Title

Personalizing Practice using Preferences for Meditation Anchor Modality

Abstract

Many new people are engaging contemplative practices and Mindfulness-Based Interventions (MBIs) have become quite popular. While MBIs positively impact well-being, drop-out and lack of practice-maintenance plagues these interventions, which use the breath to anchor attention. No study had yet compared preferences for practices using anchors from different sensory modalities (e.g. auditory, visual) thus the present study examined such individual differences, sharing resources on the OSF (osf.io/hcnz2/). Participants engaged 10-min practices within three modalities (somatosensory, auditory, visual) and post-practice preferences were modelled. Preference differences did exist: 49% preferred the breath, 30% the auditory-phrase, and 21% the visual-image. Pre-practice motivation and anchor-modality were primary predictors and cardiac responses also influenced preference. Preferences were updated through experience and over half of participants left the experiment preferring a different anchor than when entering. Tangible next-steps are discussed, including integrating additional anchor modalities into existing interventions by offering brief practices with a variety of anchors. Suggestions are made for increasing post-training contact using email-automation to answer central practice-maintenance questions, including whether and which contemplative benefits are predicated on continued practice.

Keywords

Preference; motivation; heart-rate; personalization; MBI; mindfulness; meditation; attention

1. Introduction

Growing numbers are engaging in contemplative practices to cultivate and maintain well-being. The scientific literature encourages these efforts suggesting that Mindfulness-Based Interventions (MBIs) positively impact well-being measures across a variety of domains (Goyal et al., 2014; Khoury et al., 2013). Benefits may be “gradual, progressive and [requiring] regular practice” (Grossman, Niemann, Schmidt, & Walach, 2004, p. 36) thus fostering the establishment and maintenance of daily self-directed contemplative practice is one goal of MBIs.

Unfortunately, approximately 30% of participants in MBIs drop out before completing even half the available sessions (Crane & Williams, 2010; Khoury et al., 2013; Nam & Toneatto, 2016). While attrition rates issues are known, indicators for identifying which participants will drop out are lacking (Dobkin, Irving, & Amar, 2012; Hanley, Abell, Osborn, Roehrig, & Canto, 2016; Nam & Toneatto, 2016). Further, up to half of course-completing participants skip self-directed practice (Crane et al., 2014). Failing to establish self-directed practice during a course seems a likely warning sign that practice may be dropped following MBI completion, undermining intervention-related benefits predicated on practice-maintenance (Grossman et al., 2004, Crane et al., 2014).

Why do people cease practising? Most research lacks measures addressing this question thus factors predicting practice-maintenance have yet to be found (Grossman et al., 2004; Nam & Toneatto, 2016), though time-demands and practice-difficulty are commonly reported challenges (Anderson, Suresh, & Farb, Manuscript in preparation). Little attention has been paid to the possibility that individuals may differ in partiality toward different practices. Attentional anchors differ between practices and arbitrarily prescribing one anchor-type over others may act as a

barrier to practice. Partiality - the disposition or inclination a person has toward a practice, whether favourable, neutral, or unfavourable - may be updated through experience. Preference may increase when practices promote rewarding psychophysiological states of relaxation or engagement (Shearer, Hunt, Chowdhury, & Nicol, 2015) and decrease if aversive states of frustration or confusion arise (Farias & Wikholm, 2016). Partiality may thus be diminished by difficulty and individuals may prefer practices that reflect their abilities, e.g. composers may be more motivated to try an auditory-practice while gymnasts may favour a somatosensory anchor, such as the breath. Matching prescribed-practice to preferred-practice may thereby contribute to establishing and maintaining self-directed contemplative practice (Swift, Callahan, & Vollmer, 2011).

1.1 Practice Anchors

Modern MBIs use somatosensory anchors of attention, almost universally beginning with breath-focused awareness to anchor attention. By extension, breath- and body-based practice constitutes the majority of contemplative science research and the clinical and non-clinical benefits of breath-based mindfulness practices are abundantly documented (Goyal et al., 2014; Khoury et al., 2013; Mrazek et al., 2014). These somatosensory-practices are not, however, universally established, maintained, or enjoyed: beyond the drop-out rates discussed above, research also describes adverse reactions to breath-based practices (Anderson et al., Manuscript in preparation; Lindahl, Fisher, Cooper, Rosen, & Britton, 2017).

Investigators have also explored auditory phrase-based practices, such as the phrase-based Transcendental Meditation technique (Travis & Shear, 2010). Independent work has also shown effects of silently repeated speech (Berkovich-Ohana, Wilf, Kahana, Arieli, & Malach,

2015) and semantically meaningful phrases are often used in value-based meditations, e.g. compassion/loving-kindness practices (Kristeller & Johnson, 2005). Silently-repeated auditory-anchors provoke distinct patterns of neural activation from breath-anchored practices, reducing activity in the anterior cingulate cortex and insular cortex rather than activating them (Fox et al., 2016). With both distinct and overlapping mechanisms of action, whether the choice of anchor is intrinsic to the efficacy of the intervention remains an open question worthy of research (Schoormans & Nyklíček, 2011; Travis, 2011).

Contemplative practices involving visual stimuli have been far less studied, perhaps due to the complexity of many image-based practices and the religious iconography often employed. Image-based practices may involve complex imagery, such as moving "energy fields" ("qi-gong", Burke, 2012), or deities in complex scenes ("Vajrayana", Amihai & Kozhevnikov, 2014). Performing such complex practices in a laboratory may be unrealistically demanding for a novice when compared to simpler anchors like the breath or a short phrase. Similarly, religious iconography runs counter to secular MBI mandates that allows them to thrive in Western institutions (Farb, 2014). A simple and secular visual anchor could circumvent these limitations: the plain coloured-disk used as an anchor of attention in one image-based practice ("kasina" practice, Amihai & Kozhevnikov, 2014).

