq 0.12$).

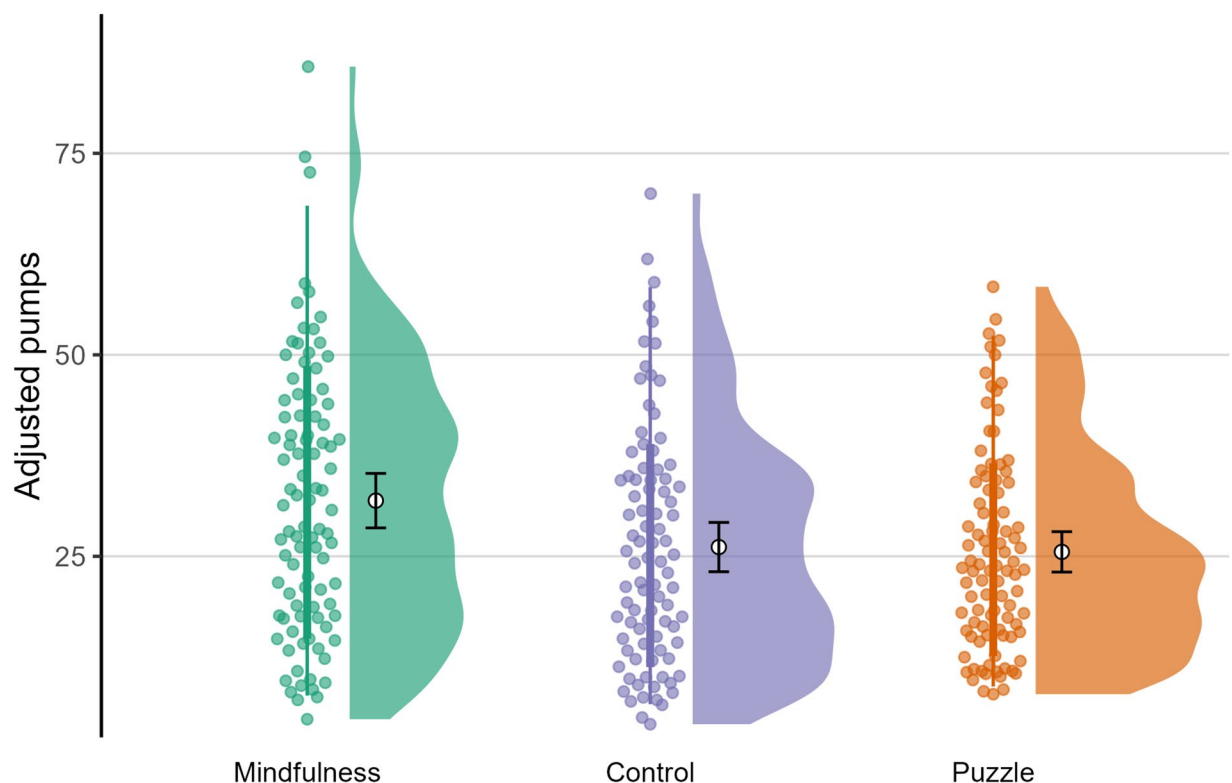


Fig. 1. Adjusted pumps as a function of Condition. Each raincloud depicts the distribution (half-violin), individual participants (dots), and the mean with 95% CI (white dot + black error bar).

Computational modeling

To complement the behavioral analyses, trial-by-trial choices during the BART were modeled using the EWMV model implemented in hBayesDM⁵⁰. The EWMV model integrates an exponentially weighted belief about the probability of a balloon burst on the next pump, with a mean-variance utility function that balances expected value against outcome variance. This approach yields psychologically meaningful parameters that directly relate to risk-taking behavior^{45,50}. At each decision point, whether to pump or cash out, the model calculates a utility difference: $\Delta u = u_{\text{pump}} - u_{\text{stop}}$. This difference is converted into a choice probability using a logistic function: $\text{Pr}(\text{pump}) = \text{logit}^{-1}(\tau \Delta u)$. Here, u_{pump} captures the mean-variance trade-off based on the decision maker's current belief about the probability of a burst. It penalizes variance according to risk preference and increases the disutility of explosions through loss aversion: $u_{\text{stop}} = 0$. Beliefs about burst probability start with a prior and are updated with experience using exponential weighting, such that more recent and frequent outcomes carry greater influence. In this way, the model reveals how decision-makers learn about risk over time⁴⁵.

The hBayesDM implementation hierarchically estimates 5 individual-level parameters: φ (i.e., initial belief about burst probability), η (i.e., learning rate – how quickly beliefs update), ρ (i.e., risk preference – how much variance is penalized; higher values = greater risk aversion), λ (i.e., loss aversion – relative weight of explosion losses vs. pump gains), and τ (i.e., inverse temperature – decisional consistency). In general, higher values of ρ and λ lead to fewer pumps and bursts (i.e., more conservative behavior), whereas lower λ and/or negative ρ are associated with riskier behavior and higher burst rates. A higher φ suggests more pessimistic expectations early in the task, while a higher η indicates faster learning from feedback. A larger τ signals more consistent, deterministic choices given the computed utilities. Collectively, these parameters provide a process-level account of any condition differences in adjusted pumps⁴⁵.

