Preprint: Trait, but not State Mindfulness Improves Resistance to Cognitive Biases.

Tianhong Tim Qiu

Emily G. Nielsen

Emma Guimaraes

John Paul Minda

Department of Psychology

The Brain and Mind Institute

Western University,

London ON

Abstract

The dual-process theory of thinking defines a heuristic-based System I which trades-off precision and accuracy in favour of speed. It is prone to consistent range of error modes formalized as cognitive biases. In contrast, System II is slower, requires deliberate engagement but can work through complex problems with lower error. Mindfulness research points to positive improvements in higher-cognition processes with specific emphasis on attention and an attitude of non-judgement; both are thought to underlie successful recruitment of System II. We hypothesized that individuals with higher mindfulness would be less susceptible to common cognitive biases. We evaluate two constructs of mindfulness. Trait mindfulness: a long-term dispositional mindfulness which can be enhanced via deliberate training but otherwise remains consistent across an individual's lifetime. State mindfulness: refers to a short-term experience of mindfulness which is subject to experimental manipulation. The present study consists of two-arms. The first arm ($N = 391$) was administered completely online and evaluates trait mindfulness. The second arm ($N = 191$) was conducted in-lab and randomized participants into one of two conditions: mindfulness induction or a sham control condition. Participants from both arms underwent performance assessment on a battery of common cognitive bias tasks. We found that trait mindfulness was associated with reduced susceptibility to specific biases: anchoring, resistance to sunk costs, availability, and logical fallacies. Contrary to expectations, experimental manipulation of state mindfulness did not influence susceptibility to cognitive biases when compared to the sham control. These findings suggest trait, but not state mindfulness may improve resistance to cognitive biases.

1. Introduction

1.1 Dual Process Theory

Thinking, reasoning, and decision-making can be described as the result of dual processes, a fast system makes quick assessments and selects behaviours according to the available contents of memory and a slower, more deliberate system relies on language and prefrontal regions to work through complex problems and decisions (Evans, 2003). Most everyday thinking tasks will involve contributions from both systems although people tend to default to the faster, intuitive process also known as System I. Conversely, System II describes the processes that lead to deliberate and often effortful reasoning (Kahneman, 2011).

As a general rule, System I and System II collaborate to reduce overall consumption of mental resources; explaining the tendency to deploy System I since it requires minimal mental effort. However, the quick and dirty properties of System I lends itself to errors of overfitting, on account of overlooking minute yet critical details (Kahneman, 2011). Thus System I thinking is associated with a range of cognitive biases and heuristics such as anchoring bias, availability heuristic, and logical fallacies (Balzan et al., 2012; Chapman, 1967; Kahneman, 2011; Roth et al., 2015).

1.2 Mindfulness

Mindfulness is a state of being, characterized by complete attentiveness to present moment experience, in a non-judgmental fashion (Brown & Ryan, 2003; Kabat-Zinn & Hanh, 2009). Mindfulness practices originate from Eastern wisdom traditions and religions but have recently become secularized and adopted in the West. These practices involve deliberate training

of attention, a process of sharpening focus onto specific contents of experience such as the breath, sounds, and sensations. Many of these secular mindfulness practices have become operationalized as mental health or medical interventions as in the case of Mindfulness-Based Stress Reduction (MBSR) or Mindfulness-Based Cognitive Therapy (MBCT) (Kabat-Zinn, 1982; Segal et al., 2001).

1.2.1 Two Constructs of Mindfulness

Mindfulness as a concept is often framed in two different ways depending on the temporal window in which we define it. One view is to see mindfulness as a long-term, dispositional trait (Shapiro et al., 2011). Similar to personality, trait mindfulness describes the subject's baseline or habitual expression of mindful behaviour. Alternatively, another framing known as state mindfulness focuses on present-moment mindfulness. State mindfulness pertains to the degree of mindfulness present in the subject during the time window of measurement (Kiken et al., 2015; Lau et al., 2006). Oftentimes, state mindfulness is measured as a dependent variable in response to a mindfulness intervention such as MBSR.

State and trait mindfulness appear to be positively correlated (Kiken et al., 2015), although the degree to which one interacts with the other remains unclear. Some studies go as far as to suggest the two constructs are distinct and unrelated (Bravo et al., 2018). Generally, reports on the relationship between state and trait mindfulness are inconsistent, and weakly correlated at best (Manuel et al., 2017; Medvedev et al., 2017; Shapiro et al., 2011). Regardless, these data suggest that state and trait mindfulness may differentially contribute to cognitive outcome variables. Measuring both constructs and studying how they interact with other cognitive processes and behaviours may provide a broader picture of the influence of mindfulness on cognition (Medvedev et al., 2017).