No study has compared partiality for anchors using different sensory modalities (somatosensory, auditory, visual), though participants differed in their preferences after trying four types of somatosensory-based practices (Burke, 2012). In the broader clinical literature matching partiality for treatment options significantly decreases likelihood of drop-out (Swift et al., 2011), yet partiality-matching is not presently offered in MBIs. Partiality-matching in MBIs may plausibly help decrease drop-out and facilitate practice-establishment, but only if partiality

for different sensory anchors exists. The current study investigated and revealed partiality between three anchors differing in their sensory modalities: breath-based somatosensory practice, phrase-based auditory practice, and image-based visual practice.

1.2 The Present Study: Partiality and its Possible Predictors

The present study examined individual differences in partiality for contemplative practice anchors. Participants attempted brief practices within each modality (somatosensory, auditory, visual) allowing for a characterization of individual differences in partiality. We attempted to model preference (the post-practice report of partiality) as a function of several candidate predictors: initial bias, pre-practice motivation, sensory discriminability, dispositional personality and mindfulness, and physiological response to practice.

1.2.1 Initial Bias and Motivation

Partiality is the disposition a person has toward a practice, whether favourable, neutral, or unfavourable. Our most basic hypothesis is that (H1) individual differences in partiality between practice anchors exist. If partiality exists, we expect that (H1a) higher motivation to engage immediately prior to practice will predict post-practice preference and that (H1b) favorable initial biases will lead to higher motivation to engage.

1.2.2 Sensory Discriminability

Individual sensory discriminability could plausibly allow some individuals to experience rewarding psychophysiological states more readily when using an anchor within their better-tuned modalities. As each anchor engages a different sensory modality we predicted that (H2) sensory discriminability would increase preference for within-modality anchors.

1.2.3 Dispositional Variables

Dispositional personality and mindfulness variables were also expected to (H3) meaningfully predict preferences. Conscientiousness predicts health-beneficial behaviours (Murray & Booth, 2015) and given the health benefits of meditation higher Conscientiousness was expected to increase preferences. Openness was expected to increase preferences as the practices were novel to all participants. The affective volatility of Neuroticism is counter to the relaxed engagement promoted by contemplative practice and thus was expected to decrease preferences. No directional predictions were made for Extraversion and Agreeableness. We expected that mindfulness would increase preferences and mind-wandering tendency would decrease preferences.

1.2.4 Physiological Response

We expected that cardiac and respiratory experiences of rewarding psychophysiological states during practice would increase post-practice preferences. Specifically, we expected that (H4a) decreases in heart-rate and (H4b) increases in high-frequency heart-rate-variability would increase preference as these have been considered physiological markers of beneficial practice (Olex, Newberg, & Figueredo, 2013; Shearer et al., 2015). Similarly, we expected that (H4c) decreases in respiration-rate would increase preference.

2. Methods

Questionnaires, stimuli, code, and practice instructions are shared on the Open Science Framework (osf.io/hcnz2/).

2.1 Participants and Procedure

Meditation-naïve undergraduates participated in exchange for course-credit or financial remuneration. Of 117 participants 82 (70%) were retained for analysis: the investigator (TA) and 3 research assistants independently reviewed open-ended comprehension/compliance questions and agreed (Fleiss' kappa = 0.365) that 35 participants did not comply with practice instructions. The final sample was, on average, 20 years old (SD: 2.25) and 59% female; age and gender did not moderate results. Participants completed computer-based questionnaires, then sensory discriminability and mind-wandering tasks. Participants read general practice instructions, then anchor-specific instructions, for three 10-minute meditation practices (breath, phrase, and image). Practice-anchor order was pseudorandomized and did not moderate results.

2.2 Practice Instructions

Practice instructions were an unsupervised, manualized practice with an attention-anchor. Instructions were uniform across meditation conditions save for anchor modality descriptions: the somatosensory anchor was the sensation of breathing, the auditory anchor was a meaningless word-like phrase ("ay-lo-ra") played through headphones during instructions only, and the visual anchor was a simple image (green circle) shown on-screen during instructions.

2.3 Questionnaires

2.3.1 Subjective Partiality

Participants were told they would experience three meditations with different anchors. Initial Bias was assessed by asking participants "For each type of meditation please rate how much you expect to enjoy it". After reading the instructions and immediately before engaging

each meditation Motivation was assessed by asking participants "Please indicate how motivated you presently feel to engage in the meditation". The literature contains no standard measure of post-meditation Preference thus a novel questionnaire was developed (sample items: "I found the experience physically relaxing or restful", "I found the meditation difficult"). All items were rated using 0 ("Not at all") to 100 ("Very much") continuous slider scales and Preference for a particular anchor was computed as the average of the 15 retained items ($\alpha = 0.92$).

2.3.2 Dispositional Personality

The Big Five Inventory (BFI; McCrae & John, 1992) measures personality using the five-factor model. The original BFI contains 44 statements ("I see myself as someone who...") that participants rate on a 5-point scale. In the present study all items were rated using 0-100 slider scales with nominal descriptors at 0 ("Strongly Disagree"), 50 ("Neutral"), and 100 ("Strongly Agree") (Matejka, Glueck, Grossman, & Fitzmaurice, 2016). This alteration did not negatively impact reliability (Extraversion $\alpha = 0.87$, Agreeableness $\alpha = 0.77$, Conscientiousness $\alpha = 0.82$, Neuroticism $\alpha = 0.83$, Openness $\alpha = 0.71$).

2.3.3 Dispositional Mindfulness

Dispositional mindfulness was assessed through two scales: The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003; five-item short-form, Osman et al., 2015; Van Dam et al., 2010), and the Cognitive and Affective Mindfulness Scale Revised (CAMS-R; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2006). MAAS and CAMS-R items were averaged into one "MIND" score: the MAAS reverse-scores constructs opposed to mindfulness, i.e. "automatic-ness", and the CAMS-R measures positive aspects of mindfulness: attention regulation, present-minded awareness, and non-judgemental acceptance. To retain uniformity

with the BFI, MAAS and CAMS-R items were rephrased to match the BFI style ("I see myself as someone who...") and were rated using the same 0-100 slider scales, which did not negatively impact reliability (MIND $\alpha = 0.75$, MAAS $\alpha = 0.73$, CAMS-R $\alpha = 0.67$).