The hierarchical model was fitted using the Hamiltonian Monte Carlo (Stan backend) as implemented in hBayesDM. In total four chains were run, with 4,000 samples and 2,000 warmup (500 for each chain). The convergence diagnostics were standard across all parameters and conditions (i.e., all $\hat{R} \leq 1.01$). Posterior contrasts between conditions were evaluated using 95% highest density intervals (HDIs), the posterior probability of direction [$P(\Delta > 0)$], and the percentage of posterior mass within a region of practical equivalence (ROPE) around zero (± 0.05 for $\phi, \rho, \lambda, \tau$; ± 0.02 for η). Together, these indices convey both the credibility and practical significance of condition differences. The HDI represents the most credible range of parameter differences, while $P(\Delta > 0)$ quantifies the consistency of the posterior's sign (e.g., the probability that Δ is positive). The ROPE indicates how much of the posterior lies near zero. Thus, when the HDI excludes zero and only a small portion of the posterior falls within the ROPE, the difference can be interpreted as credibly and practically meaningful. Conversely, when most of the posterior mass lies within the ROPE, the parameters can be considered practically equivalent across conditions, even if the mean difference deviates slightly from zero.

Exploring these parameters, the mindfulness condition showed a clear and consistent reduction in loss aversion (λ) compared to both the control and puzzle conditions (see Fig. 2). The posterior differences were credibly negative in both contrasts (95% HDIs [$-1.07, -0.16$], [$-1.83, -0.78$]), with $P(\Delta > 0) = 0.003$ and 0.000 and less than 1% of the posterior mass within the ROPE. This pattern indicates a reliable and meaningful attenuation of explosion-related loss sensitivity following mindfulness meditation. In contrast, risk preference (ρ) did not differ among the conditions (95% HDIs [$-0.0033, 0.0007$], [$-0.0018, 0.0018$]), with $P(\Delta > 0) = 0.10$ and 0.56 and 100% of the posterior mass inside the ROPE, demonstrating practical equivalence. Initial burst belief (ϕ) and learning rate (η) also showed negligible differences across all contrasts (ϕ : 95% HDIs [$-0.0021, 0.0123$], [$0.0008, 0.0146$]; $P(\Delta > 0) = 0.93$ and 0.98; ROPE = 100%; η : 95% HDIs [$-0.0129, 0.0053$], [$0.0001, 0.0129$]; $P(\Delta > 0) = 0.23$ and 0.99; ROPE = 99.9%), suggesting similar prior expectations and learning dynamics across the conditions. Finally, decisional consistency/inverse temperature (τ) was highly uncertain in the mindfulness-control contrast (95% HDI [$-0.68, 0.72$]; $P(\Delta > 0) = 0.53$; ROPE = 10.9%) but credibly lower in the mindfulness-puzzle contrast (95% HDI [$-1.49, -0.09$]; $P(\Delta > 0) = 0.02$; ROPE = 1.0%), reflecting more variable choice behavior in the mindfulness (vs. puzzle) condition.

A direct comparison between the control and puzzle conditions revealed a limited set of parameter differences. Loss aversion (λ) was credibly lower in the control relative to the puzzle condition (95% HDI [$-1.29, -0.09$]; $P(\Delta > 0) = 0.016$; ROPE = 1.4%), indicating modestly reduced sensitivity to explosion-related losses following unguided thought compared to the structured puzzle task. Inverse temperature (τ) was also credibly lower in the control than puzzle condition (95% HDI [$-1.56, -0.00$]; $P(\Delta > 0) = 0.027$; ROPE = 1.5%), reflecting less consistent (i.e., noisier) choice behavior in the control condition. Risk preference (ρ), prior burst belief (ϕ), and learning rate (η) did not credibly differ between the control and puzzle conditions (all 95% HDIs spanning zero, $P(\Delta > 0) \geq 0.77$, and $\geq 99\%$ of the posterior mass within the ROPE), indicating practical equivalence in risk sensitivity, prior expectations about burst probability, and belief updating dynamics across the two conditions.

The results of Experiment 1 demonstrated that, compared to both the control and puzzle conditions, mindfulness-based meditation increased risk-taking behavior via the valuation component of decision-making³⁵. Specifically, a single meditative episode in the laboratory was sufficient to reduce loss aversion during the BART. Parameters governing risk sensitivity, belief updating, and learning rate were not impacted by prior meditation. Although levels of risk-taking were equivalent in the control and puzzle conditions, parameter differences were observed in loss aversion and behavioral consistency. Notably, loss aversion and choice behavior were lower in the former than latter condition. These findings indicate that mindfulness reduced the emotional weighting of potential losses without broadly altering the estimation of task-related risk or feedback sensitivity.