For both state and trait mindfulness, well-standardized psychometric instruments have been developed and validated for each respective construct. Trait mindfulness is perhaps best measured by the Five-Facet Mindfulness Questionnaire (FFMQ) which measures five unique aspects of dispositional mindfulness (Baer et al., 2006). As for state mindfulness, the Toronto Mindfulness Scale is commonly used to measure moment-to-moment mindfulness and has a two-factor structure (Lau et al., 2006).

1.2.2 Mindfulness Influences Cognition

Non-interventionist mindfulness training has been associated with improvements to attention, memory, learning, and problem-solving (Basso et al., 2019; Chiesa et al., 2011; Ostafin & Kassman, 2012). Many MBSR and MBCT intervention studies have revealed similar improvements to various aspects of higher-order cognition. (Greenberg et al., 2013; Jha et al., 2010; Lao et al., 2016; van den Hurk et al., 2012). Considering the Dual Processes recruits different cognitive resources such as attention and memory; mindfulness may influence the deployment of System I & II through these very mechanisms. Since mindfulness is associated with non-judgment and deliberate focusing of attention, increased mindfulness may tilt cognition towards the use of System II, which decreases susceptibility to bias and heuristics.

Relating the properties of mindfulness to thinking and reasoning, there is preliminary evidence to suggest mindfulness training reduces cognitive biases such as sunk cost bias (Hafenbrack et al., 2014), negativity bias (Kiken & Shook, 2011), and implicit biases pertaining to race, gender, and age (Burgess et al., 2017; Lueke & Gibson, 2015). A review by Raglan and colleagues suggest mindfulness may reduce susceptibility to biases through affective mechanisms; reduced anxiety, stress, and depressive symptoms are associated with higher mindfulness (Raglan, 2014).

1.3 Hypotheses

Based on previous evidence that mindfulness improves aspects of awareness and higher-level cognition, which are primarily recruited during System II thinking; we hypothesize that increased mindfulness, as measured assessments of state and trait mindfulness, will favor deployment of System II thinking. We hypothesize the resultant effects will reduce susceptibility to common biases and heuristics. Our current study is unique in that we evaluate the impacts of both state and trait constructs of mindfulness. We predict that both state and trait mindfulness will be associated with reductions in susceptibility to the availability heuristic, anchoring bias, belief bias, logical fallacies, and sunk cost fallacies. These biases will be measured using a battery of cognitive tasks, and bias susceptibility will be inferred from task performance.

2. Methods

2.1 Study Design

2.1.1 Overview

We conducted two separate studies, each with different approaches collecting data on demography, constructs of mindfulness, and performance on a battery of cognitive bias tasks. The first study, referred to as the *Trait Study*, was administered online through two independent platforms. The Trait Study assessed participants' trait mindfulness with an online version of the FFMQ and measured susceptibility to cognitive bias with online versions of several well known cognitive bias scenarios (described in detail below). The second study, referred to as the *State Study* involved in-person participation at an in-house meditation lab suite. The State Study participants were randomized into either active and control conditions. State study recorded both

trait and state mindfulness measures. After the intervention, participant performance was assessed on a similar set of cognitive bias tasks. Further details of experimental setup for the individual studies are outlined in their respective sections. All questionnaires and tasks were administered through Qualtrics XM (Qualtrics, 2013).

2.1.2 Trait Study

The trait study measured basic demography, trait mindfulness with the FFMQ (*see materials*), and six cognitive bias tasks: anchoring, belief bias, base rate, famous names, letter frequency and resistance to sunk costs.. At the end of the study, participants were provided with an optional debriefing form.

2.1.3 State Study

The state study recorded basic demography, and both dispositional and state mindfulness with FFMQ and TMS respectively (*see materials*). However, the state study only administered four cognitive bias tasks. These are: anchoring, belief bias, famous names and base rates tasks. Verbal instructions and a touchscreen tablet with headphones were provided to participants at the beginning of the experiment. Participants were left alone in the meditation suite to progress through the experiment guided by on-screen instructions. The survey initially prompted participants to complete a demographic questionnaire and FFMQ. Then, participants were randomized into: (1) Control, where participants listened to a 10-minute excerpt of The Hobbit audiobook; (2) Intervention, where participants listened and followed a 10-minute audio clip of a guided, mindfulness meditation session. Afterwards, participants were assessed on the battery of four cognitive bias tasks. Upon completion, participants were provided with an optional debriefing form.

