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The effects of cognitive load and mindfulness meditation on decisions related to risk and time

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A B S T R A C T

This study explores how cognitive load and a preventive mindfulness meditation impact decisions related to risk and time. For this, we use a controlled laboratory experiment with university students and a sequential design in which we elicit their risk and time attitudes twice. First, we elicit them in a baseline scenario. This is followed by an intervention period, in which we vary the presence of a one-time brief guided mindfulness meditation exercise. In second elicitation period, we then vary the inclusion of a cognitive load task. To measure potential physiological responses to cognitive load and mindfulness meditation, we continuously track participants' heart rates using fitness watches throughout the experiment. We find that in treatments with cognitive load the average heart rate increases relatively more during the second elicitation than in those without it, suggesting an acute physiological response. While a neutral waiting period does not affect risk-related choices post-intervention, the one with a guided mindfulness meditation reduces the probability of risk seeking choices and decreases the probability of individuals to make no changes in choices, in the subsequent treatment with cognitive load. Attitudes towards time remain consistent.

1. Introduction

Cognitive load and its consequences are a growing source of concern nowadays, especially for younger individuals such as university students.[1] The daily routines of the latter are, e.g., often characterized by a diverse array of simultaneous cognitively demanding tasks, such as studying and working at the same time. This cumulative effect of multiple tasks encountered regularly can then lead to increased cognitive load when making decisions. In particular, acute stressors or tasks require an individual to focus their attention to address the most important stressor or task at hand (Vitt et al., 2021; Buckert et al., 2017). As a result, individuals may allocate less attention or cognitive resources to other decisions, which could also include decisions that relate to an individual's preferences, e.g., regarding risk and time.

If decisions related to an individual's preferences become increasingly dependent on the situation, a situation with cognitive load may also reduce the stability of risk and time preferences, suggesting that these preferences are, at least in part, constructed during the decision process and are not fixed traits (see e.g., Deck & Jahedi, 2015).[2] The "dual-system model of decision-making" proposed by Loewenstein and O'Donoghue (2004, 2007) offers an explanation for the underlying mechanism by which cognitive load can impact choices and behaviors, while shedding light on potential variations in economic attitudes regarding risk and time. It proposes two different but interacting

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[1] The American Psychological Association (2018) found that younger cohorts are more likely to report higher stress levels compared to their older counterparts. In Germany, 66 % of the 18–29 year olds and 82 % of the 30–39 year olds state that they feel stressed often, which also exceeds reported average adult levels (Techniker Krankenkasse, 2016).

[2] Similarly, research has increasingly established the notion that behavioral preferences such as risk and time preferences can change when their circumstances vary (Andersen et al., 2008; Deckers et al., 2015; Dohmen et al., 2011; Guiso et al., 2018; Haushofer and Fehr, 2014; Schildberg-Hörisch, 2018). In contrast, standard economic theory assumes stable economic preferences (Stigler and Becker, 1977).

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systems: the emotion-driven affective system and the cognition-driven deliberative system. A change caused by factors such as increased cognitive load often leads to the affective system dominating the decision-making process and then impacting or changing individual economic attitudes or preferences. Moreover, the cognitive demands linked to cognitive load are often accompanied by measurable physiological responses, such as variations in heart rate (Vitt et al., 2021).

A potential preventive measure to counter the cognitive demands associated with cognitive load, as well as their effects on decision-making and physiological response, is mindfulness meditation. It teaches people to face demanding situations "mindfully", responding to them rather than reacting.[3] It is a process of becoming highly aware and focused on the present moment, while trying to stay neutral about one's thoughts or emotional reactions (Bishop, 2002; Kabat-Zinn, 1990).

In this paper, we aim to investigate the short-term effects of cognitive load and a one-time brief preventive mindfulness meditation on individual decisions related to risk and time attitudes. We thereby contribute to two important strands of literature. First, research on the effects of cognitive load on economic attitudes and preferences, particularly regarding risk and time, which is still ambiguous. For risk attitudes, some studies show that individuals tend to become more risk averse in situations with cognitive load induced via number/letter memorization tasks (Benjamin et al., 2013; Deck & Jahedi, 2015; Whitney et al., 2008). A study conducted by Drichoutis and Nayga Jr (2020), in contrast, finds no significant impact on risk preferences, despite the manipulation of cognitive load through a task involving memorization of numbers as well. Increased risk aversion has also been observed when cognitive load is induced through a delayed-matching task[4] (Gerhardt et al., 2016). For time attitudes, the results are ambiguous as well. Cognitive load can either increase impatience (Deck & Jahedi, 2015) or lead to higher patience (Hinson et al., 2003) in hypothetical financial scenarios. Overall, the discrepancies in findings stem from differences in experimental designs and the methods used to induce cognitive load (see e.g., Deck et al., 2021). Second, we also add to the literature on the impact of mindfulness meditation on economic decision-making, which is still scarce and mixed in its effects. Lima de Miranda (2019), e.g., does not identify any correlation between mindfulness measured via the Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003) and risk and time attitudes in secondary school students. Duchêne et al. (2024) investigate the association between mindfulness measured via MAAS and risk and time preferences using a survey on a representative sample of the French adult population. They observe that higher mindfulness levels are linked to greater risk aversion and patience in stated preferences, but no such relationship in incentivized tasks. In a 4-week RCT, Shreekumar and Vautrey (2022) demonstrate that a mindfulness intervention using the "Headspace" app helped reduce emotional interference in decision-making under risky conditions. Alem et al. (2021), moreover, show that mindfulness meditation leads to reduced risk seeking behavior and lower perceived stress but no significant change in patience or present bias among students.

However, none of the previous studies has analyzed the combination of cognitive load and a one-time brief preventive mindfulness meditation on the heart rate as well as on risk and time attitudes within a controlled short-term laboratory setting. Analyzing the short-term effects of mindfulness meditation on the heart rate in such a controlled environment is crucial for understanding its immediate physiological impact, which may then impact the subsequent decision-making task. This is of particular importance, since meditation is known to trigger acute physiological changes. This includes the activation of the parasympathetic nervous system and the reduction of sympathetic arousal. By activating the parasympathetic nervous system, which is responsible for relaxation and regeneration, the heart rate usually drops in the short-term. As the short-term measurement takes place in a controlled setting, we can moreover reduce the impact of confounding (lifestyle-related) aspects such as diet, sleep patterns, or other cognitive triggers, which may also affect physiological changes such as the heart rate and thus decision-making behavior. A controlled short-term measurement hence ensures that observed changes in heart rate are specifically due to the meditation intervention rather than external variables that might affect potential long-term outcomes. Short-term studies thereby provide a baseline understanding about how mindfulness meditation affects the heart rate and decision-making acutely, which is essential for designing and interpreting long-term studies.