While the current findings are informative, it should be acknowledged that the BART is not without limitation⁵¹. Perhaps most notably, as decisions are made under conditions of uncertainty (i.e., burst probabilities/number of bursts are unknown), the task may not adequately capture people's general risk-taking propensities. For example, individuals who experience an early balloon burst may adjust their decision-making approach quite differently

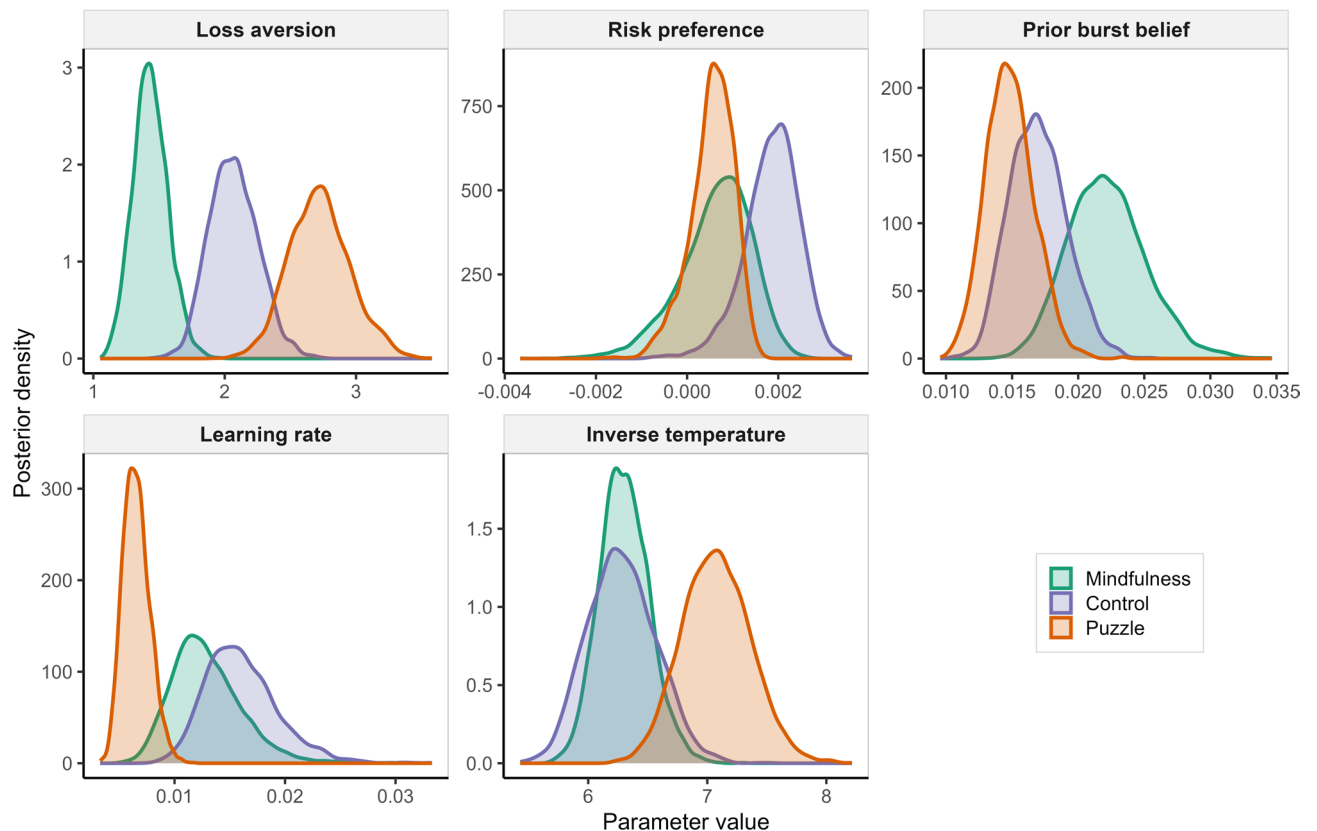


Fig. 2. Posterior parameter distributions from the Exponential-Weight Mean-Variance (EWMV) model across conditions.

from those who encounter an extended sequence of successful pumps prior to a pop⁵². In this way, at least during early trials, the BART may encourage participants to generate idiosyncratic decisional strategies to deal with the task-related uncertainty^{53,54}. Whether, therefore, the results observed in Experiment 1 extend to less ambiguous task settings remain to be seen.

Given the previous observations, in our next experiment we revisited the topic of interest (i.e., mindfulness and risk taking) in a conceptual replication that incorporated several methodological refinements. First, a different risk-taking paradigm was employed—the Bomb Risk Elicitation Task (BRET)³². During the BRET, participants are instructed to select, over a series of trials, individual boxes from a larger set (e.g., 100 boxes) with the objective of collecting as many boxes (hence money) as possible. Each box carries a small monetary award (e.g., \$0.05), and earnings increase linearly as additional boxes are collected. Crucially, however, a single box in the set contains a time bomb which, if selected, explodes and reduces earnings on the trial to zero. Thus, unlike the BART³⁴, risk parameters are transparent from the outset of each trial (i.e., 1 out of 100 boxes contains a bomb), thereby separating risk taking from decisional uncertainty.