2.2 Participants

2.2.1 Trait Study Recruitment.

Participants were recruited and assessed online through two sources: (1) Amazon's Mechanical Turk and (2) SONA, an undergraduate student pool internal to Western University. A total of 430 subjects opened the survey. However, 39 observations were removed prior to any analysis due to flagrant mischief, or participants exiting before submitting any meaningful data. Of the subjects with viable data, 308 were from MTurk, and 83 were from SONA ($N = 391$). All participants were required to be fluent in English as a first or second language. SONA participants were compensated for one course credit hour. MTurk participants received \$2.00 CAD per hour.

2.2.2 State Study Recruitment

Participants were recruited via community posters, mass email, and SONA. A total of 207 participants completed the study with 16 observations removed due to software glitches or participants deviating from protocol ($N = 191$). All participants were required to be fluent in English as a first or second language. SONA participants were compensated one course credit hour and all other participants were compensated with a \$15.00 CAD gift cards to popular merchants such as Amazon or Starbucks.

All participants for both studies read a letter of information and indicated informed consent in accordance with the Non-Medical Research Ethics Board at Western University.

2.3 Materials

3.2.1 Independent measures

Demographics Questionnaire. Age, gender, ethnicity, religious affiliation were recorded. In addition, participants were asked if they had any previous contemplative experience within the following categories: meditation, yoga, and other mind-body practices (eg. Tai-Chi, martial arts). Participants with experience were followed up with questions regarding cumulative and current practice single session duration.

Five Facet Mindfulness Scale (FFMQ). Trait mindfulness was measured using shortened, 18 item FFMQ (Medvedev et al., 2018). Authors evaluated psychometric validity via Rasch analysis and settled on an 18-item version; this was shortened from the original 39-item FFMQ (Baer et al., 2006). Participants rated agreement with items on a 1-5 point Likert scale where 5 indicated “very often or always true”. FFMQ consists of five subscales, each a unique facet of the general mindfulness construct. These are: (1) acting with awareness, (2) observation, (3) non-judgment of experience, (4) non-reaction to experience, and (5) descriptive ability of subjective experience.

Toronto Mindfulness Scale (TMS). State mindfulness was measured using a 0-4 point Likert scale with 4 representing “very much agreement” with the item (Lau et al., 2006). The instrument consists of a two-factor structure of Curiosity and Decentering. This scale was constructed to evaluate changes in state mindfulness after a period of mindfulness induction.

3.2.2 Dependent Measures

The following tasks measuring susceptibility to cognitive bias were given to participants: anchoring, belief bias, base rates, famous names, letter frequency, sunk costs. These tasks

represent measurements of anchoring, availability, extension neglect, and logical fallacy bias categories. For the trait study, participants were randomized to complete only three of six cognitive tasks in the battery. This was done with the intention to minimize experiment duration and minimize confounds due to fatigue.

Anchoring Task (ANC). Anchoring bias was measured using a modified version of the original task (Jacowitz & Kahneman, 1995). Participants were randomized to one of two 10 item lists of anchoring questions. Each question initially prompts with an anchor value (eg. Is the top speed of a house cat faster or slower than 7 mph?). Then the participant is asked to estimate the proposed value now having been influenced by the presence of the anchor. The anchoring effect would bias susceptible participants to estimate closer to the anchor value (eg. 7 mph) rather than further. The measure for this task is computed as the absolute difference between participant estimate and anchoring value, divided by the anchoring value. This anchoring score represents the ratio of estimated deviation relative to the magnitude of the original anchoring value. Higher scores represent less susceptibility to anchoring bias.

Belief Bias Task (BB). A syllogistic reasoning task was adapted from the methods developed by researchers aiming to measure deductive reasoning (Vroling & de Jong, 2009). A list of 64 syllogisms was split into two lists of 32 questions each. Participants were randomized into one of two lists for sake of brevity. These syllogisms were intentionally created to take on two distinct dimensions: (1) logical validity, (2) believability. Every syllogism has a consistent three-part structure of two premises and one conclusion. With two dimensions, each syllogism can be one of four permutations, valid-believable, valid-unbelievable, invalid-believable, invalid-unbelievable. Participants are asked to evaluate whether syllogisms are logically valid only, ignoring believability. When validity matches believability (valid-believable, invalid-

unbelievable), syllogisms are easy to evaluate. The converse is true for mismatched syllogisms, (valid-unbelievable, invalid-believable) which were more difficult to evaluate. Belief bias scores were computed as the mean difference in error rate for mismatched and matched type syllogisms. This calculation controls for baseline error rates regardless of syllogism type. Higher scores correspond to worse performance on this task. In addition, mean time duration per question was recorded in the state study only.