We conduct a controlled laboratory experiment with a sequential design and university students as participants. In particular, individuals make decisions regarding risk and time attitudes, as measured through Multiple Price List (MPL) choices following the methodology established by Andersen et al. (2008), twice. Based on a 2 × 2 design, we first vary the intervention scenario after the first elicitation of risk and time attitudes: participants are either assigned a one-time brief preventive mindfulness meditation or a brief neutral waiting period ex-ante the second elicitation of risk and time attitudes. Then, we vary whether participants are exposed to a number memorization task (Cappelletti et al., 2011; Deck & Jahedi, 2015) that manipulates (high) cognitive load during the second elicitation (of risk and time attitudes) or not. In addition, we monitor subjects' heart rates with fitness watches throughout the experiment as a proxy measure of the level of acute physiological response to cognitive load and mindfulness meditation. Given the within-subject design and the short-term nature of our experiment, we are able to observe changes in choices related to risk and time of each of the participants before and after the (preventive) intervention period. To the best of our knowledge, no other study examines these relationships in a controlled laboratory setting.

We show that cognitive load is successful at increasing the average heart rate of participants during the second elicitation of risk and time attitudes irrespective of the previous intervention, suggesting an acute physiological response to the latter. We, moreover, find that a neutral waiting period does not affect risk-related choices post-intervention. In contrast, a mindfulness meditation reduces the probability of risk seeking choices only under cognitive load while increasing the one of individuals to make no changes. In (high) cognitive load situations, an ex-ante mindfulness meditation may hence be successful in leading to fewer behavioral changes and more stable decision-making. Attitudes towards time remain consistent.

The reminder of this paper is structured as follows: Section 2 outlines our experimental design and analytical strategy. In Section 3, we present the empirical results, while Section 4 includes several robustness checks. Lastly, Section 5 discusses the limitations of our study, including power, minimum detectable effect and sample size, and Section 6 provides the conclusion.

2. Experimental design

2.1. Overall description

We run a 2 × 2 within-subject laboratory experiment with a university student subject pool in which the presence of increased cognitive

[3] The FEAST proposes that interventions aimed at modifying behaviors should include the following five key aspects: "Fun", "Easy", "Attractive", "Social" and "Timely" (Hallsworth et al., 2016; Team, B. I., 2014). In line with these aspects is the preventive task of mindfulness meditation, which has gained popularity in recent decades. The acknowledgment extends to the World Health Organization (2023) reporting that yoga and its practices such as meditation are helpful in modifying and regulating the reactions to different cognitive triggers while providing benefits in managing stress and combating associated disorders.

[4] In the "delayed-matching task" subjects are briefly confronted with an arrangement of points (sample points). After a short delay, they are asked to indicate if a single point presented to them matches any of the sample points (Gerhardt et al., 2016).

Table 1
Treatment overview.

Treatment	Mindfulness meditation	Cognitive load	N
NoMedNoCL	no	no	52
NoMedCL	no	yes	64
MedNoCL	yes	no	65
MedCL	yes	yes	65
Total			246

Notes: NoMedNoCL – "No Mindfulness Meditation + No Cognitive Load", NoMedCL – "No Mindfulness Meditation + Cognitive Load", MedNoCL – "Mindfulness Meditation + No Cognitive Load", MedCL – "Mindfulness Meditation + Cognitive Load".

load during the second elicitation of risk and time attitudes is combined with the presence of an ex-ante intervention (Table 1 shows a summary of the combinations of the two tools in each treatment). In all treatment arms, we have three periods and a post-experimental questionnaire (Fig. 1 shows an overview of each treatment by period). In the pre-intervention period, we elicit risk and time attitudes. Next, in the intervention period, we expose subjects to either a one-time brief preventive mindfulness meditation or a neutral waiting period. In the post-intervention period, we once again elicit subjects' risk and time attitudes; this time we vary the individual's cognitive load level via a number memorization task. After completing the experiment, participants fill out a post-experimental questionnaire. Throughout the experimental sessions, we measure subjects' heart rates as an indicator of physiological response to cognitive load and mindfulness meditation exercise.

2.2. Elicitation of attitudes

2.2.1. Risk attitudes

Following Andersen et al. (2008), we use the MPL design, established by Holt and Laury (2002), to elicit risk attitudes. The elicitation of risk attitudes is based on two MPLs, in which individuals choose between paired financial lotteries A and B, with each MPL containing 10 rows (ibid.). Tables 2 and 3[5] show the payoff matrices presented to subjects in our risk attitude tasks. The two matrices differ in the expected values, EVs, which are higher in the second payoff matrix. Since the university student subject pool could be heterogeneous in terms of their fields of study and understanding of probabilities, we display pie charts with corresponding probabilities of each payoff (Harrison et al., 2018). This allows for a visual representation of probabilities. We do not enforce monotonicity. Therefore, subjects are able to switch between Option A and Option B more than once.

2.2.2. Time attitudes

We use the MPL design in order to elicit time attitudes as proposed by Coller and Williams (1999). This elicitation is based on a series of choices between a sooner smaller payoff and a later larger payoff. Subjects choose to receive Euro 42.00 on a given date or Euro 42.00 + x payable at a later point in time, where x implies a rate of return on "saving" the Euro 42.00 in the laboratory for a given time period. In our experiment, x ranges from annual rates of return of 5 % to 50 % on the principal of Euro 42.00, compounded quarterly as is the standard procedure of German banking overdraft accounts. The sooner smaller payoff is payable always today, while our time horizons for the later larger payoffs are four weeks, six weeks and eight weeks (there is no front-end delay). The choices are displayed sequentially in the form of three MPLs of ten choices each (ibid.). Table 4 illustrates the first MPL shown to the subjects,[6] which differs from the other ones in terms of time horizon (see Tables B1 and B2 in Appendix B for the two other MPLs). We display calendars with the time frame of possible payment dates similar to Harrison et al. (2018) for easier understanding of the task and payment dates. We do not enforce monotonicity. Subjects are able to switch between the sooner smaller payoff and the later larger payoff more than once.

2.3. Mindfulness meditation and control intervention

Subjects who are assigned to the treatment groups "Mindfulness Meditation + No Cognitive Load" (MedNoCL) and "Mindfulness Meditation + Cognitive Load" (MedCL) are exposed to a 5-minute[7] guided mindfulness meditation exercise based on the Mindfulness-Based Stress Reduction (MBSR) principles by Kabat-Zinn (1990). Participants listen to a German-speaking mindfulness meditation based on "Meditation – der Atemraum" (English: "Meditation – The Breathing Space") according to Schneider (2012). This guided mindfulness meditation practice was recorded beforehand by a mindfulness professional for study purposes. Subjects use headphones to listen to the audio and each one is sitting in a booth, allowing for privacy.

Subjects assigned to the treatment groups "No Mindfulness Meditation + No Cognitive Load" (NoMedNoCL) and "No Mindfulness Meditation + Cognitive Load" (NoMedCL) do not listen to the mindfulness meditation but wait for 5 min. In particular, subjects encounter a screen with the request "Please wait until the experiment continues.". Such a screen message is a standard waiting setup in laboratory experiments.[8] It is reasonable to be concerned that the act of waiting itself might have a relaxing effect. While other studies provide participants with e.g., documentaries (Alem et al., 2021), we aim to avoid influencing individuals as much as possible by keeping the control intervention as neutral and as simple as possible.

