Minimal mindfulness of the world as an active control for a full mindfulness of mental states intervention: A Registered Report and Pilot study

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Summary

Mindfulness is a continual renewal of non-elaborative attention on an object of focus, without clinging or aversion, and with equanimity. As this requires the capacity to monitor and control the extent to which one is on task, it is a metacognitive exercise. Mindfulness is especially metacognitive when directed towards mental states themselves, which is largely how the practice was conceived in the original Buddhist scriptures. Alternatively, mindfulness could be directed towards the world around oneself in a less metacognitive fashion. Notably, whilst mindfulness of the world is directed towards the referents of sensory states (e.g., “the sky is blue”), mindfulness of mental states includes a higher-order awareness of the experience of a sensory state as a mental state in and of itself (e.g., “I see the sky is blue”) – as a sensation.

We aim to test the centrality of metacognition in mindfulness practice by contrasting a full Mindfulness of Mental States intervention against a minimal Mindfulness of the World intervention, to act as a potential active control for non-specific effects, alongside a Waitlist control. Survey measures of mindfulness directed at the world and mental states separately, mental health measures, and participant expectations for each of these outcomes, will be administered. Bayesian contrasts of the group by time interaction will be the primary analysis used to test, for the first time, the effects of mindfulness against a true active control (if it should turn out to be one). Pilot data presented in the first section below show some promising initial results. Between the Mental States and World focused conditions, evidence in the hypothesised direction was discovered on the Observe and Acting with Awareness facets of the 24-item FFMQ-sf (other facets were insensitive), on the PHQ-4 anxiety subscale, and on the RRS.

# Introduction

Amongst the recent explosion of scientific, clinical, and public interest in mindfulness, there are concerns as to the lack of adequate control groups and imprecise and inconsistent definitions in the scientific literature on the subject (1). Metacognition - the monitoring and control of mental processes - is a component of Buddhist renderings of mindfulness (2,3), and it has become important in many scientific theories (4–6), although this skill may be relatively under-developed in those components of modern mindfulness interventions that focus on awareness of ‘the present moment’ via sensory states. The contrast between practices that more or less fully aim to cultivate metacognitive skills opens up an opportunity to test metacognitive theories of mindfulness while controlling for other specific and non-specific effects of the practice. We present the results of a large pilot study below, followed by the specifications for an improved follow-up study.

In relation to Buddhist texts, ‘mindfulness’ is a translation of ‘sati’, which can be understood as an awareness of mental states as content bearing vehicles happening now, to be selected, labelled, or let go of according to task requirements, without clinging or craving (3,7,8). By objectifying the constituents of the mind, the subject thus ceases to be viewed as such, and is ‘dissolved’. This loss of ‘self-ness’ by objectification of experience mirrors decentring theories of mindfulness, wherein mental states are understood as separate from any outside phenomena they may represent, and less attached to a cognitive set of ‘self-ness’, consisting of concepts like ‘I’, ‘mine’, ‘me’, and ‘myself’ (5; see also ‘reperceiving’ in 9). Thus, the thought “I am annoyed” can become “there is the feeling of annoyance”, with its content being taken as a property of a representational vehicle, and therefore less ‘at face value’ and 'true', transforming the subjective experience itself. Bernstein et al. (10,11) argue that mindfulness is one term amongst many in the cognition literature which describe such metacognitive ‘decentring’ - “The capacity to shift experiential perspective—from within one’s subjective experience onto that experience” (10, p.599).

Mindfulness thus aims to train a metacognitive transformation in how we perceive and respond to mental states. Several survey measures have recorded mindfulness induced increases in decentring (5,12; *Or:* 13–16; *Or:* 17,18). Other lines of research support the theory that mindfulness actively trains metacognitive skills more generally and in different domains. Intentional binding denotes the compression of estimates of the timing of an action and resultant outcome during a consciously intended action, where either the subjective time of the action shifts towards the objective time of the outcome (action binding), or vice versa (outcome binding) (19,20, *but see:* 21). Attending to one’s inner decision-making processes, as in mindfulness, leads to earlier estimates of action timing (22), and experienced Buddhist mindfulness meditators may have greater outcome binding than non-meditators, and thus a greater awareness of intentions (23). Negative correlations between hypnosis and mindfulness scales (24–26) are explained by theories that see hypnotic suggestibility as the result ofinaccurate metacognition about one’s intentions to respond (27,28). Phrasing hypnotic suggestions in a Buddhist friendly manner to raise expectations (although not successfully equalise them) does little to alter meditator’s low hypnotic response rate (*cited in:* 29). As one might expect, hypnotisability has a negative relationship to action timing estimates, whilst meditators were significantly quicker and more consistent than averagely hypnotisable individuals (25). Finally, neurological evidence concurs, as several areas of the pre-frontal cortex appear to be involved in both metacognition (30,31) and mindfulness (*left dorsolateral:* 32–34; *medial:* 35,36; *ventrolateral:* 37), and likewise in the anterior cingulate cortex (38,39).

The clinical utility of the above is that this re-evaluation of experience in effect buffers against the self-reinforcing effect of negatively valenced cognitions as they are viewed as transient, non-factual mental states (5,40–42). Because of the apparent positive effects of mindfulness on mental health, it is offered by health services worldwide as a treatment for, notably, stress, anxiety, and depression. In the psychological literature, mindfulness is primarily conceptualised as a therapeutic practice, and the effectiveness of an intervention judged by measures of the aforementioned mental health issues (43,44). The link between metacognition and psychopathology extends beyond mindfulness - Adrian Wells has built up an extensive research enterprise which claims that metacognitive failings are a key factor in all psychopathologies (45). Therefore, according to Wells, metacognitive training is an active component of many effective therapies, including mindfulness (41,46). It is of no small practical importance, then, to understand and perhaps develop the potential contributions of the metacognitive mechanisms involved in mindfulness, and their relation to its effects on mental health.