2.4 Tasks

2.4.1 Behavioural Mind-Wandering

The Metronome Response Task (MRT) was used to behaviourally measure mind-wandering, which has been linked to response-variability when participants tap the steady beat of the MRT (Seli, Cheyne, & Smilek, 2013). For further details see Supplemental Materials.

2.4.2 Sensory Discriminability

Three psychophysical staircases measured sensory discriminability in the three anchor modalities: somatosensory (vibration-detection), auditory (pitch-discrimination), and visual (colour-saturation discrimination). For further details see Supplemental Materials.

2.5 Physiological Recording

Participants wore a heart- and respiration-rate monitor for the duration of the experiment (BioHarness 3; Zephyr Technology, Annapolis, MD, USA). Heart-rate, high-frequency heart-rate-variability, and respiration-rate were recorded (Johnstone, Ford, Hughes, Watson, & Garrett, 2012a, 2012b).

3. Results

3. 1 Data Analysis

Multilevel modelling was used to predict Preference, nested within participant (Enders & Tofighi, 2007), and model-fits are reported as Bayesian Information Criterion (BIC, Schwarz, 1978) and Akaike Information Criterion (AIC, Akaike, 1973). A priori stepwise linear regression used an intercept-only baseline model. H1 was assessed by using Anchor-type as a predictor, H1a was tested by adding Motivation, H1b by adding Bias, and H3 by adding dispositional personality and mindfulness variables.

Attrition from tasks was not anticipated thus modelling H2 has been rearranged: 77 of 82 participants completed psychophysical staircases thus the model testing H2 was computed separately to avoid limiting model sample sizes. The best model attained above served as the base-model and the modality-specific JND score was added to test H2. Similarly, as 62 of 82 participants completed the MRT thus it was computed separately as an extension of H3 (H3_{MRT}).

3.1.1 Physiological Data Preprocessing

Heart-rate (HR), high-frequency heart-rate-variability (HF-HRV), and respiration-rate (RR) were recorded as markers of physiological response to meditation. ECG was recorded at 250 Hz, R-to-R intervals interpolated at 4 Hz, and HR filtered to 30-125bpm. Following Berntson et al. (1997) two four-minute epochs were created by trimming the first and last minutes of practice periods. Within-subjects baselines were calculated as averages of the medians of two four-minute epochs (questionnaire and task periods). HR change scores (ΔHR) are the percent difference between baseline and practice-epoch median. Respiration-rate was

filtered to 6-30 breaths-per-minute and Δ RR change scores calculated in the same manner. HRVs were computed with Fourier transforms, HF band-power (0.15 to 0.4 Hz) was analyzed, medians were log-transformed, and Δ HF-HRV change scores calculated.

The Zephyr BioHarness 3 fits under the clothing thus participants affixed it themselves. Unfortunately, 30-35% of cardiac data was problematic (not properly collected, intermittent device connectivity, excessive noise) thus these data-points were dropped (HR: 25, HF-HRV: 29, RR: 3). As with JND and MRT analyses the models testing H4a-c were computed separately with the best model attained by the stepwise regression. Physiological response during both halves of practice showed considerable collinearity (Δ HR $r=0.87$, Δ HF-HRV $r=0.82$, Δ RR $r=0.68$) thus are not modelled together; the second-half recordings consistently captured more variance and are reported.

3.2 Prevalence of Partiality

Confirming H1 individual differences were found in anchor partiality at every stage of the experiment (see Fig 1A-C). At Bias most-favoured anchors were Image (41%) followed closely by Breath (34%). At Motivation most-favoured anchor was Breath (49%) followed by Image (20%). At Preference most-favoured anchor was Breath (49%) followed by Phrase (30%). A two-part updating effect was observed: the effect of reading the meditation instructions (Bias to Motivation, 52% change favourite) and the effect of engaging the meditation (Motivation to Preference, 55% change favourite). Most favoured anchor changed at some point for 77% of participants and 56% of participants left the experiment with Preference favouring a different anchor than their initial Bias.

Fig 1. Distributions of Partiality

Differences in partiality were found throughout the experiment, confirming H1. Motivation and Preference show 49% of participants favour the Breath, but these individuals are not identical: Preferences sometimes favoured one anchor despite higher Motivation for a different anchor (Breath: 18%, Phrase: 22%, Image: 11%). Similarly, Motivation sometimes favoured one anchor despite discrepant Bias (Breath: 21%, Phrase: 10%, Image: 7%).

3.3 Predicting Anchor Preference

The intraclass correlation coefficient indicated within-participant Preference ratings were not independent (ICC=0.294, Peugh, 2010). H1a was the best-fitting model demonstrating a large significant effect of Motivation ($\beta=0.456$, $p<0.0001$, $r=0.52$) with greater pre-practice Motivation predicting greater post-practice Preference. A moderate effect of Anchor (β -Breath = 0.174, β -Phrase = 0.156, β -Image = -0.330, $p<0.0001$, $r=0.38$) reflected that, on average, participants preferred Breath (M: 62.63, SD: 1.93) and Phrase (M: 59.35, SD: 2.02) practices over the Image (M: 51.32, SD: 2.23) practice (Breath: $t(81)=4.407$, $p<0.0001$, Phrase: $t(81)=3.53$, $p<0.001$). Counter to H1b, H2, and H3 (and H3_{MRT}) models with additional predictors were not superior (see Tables 1-3). Supporting H4a/b cardiac response predicted Preference (Δ HR: $\beta=0.185$, $p<0.014$, $r=0.24$, Δ HF-HRV: $\beta=0.20$, $p<0.009$, $r=0.26$), yet counter to H4c respiration did not ($p=0.526$). As Anchor did not predict cardiac responses (Δ HR: $p=0.69$, Δ HF-HRV: $p=0.39$) they were not pursued as mediators of the Anchor-Preference relationship.