2.4. Cognitive load manipulation

Similar to Benjamin et al. (2013), Deck and Jahedi (2015) and Deck et al. (2021), we implement a cognitive load task aimed at triggering an immediate response from the participant's working memory and attention systems, which quickly engages the central nervous system. This rapid response is useful for capturing the short-term physiological response and hence potential changes, likely as a form of acute stress, in attitudes and decision-making behavior. Apart from the fact that a cognitive load task may mimic the types of real-life stressors that university students could encounter in their daily student lives, it has several advantages for the implementation in laboratory experiments: it is simple to implement and offers a high level of control, including the task difficulty and duration.

The most common method to manipulate cognitive load in a controlled manner is to let individuals memorize a string of numbers or letters or a combination of both (Achtziger et al., 2020; Allred et al., 2016; Benjamin et al., 2013; Cappelletti et al., 2011; Deck & Jahedi, 2015; Duffy & Smith, 2014; Hauge et al., 2016; Kessler & Meier, 2014; Shiv & Fedorikhin, 1999; Zimmerman & Shimoga, 2014). In most cases, cognitive load is used within the framework of a dual-task paradigm.

[5] We did not show EV^A and EV^B, Difference in EVs, and the implied Constant Relative Risk Aversion intervals to subjects.

[6] We did not show the annual interest rate (AR) and annual effective interest rate (AER) to subjects.

[7] In order to determine the length of the mindfulness meditation practice, we first piloted the guided mindfulness meditation informally. Subjects stated that it was hard to follow the mindfulness meditation for a long time period (e.g., 15 min). Thus, we kept a 5-minute guided practice for a one-time analysis of the impact of mindfulness meditation.

[8] For example, when participants have to wait until all other participants have completed a certain phase of the experiment and can only move on to the next phase at the same time.

Fig. 1. Treatment timeline.

Table 2
First payoff matrix in the risk preferences task.

Lottery A				Lottery B				EV^A (Euro)	EV^B (Euro)	Difference (Euro)	Open CRRA Interval if subject switches to Lottery B and ω = 0	
ρ	Euro	ρ	Euro	ρ	Euro	ρ	Euro					
0.1	2.50	0.9	2.00	0.1	4.79	0.9	0.13	2.05	0.60	1.45	-∞,	−1.71
0.2	2.50	0.8	2.00	0.2	4.79	0.8	0.13	2.10	1.06	1.04	−1.71,	−0.95
0.3	2.50	0.7	2.00	0.3	4.79	0.7	0.13	2.15	1.53	0.62	−0.95,	−0.49
0.4	2.50	0.6	2.00	0.4	4.79	0.6	0.13	2.20	1.99	0.21	−0.49,	−0.15
0.5	2.50	0.5	2.00	0.5	4.79	0.5	0.13	2.25	2.46	−0.21	−0.15,	0.14
0.6	2.50	0.4	2.00	0.6	4.79	0.4	0.13	2.30	2.93	−0.63	0.14,	0.41
0.7	2.50	0.3	2.00	0.7	4.79	0.3	0.13	2.35	3.39	−1.04	0.41,	0.68
0.8	2.50	0.2	2.00	0.8	4.79	0.2	0.13	2.40	3.86	−1.46	0.68,	0.97
0.9	2.50	0.1	2.00	0.9	4.79	0.1	0.13	2.45	4.32	−1.87	0.97,	1.37
1	2.50	0	2.00	1	4.79	0	0.13	2.50	4.79	−2.29	1.37,	∞

Table 3
Second payoff matrix in the risk preferences task.

Lottery A				Lottery B				EV^A (Euro)	EV^B (Euro)	Difference (Euro)	Open CRRA Interval if subject switches to Lottery B and ω = 0	
ρ	Euro	ρ	Euro	ρ	Euro	ρ	Euro					
0.1	2.50	0.9	2.19	0.1	5.00	0.9	0.19	2.22	0.67	1.55	-∞,	−1.71
0.2	2.50	0.8	2.19	0.2	5.00	0.8	0.19	2.25	1.15	1.10	−1.71,	−0.95
0.3	2.50	0.7	2.19	0.3	5.00	0.7	0.19	2.28	1.63	0.65	−0.95,	−0.49
0.4	2.50	0.6	2.19	0.4	5.00	0.6	0.19	2.31	2.11	0.20	−0.49,	−0.15
0.5	2.50	0.5	2.19	0.5	5.00	0.5	0.19	2.35	2.60	−0.25	−0.15,	0.14
0.6	2.50	0.4	2.19	0.6	5.00	0.4	0.19	2.38	3.08	−0.70	0.14,	0.41
0.7	2.50	0.3	2.19	0.7	5.00	0.3	0.19	2.41	3.56	−1.15	0.41,	0.68
0.8	2.50	0.2	2.19	0.8	5.00	0.2	0.19	2.44	4.04	−1.60	0.68,	0.97
0.9	2.50	0.1	2.19	0.9	5.00	0.1	0.19	2.47	4.52	−2.05	0.97,	1.37
1	2.50	0	2.19	1	5.00	0	0.19	2.50	5.00	−2.50	1.37,	∞

Table 4
First payoff matrix in the time preferences task.

Payoff alternative	Sooner smaller payoff (Euro, today)	Later larger payoff (Euro, four weeks)	Annual interest rate (AR, percent)	Annual effective interest rate (AER, percent)
1	42.00	42.16	5	5.09
2	42.00	42.32	10	10.38
3	42.00	42.48	15	15.87
4	42.00	42.64	20	21.55
5	42.00	42.80	25	27.44
6	42.00	42.95	30	33.55
7	42.00	43.10	35	39.87
8	42.00	43.25	40	46.41
9	42.00	43.40	45	53.18
10	42.00	43.55	50	60.18

That is, individuals perform the primary task of interest (e.g., a decision-making task) while simultaneously going over a memorization task (Cappelletti et al., 2011). We manipulate (high) cognitive load using a number memorization task based on Cappelletti et al. (2011) and Deck and Jahedi (2015). We integrate the cognitive load task into the second measurement of risk and time attitudes for those in treatments NoMedCL and MedCL. In particular, we ask subjects to memorize two 7-digit number sequences,[9] one during the risk-related choice task, and the other one during the time-related choice task. The exact 7-digit number sequences we show to subjects are "8649683″ and "3359398".[10] We show the two 7-digit number sequences to each subject in the same order. Every subject has 10 s to memorize each sequence and afterwards they are automatically forwarded to post-intervention, where the risk- and time-related choice tasks are re-elicited. Once each of the risk- and time-related choice tasks are completed, subjects are asked to input the 7-digit numbers in a separate screen, earning money for remembering each sequence correctly. In contrast, subjects in treatments NoMedNoCL and MedNoCL do not experience the number memorization task.

[9] We decide to use a 7-digit number sequence, which is the standard way of increasing cognitive load (Achtziger et al., 2020; Benjamin et al., 2013; Duffy and Smith, 2014; Hauge et al., 2016; Shiv and Fedorikhin, 1999; Zimmerman and Shimoga, 2014).