Second, to establish the generalizability of the effects observed thus far, Experiment 2 was conducted in a different cultural milieu (i.e., Singapore) and testing environment (i.e., in-person). Grounded in diverse patterns of self-construal (i.e., individualistic vs. collectivistic), cultural forces are acknowledged to exert a significant influence on core aspects of cognition⁵⁵. Whether these cultural differences extend to risk-taking behavior, however, remains uncertain. Although research has demonstrated a positive relationship between individualism and corporate risk taking^{56,57}, little attention has been directed to performance in laboratory tasks that probe sensitivity to risk over multiple trials⁵⁸. Accordingly, in Experiment 2, participants were recruited in the (more) collectivistic culture of Singapore to explore this matter. Of interest was whether, like their counterparts in the UK, Singaporeans would similarly exhibit increased risk taking following a single episode of mindfulness meditation.

Third, to confirm the effectiveness of the experimental manipulation, participants completed the state version of the Mindful Attention Awareness Scale (MAAS-State)². As previously, data were submitted to a computational analysis.

Experiment 2: exploding bombs

Method

Participants and design

Three hundred participants (177 female; $M_{age} = 30.04$, $SD_{age} = 12.43$; 58% Chinese, 20% Indian, 9% Malay, 13% other nationalities) with normal or corrected-to-normal visual acuity, were recruited in Singapore via

convenience sampling. A total of 24 participants (13 female) were excluded from the study for failing to follow the instructions. The protocol was reviewed and approved by the Ethics Committee at James Cook University, Singapore, and the experiment was conducted in accordance with the principles outlined in the Declaration of Helsinki. The experiment had single factor (Condition: mindfulness or control or puzzle) between-participants design. The sample size calculation was as in Experiment 1.

Stimulus materials and procedure

Participants arrived at the laboratory individually and were greeted by an experimenter. After being seated at a desktop computer, participants completed an online informed consent form and were randomly assigned to one of the 3 treatment conditions used in Experiment 1 (i.e., mindfulness or control or puzzle). Next, participants completed the state version of the Mindful Attention Awareness Scale (MAAS-State) online. This comprised 5 questions, answered on a 6-point rating scale (1 = not at all to 6 = very much), probing levels of state mindfulness². Finally, using Inquisit software, participants completed the online version of the BRET³², with the goal of accruing as much money as possible. During the task, participants were presented with a grid of boxes (100 boxes, arranged 10 × 10), and told one box contained a bomb, and all the other boxes were worth \$0.10 each. The task was to collect as many boxes as possible to maximize their earnings. If, however, they collected the box containing the bomb, all money accumulated on the trial would be lost. At any point in the trial, pressing the 'escape' key (i.e., "X" on the keyboard) enabled participants to cash out and collect their earnings. In total, participants completed 10 trials. On completion of the task, participants were debriefed, thanked, and dismissed.

Results and discussion

After exclusions, there were ninety-three participants in the mindfulness condition (50 female; $M_{age} = 27.95$, $SD_{age} = 8.38$), ninety-four in the control condition (72 female; $M_{age} = 24.83$, $SD_{age} = 10.42$), and eighty-nine in the puzzle condition (42 female; $M_{age} = 37.42$, $SD_{age} = 14.06$). As a manipulation check, MAAS scores were analyzed using a linear model with Condition (mindfulness acting as reference) as a fixed effect and Gender as a covariate. Compared to the mindfulness condition ($M = 3.81$, $SE = 0.12$, 95% CI [3.57, 4.05]), participants in the control condition ($M = 3.28$, $SE = 0.12$, 95% CI [3.04, 3.52]) reported significantly lower MAAS scores ($b = -0.53$, $SE = 0.15$, $t = -3.57$, $p < .001$), as did their counterparts in the puzzle condition ($M = 3.49$, $SE = 0.12$, 95% CI [3.25, 3.73]; $b = -0.31$, $SE = 0.15$, $t = -2.12$, $p = .035$). An additional comparison between the control and puzzle conditions revealed no reliable difference in MAAS scores ($b = -0.22$, $SE = 0.15$, $t = -1.43$, $p = .328$). An effect of Gender was also observed, indicating that male participants reported higher MAAS scores than the reference group ($b = 0.29$, $SE = 0.13$, $t = 2.30$, $p = .022$).

To investigate risk taking during the BRET, the number of boxes collected per trial were analyzed using a LMM with fixed effects of Condition (mindfulness [reference], control, and puzzle), Trial (centered), State Mindfulness (MAAS; centered) and all interactions, controlling for previous Trial Outcome and Gender. Random intercepts and trial slopes were specified for Participants (optimizer = bobyqa). The analysis revealed that, in the mindfulness condition, more boxes were collected than in either the control ($b = -7.07$, $SE = 2.16$, $t = -3.27$, $p = .001$) or puzzle ($b = -5.05$, $SE = 2.12$, $t = -2.38$, $p = .018$) conditions. As indicated by the estimated marginal means, participants in the mindfulness condition gathered the most boxes ($M = 38.2$, $SE = 3.59$, 95% CI [31.1, 45.2]), followed by those in the puzzle ($M = 33.2$, $SE = 3.66$, 95% CI [25.9, 40.4]) and then the control ($M = 31.0$, $SE = 3.77$, 95% CI [23.6, 38.5]) condition (see Fig. 3). An additional comparison between the control and puzzle conditions revealed no significant difference in the number of boxes collected ($b = -2.02$, $SE = 2.17$, $t = -0.93$, $p = .623$).