Notably, a set definition of sati is not constitutive of the practice of what we might call ‘mindfulness meditation’ – the modern use of which refers to a broad, sometimes contradictory (e.g. 47), class of concepts and exercises scattered throughout the Buddhist canons and wider commentaries. An early account of mindfulness practice central to both many Buddhist meditation practices (3) and the current clinical approach (48–50), can be found in the Satipatthana Sutta. At its core, this practice instructs a continual renewal of non-elaborative attention on an object of focus. As this requires the capacity to monitor and control the extent to which one is on task, it is a metacognitive exercise (for a related but different approach to meditation see 51). Furthermore, one is to be ‘non-clinging’ (letting mental states go, holding in mind only that which is relevant to the practice), and equanimous (maintaining a calm composure in the face of both positive and negative mental states). These are metacognitive skills in that they require seeing mental states in terms of content carried by vehicles, accompanied by executive evaluation and management.

The four groupings of experiential phenomena to which this mindset is directed, the four Satipatthanas, are the body, feelings, the mind, and mental states relevant to flourishing (dhamma, c.f. 3). The last three of these explicitly concern types of mental states, and so mindfulness involves metacognition in this sense also. Even when the body (e.g. the breath) is used as the persisting target, the Anapanasati Sutta (MN iii 78; 52) extends mindfulness of breathing to cover all four Satipatthanas (3, pp. 21-22), developing an awareness of sensory states as sensations. Correspondingly, Dienes et al., (29) understand mindfulness using Higher Order Thought (HOT; 53) theory to distinguish mental states with content simply about the world (e.g. seeing that “The sky is blue”), from second-order states which refer to those first-order states (e.g. being aware that “I see the sky is blue”), which in turn can be the subject of yet higher third-order states (e.g. being aware that “I am aware that I am aware the sky is blue”). Similarly, mindfulness may target the external world itself, or, as is more typical in Buddhism, mental states. Appealingly, others have pointed to similarities between HOT theory and Buddhist descriptions of consciousness (54–56), although one need not subscribe to HOT theory as a theory of consciousness to realise the distinctions it makes are useful.

With that being said, continually redirecting attention, when distracted, to the world around oneself (including one’s own body as a non-mental object), whilst avoiding elaborative thinking, is in-line with many mindfulness practices. Even in the Buddhist literature, The Vimuttimagga (second century) instructs practitioners to focus on earth or soil around them as an external visual object until they can form a mental image of it (57), whilst a passage in the Majjhima Nikāya instructs: “Not perceiving form internally, someone sees visions externally, blue, with blue color, blue hue, and blue tint” (58, p. 639). We will use such an external, world-focused variant of mindfulness to actively control, to some degree, for the metacognitive faculty which is emphasized in the experimental condition. As participants may accept such practices to be genuine mindfulness - as indeed they are - we avoid deceiving participants, whilst (potentially) controlling for non-specific factors like expectations.

As current theoretical work does not distinguish between mindfulness directed to the world as such versus to mental states, interventions may emphasise the former over the latter. Breath and body-scan meditations, hatha yoga, and mindful eating take up most of MBSR (59) courses, and are not necessarily done so in a mental states rather than world-focused manner, although in MBCT in particular focusing on thoughts and emotions is a central part of the mindfulness training (60,61). That is not to say there is no clinical utility in a world-focused meditation - a non-metacognitive focus may provide respite from difficult mental states like extreme anxiety. As such, we will compare this intervention to a Waitlist control. Nevertheless, as mindfulness of the world involves less metacognitive training than a full mindfulness intervention, the Mindfulness of World intervention may constitute a minimal mindfulness intervention.

Mindfulness of the World is therefore a possible placebo control for a mental states focused condition, insofar as metacognition is theorised to be a key mindfulness component. This faculty is not cleanly isolated from the World condition - an awareness of whether one is being aware of the object of focus or not requires metacognition, as does becoming aware of any disruptive thoughts. Still, the extent of metacognitive training should be greater when mindfulness is primarily directed towards mental states rather than the world. Moreover, mindfulness is conceptualised exclusively in our mental states intervention to include metacognitive skills such as non-suppression, non-clinging, and equanimity.

This design is an improvement on the abundance of Waitlist-controlled trials in the literature (43,62). Of those studies that do use active controls, the majority are therapies against which available measures struggle to differentiate the active components of the mindfulness condition (63–67); perhaps as these therapies often contain mindfulness components (68,40,69). Some studies have employed a 'sham-mediation' intervention as a placebo condition (70; *similar in:* 71), which asks participants to just sit and ‘meditate’ with minimal instructions as to how. Specifically, instructions are to “Just relax, reduce any expectations” and “take a couple of deep breathes, in through the nose out through the nose as we sit here in meditation” and “stillness” (72). Similarities to Zen Shikantaza ‘just sitting’ meditation (73–75) aside, just asking participants to breathe may lead to a focus on the breath. Whilst initially appearing inactive compared to mindfulness (70,76), later studies have not recorded a significant difference between "sham" mindfulness and regular mindfulness conditions (72,77). It should also be noted that, although these studies presented both their interventions as mindfulness, expectations of outcome variables were not necessarily equalised - different meditation exercises may confer different presumptions about their effects. For example, participants may assume that attending to negative affect can be distressing (78).

Likewise, although not technically a placebo as neither condition was presented as mindfulness, the ‘mind-wandering’ intervention of (79–84) was deployed to account for all non-specific effects. This intervention asks participants to ‘‘simply think about whatever comes to mind. Let your mind wander freely without trying to focus on anything in particular’’ (85). The original intent of this intervention was not mind-wandering, but ‘unfocused attention’ (85,86), a name that highlights its similarity to the ‘effortlessness’ and ‘lack of grasping or focus’ of Open Monitoring meditation (87,88). Allowing thoughts to come and go is common to mindfulness interventions and definitions (89–91; *headspace:* 77 [supplementary]) - for some, it is actually stopping the ebb and flow of thoughts that is inconsistent with mindfulness practice. Trying to mind-wander may counter-intuitively bring attention and a metacognitive distance to such mental activity, despite true mind-wandering consisting of a “task unrelated thought, that is, engaging in cognition unrelated to what one is supposed to be doing in the here and now” (92, p.389, c.f. 93). If conditions contained equivalent amounts of mindfulness but differed only in expectations, the contrast between conditions would have been actually reflective of the placebo effect and not of mindfulness. Where these attempts at making placebo-esque mindfulness control interventions have essentially asked participants to not focus, we ask participants focus on things which aren’t mental states.