[10] The two 7-digit number sequences were randomly generated using https://www.randomcodegenerator.com/en/generate-codes.

2.5. Measuring physiological response

We track subjects' heart rates in a continuous manner throughout the entire experimental session as a measure of a physiological response to cognitive load and mindfulness meditation. Apart from additional measures such as salivary cortisol, this has also been used in various studies to measure physiological responses such as (acute) stress levels (see e.g., Buckert et al., 2017, 2014; Von Dawans et al., 2012; Vitt et al., 2021). For this, we use fitness watches ("fitbit Alta HR"), which can track the heart rate in beats per minute (bpm)[11] while being non-invasive and the type of wearables[12] that our participants could wear in real life. While it would have been ideal to measure both the heart rate and salivary cortisol levels as a combined and more comprehensive measure for participants' physiological responses, we decided to use only the heart rate, as this is more practical and efficient regarding the implementation in a laboratory experiment. Particularly, measuring the heart rate avoids the complexities and invasiveness of a biological sample collection, such as saliva cortisol measurements. This ensures that data collection is convenient for participants and does not require any special prior requirements or procedures.[13] Moreover, given the focus of our research on the everyday-like stressors such as increased cognitive load faced by university students, we do expect that the physiological response will be relatively mild. Consequently, we do not anticipate observing significant variations in cortisol levels. Our approach thereby follows Vecchi and Vitt (2024), who suggest that the heart rate may be a more suitable physiological measure for assessing mild physiological response or stress levels.

2.6. Post-experimental questionnaire

After the experiment, all subjects complete a short questionnaire (see Appendix A for the exact questions of the post-experimental questionnaire) on social demographics (e.g., age, gender, field of studies), their self-reported level of rest on the day of the session, and knowledge and practice of mindfulness meditation. We also assess participants' overall long-term stress levels. For this, we ask subjects about their perceived stress level (in a general, long-term manner) via the 4-item version of the Perceived Stress Scale (PSS 4) (Cohen et al., 1983). We collect information on academic deadlines during the week of the experiment and ask subjects to list activities that they usually perform for active stress management. Since we increase the cognitive load of the subjects during the experiment, we also measure abilities by including the 3-item Cognitive Reflection Test (CRT) (Frederick, 2005), which gives subjects short abstract mathematical problems. Finally, we ask debriefing questions about the experiment.

[11] Subjects do not receive any feedback on their heart rate because the screen of the fitness watch is taped up and the heart rate is therefore invisible to them.

[12] As discussed by Veltmann et al. (2021), since the technical progress in medicine, there is no need to exclusively use professional medical devices for the measurement of the heart rate, but also wearables enable this type of recording in a simple way by laypeople. It has been shown that data recorded by wearables has the potential to detect, for example, symptomatic and asymptomatic arrhythmias (especially atrial fibrillation) with a high level of sensitivity and specificity.

[13] For example, subjects should not drink, eat and smoke an hour prior to the experiment (Alem et al., 2021; Buckert et al., 2017, 2014), which is difficult to monitor. Furthermore, the menstrual cycle affects the hormone level, so for females in our study we would need to control for the phase of the menstrual cycle, which could lead to ethics issues and stress levels in the laboratory which might not be part of those encountered in real life (Buckert et al., 2017). Since the cortisol level typically follows a daily cycle, the cortisol diurnal rhythm must be taken into account. Besides, several saliva-cortisol samples must be taken at certain points in time during an experimental session (Alem et al., 2021; Buckert et al., 2017, 2014). While cortisol peaks only after a few minutes, it complicates timing and rapid response assessments.

2.7. Experimental protocol

The laboratory experiment was programmed with oTree (Chen et al., 2016) and conducted at the Essen Laboratory for Experimental Economics (elfe) at the University of Duisburg-Essen, Germany. The experimental sessions took place in May/Nov./Dec. 2019, January 2020, Nov./Dec. 2021 and June 2022.[14] All sessions were conducted during the teaching semester at University of Duisburg-Essen trying to avoid examination weeks. Each session took place either at 10 am or 2 pm either on a Tuesday or a Wednesday to keep times homogeneous across sessions. A total of 246 university students participated. All subjects were recruited through the online recruiting system ORSEE (Greiner, 2015), and the invitation stated that we would measure heart rates.

Upon arrival, subjects were randomly assigned to computer-equipped booths. The booths do not allow communication or visual interaction among the participants and more privacy for the mindfulness meditation practice or waiting period. The glass doors of the cubicles were closed so that participants could work on the experiment undisturbed. After everyone had an assigned booth, we allowed participants to read the preliminary remarks of the experimental instructions (see Appendix A for the experimental instructions). During this phase, they were instructed to place their heart rate monitoring fitness watches on their wrists. All fitness watches were numbered based on the associated booth number and the displays were covered so that participants could not monitor their heart rates themselves. The experimenters checked that the watches were set up correctly before the start of the session. Participants started at the same time but were able to work at their own pace, given the privacy of the cubicles. Questions about the experiment were answered in private.

Every subject was randomly paid for each of the two risk-related choice tasks (in pre-intervention and post-intervention). For the time-related choice tasks, only two people within a session were paid,[15] i.e. one person for the task in the pre-intervention period and a second person for the task in the post-intervention period, again randomly determined. Who was going to be paid was decided via a lottery drawing. In case of that the subjects had to be paid in the future for their decisions in the time-related choice tasks, a money transfer was made by the financial department of the University at the appropriate time point. Every subject also received an extra Euro 5.00 for listening to the 5-minute guided mindfulness meditation or the 5-minute waiting period. Every subject was paid Euro 5.00 for each correctly reported 7-digit number sequence (a subject could get a maximum of Euro 10.00 if both number sequences were entered correctly and a minimum of Euro 0 if both sequences were entered incorrectly). Subjects earned, on average, Euro 22.35 including payment for time attitude tasks (Euro 15.27 without considering the payoff for time attitudes). Sessions lasted an average of 60 min.

2.8. Analytical strategy

We first describe the data collected from our subject pool. Then, we examine potential changes in the heart rate under both interventions (mindfulness meditation, cognitive load task). We next turn to average changes in choices related to risk and time attitudes, where we consider the distributions pre- vs. post-intervention. We also run a series of econometric specifications to examine changes in the switching row of our MPLs for both risk and time related choice tasks in order to model the probability of switching row in the short-term. Each of the four

[14] Due to Covid-19 and the resulting measures, such as the closure of the university, our time span for conducting the laboratory sessions is longer than that of a "typical" laboratory experiment.

[15] This was done due to the university's guidelines for paying subjects at future points in time.

treatments are set up as a dummy variable where 1 means that the subject was randomly selected into the treatment and 0 otherwise. We keep the treatment without any interventions (NoMedNoCL) as the omitted treatment for comparison purposes.