Base Rate Task (BR). This task is taken from an adaptation of the original base rate task from Tversky & Kahneman involving the classic stereotypes of the lawyer and engineer (Balzan et al., 2012; Tversky & Kahneman, 1974). A series of four questions each presented information in two separate phases: Lure and Reveal. This task is described using the lawyer-engineer problem as an example. In the Lure phase, stereotype information suggestive of a lawyer is presented: a man who dresses well, drives flashy cars, and is obnoxiously argumentative. Participants are asked to rate on a 1-10 point Likert scale whether this man is more likely to be an engineer or lawyer, 10 always represents the direction of the biased answer, in this case, the lawyer. In the Reveal phase, true base rate information is revealed about the situation, the man in question belongs to a club in which 69 men are engineers and 31 men are lawyers. Once again, participants are asked to assess the likelihood of the described man being an engineer or lawyer. In this case, the true base rate information suggests 7:3 higher statistical odds that the man in question is an engineer and thus is coded as the correct answer. Two measures were computed to assess performance; Lure Endorsement and Uprating score. Lure Endorsement is simply the response given during the Lure phase. Higher Lure Endorsement scores represent susceptibility to bias from the lure information. Uprating score is computed as the change in score towards true base rate direction relative to the initial lure endorsement score.

Higher updating scores correspond to larger corrections after true base rate information is presented indicating less susceptibility to base rate neglect.

Famous Names Task (FN). This task was adopted from (Balzan et al., 2012).

Participants were presented a random order sequence of 39 celebrity names shown for 3 seconds each. There are 19 famous names and 20 less famous names in each list. Participants were randomized into either the male list or the female list, in which the respective gender constitutes the 19 famous names of the list. After viewing the name sequence, participants were asked to estimate the proportion of male to female names on the list. FN gauges availability bias due to participants being more likely to recognize famous names, and assigning a higher proportion to the gender with famous names, even though there is one less name in the famous gender than the non-famous gender. Both female and male lists were combined by taking the proportion estimate in the biased direction for each respective list. High proportion estimates correspond to stronger availability bias.

Letter Frequency Task (LF). This task was adopted from (Balzan et al., 2012).

Participants are presented with five letters: K, L, N, R, V and asked whether each letter is more likely to exist as the first or third letter in all English words. They are then asked to estimate the proportion in which they believe each letter exists in 1st or 3rd position. In English, these five letters all exist in higher proportions at the third position. However, participants are likely to recall words that begin with the presented letter. Thus, they may bias their estimates to favour 1st position. The two measures were taken: letter position estimate and proportion estimate were both dummy coded such that 1 represents 3rd position, and 0 represents the 1st position. Estimates of 1st position represent ceding to availability bias in this task.

Resistance to Sunk Costs (RSC). In order to measure sunk cost bias, the Resistance to Sunk Costs subscale derived from the Adult Decision-Making Competence scale was adopted for use in the current study (Bruin et al., 2007). A scale of 10 items rated on a 1-6 point Likert scale tested participant's ability to resist doubling down on a prior invested situation. RSC is scored by taking the mean value of the 10 items. Higher scores are associated with stronger resistance to sunk cost scenarios.

2.4 Statistical Analysis

All data preprocessing and subsequent statistical analysis were conducted using R and RStudio IDE.

Groupwise comparisons were conducted using Welch's independent two-sample t-tests for the difference in means, and Wilcoxon Rank Sum tests for difference in medians when samples failed to meet normality assumption as evaluated by Shapiro-Wilk tests. Holm-Bonferroni method was used to control family-wise error in group comparisons. Individual facets of FFMQ, total FFMQ score, and the six cognitive bias tasks mentioned earlier were subject to comparisons grouped by meditation and contemplative experience. Significance is reported as $p < 0.05$, post family-wise error correction.

In the trait study, multiple regression models implemented FFMQ factors as predictors while controlling for the source of data (mTurk vs SONA), and survey version for tasks with more than one version. Performance on the six cognitive bias tasks was assessed by these models. In the state study, multiple regression models also tested FFMQ facets as predictors, controlling for experimental condition and task version. In addition, TMS was separately

modeled as a predictor, without controlling for the experimental conditions to evaluate state mindfulness effects.

3. Results

3.1 Subject Description

Table 1. Demographic Data and Contemplative Experience for Trait and State Studies. In addition to standard demographics, questions were asked about previous contemplative practices and total practice experience. Mean ages were ($M = 34$, $SD = 11$), and ($M = 26$, $SD = 10$) for Trait and State studies respectively.