Similar to our own study, Schmidt et al. (94) split MBSR into either body or mental states focused material. Schmidt relied on a measure of metacognition termed metacognitive efficiency - the correspondence between objectively correct decision-making and subjective confidence in those decisions (see Methods). Whilst one’s accuracy on a two-alternate forced choice task reflects the function of sensory organs and low-level sensory processing, the ability to assess one’s own task performance (i.e., confidence) is used as an index of one’s ability to consciously discern the quality of that perceptual information. Rather than use a simple correlation of accuracy and performance, the meta-d’ statistic (95) relies on the probabilities of high or low confidence and correct or incorrect decisions to estimate the correspondence between these two metrics in a way unbiased by each participants’ idiosyncratic use of the confidence scale (‘metacognitive sensitivity’). meta-d’ can then divided by a measure of participant accuracy (i.e. meta-d’/d’) to give us a participant’s ‘metacognitive efficiency’ – their metacognitive sensitivity for a given level of accuracy.

Schmidt et al. (94) recorded a significant time-group interaction, which was further analysed to reveal that the mental states condition did not produce a significant change in metacognitive efficiency, although a decrease of such abilities in the body focused condition suggests the latter intervention exercised skills other than metacognition. Although using an 8-week 30 mins+ per-day MBSR course, numbers were small (N = 27; compare e.g. N = 104 for a just significant increase after a 10-day course compared to Waitlist in Cavanagh et al. (96), although this course was unsupported and online), with an only just significant interaction. Without a Waitlist control and recorded expectations, expectation effects cannot be ruled out. Other papers have empirically separated different contemplative practices but not necessarily different types of mindfulness per se (see e.g. 97). Precursors to the Schmidt et al. (94) study did find metacognitive efficiency to be malleable through both feedback (98) and mindfulness (99). Notably, Carpenter et al. (98) improvements in experimental groups trained on metacognitive performance on either perceptual or memory tasks transferred to the other untrained domain. Domain generality in metacognitive efficiency has also been demonstrated by significant correlations between tasks measuring this construct (100). The current study will build on these findings by examining if visual metacognitive *sensitivity* (adjusted for d’, see below) improves in our Mindfulness of Mental States intervention.

# Pilot Study

For brevity, we present an abridged write-up of the pilot study here. A full write up of the pilot study, along with data, analysis code, and materials can be found in the online supplementary.

## Methods

The pilot study consisted of a 10-minute meditation each day for 10 days, with a 3-day limit between practices before a participant was assumed to have withdrawn from the study. Pre-test surveys were conducted over video call, after which participant information was passed to a second experimenter who randomly assigned conditions by pulling the condition names out of a hat. This second experimenter handled daily standardised emails (which indicated what meditation to do and asked a question about the experience) and alerted the first experimenter (who was condition-blind) when the participant was ready for their second survey video call.

Mindfulness of World and Mental States groups were given access to a condition-relevant website which featured information about mindfulness, a prompt to do mindfulness during daily activities, and the guided meditation audio. Separate instructions were emailed each day, with a response to questions probing intervention adherence required for the next day's email to be sent. Although the audio file remained consistent throughout each intervention, emailed instructions differed each day. The Mindfulness of the World condition (*N*=40) audio instructed participants to attend to their breath and body, whilst email instructions asked participants to become aware of the world around them in a radius that became progressively bigger each day. The Mindfulness of Mental States condition (*N*=47) audio started on the breath and moved on to an awareness of passing thoughts and sensations in a detached manner as “just thoughts”, whilst emails instructed participants to focus on different mental states each day including: intentions, feeling tone (positive, negative, or neutral), desires, emotions, the beginning, end, and transition between states, and finally an open-monitoring style. Participants in the waitlist control (*N*=35) were given access to the post-test survey and one of the conditions after 10 working days.

We hypothesised superior performance on a mindfulness questionnaire (FFMQ) from pre- to post-test in a Mindfulness of Mental States condition compared to a Mindfulness of the World condition - the latter of which was in turn hypothesised to perform superior to a Waitlist condition. We also reasoned that, if Mindfulness of the World was shown to have equivalent FFMQ to waitlist and inferior performance to the Mental States condition, this would indicate it could be a useful active control condition. If Mindfulness of Mental States and Mindfulness of World had equivalent expectations for change on outcome variables (depression, anxiety), the latter would show itself to be a good active control condition. Data was collected over several years by student researchers. A final dataset contained 94 participants (52 Female; Ages 18-50, *M*=24, *SD*=5.79). Missing data was handled by Multiple Imputation using a Fully Conditional Specification method with Bayesian Regression, details can be found below and in the online supplementary. Analysis was largely in line with the main study (see below) - in short, a change analysis was run wherein interactions were immediately decomposed into contrasts, with the differences between conditions over time compared to a likely effect size (.2 Likert units) using Bayes Factors. Sensitive results were taken to involve Bayes factors <1/3 and or >3.

## Results and learnings

in terms of mindfulness of the world being a good active control because it elicits the same expectations as mindfulness of mental states for the reduction of depression and anxiety, there was evidence for no difference between the interventions in expectations – therefore passing our initial manipulation check. This is the first time that Bayesian evidence for equivalence of expectations has been shown for a control group for mindfulness compared to the mindfulness intervention itself.

Regarding the FFMQ-sf, both the Observe and Acting with Awareness facets were higher in the Mental States group than the World group (*B*HN(0,.2) = 8.9, and 5.92, respectively). As all other facets and comparisons (along with our two bespoke ‘awareness of the world/mental states in the last hour’ questions) were insensitive, there is only partial evidence that our manipulation checks of mindfulness were passed. The finding on the Acting with Awareness subscale reproduces findings with this dataset in a previous study which showed a negative regression slope between this facet and hypnotisability (14). The AA facet features several questions about being aware of one’s actions, and therefore relates to one's awareness of intentions (i.e., a form of mental state). Interestingly, in the Buddhist literature, one of the four 'foundations' (i.e., objects of focus of central importance to the practice) include intentions (45) – and, taking inspiration, so did our mental states intervention.