Given our aim to understand the change in behavior in each task, our econometric specification is a multinomial logit defined as:

$$SwitchRow_i = \alpha_0 + \alpha_1 NoMedCL_i + \alpha_2 MedNoCL_i + \alpha_3 MedCL_i + \alpha_4 X_i + \varepsilon_i \quad (1)$$

For the risk-related choice tasks, $SwitchRow_i$ is defined as 1 if the participant switches to a more risk averse row post-intervention, 0 if no change in the switching row and −1 if the participant switches to a more risk seeking row post-intervention. For the time-related choice tasks, $SwitchRow_i$ is defined as 1 if the participant switches to a more patient row post-intervention, 0 if no change in the switching row and −1 if the participant switches to a more impatient row post-intervention.

X_i includes a series of controls (gender, economics majors, results of the Cognitive Reflection Test, results of the Perceived Stress Scale and frequency of mindfulness meditation). For the time-related choice tasks regressions, we include the time horizon of the task as controls. Errors are clustered by participant. We present the results as probabilities of switching for each treatment.

In Appendix E, we also provide alternative econometric specifications as a robustness test. These include an OLS model with the switching row as a continuous variable and a logit where 1 depicts more risk aversion or more patience, respectively. For the case of time attitudes, we also include a zero inflated logit specification to account for the high number of impatient responses. Full regression results (with controls) can be found in Appendix E as well.

3. Results

3.1. Descriptive sample characteristics

Table 5 presents descriptive statistics for our sample by treatment. The four treatment groups are statistically equal in terms of gender split, age, social sciences majors, economics majors, perceived stress levels (using the 4-item PSS) and (mindfulness) meditation frequency of participants. Using the 4-item PSS (scores range from 0 to 16; a higher value equals greater stress) as an outcome measure (in a general, long-term manner), over a half of the subjects in each treatment have an average PSS score of 7 or higher, presenting moderate levels of stress (comparable to findings by Alem et al. (2021) and Herbst et al. (2016)). The most stressed individuals are in MedNoCL (average PSS score: 7.32) while those in MedCL are the least stressed (average PSS score: 6.68). The average heart rate at pre-intervention for our participants ranges from a minimum of 83.98 bpm in MedCL to a maximum of 86.57 bpm in MedNoCL.

3.2. Effects of cognitive load and mindfulness meditation on heart rate

In this section, we examine how the presence of an ex-ante mindfulness meditation and a cognitive load task during the second set of risk- and time-related choice tasks (post-intervention) affect the heart rate (measure for physiological response). For this, we focus on the differences in the average heart rate between the three periods (pre-intervention, intervention and post-intervention).

The clinical threshold for the adult resting heart rate ranges from 60 to 100 bpm[16] (Avram et al., 2019). Studies find an average real-world resting heart rate of 72 bpm (Ostchega et al., 2011), or 79 bpm (Avram et al., 2019) in adults based on large cohorts. The average heart rate in our student population in pre-intervention is 85.2 bpm (s.d. 15.7), which is within the clinical threshold for an adult population (see Table 5 for average heart rates by treatment). An increase or reduction in the average heart rate would suggest a successful induction of a physiological response.

Fig. 2 illustrates the change in the average heart rate when comparing intervention – pre-intervention (orange bars) and post-intervention – intervention (blue bars).[17] A comparison between the pre-intervention and intervention periods reveals a significant reduction in the average heart rate for the treatments NoMedNoCL ($p = 0.000$), NoMedCL ($p = 0.000$) and MedCL ($p = 0.000$). When comparing the post-intervention with the intervention period, the increase in average heart rate is largest and significant in the treatments including cognitive load (87.6 bpm vs. 82.6 bpm in NoMedCL, a 6 % increase, $p = 0.000$, and 85.6 bpm vs. 80.0 bpm in MedCL, a 7 % increase, $p = 0.000$). This suggests an acute physiological response to cognitive load. Results for all treatments are summarized in Table 6.

Moreover, to check for the robustness of our results with regard to potentially relevant observable variables, we focus on both meditation frequency and gender. For this, we compare non-meditators versus meditators and show that incorporating cognitive load (compared to no cognitive load, NoMedCL vs. MedCL) for a person who has never meditated yields a consistent, immediate (short-term) and significant change in the heart rate. We see a significant decrease in the average heart rate between pre-intervention and intervention periods and a significant increase in the average heart rate between intervention and post-intervention periods (p-value for mean tests $p < 0.000$) for these two treatments. No significant changes are found for meditators. Gender is subject to the similar considerations: both males and females show a significant decrease in the average heart rate between pre-intervention and intervention periods as well as a significant increase in the average heart rate between intervention and post-intervention periods (p-value for mean tests $p < 0.005$ for all comparisons in NoMedCL vs. MedCL but for females in NoMedCL pre-intervention vs. intervention, $p = 0.273$).

3.3. Average changes in decisions related to risk and time

To study the effect of the one-time brief guided mindfulness meditation on decisions in the risk- and time-related choice tasks in the post-intervention period, we consider the changes in the average switching row of each task between the pre-intervention and the post-intervention periods.

3.3.1. Regression analysis of switching row for decisions related to risk and time attitudes

We now explore potential changes in choices related to risk and time attitudes from an individual perspective, moving from average changes. We run a series of econometric specifications to find the probability of switching rows in the MPLs for both risk and time attitudes. As a general overview, Tables C1 and C2 (Appendix C) show average row switches for risk- and time-related choice tasks.

With regards to risk attitudes, we examine changes in switching rows to account for different behavior changes. We first run a multinomial logit, in which we define 3 categories, −1 depicts a negative difference between the switching row post-intervention and pre-intervention (more risk seeking behavior), 0 no change in switching row, and 1 a

[16] A resting heart rate less than normal (<60 bpm) is clinically defined as "bradycardia" and an elevated resting heart rate above normal (>100 bpm) is defined as "tachycardia" (Ostchega et al., 2011).

[17] Heart rate data are aggregated into three intervals. Pre-intervention begins with the start of the experiment, intervention begins with the mindfulness meditation/waiting period and lasts 5 min, while post-intervention begins immediately afterwards and lasts until participants finish this period.

Table 5
Descriptive statistics by treatment.

Variables	NoMedNoCL	NoMedCL	MedNoCL	MedCL	*p*-value mean test across treatments
Female (%)	0.48	0.50	0.49	0.49	1.00
	(0.50)	(0.50)	(0.50)	(0.50)	
Age (mean)	22.42	23.62	23.29	22.72	0.31
	(2.88)	(4.84)	(3.91)	(3.85)	
Social Sciences Majors (%)	0.60	0.61	0.61	0.62	0.99
	(0.49)	(0.49)	(0.49)	(0.49)	
Economics Majors (%)	0.35	0.31	0.32	0.43	0.51
	(0.48)	(0.47)	(0.47)	(0.50)	
Does not meditate (%)	0.73	0.66	0.72	0.83	0.13
	(0.45)	(0.48)	(0.45)	(0.38)	
PSS score (mean)	6.90	7.20	7.32	6.68	0.59
	(2.87)	(2.99)	(2.96)	(2.82)	
PSS score 7 or higher (%)	0.60	0.58	0.58	0.51	0.76
	(0.49)	(0.50)	(0.50)	(0.50)	
PSS score 11 or higher (%)	0.08	0.16	0.14	0.09	0.48
	(0.27)	(0.37)	(0.35)	(0.29)	
Heart rate pre-intervention (mean)	84.71	85.45	86.57	83.98	0.85
	(11.68)	(12.82)	(22.25)	(13.23)	
N	52	64	65	65	

Notes: NoMedNoCL – "No Mindfulness Meditation + No Cognitive Load", NoMedCL – "No Mindfulness Meditation + Cognitive Load", MedNoCL – "Mindfulness Meditation + No Cognitive Load", MedCL – "Mindfulness Meditation + Cognitive Load". Standard deviation in parentheses. Social Sciences Majors includes Economics. PSS score range 0–14, mean/median=7, 75 % percentile=9, 90 % percentile=11.