State mindfulness was a significant positive predictor of risk-taking in the mindfulness condition ($b = 8.39$, $SE = 1.43$, $t = 5.85$, $p < .001$), such that each one-point increase in MAAS corresponded to the collection of approximately 8.4 additional boxes. This association was substantially weaker in both comparison groups, as indicated by significant Condition X MAAS interactions. Specifically, the slope relating MAAS to boxes was reduced by 6.76 in the control condition ($b = -6.76$, $SE = 2.00$, $t = -3.38$, $p = .001$) and 7.78 in the puzzle condition ($b = -7.78$, $SE = 2.05$, $t = -3.79$, $p < .001$). In other words, higher state mindfulness predicted greater risk-taking but only following a brief meditative episode. Trial number and associated interactions were not significant ($|t| \leq 1.77$, $ps \geq 0.078$). As expected, participants collected fewer boxes following a bomb explosion on the previous trial ($b = -3.65$, $SE = 0.62$, $t = -5.91$, $p < .001$). Finally, Gender yielded a significant effect, such that male participants collected more boxes than females ($b = 3.64$, $SE = 1.82$, $t = 2.01$, $p = .046$).

Computational modeling

Following the analytical strategy in Experiment 1, trial-by-trial choices on the BRET were modeled using the EWMV model implemented in hBayesDM⁵⁰, adopting the same procedures for model estimation and convergence diagnostics. This revealed that the mindfulness condition showed a clear reduction in loss aversion (λ) compared to both the control and puzzle conditions (see Fig. 4). Posterior differences were credibly negative in both contrasts (95% HDIs [-1.17, -0.05], [-1.19, -0.14]), with $P(\Delta > 0) = 0.017$ and 0.006 and less than 1% of the posterior mass within the ROPE. This indicates a meaningful attenuation of explosion-related loss sensitivity following mindfulness meditation. Differences in risk preference (ρ) were also negative (95% HDIs [-0.28, -0.00], [-0.26, -0.00]), with $P(\Delta > 0) = 0.013$ and 0.003 and approximately 25% of the posterior mass within the ROPE. This suggests a small but significant reduction in risk aversion following mindfulness meditation. In contrast, initial belief (ϕ) and learning rate (η) showed negligible or equivalent differences across all contrasts (ϕ : 95% HDIs [-0.003, 0.005], [-0.006, 0.003]; $P(\Delta > 0) = 0.68$ and 0.29; ROPE = 100%; η : 95% HDIs [-0.020, -0.001], [-0.007, 0.005]; $P(\Delta > 0) = 0.004$ and 0.42; ROPE = 97–100%), suggesting comparable prior expectations and updating dynamics across conditions. Finally, decisional consistency (τ) was credibly higher in the mindfulness condition compared to the control condition (95% HDI [0.35, 1.74]; $P(\Delta > 0) = 0.999$; ROPE =