The Observe facet, which we made no clear predictions about, has been shown to exhibit the expected positive intercorrelations with other FFMQ-facets (101–105) and negative correlations with psychopathological symptoms (106,107), but only in those with meditation experience. Whilst baseline performance may affect reliability, we may have found a result on this subscale because it is sensitive to differentiating meditators from non-meditators. On the other hand, the direction of this increase is somewhat surprising given that Baer et al (101) explained inconsistent results on this subscale by its focus on bodily and external perceptions, over cognitions – an issue worsened in the FFMQ-sf we used (compare 108 and 109, p. 236). We should consider that the Observe questions can be interpreted in two ways: As being aware of qualities as existing in the world, for example, colours, aromas, or sounds out there; or as being aware of perceptions of these qualities as experiences. If participants in the Mental States intervention interpreted the questions as referring to sensations and perceptions, it is not surprising that they scored highly on the facet. We will therefore extend the Observe scale by carefully wording two versions in terms of both awareness of the world, and awareness of perceiving the world, with a prompt instructing participants of this distinction. The Mental States group should score highly relative to the active control only when the scale refers to awareness of perceptions.

The main study would also benefit from a scale measuring an awareness of mental states in general. Upon review we feel that the FFMQ is unsuited to our needs as it deals largely with emotions, thought suppression, observation of the body and world, and actions. The same is true of the 5 scales used in the creation of the FFMQ, of other measures of mindfulness (109,110), and to a lesser extent scales dealing with decentring more directly (111,112). The decentring sub-scale of the trait version of the Toronto Mindfulness Scale (TMS; 113) meets the requirements of a manipulation check for mindfulness of mental states in the breadth with which it refers to mental states. Alongside these scales, an objective measure of metacognition using a Two-Alternate Forced Choice task coupled with a meta-d’ analysis of the resulting data will be used in the main study (see below).

Evidence was strong for a greater decrease in the Mental States condition compared to the World condition on the PHQ-4 Anxiety subscale (B=8.77) - combined with the sensitive finding of no difference in expectations for anxiety and depression, this finding is encouraging for regarding the Mindfulness of the World as an active control against which the benefits of mindfulness, seen as a metacognitive skill, can be shown when expectancies are controlled. Reliability of this sub-scale will be increased using a longer version from the same family of scales, which contains this two-item subscale, the GAD-7 (114). Although the two depression-related items of the PHQ-4 showed little change, in order to capture the broader construct of ‘mental health’, the PHQ-8 (115) (an expansion of this two-item measure of depression) will also be included in the main study.

The RRS measures rumination, a proposed core metacognitive mechanism of depression (116) of which there is evidence of change as a result of mindfulness interventions from several previous studies (117). Our finding that scores on this subscale reduced in the Mental States intervention compared to the world intervention indicates the former course was indeed successful in training metacognitive skills. However, thought suppression as measured by the WBSI, also a metacognitive mechanism of depression (118), was evidential only in decreases in the world condition, although lack of evidence in the mental states to world comparison cannot be interpreted as evidence of a lack of effect. Still, this may indicate that the world condition was indeed successful as a mindfulness intervention, at least compared to doing nothing in the waitlist group. For parsimony, these scales will only be included as exploratory scales in the main study.

In conclusion, we found some small indication of success in the pilot study - the main study will use these results in a data driven manner, with several changes to measures used listed above. Other methodological improvements are listed below.

# Main Study

## Hypotheses

On the theory that mindfulness is a metacognitive skill, our crucial manipulation check requires an increase in measures of metacognition and mindfulness in the Mindfulness of Mental States condition over the Mindfulness of the World condition. On the theory that mindfulness of the world contains some metacognitive training (e.g., control of attention), an increase in mindfulness and metacognition measures is also predicted in the Mindfulness of the World condition over that seen in the Waitlist control group.

Our second crucial manipulation check examines the theory that the World group is a good active control by testing for equivalence in expectancies between the World and Mental States groups. A final non-crucial manipulation check will examine the theory that between group differences are unrelated to intervention completion time, by testing that the difference in completion time is not more than would be needed to account for differences in outcomes.

On the theory that the metacognitive component of mindfulness accounts for much of the practice's positive effect on mental health, it is predicted that anxiety will decrease in the Mental States condition compared to the Mindfulness of the World condition. On the theory Mindfulness of the World has beneficial effects as well, anxiety will decrease as a result of this intervention, compared to a Waitlist group.

# Methods

## Participants

Participants will be recruited on social media websites (Facebook, Instagram, Twitter, and Reddit), using the third-party recruitment platforms (<https://www.findparticipants.com/>), Prolific (<https://www.prolific.co>), and MTurk (https://www.mturk.com/), via physical posters, through personal correspondence, or using the Sona platform to advertise to Undergraduate Psychology students at the University of Sussex. Participants will be either unpaid volunteers interested in meditation, paid £20 for participation via Prolific/MTurk, or students rewarded with research participation credits needed for completion of their degree. All participants will confirm to be above 18 years old and to have experienced <10 hours’ meditation practice. Ethical approval was received from the University of Sussex ethical committee (ER/MEL29/7). Informed consent will be obtained from each participant before participation. Estimations of required sample size (*N*=~220) can be found below.

## Procedure

To allow for efficient data collection with a larger sample, the main study will be fully automated using the Qualtrics survey platform. An initial link allows participants to sign up to the study and complete the pre-test survey, after which a random condition is automatically assigned using randomisation features of the Qualtrics platform. Follow up emails either inform participants they are in the Waitlist condition or contain a link to the first survey and meditation. This first survey contains an induction audio where the condition-relevant practice of mindfulness and the course structure is described, after which participants are asked about their expectations for the intervention to affect each measure. The next page of the survey contains the first day's meditation, after which participants are asked for the percentage of time they paid attention to the practice. The next day's survey is sent out at 7:00AM GMT, which initially asks participants if they practiced mindfulness during a daily activity, before continuing onto the meditation and attention probe as in the first day. A reminder email is sent out each day for 3 days, after which an email is sent asking participants to complete the post-test survey in order to access the full intervention recordings. Throughout the study, participants are asked (but not required) to complete the post-test survey if they wish to drop-out of the study. There is no post-test reminder email upon dropping out as the Qualtrics system only allows for one reminder email per-survey. After the 14th meditation the post-test survey is sent to participants immediately, or after 20 days in the Waitlist control group, which was the mean amount of time taken to complete the study in the pilot. All materials are provided in the online supplementary.

**Intervention Design**

Participant motivation is key to curtailing the trade-off between intervention length and fatigue, particularly with non-clinical samples using pre-recorded, automated interventions. With limited resources, we opted for a 14-day course following from the mixed results of our 10-day pilot and previous similar studies (96,119). Our pilot study saw a dropout rate of about 1/3, prompting us to design a more interesting and engaging course. Influence was primarily taken from the Satipatthana Sutta, which functioned as a pre-made, varied selection of foci, structured in a progressive pattern of increasing subtlety (3).