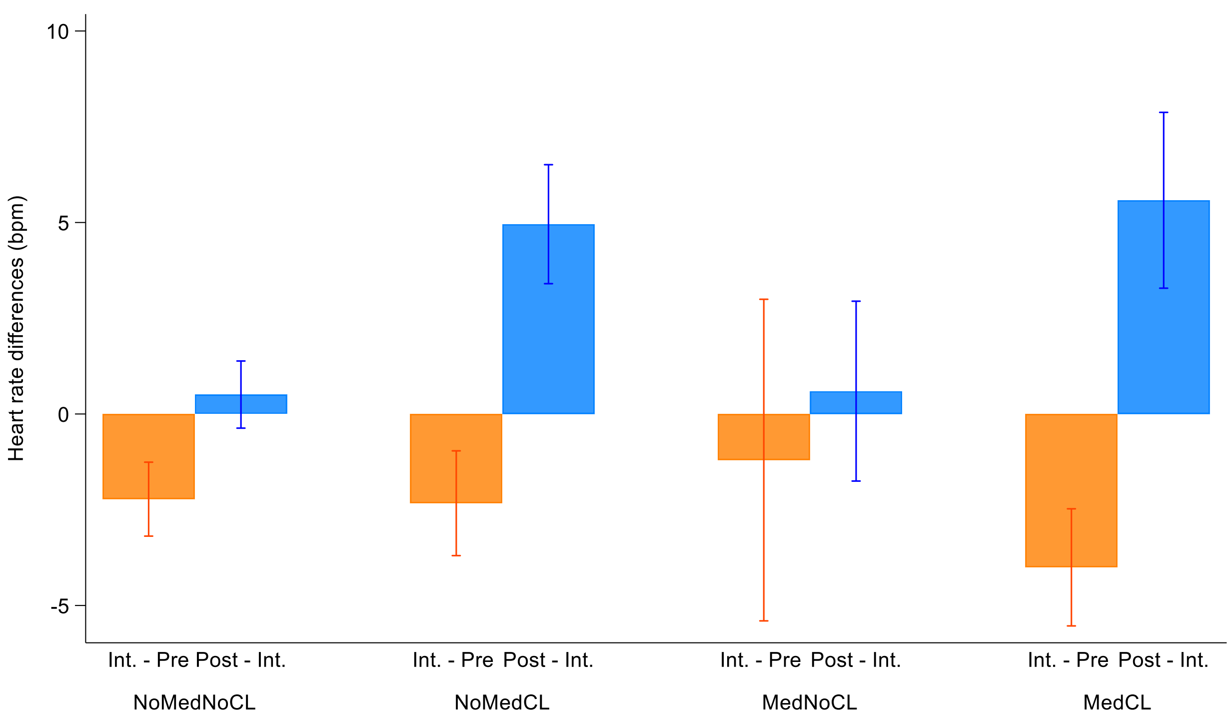

Fig. 2. Change in average heart rate between periods, by treatment.
Notes: For visualization purposes, average heart rate data are aggregated into differences: 1. intervention – pre-intervention (orange bars) and 2. post-intervention – intervention (blue bars). Pre-intervention begins with the start of the experiment, intervention begins with the mindfulness meditation/waiting period and lasts 5 min, while post-intervention begins immediately afterwards and lasts until participants finish this period.

positive difference between the switching row post-intervention and pre-intervention (more risk averse behavior).[18] The results of the multinomial regression analysis for risk attitudes with predicted probabilities of choosing more risk seeking, risk neutral and risk averse rows in the risk-related choice tasks and associated standard errors are presented in Table 7.

First, we investigate the effects that the prior respective intervention has on the probability to switch in risk-related choices in the scenarios with and without cognitive load. In the treatments with an ex-ante waiting period (NoMedNoCL, NoMedCL), there are no differences in the switching rows in the MPL tasks, irrespective of the presence or absence of (high) cognitive load post-intervention. In contrast, in the

[18] Figure D1 (Appendix D) shows the distribution of switching row differences.

Table 6
Average heart rate and percentage change, by period and treatment.

Treatment	Mean heart rate (in bpm)			Test of means (*p*-value)		Percentage change (in%)		N
	Pre	Intervention	Post	Test pre vs. intervention *p*-value	Test post vs. intervention *p*-value	Pre vs. Intervention	Post vs. Intervention	
NoMedNoCL	84.7	82.5	83.0	0.000	0.251	−2.6	0.6	52
NoMedCL	85.5	82.6	87.6	0.001	0.000	−3.3	6.0	64
MedNoCL	86.6	85.4	86.0	0.569	0.613	−1.4	0.7	65
MedCL	84.0	80.0	85.6	0.000	0.000	−4.8	7.0	65

Notes: NoMedNoCL – ”No Mindfulness Meditation + No Cognitive Load”, NoMedCL – “No Mindfulness Meditation + Cognitive Load”, MedNoCL – “Mindfulness Meditation + No Cognitive Load”, MedCL – “Mindfulness Meditation + Cognitive Load”.

Table 7
Regression analysis for risk attitudes.

d.v.: Switch row post-intervention - pre-intervention	Simplified difference Multinomial logit (1)			Simplified difference Multinomial logit (2)		
	More risk seeking	No change in risk aversion	More risk averse	More risk seeking	No change in risk aversion	More risk averse
NoMedNoCL	0.123	0.629	0.247	0.120	0.632	0.247
	(0.042)	(0.063)	(0.055)	(0.042)	(0.064)	(0.055)
NoMedCL	0.146	0.594	0.258	0.162	0.585	0.251
	(0.037)	(0.049)	(0.042)	(0.036)	(0.047)	(0.042)
MedNoCL	0.201	0.451	0.346	0.198	0.456	0.345
	(0.042)	(0.052)	(0.051)	(0.040)	(0.053)	(0.051)
MedCL	0.075	0.683	0.241	0.070	0.681	0.248
	(0.023)	(0.044)	(0.040)	(0.022)	(0.043)	(0.041)
Controls		No			Yes	
Cluster by participant		Yes			Yes	
N		458			458	
NoMedNoCL = NoMedCL (*p*-value)	0.684	0.669	0.870	0.447	0.557	0.947
MedNoCL = MedCL (*p*-value)	0.009	0.000	0.112	0.006	0.001	0.144

Notes: Results from the multinomial logit model are presented as probabilities (margins). Table presents the predicted probabilities of choosing more risk seeking, risk neutral and risk averse rows in the risk tasks and associated standard errors. For this specification, we define a 3-outcome variable = 1, if the individual becomes more risk averse, 0 if there is no change in switching row and −1 if more risk seeking. NoMedNoCL – ”No Mindfulness Meditation + No Cognitive Load”, NoMedCL – “No Mindfulness Meditation + Cognitive Load”, MedNoCL – “Mindfulness Meditation + No Cognitive Load”, MedCL – “Mindfulness Meditation + Cognitive Load”.

treatments with an ex-ante mindfulness meditation (MedCL, MedNoCL), there is a significant decrease in the probability of making more risk seeking choices (between pre- and post-intervention) from 20.1 % to 7.5 % ($p = 0.009$) and an increase in the probability of no changes in risk-related decisions (between pre- and post-intervention) from 45.1 % to 68.3 % ($p = 0.000$). In Table E1 in Appendix E, we also show that our results are robust towards other more simplistic econometric specifications. In (high) cognitive load situations, a mindfulness meditation practice may hence be successful in leading to fewer behavioral changes and more stable decision-making.