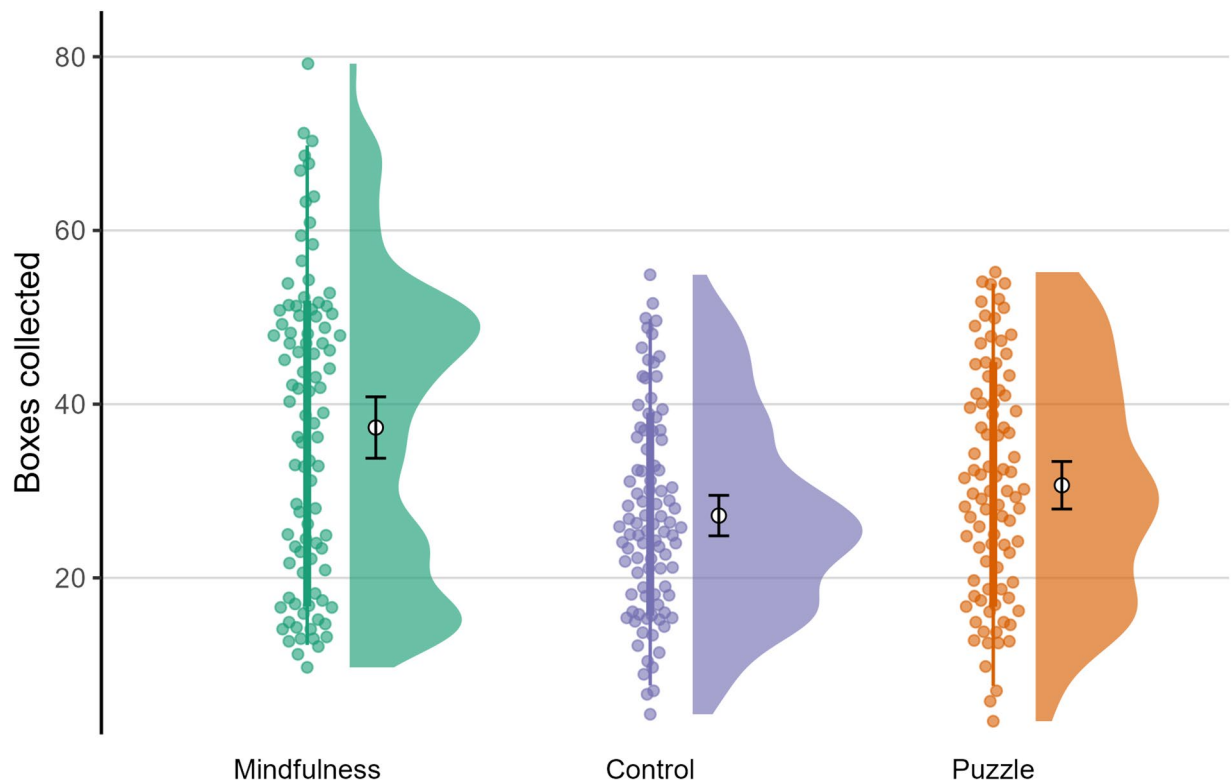


Fig. 3. Average number of boxes collected as a function of Condition. Each raincloud depicts the distribution (half-violin), individual participants (dots), and the mean with 95% CI (white dot + black error bar).

0.2%) but not in the mindfulness versus puzzle comparison (95% HDI $[-0.27, 1.32]$; $P(\Delta > 0) = 0.915$; ROPE = 3.7%).

A direct comparison between the control and puzzle conditions revealed no reliable differences across the EWMV parameters. Loss aversion (λ) did not credibly differ between the control and puzzle conditions (95% HDI $[-0.69, 0.65]$; $P(\Delta > 0) = 0.50$; ROPE = 11.7%), indicating comparable sensitivity to explosion-related losses. Risk preference (ρ) likewise showed equivalence across conditions (95% HDI $[-0.028, 0.024]$; $P(\Delta > 0) = 0.46$; ROPE = 98.3%). Prior burst belief (ϕ) was highly overlapping between the two groups (95% HDI $[-0.0068, 0.0022]$; $P(\Delta > 0) = 0.17$; ROPE = 100%), suggesting similar initial expectations about bomb probability. Learning rate (η) showed a small, directionally positive shift in the control compared to puzzle condition (95% HDI $[-0.0004, 0.0201]$; $P(\Delta > 0) = 0.97$); however, because most of the posterior mass fell within the ROPE (97.3%) this difference was practically negligible. Finally, inverse temperature (τ) did not credibly differ between control and puzzle conditions (95% HDI $[-1.13, 0.19]$; $P(\Delta > 0) = 0.08$; ROPE = 4.5%), indicating comparable levels of decisional consistency across the conditions.

Despite the adoption of a different risk-taking task (i.e., BRET vs. BART), participant sample (i.e., Singapore vs. UK), and testing environment (i.e., in-person vs. online), the current results replicated Experiment 1. As previously, compared to both the control and puzzle conditions, brief mindfulness-based meditation (vs. active & passive controls) increased risk-taking behavior via the valuation component of decision-making. Specifically, loss aversion was reduced following a brief meditative episode. In addition, albeit to a lesser extent, mindfulness meditation also lowered risk aversion during the BRET.

General discussion

Using two well-established paradigms (i.e., BART & BRET), samples drawn from different countries (i.e., UK & Singapore) and varied testing conditions (i.e., on-line & in-person), here we demonstrated that brief mindfulness-based meditation increased risk-taking behavior³⁵. Moreover, across each of the reported experiments, additional computational analyses (i.e., EWMV model) traced the origin of this effect to a reduction in loss aversion (λ) during decision-making^{45,46}. Compared to both active and passive control conditions, a single meditative episode reduced sensitivity to losses from bursting balloons (i.e., Expt. 1) and exploding bombs (i.e., Expt. 2), prompting increasing risk taking. At least during the BRET, mindfulness meditation also influenced risk preference (ρ), such that participants displayed a higher risk propensity than their counterparts in the control conditions. In the first investigation of its kind, these findings furnish a mechanistic account of how mindfulness meditation impacts the cognitive sub-processes that underpin risk-taking behavior in the laboratory¹⁷.