Variable	Trait Study		State Study	
	<i>N</i>	%	<i>N</i>	%
Participant Source				
MTurk	308	79		
SONA	83	21		
Gender				
Male	188	48	60	31
Female	201	52	127	66
Other	1	0	4	2
Ethnicity				
White	299	77	78	41
Black	11	3	5	3
Asian	28	7	81	42
Other	52	13	27	14
Religion				
Catholic	41	10	21	11
Protestant	61	15	10	5
Christian	38	10	20	11
Muslim	13	3	24	13
Hindu	17	4	17	9
Buddhist	5	1	5	3
Sikh	4	1	3	2
Eastern Religions	11	3	1	0
Agnostic or Other	198	50	87	46
Previous Meditation Practice				
Yes	133	34	94	49
No	258	66	97	51
Meditation Experience				

None	258	66	97	51
<1 month	23	6	29	15
1-6 months	28	7	22	12
7-12 months	16	4	5	3
>1 year	66	17	38	20
Previous Contemplative Practice				
Yes	202	52	132	69
No	189	48	59	31
Contemplative Experience				
None	189	48	59	31
<1 month	42	10	35	18
1-6 months	41	10	30	16
7-12 months	19	5	8	4
>1 year	100	26	59	31

3.2 Trait Study

3.2.1 Differences in Meditation Experience

Within the trait study, participants were grouped and compared by experience for FFMQ and bias tasks. Experienced meditators were defined as having reported 6 or more months of consistent meditation practice and they showed higher scores on the Observe facet of FFMQ (Fig 1.) All other measures did not significantly differ by meditation experience, or did not survive correction for multiple comparisons.

Fig 1. Experienced meditators have higher trait mindfulness. Observe-facet of trait mindfulness as measured by FFMQ was higher in experienced meditators ($M = 3.96$, $SD = 0.77$) when compared to meditation-naïve participants ($M = 3.67$, $SD = 0.76$); $t(223) = 3.46$, $p = 0.004$, $d = 0.38$.

3.2.2 FFMQ Predicts Modest Variations in Task Performance

We regressed FFMQ facets as a predictor concomitant with participant source and task version significantly accounts for variation in anchoring, resistance to sunk costs, belief bias and both base rates task scores. Famous names and letter frequency tasks failed to be explained by FFMQ. Significant models explain a range of 5-15% of the total score variance for bias tasks. In some tasks, participant source and task version were significant predictors along with FFMQ facet predictors. FFMQ facets only predict small changes in task performance, even when the overall model is significant.

Of the significant models, anchoring was the most affected. (Table 2) Non-react facet explained increases in anchoring score which represents participants deviating from the presented anchoring value—suggesting increased resistance to anchoring bias. The other

significant model fit was for the BR lure endorsement rating. Unexpectedly, FFMQ-Observe facet predicted increased BR lure score, suggesting higher mindfulness participants were more susceptible to lure effects. Higher non-judge facet score predicts decreased errors committed on belief bias tasks, though task version also seemed to influence performance. Increases in FFMQ-Observe facet also predict increased resistance to sunk costs bias, though participant source again accounts for significant variation in task scores. All other task models pertaining FFMQ facets were non-significant.

Table 2. Trait Study: multiple regression of FFMQ facets as predictors of task performance. Five facets of FFMQ in addition to participant sources were entered as regressors in all models. For tasks that contain different versions (ie. FN male vs female names), task version is also entered as a predictor. All regression slopes are shown in the table.

Predictors	Cognitive Bias Measures							
	ANC	FN	RSC	LF position	LF proportion	BB	BR Lure endorse	BR Uprate
FFMQ								
Observe	-0.10	0.67	0.18*	0.01	1.52	-0.16	0.50***	0.24*
Act-Aware	0.22	1.60	-0.03	-0.01	1.06	-0.02	-0.02	-0.10
Non-Judge	-0.22	-0.13	0.11	-0.00	0.26	-1.36***	-0.14	-0.00
Describe	-0.52	-2.54	0.04	-0.03	6.67*	-0.02	0.33	0.33*
Non-React	0.63**	-1.02	-0.04	-0.01	-2.30	0.68	0.09	-0.25*
Source	-0.95	2.54	-0.43*	0.04	8.94*	-1.83*	-0.14	-0.27
Version	-0.91**	0.18				-0.70		
F	4.38	0.65	3.89	0.57	1.62	3.16	5.76	2.83
DF	7, 128	7, 175	6, 177	6, 184	6, 184	7, 172	6, 183	6, 182
R ²	0.149	-0.014	0.087	-0.014	0.019	0.078	0.131	0.055

Sources indicate the source of participant recruitment as a factor variable (MTurk or SONA). Version is also a factor variable coding for tasks which have more than one version such as the FN task which uses either a female or male name list. Significant predictors are indicated in bold with asterisk (*p < .05, **p < .01, ***p < .001). Model R squared shown is adjusted for number of predictor variables, bolded values indicate significant model fit p < .05.