Table 1. Predicting Preference - Questionnaires

Intercept		H1			H1a			H1b			H3		
Model BIC	695	683			637			642			671		
Model AIC	684	665			616			618			625		
Predictor		β	SE	r	β	SE	r	β	SE	r	β	SE	r
Anchor	Breath	0.25	0.11		0.17	0.09		0.17	0.10		0.18	0.10	
	Phrase	0.08	0.11	0.36	0.16	0.09	0.38	0.15	0.10	0.38	0.14	0.10	0.37
	Image	-0.34	0.11		-0.33	0.09		-0.32	0.10		-0.32	0.10	
Motivation					0.46	0.06	0.52	0.47	0.07	0.49	0.45	0.07	0.46
Bias								-0.03	0.06	0.04	-0.04	0.06	0.05
Mindfulness											0.11	0.09	0.13
Conscientiousness											-0.04	0.08	0.06
Openness											0.06	0.07	0.09
Neuroticism											-0.02	0.08	0.02
Extraversion											0.01	0.07	0.01
Agreeableness											0.05	0.07	0.08

Table 2. Predicting Preference - Tasks

		H1a	H2			H1a	H3 _{MRT}		
sample n		77	77			62	62		
Model BIC		562	566			498	503		
Model AIC		542	542			479	481		
Predictor			β	SE	r		β	SE	r
Anchor	Breath		0.19	0.10			0.15	0.11	
	Phrase		0.14	0.10	0.39		0.15	0.11	0.41
	Image		-0.36	0.10			-0.42	0.11	
Motivation			0.45	0.06	0.54		0.49	0.07	0.54
JND Threshold			-0.08	0.06	0.12				
MRT Variability							0.01	0.07	0.01

Table 3. Predicting Preference - Physiological Response

	H1a	H4a			H1a	H4b			H1a	H4c		
sample n	57	57			53	53			79	79		
Model BIC	457	456			427	425			600	606		
Model AIC	438	434			409	404			580	582		
Predictor		β	SE	r		β	SE	r		β	SE	r
Anchor	Breath	0.15	0.12			0.10	0.12			0.18	0.10	
	Phrase	0.12	0.12	0.42		0.14	0.12	0.38		0.13	0.10	0.35
	Image	-0.47	0.12			-0.43	0.12			-0.34	0.10	
Motivation		0.42	0.07	0.51		0.43	0.07	0.52		0.46	0.06	0.53
Δ HR		0.19	0.07	0.24								
Δ HF-HRV						0.20	0.08	0.26				
Δ RR										-0.04	0.06	0.05

3.3.1 Predicting Motivation and Bias

Motivation was uncovered as the primary predictor of post-practice Preference. While an interesting and expected finding, this result begs the question of what predicts Motivation and initial Bias. We explored these questions in detail in the Supplemental Materials: Motivation was predicted by Bias ($\beta=0.324$, $p<0.0001$, $r=0.44$) and Anchor (β -Breath=0.143, β -Phrase=-0.034, β -Image=-0.108, $p<0.0124$, $r=0.26$) and Bias was predicted by Anchor (β -Breath=0.096, β -Phrase=-0.389, β -Image=0.293, $p<0.0001$, $r=0.37$).

4. Discussion

The present study tested the hypothesis that there exist substantive individual differences in partiality toward meditative anchors of attention, variability not previously described. Breath-anchored meditation is the most popular contemporary practice and is central to popular mindfulness-based interventions, but only one third of participants favored the breath at study

entry; more participants expected to enjoy an Image-based practice. The lack of consensus was not present only as initial Bias: after trying three different anchors only 49% of the participants favored the Breath. These results suggest that, while the Breath anchor does have popular appeal, this Preference is not universal and indeed at least half of participants would choose other anchors if given the choice. Focusing initial training exclusively on somatosensory anchors may constitute lost opportunities to incentivize early meditation training and some aspiring meditators may be more likely to establish and maintain self-directed practice habits if taught an auditory-Phrase or visual-Image practice. Offering alternate anchors is a tangible next-step that could be integrated into existing interventions.

While asking a potential meditator about anticipated favourites offers a starting point for improving engagement, reviewing instructions and offering actual experience are potent ways of informing which anchor is preferred and could be suggested for self-directed practice. Partiality shifted when participants considered the mediation instructions and through their brief practice with the anchors thus both conceptual and experiential knowledge updated partiality. Indeed, partiality was surprisingly flexible and a mere ten minutes of practice with each anchor was sufficient to shift favourite anchor at some point for 77% of participants. Over half of participants left the experiment preferring a different anchor than when entering and while initial Bias was not a significant predictor of final Preference, pre-practice Motivation to engage the anchor was. The Image anchor showed a particularly precipitous drop from its status as most-popular to least-popular anchor (41% to 20%); it may be that participants anticipated elaborate, guided visualizations that our simple anchor did not match.

Homeostasis-facilitating states may be one beneficial pathway of meditation (Farb et al., 2015) thus understanding the different physiological states promoted by different anchors could

help pair new meditators with individually-adaptive practices. Breath-anchored practice promoted respiratory slowing, but respiration changes were unrelated to Preference; in contrast, no anchor uniquely promoted cardiac response, though cardiac responses were associated with Preferences. Unfortunately, the technology we employed to monitor cardiac response was somewhat unreliable (30-35% data-loss). With this limitation in mind, and with the broader awareness that the physiological effects of different anchors have not been fully categorized, future studies should continue to explore anchor-specific physiological responses and how they inform practice-optimization.

Our results did not support the hypothesis that sensory discriminability would lead to higher Preference for within-modality anchors. Sensory modalities parallel the literature on modality-specific "learning styles", which have rich public appeal despite research showing no true effects (Kampwirth & Bates, 1980; Pashler, McDaniel, Rohrer, & Bjork, 2008; Willingham, Hughes, & Dobolyi, 2015). Perhaps, as with "learning styles", this hypothesis is best abandoned. Similarly, dispositional personality and mindfulness were not meaningfully predictive of Preference, which was best explained by Anchor type and Motivation; we suggest that dispositional traits not be retained at this time.

5. Limitations and Future Directions

Participants were screened for understanding of practice instructions (osf.io/hcnz2/) and thirty-five participants (30%) were removed for comprehension/compliance issues (implications explored in a separate report). While any reduction in sample-size decreases power, this 30% parallels the 30% drop out rates in MBSR courses (Crane & Williams, 2010). We recommend

including open-ended qualitative comprehension/compliance checks anywhere meditation is taught or researched.