**Induction**

An induction session defined mindfulness as focusing on the world around us, which in this case includes the body, or as ‘paying attention to what is happening in our minds’, including sensations by being aware that we are aware of sensory information, in the respective conditions. When distracted, participants were to gently return back to the object of focus. Participants in in the current study were directed to avoid elaborations, aided by simple categorisations such as seeing the breath as long or short. Participants were told that this exercise is not controlled breathing, and whilst they are welcome to try to relax into it if they like, they can be mindful no matter what state they are in and can let the breath come and go as it pleases. Slight wording changes between each condition made sure to reference either the world or mental states only. The induction featured several metacognitive skills that were exclusive to the mental states group: non-suppression (not stopping thoughts before they appear), non-clinging (not engaging with the content of thoughts), and equanimity/objectivity (that either positive or negative, thoughts and sensations are like objects passing through our awareness).

**World**

The Mindfulness of the World condition used mindfulness of breathing, posture, and the body (‘anatomical parts’), along with ‘activities’ during optional extra-curricular practice, all from the body Satipatthana (3). Participants attended to the world through various senses, with the focus on the world rather than the sensory states as such. To create a first-order mindfulness of the breath we instructed participants to ‘focus on’ and ‘become completely absorbed in’ the breath. Whilst there is no guarantee our instructions are encouraging the condition-relevant order of thoughts, intervention success would be demonstrated if the World condition cultivates mindfulness of mental states to an inferior extent than the Mental States condition.

Specifically, participants attended to their breath at the stomach and chest in Day 1, and nostrils and then in general on Day 2. Next were body-scans, with the skin on Day 3, and other features like muscles and tendons on Day 4. Day 5 used sounds, and Day 6 used posture, weight, and the body as a whole. Day 7 used smell and taste, whilst Day 8 uses vision of both the inside of the eyelids and with the eyes open. Day 9 used the heart and blood. Day 10 cycles through all previous meditations whilst Day 11 uses open monitoring of the world. Day 12 returns to the breath at the nostrils with minimal guidance, and Day 13 returns to contact with the world with sound and vision. The final session is self-directed with minimal guidance using any of the previously learned techniques. In all these cases the foci of attention were described as objects in the world rather than sensory experiences.

**Mental States**

The mental states condition is a more faithful reproduction of the Satipatthana Sutta, which offers a ready-made progression of categorisations of mental states. We translate these concepts in a way we feel suitable for novice meditators unversed in Buddhist theory. Participants are to remain open to whatever the contents of their mind may be, whilst labelling their mental states using the categorisations provided (120). This intervention begins with an initial breath and body focus which participants could return to during the course, thus keeping a focus on sensory states controlled between conditions. The emphasis, unlike in the world intervention, is on the breath as an experience rather than a physical object.

As we detail this course, the relevant verse of the Satipatthana sutta can be found in square brackets - refer to (3) for more information. Day 1 focuses on the breath [Breath] and Day 2 on the body [Anatomical parts]. Day 3 introduces an awareness of mental states in general, allowing participants to explore this new mode of attention. Day 4 asks participants to label states as positive, negative, or neutral (second Satipatthana), whilst Day 5 looks at those skilful states which meditation cultivates (being mindful, concentrating, being curious, and kind) versus worldly states (e.g., sensations, perceptions, sensual pleasures, pains, distractions) [Feelings]. Day 6 focused on emotions [mind; third Satipatthana]. Day 7 uses the labels of desire (“to have or get something that we want” like “a desire to get up and do something”) and aversion (“to get rid of something we don’t want” like “the pain in your legs from sitting down”) [hindrances]. Day 8 uses states that interrupt our ability to focus: 1) lethargy, laziness, tiredness, or not being bothered with the practice, 2) anxiety, worrying about things, and feeling restless and like you need to do something else, and 3) ‘doubt’ as to the usefulness of this practice [hindrances, part of third and fourth Satipatthana]. Day 9 highlights ‘the relationship *between* thoughts’ from feature extraction, conceptualisation, to elaborations, whilst intentions are used on Day 10, initially by asking participants to consciously choose to breathe in and out [aggregates, fourth Satipatthana]. Day 11 uses the sensory modalities of sound, sight, smell, taste, and touch, but with a focus on the difference between the sense organ, and an awareness of one’s awareness of the relevant sensations and the different ways they are conceptualised [sense spheres, fourth Satipatthana]. Day 12 trains an awareness of awareness, that is: of mindfulness itself, concentration and level of focus, the breadth of awareness and receptivity to new information, how one investigates, probes, and considers phenomena with this mindset, and finally that one can gain a mindful distance from a state, whether they are positive or negative, they are just ‘states’ none-the-less [awakening factors & consciousness aggregate]. Day 13 cycles through most of the previous objects of meditation, also mentioning some positive states which can be cultivated for a change: energy, joy, and tranquillity [awakening factors]. The final meditation is self-directed using what has been learned, with the option to also do open monitoring (c.f. 3, p. 270).

## Measures

Measures were presented in the order listed below, see supplementary for copies of the survey and task.

**Metacognition task**: One crucial manipulation check utilises an objective measure of metacognition which has been successfully utilised in online studies in several papers to date (121–125). In this Two-Alternate Forced Choice (2AFC) task, participants are presented with two 250x250 pixel black boxes invisibly divided into 625 cells that are at least half filled with white dots. On each trial, one of the boxes is randomly chosen to have more dots than the other, and participants are tasked with selecting the box that has more dots. Five variations of dot positions were presented for 150ms each, giving the appearance of flickering dots, and a stimulus duration of 750ms (e.g. 123). In line with (121), the box with more dots was initialised at ~70 extra dots (a figure that will go up or down according to the staircase). The difference in the number of dots between the target and half-filled box is controlled by a ‘2 down 1 up’ (2D1U) staircasing procedure which altered the logarithm of dot-difference; where the difference decreases after two consecutive correct answers and increases after each incorrect answer. In the first 6 trials, dot difference changed by .4 natural log number of dots, with this reducing to a change of .2 for trials 6-11, and .1 after trial 12. Changes in staircasing were initiated during practice trials. 2D1U staircasing should lead to ~71% accuracy for each participant on this task (126). Answers were given by pressing the ‘E’ or ‘I’ key, and the choice was not time limited. 26 practice trials were run where feedback was given, with the words ‘correct’ or ‘incorrect’ displayed, and the chosen square highlighted in either green or red, respectively. The task proper consists of 4 blocks of 42 trials each (168 total) in which no feedback is given, and confidence is rated after every task on a 1 ‘guessing’ to 6 ‘certain’ scale. The data will then analysed using the meta-d’ method to estimate the correspondence between task accuracy and performance (see analysis section below). The task was programmed in JavaScript using JSPsych (version 6.3.1; 127) and integrated into the Qualtrics survey using Qualtrics’ JavaScript API (code available in online supplementary and GitHub listed below).