3.3 State Study

3.3.1 Differences between Experimental Conditions.

Participants were equally randomized into either a mindfulness induction group or a control group. State mindfulness and cognitive task measures were compared across conditions. Participants in the meditation group had higher state mindfulness post-intervention suggesting the mindfulness intervention was successful (Fig 2). However, there were no significant differences in cognitive task performance across conditions.

Fig 2. Meditation intervention increased state mindfulness. Participants in the meditation intervention group had higher state mindfulness (Mdn = 14) post intervention relative to the control group (Mdn = 11), $W = 3574$, $p = 0.03$; as measured by curiosity subscale of the TMS.

3.3.2 Experienced Meditators Exhibit Higher Trait Mindfulness.

Experienced meditators were defined as those reporting more than 6 months of consistent mindfulness practice. Meditators were compared against non-meditators for trait mindfulness, state mindfulness, and cognitive bias task performance. Experienced meditators scored higher on trait mindfulness in total FFMQ score, Non-Judge and Describe subscales (Fig 3). Experienced

meditators did not significantly differ from inexperienced participants in task performance or state mindfulness.

Fig 3. Experienced participants have higher trait mindfulness. Experienced meditators had higher total trait mindfulness ($M = 3.32$, $SD = 0.38$) than inexperienced participants ($M = 3.12$, $SD = 0.37$), $t(136) = 3.51$, $p = .009$. Meditators also had higher Non-Judge facet scores ($M = 3.04$, $SD = 0.92$) than non-meditators ($M = 2.55$, $SD = 0.71$), $t(111) = 3.81$, $p = .002$. Meditators scored higher on Describe-subscale ($M = 3.36$, $SD = 0.45$) than non-meditators ($M = 3.14$, $SD = 0.47$), $t(142) = 3.28$, $p = .010$. Pointranges indicate mean and standard deviation.

3.3.3 Trait Mindfulness predicts limited aspects of state mindfulness and task performance.

Facets of FFMQ were regressed along with experimental conditions and task versions as predictors (Table 3). FFMQ significantly predicted both subscale scores of TMS. Higher FFMQ-Observe subscale predicts increased TMS curiosity scores, but within the same model, higher FFMQ Non-judge facet discrepantly predicts decreased TMS curiosity scores. These discordant predictions suggest the curiosity subscale of TMS has a weak relationship with trait mindfulness.

TMS decentering is also weakly predictable from FFMQ facets. High FFMQ Observe facet scores predict increased TMS decentering scores and FFMQ Non-react facet similarly predicts increased TMS decentering, as expected.

FFMQ had limited success at predicting performance on cognitive bias tasks. Trait mindfulness facets predicted increased performance on resisting anchoring bias. Counter to our hypotheses, trait mindfulness also predicted higher susceptibility to famous names and base rate endorsement. Belief bias score, task duration and Base rate uprating failed to be significantly explained by FFMQ facets.

Table 3. State Study: regression modeling of FFMQ as predictors of cognitive bias task performance and state mindfulness.

Predictors	TMS		Cognitive Bias Measures					
	curiosity	decenter	ANC	FN	BB score	BB time	BR lure	BR uprate
FFMQ								
Observe	1.32*	1.38*	0.06	-0.13	0.30	0.69	-0.03	-0.05
Act-Aware	0.90	0.77	0.16	0.23	0.29	0.45	-0.07	-0.14
Non-Judge	-1.46*	-0.45	0.07	0.31	-0.19	0.08	-0.30**	0.08
Describe	0.46	-0.39	0.11	4.34*	-0.17	0.55	-0.01	0.19
Non-React	0.29	0.97	0.21	1.00	-0.14	0.12	0.05	0.06
Condition	1.93**	-0.13	0.02	-1.59	0.03	-0.60	0.35*	0.04
Version			-0.51**	-4.54**				
F	3.43	2.07	3.95	2.19	1.07	0.60	2.58	0.39
DF	6, 174	6, 174	7, 147	7, 169	6, 174	6, 174	6, 171	6, 171
R ²	.075	.034	.118	.045	.002	-.013	.051	-.021

Condition refers to experimental condition dummy coded as factors: 0 for control, 1 for intervention. Version is also a factor variable coding for tasks that have more than one version such as the famous names task which uses either a female or male name list. Significant betas are indicated in bold with asterisk (* $p < .05$, ** $p < .01$, *** $p < .001$). Model R squared shown is adjusted for number of predictor variables, bolded values indicate significant model fit $p < .05$.