Given the acknowledged benefits of mindfulness meditation, it may appear puzzling this practice increased rather than decreased risk taking. Two observations are pertinent in this regard. First, risk taking is a multifaceted construct comprising several components (e.g., risk preferences, risk-related attitudes, loss

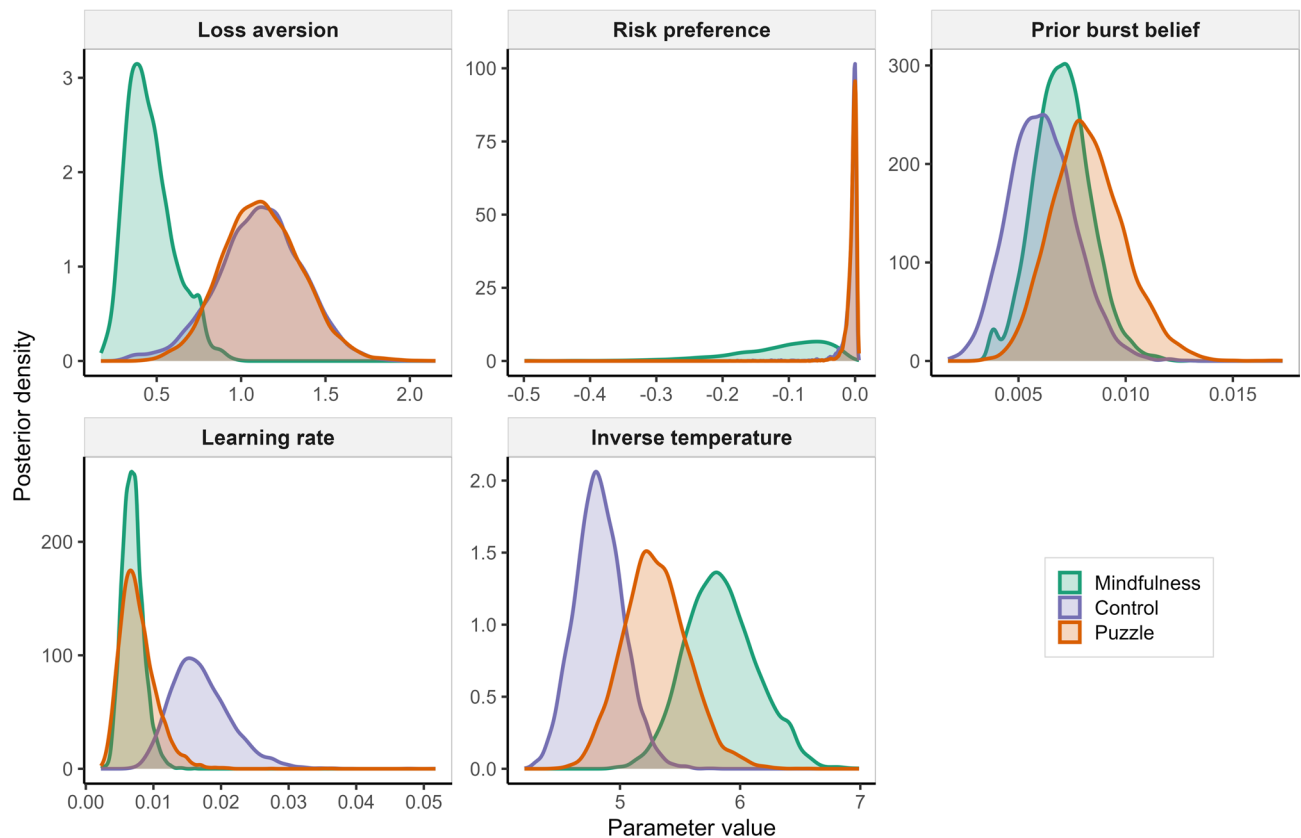


Fig. 4. Posterior parameter distributions from the Exponential-Weight Mean-Variance (EWMV) model across conditions.

aversion, risk perception) and exhibiting contextual nuance^{28,29,59}. For example, pondering whether to continue inflating a balloon during the BART is not the same as contemplating if it is safe to overtake a slow-moving vehicle in inclement driving conditions²⁸. Although both activities unquestionably involve risk, they do so in quite different ways. Thus, it would be unwise to extrapolate the current findings to single-shot activities in which risk taking (in its various forms) is involved. Second, rather than reflecting the operation of a maladaptive decisional strategy, reduced loss aversion (i.e., increased risk taking) can be advantageous in many situations^{60,61}. Specifically, downplaying the experiential impact of losses can facilitate the objective (i.e., non-emotional) appraisal of choice-related outcomes, thereby enhancing task performance. In multi-trial decision-making settings, such as the BART and BRET^{32,34}, such a tactic would be beneficial.

The current findings align with theoretical accounts proposing that mindfulness reduces reactivity to experiences (e.g., gains/losses) through the interplay of metacognitive, interoceptive, and self-regulatory (e.g., emotion management) mechanisms^{13,14,16,62,63}. Central to mindfulness practices is the cultivation of a non-judgmental psychological perspective in which thoughts, feelings, and memories are treated as fleeting experiences that do not merit additional inspection or analysis^{1–3}. Adoption of this mental stance has direct implications for interoception, the process of sensing, appraising, and integrating inner bodily signals^{63–65}. A widely advanced viewpoint is that mindfulness meditation modulates the impact of interoceptive cues by reducing experiential avoidance, the unwillingness to engage with certain personal experiences⁶⁶. In the experiments reported here, such evasion would be associated with the ramifications (e.g., disappointment) of bursting balloons (Expt. 1) and exploding bombs (Expt. 2). Underpinned by a reduction in loss aversion, however, mindfulness meditation eliminated (or at least attenuated) this tendency, with participants continuing to make risky choices. Of theoretical note, triggered by a single meditative episode, loss aversion served as a computational marker of the metacognitive experiences that guide risk-taking behavior^{12,14}.