Several scale measures were also used, all of which were reworded to refer to the last week, and scores were calculated as means. Pre-registered scales are:

**Toronto Mindfulness Scale – Decentring** subscale: The 7-item Decentring subscale of the trait version of the Toronto Mindfulness Scale (TMS-D; 128) was selected as a measure of awareness of mental states. Scores are given on a Likert-type Scale ranging from 0 (Not at all) to 4 (Very much).

**Generalised Anxiety Disorder** scale: The GAD-7 (129) is a 7-item scale which measures anxiety. Scores range from 0 (not at all) to 3 (nearly every day).

**Patient Health Questionnaire**: the short-form PHQ-8 (115) is an 8-item scale which measures depression. Scores range from 0 (not at all) to 3 (nearly every day).

**Expectations:** After the induction session, participants were presented with the following question:

“Mindfulness has been claimed to produce several effects. We want to know what you actually expect about this two-week intervention, given what you have just read.

For each question below, please use the sliders to indicate by how many scale points you expect taking this course will change your answer. We have provided the original scale labels for reference, but please use the sliders to tell us the number of units you expect your score to increase or decrease by compared to before the course.

For example, say that before taking this course you answered the question 'Over the last week, how often have you had trouble relaxing?' with the answer '3. Moderately' on the 5-point scale provided. if you expect that, by the end of this course, your answer will have changed to '2. A little' on the same scale, then you are expecting a reduction of 1 point on the scale, and your answer below would be '-1'.

Likewise, if you expect your score will remain the same after versus before the intervention, say 0. If you think your score will be larger by a certain number of units say +that number, e.g., +2; if you think your score will have reduced by a certain number of units say - that number, e.g., -2.

Please check the axis label for each section before answering!”

One item will be included for each exploratory scale, along with each item of the TMS, GAD-7 and PHQ-8. The questions, scale-points and labels will be the same as in the original scales, symmetrical around 0. In analysis, we will create an average expectation score for each scale with more than one expectation related question (i.e., TMS, GAD-7, and PHQ-8), whilst the single item expectations for exploratory scales will be analysed separately.

**Completion time:** Time taken in days to complete the intervention will be measured to check that this variable does not account for differences in outcomes.

The following scales from the pilot study will also be ran for exploratory analyses (see pilot study methods section in online supplementary for more info):

* The RRS (130)
* The 15-item WBSI (118)

The following scales are also exploratory but did not feature in the pilot study:

1. **FFMQ Observe – Perceptual vs World versions:** Following from the Observe sub-scale providing sensitive evidence in the pilot study, we have taken the Observe subscale from the full FFMQ (101), and reworded it to reflect an awareness of the world and mental states, separately. The scale was structured so that a first order question was asked before the corresponding second-order item. For example, a worldly observation question asks, “I pay attention to sounds in the world, such as clocks ticking, birds chirping, or cars passing.”, which is followed by a mental states focused variant “I pay attention to hearing sounds, such as clocks ticking, birds chirping, or cars passing.”. The last question of the Observe subscale “I pay attention to how my emotions affect my thoughts and behaviour” was removed from the questionnaire as it does not refer to sensory perception. The two versions of the scale can be found in the supplementary materials.
* **Engagement:** At the beginning of each day’s survey, before meditating, participants will be asked if they were mindful during an activity after the previous session. After each practice, participants will be asked how long they spent focusing on the task just completed. At the very end of the post-test survey, participants will be asked how well they stuck to the course content.

# Analysis Plan

**Multiple Imputation**

Missing data will be imputed using Multiple Imputation methods. Surveys will force responses on all questions, and so we only expect missing data due to drop-outs. Condition will be included in all imputation models, as the main ‘covariate’ of missingness we require to be equalised between conditions for our analyses, and as differences in intervention content are most likely a motivator of dropouts. Computing data separately by condition may make little effect either way (131).

Our dataset will contain 73 items and a cognitive task, plus additional auxiliary variables, per-test. Although an item-level analysis is recommended for MI (132), along with one which is inclusive of available variables (133), in our case this would create an unwieldy regression equation that will likely not converge (see pilot study; 134 pp. 259-271). In line with the approach suggested by Plumpton et al., (135), we will impute missing data on each item using all pre-test items on that scale and sub-scale means for other scales in the dataset – in the case where the entirety of post-test scores are missing, a scale-level analysis should be suitable anyway (136). Metacognitive efficiency will be calculated for each participant before imputation and will similarly rely subscale-level pre-test predictors.

Multiple Imputation will be handled using a fully conditional specification approach (137 pp. 116-118; 138), with a Bayesian Regression imputation method (137,139), using the ‘mice’ R package (140). Imputed values will be unconstrained by possible scale values, including negativity (c.f. 141,142). 100 imputed datasets will be generated, in accordance with the upper-end of that tested by Graham, Olchowski, & Gilreath (143; see also: 144). Number of iterations will be estimated by the percentage of participants with missing post-test data, although a minimum of 30 will be used (145,146). Each statistical test (along with means and SEs) will be carried out on each imputed dataset separately, and the mean of these results are presented in the table below and taken as the final result.