3.3.4 State mindfulness is a poor predictor of Task Performance

The two facets of TMS state mindfulness scale: curiosity and decentering were regressed in addition to task version as a factor variable. Of all model fits, only anchoring task and base rates lure endorsement were significant. Of the anchoring task, the only significant predictor was task version thus relegating TMS subscales as irrelevant to anchoring task performance. The base rates lure endorsement measure had both subscales: curiosity and decentering as significant predictors of task performance. Curiosity scores predicted increased susceptibility to lure, while decentering predicted decreased susceptibility. All other tasks were not significantly predicted by TMS models. These weak and contradictory predictions suggest that state mindfulness may be unrelated to susceptibility to cognitive biases.

Table 4. State Study: regression modelling of TMS as predictors of cognitive bias task performance. TMS subscale measures Curiosity and De-centering are used as regressors in addition to task version.

Predictors	Cognitive Bias Measures					
	ANC	FN	BB score	BB time	BR lure	BR uprate
TMS						
curiosity	-0.01	0.13	0.03	0.02	0.03*	-0.02
decenter	0.02	-0.10	0.00	0.12	-0.05**	0.01
Version	-0.54***	-4.34*				
F	4.72	2.44	1.08	1.67	4.40	0.88
DF	3, 159	3, 183	2, 188	2, 188	2, 185	2, 185
R ²	0.064	0.023	0.001	0.007	0.035	-0.001

Version is a factor variable coding for tasks that have more than one version such as the famous names task which uses either a female or male name list. Significant betas are indicated in bold with asterisk (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Model R squared shown is adjusted for number of predictor variables, bolded values indicate significant model fit $p < 0.05$.

4. Discussion

4.1 Trait Mindfulness and Decision Making

Regarding our sample of participants, experienced participants had overall higher trait mindfulness as measured by the FFMQ. This is to be expected, engaging in consistent mindfulness practice has been shown to raise basal trait mindfulness (Manuel et al., 2017; Shapiro et al., 2011).

As for the influence of trait mindfulness on bias and heuristic use, we found a handful of tasks; anchoring, resistance to sunk costs, letter frequency, and base rates had higher performance on outcome measures as explained by FFMQ scores. It has previously been hypothesized that mindfulness may reduce susceptibility to cognitive bias use for tasks such as anchoring and availability (Goyal et al., 2014; Sibinga & Wu, 2010). Our results are in support of these previous hypotheses. Previous work has also shown trait mindfulness to influence resistance to sunk costs biases (Hafenbrack et al., 2014). Although our study provides weaker evidence than the data by Hafenbrack and colleagues, our results nonetheless corroborate their conclusions; trait mindfulness explains a reduced susceptibility to sunk costs biases.

We hypothesized that increased trait mindfulness would be associated with higher resistance to cognitive biases and heuristics. We found evidence in support of these hypotheses in four of our six tasks; anchoring, resistance to sunk costs, letter frequency, and base rates. However, our hypotheses were not supported for two tasks; famous names and belief bias, which represent availability heuristic and logical fallacy bias. Reduced engagement in biased cognition suggests higher recruitment of System II in individuals with higher mindfulness.

4.2 State Mindfulness and Decision Making

In the state study, we also collected FFMQ data regarding trait mindfulness. We found consistent results regarding meditation experience. Experienced practitioners show significant overall higher mindfulness, and in factors; non-judgment and describing. These results are

consistent with previous evidence on the matter (Manuel et al., 2017; Shapiro et al., 2011). Similar to the trait study, FFMQ scores were predictive of anchoring, famous names and base rates task performance. Likewise, the belief bias task was not meaningfully explained by trait mindfulness, indicating that logical fallacy biases might be uniquely indifferent to trait mindfulness effects. Notably, TMS state mindfulness scores were well predicted by FFMQ scores, which is a common interpretation in the literature (Bravo et al., 2018; Kiken et al., 2015). Although disparate at times, state and trait mindfulness constructs appear to be distantly related at minimum (Bravo et al., 2018; Medvedev et al., 2017).