This study reveals research-gaps concerning the relationships between partiality, practice-maintenance, and benefits. To facilitate practice-maintenance we must take into account the circumstances precipitating practice-cessation (Anderson et al., Manuscript in preparation; Vuckovich, 2010), but this study lacked a longitudinal practice-maintenance component. Future research should measure partiality, practice-maintenance, and benefits in the weeks, months, and years following initial meditation training. Measuring practice-maintenance and cessation would not be difficult and more emphasis should be put on automating very-long-term follow-up of self-directed practice. We recommend increasing post-training contact using email-automation: sending short digital questionnaires at regular intervals and collecting data indefinitely. Probing participants every six- to twelve-months about if and how often they practice would be an easy and extremely effective next step for answering practice-maintenance questions, including whether and which contemplative benefits are predicated on continued practice (Grossman et al., 2004). Individuals likely differ in prioritization of immediate enjoyment versus mastering challenges so individual goals must be taken into account above and beyond partiality.

6. Conclusions

Research into various anchors should continue. New meditators show partiality toward different anchors and this partiality can be strongly influenced by experience: meditation teachers should offer anchors in different sensory modalities, having novices experience each practice before picking one. Meditation teachers and researchers should ensure that new meditators demonstrate instruction-comprehension as without proper understanding and

implementation there is little hope of establishing beneficial practice. Even when self-directed practice is established we lack an understanding of practice-cessation. We should encourage very-long-term follow-up of practice-maintenance trajectories to measure how self-directed practice relates to benefits and to understand when and why practice is ceased. Such a picture of real-world practice over months and years would allow us to adapt practices for the influx of people seeking health and well-being through contemplative practice.

References

- Akaike, H. (1973). Information Theory and an Extension of the Maximum Likelihood Principle. In B. N. Petrov & F. Caski (Eds.), *2nd International Symposium on Information Theory* (pp. 267–281). Akademiai Kiado, Budapest.
- Amihai, I., & Kozhevnikov, M. (2014). Arousal vs. Relaxation: A Comparison of the Neurophysiological and Cognitive Correlates of Vajrayana and Theravada Meditative Practices. *PLOS ONE*, 9(7), e102990. <https://doi.org/10.1371/journal.pone.0102990>
- Anderson, T., Suresh, M., & Farb, N. (Manuscript in preparation). Benefits and Drawbacks of Meditation. *University of Toronto, Canada*. Retrieved from osf.io/b2hxu
- Berkovich-Ohana, A., Wilf, M., Kahana, R., Arieli, A., & Malach, R. (2015). Repetitive speech elicits widespread deactivation in the human cortex: the “Mantra” effect? *Brain and Behavior*, 5(7), 1–13. <https://doi.org/10.1002/brb3.346>
- Berntson, G. G., Thomas Bigger Jr., J., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., ... Van Der Molen, M. W. (1997). Heart rate variability: Origins methods, and interpretive caveats. *Psychophysiology*, 34(6), 623–648.

- Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *J Pers Soc Psychol*, 84(4), 822–48.
- Burke, A. (2012). Comparing individual preferences for four meditation techniques: Zen, Vipassana (Mindfulness), Qigong, and Mantra. *Explore: The Journal of Science and Healing*, 8(4), 237–242. <https://doi.org/10.1016/j.explore.2012.04.003>
- Crane, C., Crane, R. S., Eames, C., Fennell, M. J. V., Silverton, S., Williams, J. M. G., & Barnhofer, T. (2014). The effects of amount of home meditation practice in Mindfulness Based Cognitive Therapy on hazard of relapse to depression in the Staying Well after Depression Trial. *Behaviour Research and Therapy*, 63, 17–24. <https://doi.org/10.1016/j.brat.2014.08.015>
- Crane, C., & Williams, J. M. G. (2010). Factors Associated with Attrition from Mindfulness-Based Cognitive Therapy in Patients with a History of Suicidal Depression. *Mindfulness*, 1(1), 10–20. <https://doi.org/10.1007/s12671-010-0003-8>
- Dobkin, P. L., Irving, J. A., & Amar, S. (2012). For whom may participation in a mindfulness-based stress reduction program be contraindicated? *Mindfulness*, 3(1), 44–50. <https://doi.org/10.1007/s12671-011-0079-9>
- Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel models: A new look at an old issue. *Psychological Methods*, 12(2), 121–138. <https://doi.org/10.1037/1082-989X.12.2.121>

- Farb, N. (2014). From Retreat Center to Clinic to Boardroom? Perils and Promises of the Modern Mindfulness Movement. *Religions*, 5(4), 1062–1086.
<https://doi.org/10.3390/rel5041062>
- Farb, N., Daubenmier, J., Price, C. J., Gard, T., Kerr, C., Dunn, B. D., ... Mehling, W. E. (2015). Interoception, contemplative practice, and health. *Frontiers in Psychology*, 6.
<https://doi.org/10.3389/fpsyg.2015.00763>
- Farias, M., & Wikholm, C. (2016). Has the science of mindfulness lost its mind? *BJPsych Bulletin*, 40(6), 329–332. <https://doi.org/10.1192/pb.bp.116.053686>
- Feldman, G., Hayes, A., Kumar, S., Greeson, J., & Laurenceau, J.-P. (2006). Mindfulness and Emotion Regulation: The Development and Initial Validation of the Cognitive and Affective Mindfulness Scale-Revised (CAMS-R). *Journal of Psychopathology and Behavioral Assessment*, 29(3), 177–190. <https://doi.org/10.1007/s10862-006-9035-8>
- Fox, K. C. R., Dixon, M. L., Nijeboer, S., Girn, M., Floman, J. L., Lifshitz, M., ... Christoff, K. (2016). Functional neuroanatomy of meditation: A review and meta-analysis of 78 functional neuroimaging investigations. *Neuroscience & Biobehavioral Reviews*, 65, 208–228. <https://doi.org/10.1016/j.neubiorev.2016.03.021>
- Goyal, M., Singh, S., Sibinga, E. M. S., Gould, N. F., Rowland-Seymour, A., Sharma, R., ... Haythornthwaite, J. A. (2014). Meditation programs for psychological stress and well-being: a systematic review and meta-analysis. *JAMA Internal Medicine*, 174(3), 357–368.
<https://doi.org/10.1001/jamainternmed.2013.13018>

- Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research*, 57(1), 35–43. [https://doi.org/10.1016/S0022-3999\(03\)00573-7](https://doi.org/10.1016/S0022-3999(03)00573-7)
- Hanley, A. W., Abell, N., Osborn, D. S., Roehrig, A. D., & Canto, A. I. (2016). Mind the Gaps: Are Conclusions About Mindfulness Entirely Conclusive? *Journal of Counseling & Development*, 94(1), 103–113. <https://doi.org/10.1002/jcad.12066>
- Johnstone, J. A., Ford, P. A., Hughes, G., Watson, T., & Garrett, A. T. (2012a). Bioharness™ multivariable monitoring device. Part I: Validity. *Journal of Sports Science and Medicine*, 11(3), 400–408.
- Johnstone, J. A., Ford, P. A., Hughes, G., Watson, T., & Garrett, A. T. (2012b). Bioharness™ multivariable monitoring device. Part II: Reliability. *Journal of Sports Science and Medicine*, 11(3), 409–417.
- Kampwirth, T., & Bates, M. (1980). Modality Preference and Teaching Method: a Review of the Research. *Intervention in School and Clinic*, 15(5), 597–605.
<https://doi.org/10.1177/105345128001500509>
- Khoury, B., Lecomte, T., Fortin, G., Masse, M., Therien, P., Bouchard, V., ... Hofmann, S. G. (2013). Mindfulness-based therapy: A comprehensive meta-analysis. *Clinical Psychology Review*, 33(6), 763–771. <https://doi.org/10.1016/j.cpr.2013.05.005>
- Kristeller, J. L., & Johnson, T. (2005). Cultivating Loving Kindness: A Two-Stage Model of the Effects of Meditation on Empathy, Compassion, and Altruism. *Zygon®*, 40(2), 391–408.
<https://doi.org/10.1111/j.1467-9744.2005.00671.x>

- Lindahl, J. R., Fisher, N. E., Cooper, D. J., Rosen, R. K., & Britton, W. B. (2017). The varieties of contemplative experience: A mixed-methods study of meditation-related challenges in Western Buddhists. *PLOS ONE*, *12*(5), e0176239. <https://doi.org/10.1371/journal.pone.0176239>
- Matejka, J., Glueck, M., Grossman, T., & Fitzmaurice, G. (2016). The Effect of Visual Appearance on the Performance of Continuous Sliders and Visual Analogue Scales. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 5421–5432). New York, NY, USA: ACM. <https://doi.org/10.1145/2858036.2858063>
- McCrae, R. R., & John, O. P. (1992). An introduction to the five-factor model and its applications. *Journal of Personality*, *60*(2), 175–215.
- Mrazek, M. D., Broadway, J. M., Phillips, D. T., Franklin, M. S., Mooneyham, B. W., & Schooler, J. W. (2014). Mindfulness: An Antidote for Wandering Minds. In A. Ie, C. T. Ngnoumen, & E. J. Langer (Eds.), *The Wiley Blackwell Handbook of Mindfulness* (pp. 153–167). John Wiley & Sons, Ltd. Retrieved from <http://dx.doi.org/10.1002/9781118294895.ch8>
- Murray, A. L., & Booth, T. (2015). Personality and physical health. *Current Opinion in Psychology*, *5*, 50–55. <https://doi.org/10.1016/j.copsyc.2015.03.011>
- Nam, S., & Toneatto, T. (2016). The Influence of Attrition in Evaluating the Efficacy and Effectiveness of Mindfulness-Based Interventions. *International Journal of Mental Health and Addiction*, *14*(6), 969–981. <https://doi.org/10.1007/s11469-016-9667-1>

- Olex, S., Newberg, A., & Figueredo, V. M. (2013). Meditation: Should a cardiologist care? *International Journal of Cardiology*, 168(3), 1805–1810.
<https://doi.org/10.1016/j.ijcard.2013.06.086>
- Osman, A., Lamis, D. A., Bagge, C. L., Freedenthal, S., & Barnes, S. M. (2015). The Mindful Attention Awareness Scale: Further Examination of Dimensionality, Reliability, and Concurrent Validity Estimates. *Journal of Personality Assessment*, 1–11.
<https://doi.org/10.1080/00223891.2015.1095761>
- Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning Styles: Concepts and Evidence. *Psychological Science in the Public Interest*, 9(3), 105–119.
<https://doi.org/10.1111/j.1539-6053.2009.01038.x>
- Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology*, 48(1), 85–112. <https://doi.org/10.1016/j.jsp.2009.09.002>
- Schoormans, D., & Nyklíček, I. (2011). Mindfulness and psychologic well-being: are they related to type of meditation technique practiced? *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, 17(7), 629–634.
<https://doi.org/10.1089/acm.2010.0332>
- Schwarz, G. (1978). Estimating the Dimension of a Model. *The Annals of Statistics*, 6(2), 461–464. <https://doi.org/10.1214/aos/1176344136>
- Seli, P., Cheyne, J. A., & Smilek, D. (2013). Wandering minds and wavering rhythms: Linking mind wandering and behavioral variability. *Journal of Experimental Psychology: Human Perception and Performance*, 39(1), 1–5. <https://doi.org/10.1037/a0030954>