**Metacognitive Efficiency and Sensitivity**

The metacognition task (see ‘materials’ above) will be analysed using the meta-d’ method (95,147). Meta-d’ is a measure of the correspondence between task accuracy (selecting the correct box – the ‘type 1’ task) and confidence on that task (type-2 task), in a way which is unaffected by one’s idiosyncratic use of the confidence scale (i.e., bias). Meta d’ is the Type I d’ that would exist if the first order discrimination was based on the same signal and noise first order evidence distributions as the confidence decisions – this is called ‘metacognitive sensitivity’. As this metric is in type-1 units, it can be divided by a participant’s actual type-1 performance to estimate how far off from metacognitively ideal their performance was (i.e., meta-d’/d’; ‘metacognitive efficiency’). A score of 1 then indicates one was ‘metacognitively ideal’, although meta-d’ can exceed d’ for several proposed reasons (148). Whether this is the best way of controlling for Type I performance in assessing metacognition is a point we now explore.

Metacognitive efficiency is a ratio, and this way of factoring d’ into the metric may introduce more noise than it removes (roughly, the proportional error of a ratio is the sum of proportional errors of its terms). To examine this possibility, data from two previous similar studies were examined for changes in meta-d’ and meta-d’/d’ in their group\*time interaction (94,98; exactly which data is detailed in ‘models for H1 below, models were fitted individually by maximum likelihood estimation). Results show that meta-d’ recorded a change of M=0.61, SE=0.29 and whilst meta-d’/d’ saw the mean halved, the SE did not see notable reductions (M=0.33, SE=0.24; N.B. SEs from Schmidt et al. adjusted to Carpenter et al.’s N=61). Typically, one can logarithmically transform a ratio measure to normalise the distribution, as suggested in previous papers on meta-d’ (e.g. 95,149). In practice, the log transformed meta-d’/d’ from these previous studies had M=.30, SE=.25 in ln units. Crucially, the estimated required sample sizes were meta-d’ N=110, meta-d’/d’ N=300, log(meta-d’/d’) N=330. That meta-d’/d’ introduces more noise than it takes out from the meta-d’ measure, and that this appears unaffected by logging this ratio, is worth noting for future research. A further widely used method for controlling for a variable is of course regression; so we also tried analysing meta-d’ as the DV, with d’ as a covariate. Doing so yields change data from previous studies of M=0.54 (with SE=0.29, as above), with a required sample size estimated at N=160. So, regression turns out more sensitive than taking a ratio. Our study will use this covariate adjustment method to analyse meta-d’ data, which we call ‘Adjusted Metacognitive Sensitivity’. Models will be fit on an individual basis with a Bayesian estimation method using Fleming’s Hmeta-d (149) MATLAB (150) toolbox. Group-level hierarchical model fits as suggested in (149) would be unsuitable for the adjustment method we rely on as estimations of meta-d’ values are in part based on estimations of meta-d’/d’ at the group level, and thus become non-independent.

**Change Analysis**

We will contrast the Mindfulness of Mental States condition against the Mindfulness of the World condition, with the latter in turn compared to the Waitlist condition. We rely on a change analysis method by decomposing the interaction between group (Mental, World, Waitlist) and time (pre vs. post) into contrasts between 1) the mental states and the world condition and 2) the world condition and the Waitlist condition. T-ratios and associated p-values will be calculated from follow-up contrasts on an ANOVA of post-test value by condition, although these are not pre-registered as we rely on a Bayesian analysis upon which we draw conclusions.

**Bayes Factors**

Analyses are interpreted with respect to Bayes factors (*B*), although p values are provided as well (151,152). A *B* of above 3 indicates “substantial” (153) or, better, “moderate” (154) evidence for the alternative hypothesis (H1) over the null hypothesis (H0); thus by symmetry a *B* below 1/3 indicates substantial (/moderate) evidence for H0 over H1 (“substantial” in the sense of just worth taking note of). *B*s between 3 and 1/3 indicate the data collected do not sensitively distinguish H0 from H1. Thus, we will report that there was no effect only when *B* < 1/3. H0 will always be modelled as a spike on 0 (155, pp 24-26). Here, *B*H(0, x) refers to a Bayes factor in which the predictions of H1 were modelled as a half-normal distribution with an SD of x where x scales the size of effect that could be expected (*see* 156). To indicate the robustness of Bayesian conclusions, for each *B*, a robustness region is reported (157), giving the range of scales that qualitatively support the same conclusion (i.e. evidence as supporting H0, or as supporting H1, or there not being much evidence at all), notated as: RRconclusion [x1, x2] where x1 is the smallest SD that gives the same conclusion and x2 is the largest. “Conclusion” means “*B* < 1/3”, or “1/3 < *B* < 3”, or “*B* > 3”.

## Models of H1 for Bayes factors

*See online supplementary for data and r code to reproduce the following analyses.*

Bayes factors will use a point estimate of 0 for the model of the null hypothesis (H0; 155).

**Adjusted Metacognitive Sensitivity**

Data from two previous similar studies was available - means differences and SEs from the group by time interactions for their perception measures only (similar to the task used in our own study) were extracted. Schmidt et al. (94) had a similar paradigm to the current study, pairing an 8-week mindfulness of the body to a mindfulness of mental states (for this study the SE was adjusted by the ratio of the square root of sample sizes). Carpenter et al. (98) trained individuals directly on either type-1 task accuracy or metacognition - we extracted data from those stimuli participants were trained on. The mean interaction (pre vs post by metacognitive training vs control) for these studies was M=0.54, SE=0.29 meta-d’ units, adjusted for type-1 d’ (see above). Thus, our prior will be set to a half-normal with an SD of 0.5 meta-d’ units (code, data, and sources available in supplementary).

**d’**

We expect equivalent task performance in d’ as a result of staircasing task difficulty. It is not necessary to assume equivalent d’s for our analysis of meta-d’, because we adjust for d’. Nonetheless we will test this assumption with a Bayes Factor between the mean d’ of each group, against a model of H1 with an SD of the unadjusted meta-d’ difference between groups. Thus, we will examine the amount of type-1 d’ that would be needed to explain the recorded difference in meta-d’ (i.e. type-2 performance in d’ units). Note this test is non-crucial.

**Likert scales**

The SD of the half-normal distribution should be set to a roughly expected scale of effect, or half a plausible maximum (156). Thus, we base our estimates of expected effect size under the experimental hypothesis on effect sizes found in previous studies (c.f. 157). Studies were considered for use in calculation of a model of H1 if they were short (10 minutes, 10-14 days) online controlled trails with Likert-scale measures and available with cell means available for measures at pre- and post-test. Four studies using the Learning Mindfulness Online intervention upon which our own was based were located (96,119,158,159), along with 3 others using the Headspace app (160–162). The average interaction for mean scores between conditions over time, on a per-question basis and placed on a common 4-point Likert-scale, was .2 Likert units, which will be used as the model of H1 for all scale measures.