The state study included an intervention that split subjects into control vs mindfulness conditions. Comparing outcome measures between the two conditions revealed participants of the mindfulness condition had significantly higher TMS curiosity subscale scores. These results indicate that our mindfulness induction was sufficient for inducing a mindful state. This is unsurprising, as previous work has demonstrated; short interventions no longer than 15 minutes are sufficient for eliciting increased state mindfulness (Kiken et al., 2015; Lau et al., 2006). Unexpectedly, cognitive bias task performance did not differ between intervention conditions, suggesting that mindfulness induction did not alter system I and system II cognition to any noticeable degree. These results are contrary to existing data (Burgess et al., 2017; Hafenbrack et al., 2014; Kiken & Shook, 2011; Lueke & Gibson, 2015; Raglan, 2014), which claims mindfulness improves resistance to cognitive biases. This result is interesting considering TMS state mindfulness scores were significantly higher for the mindfulness condition, yet no effect on bias reduction was noticeable. Furthermore, regression analysis revealed TMS to be a poor predictor of task performance. Task version: an external confound, often accounted for more

variance in task performance than TMS scores. All of these results suggest state mindfulness does not affect bias and heuristic cognition.

We propose two possible explanations for why our data contradict existing studies. (1) It might be the case that our mindfulness induction wasn't of sufficient magnitude or intensity. The intervention was only 10 minutes in duration and was an audio-guided meditation. Not much research has been done comparing state effects of guided versus self-directed mindfulness meditation. We speculate that guided meditation may be more distracting, especially for beginners. As a result, subjects may not experience sufficiently deep state mindfulness to meaningfully alter cognition. (2) State mindfulness is known to be somewhat distinct from trait mindfulness, as shown by a handful of studies comparing the two (Bravo et al., 2018; Kiken et al., 2015; Medvedev et al., 2017). Although state and trait mindfulness measures may correlate, they may differ mechanistically regarding higher cognition; state and trait mindfulness may differentially influence executive functions like attention, working memory, and inhibition (Basso et al., 2019; Chiesa et al., 2011). The difference in mechanisms may explain the varying outcomes in regards to cognitive biases and heuristic susceptibility.

4.3 Mechanisms influencing Decision Making

Several studies have suggested that either trait or state mindfulness can lead to an increased tendency to omit common cognitive biases (Burgess et al., 2017; Hafenbrack et al., 2014; Kiken & Shook, 2011; Lueke & Gibson, 2015). It has been hypothesized that mindfulness may improve performance in higher-order cognition through affective mechanisms (Hafenbrack et al., 2014; Raglan, 2014). Mounting evidence has shown mindfulness interventions can lead to increased positive affect while decreasing negative affect (Basso et al., 2019; Gu et al., 2015; Jha et al., 2010; Lao et al., 2016). Subsequently, much work has revealed mood can meaningfully

alter cognition, including direct changes to decision-making processes (Blanchette & Richards, 2010; Hockey et al., 2000; Medlin & Warman, 2014). Reduction of negative affect has been shown to improve higher-order cognitive processes such as attention, working memory, and inhibition (Basso et al., 2019; Chiesa et al., 2011; Jha et al., 2010; Lao et al., 2016), which are undoubtedly recruited when subjects are actively resisting biases and heuristics.

4.4 Limitations

Our results suggest that mindfulness improves resistance to select biases. However, because we did not include measures of affect, we cannot conclude whether changes in mood could have mediated the resistance to cognitive bias.

In our state study, we reasoned based on previous literature that a short mindfulness induction would be sufficient to elicit the desired state mindfulness effects (Kiken et al., 2015; Lau et al., 2006). However, a significant portion of our participants turned out to be inexperienced meditators, with many reporting having never engaged in meditative practices ever. Although we had used guided meditation, it may be unreasonable to expect complete novices to reliably induce a state of mindfulness within such a short time.

For trait mindfulness measures in both the trait and state studies, we utilized a shortened 18-item version (Medvedev et al., 2018), of the original 39-item FFMQ (Baer et al., 2006), for sake of brevity. Although the shortened version has been validated to generally reproduce similar measurements as the original; analyzing FFMQ facets leads to a pseudo-continuous distribution of values simply due to the low number of items per facet. As a result, individual facets may lose explanatory power in the shortened version as compared to the original.

5. Conclusion

In sum, trait mindfulness is associated with a reduction in susceptibility to anchoring, resistance to sunk costs, logical fallacies, and availability type biases. Improved state mindfulness was not associated with any meaningful improvements in resistance to any of the aforementioned cognitive biases. It appears that trait, but not state mindfulness, is operative in changing susceptibility to cognitive bias. Future work will do well to include measures of affect, which may provide deeper insight into the mechanism by which mindfulness relieves bias susceptibility.

6. References

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