- Shearer, A., Hunt, M., Chowdhury, M., & Nicol, L. (2015). *Effects of a Brief Mindfulness Meditation Intervention on Student Stress and Heart Rate Variability*. Retrieved from <http://www.scopus.com/inward/record.url?eid=2-s2.0-84946429583&partnerID=40&md5=0436ec9eca1a0305eed89b88b270bbba>
- Swift, J. K., Callahan, J. L., & Vollmer, B. M. (2011). Preferences. *Journal of Clinical Psychology*, 67(2), 155–165. <https://doi.org/10.1002/jclp.20759>
- Travis, F. (2011). Mindfulness and psychologic well-being: are they related to type of meditation technique practiced? *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, 17(11), 983–984. <https://doi.org/10.1089/acm.2011.0507>
- Travis, F., & Shear, J. (2010). Focused attention, open monitoring and automatic self-transcending: Categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Consciousness and Cognition*, 19(4), 1110–1118. <https://doi.org/10.1016/j.concog.2010.01.007>
- Van Dam, N. T., Earleywine, M., & Borders, A. (2010). Measuring mindfulness? An Item Response Theory analysis of the Mindful Attention Awareness Scale. *Personality and Individual Differences*, 49(7), 805–810. <https://doi.org/10.1016/j.paid.2010.07.020>
- Vuckovich, P. (2010). Compliance versus adherence in serious and persistent mental illness. *Nursing Ethics*, 17(1), 77–85. <https://doi.org/10.1177/0969733009352047>
- Willingham, D. T., Hughes, E. M., & Dobolyi, D. G. (2015). The Scientific Status of Learning Styles Theories. *Teaching of Psychology*, 42(3), 266–271. <https://doi.org/10.1177/0098628315589505>

Supplemental Materials

2. Methods

Questionnaires, stimuli, code, and practice instructions shared on the Open Science Framework (osf.io/hcnz2/).

2.4 Tasks

2.4.1 Behavioural Mind-Wandering

The Metronome Response Task (MRT) was used to behaviourally measure mind-wandering, which has been linked to response-variability when participants tap the steady beat of the MRT (Seli, Cheyne, & Smilek, 2013). As in Seli et al. (2013) MRT trials were as follows: 650 ms of silence followed by a tone lasting 75 ms followed by another 575 ms of silence, resulting in a total trial duration of 1300 ms. In the original, total MRT duration was 20min, but due to time constraints participants instead completed a 1 min practice block followed by a 5 min MRT block. Response time variability was computed as in Seli et al. (2013): participants missing more than 10% of trials dropped, missed trials dropped, and scores log-transformed.

2.4.2 Sensory Discriminability

Three psychophysical staircases measured sensory discriminability in the three anchor modalities: somatosensory (vibration-detection), auditory (pitch-discrimination), and visual (colour-saturation discrimination). Sensory discriminability was measured using three modalities of psychophysical staircase programmed in PsychoPy (Peirce, 2007, 2009). As per García-Pérez (1998) the staircases followed a 2-Alternative Forced-Choice (2AFC) 1-Up/3-Down procedure with 10 reversals. The final 6 reversals were used to calculate individual Just-Noticeable Difference (JND) thresholds, which were Winsorized to two standard deviations and log-transformed. Failure to discriminate was rare (9% of staircases); technical issues prevented five participants from completing any staircases.

Somatosensory-discrimination involved indicating which of two intervals contained a vibrating stimulus (vs non-vibrating), an index of bodily awareness (Mirams et al., 2013). Auditory-discrimination involved indicating which of two intervals contained a 440 Hz reference

tone (vs foil tone, higher or lower in pitch). Visual-discrimination involved indicating which of two intervals contained the reference image (a dim green circle vs foil colour, more or less saturated).

At the start of each staircase participants were presented with the reference stimulus (vibration, tone, circle) and then asked to judge which of two sequential stimuli matched the reference stimulus. Every trial contained a "target" stimulus matching the reference stimulus and was contrasted with a non-matching "foil" stimulus. The staircase procedure began with trials in which the difference between the target and foil was large. Each incorrect trial resulted in the difference between target and foil increasing one step (1-Up); three consecutive correct trials resulted in the difference between target and foil decreasing one step (3-Down). A "reversal" - a change in direction from increasing difference to decreasing or vice versa - reflects a crossing of the participants' Just Noticeable Difference threshold (JND). For each two reversals the step size decreased by half, narrowing around the specific boundary of the JND threshold. Ten reversals were collected, the last six were averaged, then Winsorized and log-transformed, creating JND scores.

To improve data quality within-task screening was employed for the staircases. If participants failed to evince discrimination between target and foil stimuli at the maximally distinct thresholds (MDT) the instructions and reference were reviewed and the staircase began anew. If participants were again unable to demonstrate stimulus discrimination at MDT the task terminated early and the participant's JND for the task was treated as missing data. Failure to discriminate above threshold was rare and occurred in 33 staircases (9% of all staircases: 10 vibration, 11 auditory, and 11 visual). Five participants could not complete any of the staircases due to technical issues with the testing computers.

In somatosensory-discrimination participants were asked to indicate which of the two intervals contained a vibrating stimulus, an index of bodily awareness (Mirams et al., 2013), using a bone-conductor hearing-aid (Connevens Ltd., United Kingdom) and told to hold the device lightly yet firmly between the thumb and index-finger of their left hand. Intensity of vibration increased or decreased until ten staircase reversals were collected and the threshold was determined (MDT: maximum-amplitude-vibrating vs non-vibrating). In the case of auditory-

discrimination participants were asked to indicate which of the two intervals contained a 440 Hz sine-wave tone. Participants wore headphones and foil tones were randomly higher or lower in pitch (MDT: 4 times or $\frac{1}{4}$ the reference: 1760 Hz - 110 Hz). In the case of visual-discrimination participants were asked to indicate which of the two intervals contained an on-screen circle filled with a dim green (RGB values (0%, 50%, 0%)). Foil colours were randomly more or less saturated (MDT: white or black circle).

3. Results

3.3.1 Predicting Motivation and Bias

Motivation was uncovered as the primary predictor of post-practice Preference. While an interesting and expected finding (H1a) this result begs the question of what predicts Motivation and initial Bias. We explored these questions using a series of models of the same form as those planned for Preference with Motivation and Bias as the outcome variables. While based on planned models for Preference, the application of these models to these outcome variables was not strictly a priori planned and as such this analysis must be taken as somewhat exploratory.