As a robustness test, we run our multinomial specification for non-meditators only (following findings from Taylor et al. (2011)) and show that the results hold. The incorporation of a brief mindfulness meditation (compared to no mindfulness meditation, NoMedNoCL vs. MedNoCL) for a person who has never meditated has an immediate (short-term) and significant movement towards less risk seeking behavior (see Appendix E, Table E3).

In terms of time attitudes, we analogously define 3 categories, −1 depicts a negative difference between the switching row post-intervention and pre-intervention (more impatient behavior), 0 no change in switching row, and 1 a positive difference between the switching row post-intervention and pre-intervention (more patient behavior).[19] Results from a multinomial logit and other specifications accounting for the high number of zeros or simplified to show only patience does not yield significant results in terms of changes in decision-making (see Tables 8 and E2 in Appendix E for alternative specifications). Participants in our experiment are consistent in their time-related choices, when comparing post- and pre-intervention periods.

4. Robustness checks – cognitive load manipulation

In this section, we check for the robustness of our results with regard to cognitive load by assessing whether our way of manipulating cognitive load was successful in potentially limiting the deliberative processing of our subjects.

First, the manipulation of cognitive load is successful if subjects actually exert (cognitive) effort in the number memorization task. Cappelletti et al. (2011) argue that the number of correct recalls in the number memorization task can be viewed as a measure of the actual (cognitive) effort that the subjects exerted during the task. In our lab experiment, the majority of subjects who participated in the NoMedCL and MedCL treatments correctly recalled both of the 7-digit number sequences (90.5 % in NoMedCL and 81.6 % in MedCL). In NoMedCL, 95.2 % of participants recalled the first and/or the second number correctly, while in MedCL, the percentage was a bit lower by 92.1 % for the first and 89.5 % for the second number. Around 5 - 10 % in both NoMedCL and MedCL could not remember any of the numbers (see Table F1 in Appendix F). These high proportions of correct responses suggest that subjects made an (cognitive) effort.

Second, the number of correctly reported 7-digit number sequences could also be an indication of individual cognitive abilities (Frederick, 2005). To assess cognitive abilities, we follow Frederick (ibid.) and report (mean) CRT scores in Table F2 in Appendix F. Accordingly, the mean CRT scores in each of the treatment groups range from 1.8 - 2.0, and we find no significant differences in average cognitive ability

[19] Figure D2 (Appendix D) shows the distribution of switching row differences.

Table 8
Regression analysis for time attitudes.

d.v.: Switch row post-intervention - pre-intervention	Simplified difference Multinomial logit (1)			Simplified difference Multinomial logit (2)		
	More patient	No change in patience	More impatient	More patient	No change in patience	More impatient
NoMedNoCL	0.193	0.693	0.234	0.234	0.699	0.111
	(0.040)	(0.052)	(0.052)	(0.052)	(0.050)	(0.034)
NoMedCL	0.178	0.695	0.250	0.243	0.691	0.128
	(0.035)	(0.041)	(0.041)	(0.041)	(0.040)	(0.026)
MedNoCL	0.200	0.647	0.346	0.343	0.652	0.152
	(0.037)	(0.050)	(0.051)	(0.052)	(0.049)	(0.036)
MedCL	0.183	0.670	0.241	0.249	0.663	0.146
	(0.035)	(0.049)	(0.040)	(0.041)	(0.049)	(0.034)
Controls		No			Yes	
Cluster by participant		Yes			Yes	
N		721			721	
NoMedNoCL = NoMedCL (*p*-value)	0.788	0.983	0.766	0.861	0.898	0.692
MedNoCL = MedCL (*p*-value)	0.742	0.746	0.905	0.918	0.871	0.902

Notes: Results from the multinomial logit model are presented as probabilities (margins). Table presents the predicted probabilities of choosing more impatient, patient "neutral" and patient rows in the risk tasks and associated standard errors. For this specification, we define a 3-outcome variable = 1, if the individual becomes more patient, and 0, if there is no change in switching row and −1 if more impatient. NoMedNoCL – "No Mindfulness Meditation + No Cognitive Load", NoMedCL – "No Mindfulness Meditation + Cognitive Load", MedNoCL – "Mindfulness Meditation + No Cognitive Load", MedCL – "Mindfulness Meditation + Cognitive Load".

between the participants in the four treatments (test of equality of the mean CRT score for the four treatments: $p = 0.767$). We also present the percentage of subjects who belong to the "low" group (0 correct items) and the "high" group (3 correct items) (ibid.). In each of the treatments, more than a third of the individuals are classified into the "high" group (35 % in NoMedNoCL, MedNoCL, MedCL and 44 % in NoMedCL), while only 13 % - 20 % in each treatment group are classified into the "low" group (13 % in NoMedNoCL and NoMedCL, 15 % in MedNoCL and 20 % in MedCL). Therefore, we can conclude that our results are not driven by individual cognitive abilities of our subjects (to successfully perform the number memorization task).

Third, we follow Achtziger et al. (2020), who provide a manipulation check for economic experiments allowing to determine whether a cognitive load manipulation has been successfully induced with the help of evaluating response times. Accordingly, the average response times must be shorter in the presence of cognitive load in contrast to situations without cognitive load, respectively. Although our laboratory experiment was not intended to measure response times, response times are automatically recorded, allowing us to analyze them accordingly. Nonetheless, our response times are measured in seconds, while they should be measured in milliseconds in order to reveal precise results (as e.g., in Gerhardt et al. (2016) and Whitney et al. (2008) who look at risk and time attitudes). On the other hand, Olschewski and Rieskamp (2021) look at risk preferences and choice consistency (despite their stress task being based on time pressure) measuring response times in seconds. Although this may not be the most ideal test (since changes are typically noticeable in milliseconds), we still conduct the manipulation check.