Further evidence that mindfulness meditation can potentially increase risk taking comes from neurobiological research. Although not directly examining risk taking, this work has considered how meditative practices influence responses in a closely related domain; value-based decision-making^{36–38,64}. In these investigations, mindfulness training has been shown to decouple activity in the insula (i.e., indexing interoception) from responsiveness in cortical regions involved in valuation and self-referential processing, notably the ventromedial prefrontal cortex [vmPFC]^{64,67}. What this suggests is that, via simple mental routines such as focusing on one's breathing, mindfulness enhances interoception with attendant effects on value-based decision-making. Of significance in this regard is the salience of reward-related prediction errors^{36–38}. An interesting possibility is that increased interoceptive awareness diminishes the influence of the reward-system (i.e., gains & losses) during decision-making. By implication, this dampening of reward-related signals modulates risk taking, especially

for losses³⁹. Specifically, less concerned by bursts and explosions during the BART and BRET respectively^{32,34}, mindful participants continue making risky choices.

Based on recommendations in the literature, here we employed computational modeling to provide insights into the mechanisms through which mindfulness-based meditation influences risk taking^{17,68,69}. This follows previous work in which various computational approaches have been used to inform understanding of how mindfulness impacts a range of psychological processes and outcomes, including self-referential processing, egocentrism, learning, attentional cueing, and working memory^{8,40,47,48,68}. As in prior research, adoption of a computational analytical strategy once again proved to be enlightening. Applying the EWMV model⁴⁵, the results of two experiments indicated that mindfulness primarily influenced risk taking by reducing loss aversion, although at least in the case of the BRET it also lessened participants' aversion to risk. These findings further underscore the utility of computational approaches in delineating the pathways through which mindfulness meditation influence decision-making^{17,69}. Additionally, they provide a much-needed level of process specificity to theoretical accounts of how exactly meditative practices impact cognition^{12–17,62}.

Although replicating the effects of brief mindfulness meditation across different risk-taking tasks, nationalities, and testing environments, the current inquiry has several limitations which open avenues for refinement and further investigation. First, based on previous work^{7–9,40,70–72}, here a meditative practice was adopted that focused on breathing and the cultivation of a non-judgmental awareness of thoughts and sensations. While this approach was successful, it would be interesting to examine whether other interventions (e.g., body scan meditation, mindful eating) similarly increase risk taking, and identify the specific cognitive pathways (e.g., risk preference, loss aversion) through which these effects emerge³⁵. Second, the current experiments utilized a single meditative episode prior to completion of the risk-taking tasks. This therefore raises questions pertaining to the dosage, temporal persistence, and origin of the observed effects⁴⁹. For example, would an extended period of mindfulness training exert a larger and more enduring influence on risk taking via additional sub-components of decision-making?

Third, the current findings were observed using two very similar laboratory-based paradigms²⁸. Clearly a plethora of other activities can be used to examine risk-taking behavior (e.g., gambling, lotteries, investments), notably tasks that vary in arousal, emotional engagement, and real-world applicability⁷¹. A useful pursuit for future research will therefore be to explore the effects of mindfulness meditation in a range of risk-taking settings. Finally, although male (vs. female) participants exhibited greater risk taking in one of the reported experiments (i.e., Expt. 2), here we did not consider the potentially important role that gender may play in moderating the effect of brief mindfulness-based meditation on performance. A limitation of the present investigation was that female participants were overrepresented in both experiments (i.e., Expt. 1 = 67%, Expt. 2 = 59%). This imbalance should be acknowledged as prior research has indicated that men are generally more inclined than women to engage in risky activities⁷³, particularly when risk is assessed using direct behavioral measures such as the BART and BRET^{32,34}. It is possible therefore that the influence of mindfulness-based meditation on risk taking was underestimated in the current inquiry because of the gender composition of the samples. Future research should address this issue.

Across two experiments using standard paradigms (i.e., BART & BRET), here we probed the effects of brief mindfulness-based meditation on risk-taking behavior³⁵. A consistent pattern of results was observed regardless of the task that was used, the countries from which participants were sampled (i.e., UK vs. Singapore), and the conditions under which data were collected (i.e., on-line vs. in-person). Compared with their colleagues in both active and passive control conditions, participants who underwent 5-minutes of mindfulness-based meditation displayed increased risk taking. Additional computational analyses traced the origin of this effect to a reduction in loss aversion during decision-making⁴⁵. Collectively, these findings elucidate the mechanisms through which mindfulness meditation influences behavioral risk taking^{17,68,69}.

Data availability

Data are available at: (https://osf.io/aux4w/overview?view_only=228afa6e8ded496cbc7480f5e38767d9).

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Author contributions

Conceptualization (LBGT, MG, CNM), Software (MG), Data collection (LBGT, MG), Formal analysis (MG), Visualization (MG), Writing – original draft (LBGT, MG, CNM), Writing – review and editing (LBGT, MG, CNM).

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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