3.3.1.1 Predicting Motivation

Within-participant Motivation levels across Anchor types were highly related (ICC=0.542). The model with the best BIC supported H1b by showing a significant moderate effect of Bias ($\beta=0.324$, $p<0.0001$, $r=0.44$) and of Anchor (β -Breath=0.143, β -Phrase=-0.034, β -Image=-0.108, $p<0.0124$, $r=0.26$), reflecting that, on average, participants were more motivated to engage the Breath (M: 69.15, SD: 23.02) practice over the Phrase (M: 61.80, SD: 23.49) practice ($t(81)=3.056$, $p<0.003$); the Image (M: 65.04, SD: 18.78) practice was in-between. Counter to H2 JND models were again not superior. The model with the best AIC supported H3 as superior with higher responses on Mindfulness, Conscientiousness, Openness, Neuroticism, Extraversion, and Agreeableness predicting higher Motivation (β -M: 0.221, β -C: 0.029, β -O: 0.189, β -N: 0.214, β -E: 0.073, β -A: 0.053). H3_{MRT} was not supported.

	Intercept	H1			H1b			H3		
Model BIC	646	647			617			634		
Model AIC	635	629			596			592		
Predictor		β	SE	r	β	SE	r	β	SE	r
Anchor	Breath	0.17	0.11	0.25	0.14	0.10	0.26	0.14	0.09	0.25
	Phrase	-0.16	0.11		-0.03	0.10		-0.04	0.10	
	Image	-0.01	0.11		-0.11	0.10		-0.10	0.10	
Bias					0.32	0.05	0.44	0.31	0.05	0.41
Mindfulness								0.22	0.10	0.24
Conscientiousness								0.03	0.09	0.04
Openness								0.19	0.08	0.28
Neuroticism								0.21	0.09	0.26
Extraversion								0.07	0.08	0.11
Agreeableness								0.05	0.08	0.07

		H1b	H2			H1b	H3 _{MRT}		
sample n		77	77			62	62		
Model BIC		549	555			471	475		
Model AIC		529	531			452	453		
Predictor			β	SE	r		β	SE	r
Anchor	Breath		0.12	0.11	0.29		0.16	0.11	0.27
	Phrase		-0.11	0.11			-0.04	0.11	
	Image		-0.13	0.11			-0.10	0.11	
Bias			0.35	0.06	0.47		0.30	0.06	0.41
JND Threshold			-0.02	0.05	0.03				
MRT Variability							0.10	0.09	0.15

3.3.1.2 Predicting Bias

Initial Bias was much less predictable (ICC=0.118). The model with the best BIC supported H1 by showing a significant effect only for Anchor (β -Breath=0.096, β -Phrase=-0.389, β -Image=0.293, $p<0.0001$, $r=0.37$) reflecting, on the average, more positive Bias in favour of the Image (M: 70.0, SD: 19.50) and Breath (M: 65.66, SD: 22.85) practices over the Phrase (M: 54.99, SD: 21.01) practice (Image: $t(81)=5.19$, $p<0.00001$, Breath: $t(81)=3.62$, $p<0.001$). H2 was again not supported. The model with the best AIC supported H3 as superior with higher responses on Mindfulness, Openness, Neuroticism, Extraversion, and Agreeableness predicting

higher Bias and lower Conscientiousness predicting higher Bias (β -M: 0.237, β -C: -0.214, β -O: 0.149, β -N: 0.174, β -E: 0.081, β -A: 0.175). H3_{MRT} was again not supported.

	Intercept	H1			H3		
Model BIC	710	697			708		
Model AIC	700	679			670		
Predictor		β	SE	r	β	SE	r
Anchor	Breath	0.10	0.11	0.37	0.10	0.10	0.37
	Phrase	-0.39	0.11		-0.39	0.10	
	Image	0.29	0.11		0.29	0.10	
Mindfulness					0.24	0.09	0.30
Conscientiousness					-0.21	0.08	0.30
Openness					0.15	0.07	0.26
Neuroticism					0.17	0.08	0.25
Extraversion					0.08	0.07	0.14
Agreeableness					0.18	0.07	0.28

		H1	H2			H1	H3 _{MRT}		
sample n		77	77			62	62		
Model BIC		612	617			532	536		
Model AIC		595	596			516	517		
Predictor			β	SE	r		β	SE	r
Anchor	Breath		0.09	0.11	0.35		0.11	0.12	0.36
	Phrase		-0.35	0.12			-0.40	0.12	
	Image		0.26	0.12			0.21	0.12	
JND Threshold			-0.04	0.07	0.05				
MRT Variability							0.10	0.08	0.15

4. Supplemental Discussion

Dispositional personality and mindfulness show a less clear relationships with Bias and Motivation. Model comparisons showed lower AIC when dispositional traits were included yet BIC was lower for more concise models. As the additional variables offer little theoretically interpretable nuance and more variance was explained by simpler predictors - Anchor-type and Bias predicted Motivation while Anchor type predicted Bias - we suggest that it may not be meaningful to retain dispositional traits (Dziak, Coffman, Lanza, & Li, 2015).

Supplemental References

- Dziak, J. J., Coffman, D. L., Lanza, S. T., & Li, R. (2015). *Sensitivity and specificity of information criteria* (No. e1350). PeerJ PrePrints.
<https://doi.org/10.7287/peerj.preprints.1103v2>
- García-Pérez, M. A. (1998). Forced-choice staircases with fixed step sizes: asymptotic and small-sample properties. *Vision Research*, 38(12), 1861–1881.
[https://doi.org/10.1016/S0042-6989\(97\)00340-4](https://doi.org/10.1016/S0042-6989(97)00340-4)
- Mirams L., Poliakoff E., Brown R.J., & Lloyd D.M. (2013). Brief body-scan meditation practice improves somatosensory perceptual decision making. *Consciousness and Cognition*, 22(1), 348–359. <https://doi.org/10.1016/j.concog.2012.07.009>
- Peirce, J. W. (2007). PsychoPy—Psychophysics software in Python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. <https://doi.org/10.1016/j.jneumeth.2006.11.017>
- Peirce, J. W. (2009). Generating Stimuli for Neuroscience Using PsychoPy. *Frontiers in Neuroinformatics*, 2. <https://doi.org/10.3389/neuro.11.010.2008>
- Seli, P., Cheyne, J. A., & Smilek, D. (2013). Wandering minds and wavering rhythms: Linking mind wandering and behavioral variability. *Journal of Experimental Psychology: Human Perception and Performance*, 39(1), 1–5. <https://doi.org/10.1037/a0030954>