We compute the average response times for each of the risk and time task decisions for every treatment. Our results indicate a significant average reduction in response times comparing pre- vs. post-intervention (response time post-intervention - response time pre-intervention) in most of the treatments (see Tables F3 and F4 in Appendix F). As in Table F5, the largest average response times drop in percentages by treatment can be seen in MedCL and NoMedCL, which are the two treatments with cognitive load. We suggest that since answers were on average faster in all the treatments, there may be a learning aspect influencing the response times for both risk- and time-related choices in each task. However, the situations with cognitive load exhibited the largest percentage drop in average response times. Hence, we can conclude that our number memorization task had the desired effect of successfully inducing cognitive load.

5. Limitations

This study has several potential limitations. First, we recognize that our findings may be biased, particularly regarding choices related to risk attitudes, as the data collection was also conducted during and post-Covid-19 pandemic, when the overall uncertainty was still high regarding the risk of infection, timeline of vaccine rollout (for younger cohorts), and return to "normality". There may also be a degree of self-selection bias, as certain groups may have skipped taking part in economic laboratory experiments directly post-pandemic (for example, university students who would not have been vaccinated).

Second, we are aware that the controlled laboratory setting has several limitations. While we believe that the controlled setting provides a baseline understanding about the interplay of a brief mindfulness meditation and the heart rate, thereby informing the design and interpretation of long-term studies, a one-time brief mindfulness meditation intervention has several limitations. A one-time brief mindfulness meditation intervention in the laboratory may, e.g., not provide enough time to develop effective meditation skills, especially for beginners. Although, this could lead to lower or inconsistent changes in the physiological response compared to a long-term practice, the collection and analysis of data of beginner meditators is a rather conservative strategy to understand the short-term effects on the heart rate and decision-making (Taylor et al., 2011). Running the multinomial econometric specification only with non-meditators as a robustness test, shows that the full sample results hold, see Appendix E.

A further aspect that relates to the controlled laboratory setting is that participants could react differently to a laboratory-induced cognitive load task than to cognitive load in real-life situations. This could limit the external validity of the (high) cognitive load situation and thus also of the mindfulness meditation intervention.

Another limitation relates to the way we measure the physiological response to cognitive load. The heart rate measurement with fitness watches, while practical and non-invasive, may not provide a comprehensive measurement, e.g., such as combining measures of heart rate and salivary cortisol to also measure hormonal stress responses (see e.g., Buckert et al., 2017, 2014; Von Dawans et al., 2012; Vitt et al., 2021). Consequently, we cannot conclude that changes in the (average) heart rate specifically serve as an indicator of acute stress. Rather, our results are exploratory and indicative, as the observed physiological responses to cognitive load and preventive mindfulness meditation shown in changes in the (average) heart rate suggest that the body reacts without revealing the exact underlying mechanisms.

In addition to that, our control treatment consists of a 5-minute waiting period during which a screen is presented, requesting participants to wait, adhering to the standard waiting protocol of laboratory experiments. We believe that this approach serves as the most neutral control treatment, designed to minimize any potential influence on participants while maintaining simplicity. However, we recognize that participants may utilize this time for rest, which could potentially bias the results of our study.

Moreover, we chose only mild interventions to induce potential cognitive load, which may have impacted the results, given our sample size.[20] Given the restrictions of the Covid-19 pandemic and the subject pool, we were not able to increase the sample sizes in any of our treatments. Although online experiments could have potentially yielded a larger sample size, they would not have allowed us to maintain control over the 5-minute mindfulness meditation or waiting period and the number memorization task. Mild interventions come at the advantage that they may mimic typical, real-life triggers of university students quite closely and provide an ethically sound setting for studying baseline effects of stress reduction by a brief mindfulness meditation before advancing to more intensive intervention designs.

Lastly, since studies in economics have only recently begun to incorporate response time modelling and experimental design as a means to assess the successful induction of cognitive load, our laboratory experiment is not designed for response times evaluation purposes. We have the capability to track the response times of our subjects, however, these measurements are expressed in seconds, which only provides indicative results. We are confident that the robustness checks we consider regarding successful induction of cognitive load are sufficient to prove that our cognitive load induction led to the desired effect.

6. Conclusion

We conducted a controlled laboratory experiment with university students to examine choices related to risk and time attitudes, accounting for the short-term impact of cognitive load. We measured the resulting changes in the average heart rate as a proxy for a physiological response. We further analyzed the effect of a preventive intervention in the form of a one-time 5-minute guided mindfulness meditation on the heart rate and decisions related to risk and time.

Our results indicate that cognitive load is successful at increasing the average heart rate during the second elicitation irrespective of the previous intervention, suggesting an acute physiological response, i.e. an increase by 6 % with an ex-ante neutral waiting period and one by 7 % with an ex-ante mindfulness meditation. Moreover, we show that a neutral waiting period does not affect risk-related choices post-intervention. In contrast, a mindfulness meditation reduces the probability of risk seeking choices only under cognitive load while increasing the one of individuals to make no changes in choices. Attitudes towards time remain consistent. Our results hence indicate that in decision situations under cognitive load, a mindfulness meditation could lead to less behavioral changes and more stable decision-making.[21] These findings could be situated under the theoretical implications of the “dual-system model of decision-making” by Loewenstein and O’Donoghue (2004, 2007), although we did not specifically test for underlying mechanisms of the two interacting systems by which cognitive load can impact choices and behaviors. Accordingly, cognitive load may lead individuals to shift from a deliberative to an affective system, potentially resulting in more affective choices that do not align with their deliberatively made risk and time choices in the absence of cognitive load. In contrast, a prior mindfulness meditation may decrease the extent to which individuals shift to the affective system when making decisions under cognitive load.

Research from neuroeconomics on short-term effects of meditation and decision-making may potentially explain our results. It shows that meditation changes brain activity directly related to cognitive and impulse control, contributing to more “rational” decisions in choice tasks, and specifically in the case of tasks associated with risk and uncertainty (Bhatt & Camerer 2005; Volz et al., 2003; Sun et al., 2015). This could be related to the increase in the probability of no changes in risk-related decisions observed in our experiment in the treatment with cognitive load and an ex-ante mindfulness meditation. Specifically, this suggests that with cognitive load, mindfulness meditation works well in decreasing the probability of changes in risk attitudes.

Our short-term controlled analysis provides a valuable basis for future research investigating the interplay of cognitive load, preventive interventions such as mindfulness mediation, and attitudes towards risk and time in decision-making. Future studies could investigate alternative tasks that alter the level and type of cognitive load and their interactions with various mindfulness or alternative relaxation practices. Moreover, a long-term controlled analysis is needed to further disentangle the complex relationship between mindfulness meditation, cognitive load, and risk and time attitudes and to gain further insights into the lasting effects of mindfulness meditation.

CRediT authorship contribution statement

Natalia Bulla-Holthaus: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Nadja Kairies-Schwarz:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Irene Mussio:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization.

Declaration of competing interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.socec.2025.102412.

Data availability

Data will be made available on request.

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[20] Finding minor changes in the MPL decision rows would entail larger samples – over 380 per group, per two-by-two treatment comparison – with a power of 80 % and significance of 5 %.

[21] An alternative explanation to the stability of choices is the one of the speed-accuracy trade-off, where less time, here more cognitive load, for decisions is associated with more decision errors or reduced consistency (see Heitz, 2014).

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