**Expectancies**

Expectancy scales for mindfulness (TMS), anxiety (GAD-7) and exploratory scales will be administered - averages on each of these will be calculated. As we expect a roughly 0.2 Likert unit change on each outcome variable, this is the relevant amount of expected change we need to rule out. We assume that an expectancy to change by X units could at most produce a change of X units. Thus, expectancy changes more like 0.4 rather than 0.2 units would be needed to account for an outcome change of 0.2 units. Further, in this case, smaller differences in expectancy are not more likely in terms of explaining a change in outcome variables than larger changes. Thus, H1 would be modelled as a normal distribution with a mean of 0.2 Likert units and SD = 0.1. If expectancy has not been controlled, we will enter it as a covariate in all above analyses, and conclusions will follow from this analysis.

**Time on intervention**

We will also take the time taken to complete the interventions into account – that is, we will evaluate equivalence between interventions for the effect that time taken to complete that intervention had on mindfulness training. In order to estimate the relevant effect size on which to base our model of H1, we will regress TMS scores against time taken to complete an intervention, and then divide the raw difference in TMS scores between interventions by this slope. Our estimate of the amount of time taken to complete the intervention that would be needed to explain the difference in TMS scores between interventions will be the SD of a half-normal, against which the obtained difference in intervention completion time between interventions will be compared, with a Bayes Factor. This analysis is considered non-crucial.

# Sample size estimation

**Scale Measures**

We estimated the sample size required to reach a result sensitive to a Bayes Factor of 1/3 and 3. The sample SE was modelled using 100 participant mean difference scores over time on a random selection of 7 items (i.e., the length of the TMS-D and GAD-7) and 8 items (for the PHQ-8) from the FFMQ-sf in the pilot study. The SD of the resulting distribution of sample means was used as the SD of the distribution of our hypothetically obtained data. Using the method described by (163), this sample SE was multiplied by the square root of: the harmonic mean of the group size in the pilot study divided by the estimated required sample size (per group), for a final sample SE. Obtained data were modelled with a mean of 0, whilst H1 was a half-normal with SD=.2 Likert units, as estimated above. Results across imputed datasets were meaned, and the minimum sample size leading to a Bayes Factor <.33 extracted. As a result of this procedure, we estimate a minimum of 180 (for the PHQ-8) to 220 (for the TMS-D and GAD-7) participants would be needed for comparisons between the mental states and world group, and 150 (PHQ-8) to 180 (TMS-D and GAD-7) participants for comparisons between the world and waitlist group.

**Expectations**

Subsequently, a similar analysis was run for expectations, using the H1 of a normal distribution with Mean = .2, SD=.1 Likert units (See ‘models of H1’, above). Seeking to avoid single item-measures for key outcome variables, a sample SE was estimated for a random selection of 4-7 FFMQ items, as above, as we had little other information to go on. Required sample size (n=120) seemed to plateau around 5 questions. One question will be asked for each item of the GAD-7, PHQ-8 and TMS-D for completeness.

**Meta-d’**

Previous likely effect size for meta-d’ is estimated at M=0.5, SE=0.29 meta-d’ units (see above). H1 was thus modelled as a half-normal with SD=.5. The SE for a given sample size was estimated as: 0.29 times the square root of: the harmonic mean of the group sizes in Schmidt et al. and Carpenter et al. (harmonic n=19), divided by the estimated group size required for our own study. Thus, an estimated minimum required effect size was obtained of 160 participants in total.

We will thus run 220 participants and stop data collection when either the Bayes factors of all crucial tests are above 3 or less than 1/3, or we have reached a maximum of 300 participants in total.

# Disclosures

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**Ethical Statement**

Ethical approval for the main study has been received from the University of Sussex ethical committee (ER/MEL29/7).

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**Data Accessibility**

All data and code used in this project are freely available in the online supplementary and following GitHub repository: <https://github.com/Max-Lovell/MindfulnessOfMentalStates> (DOI: 10.5281/zenodo.4390462; [164]) and at this OSF repository: <https://osf.io/vu2dk/files/>.

**Competing Interests**

We have no competing interests.

**Authors' Contributions**
Author’s contributions: Pilot data was collected by several undergraduate and master’s students for final projects over several years (see Acknowledgements, above; ML also helped collect pilot data on his MSc). ML wrote the code for the materials and analysis, drafted the manuscript, and contributed to design changes for the main study. ZD conceived of the study, designed the pilot and co-designed the main study, participated in pilot data collection, largely decided the statistical analyses, and provided feedback on the manuscript. This project is in contribution to ML’s PhD thesis, with ZD as supervisor. Both authors gave final approval for publication and agree to be held accountable for the work performed therein.

# Hypothesis registration table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Question** | **Hypothesis** | **Sampling plan** | **Analysis Plan** | **Rationale for deciding the sensitivity of the test for confirming or disconfirming the hypothesis** | **Interpretation given different possible outcomes** | **Theory that could be shown wrong by the outcomes** |
| Do expectations to improve account for difference in outcomes? | Mindfulness of Mental States and Mindfulness of the World will have ‘equivalent’ expectations for a change in mindfulness and for depression and anxiety. | Estimated 120 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | Separate analyses run for mindfulness and for depression/anxiety expectations. Bayes Factor of expectancy difference between Mental States and World group. As expectations should be limited to tracking outcome changes, H1 estimated at double the likely effect size (2x.2=.4) - and modelled as a normal distribution (M=.2,SD=.1) as larger, not smaller expectations likely to lead to larger outcomes. If expectations are non-equivalent but this difference is small, we will factor this out by adjusting the means for expectation effects. | *B* > 3 is the amount of evidence just worth taking note of, by tradition | *B* > 3, expectations non-equivalent, *B* < 1/3, expectations equivalent. | Any effects noticed in the mindfulness of mental states intervention are not due to the placebo effect. If expectations track outcome changes, the effect of the manipulation cannot be determined as separate from these expectation effects (manipulation check). |
| Did the time taken to complete the intervention affect the outcome obtained? (non-crucial) | Mindfulness of Mental States and Mindfulness of the World will take ‘equivalent’ amounts of time to complete. | Non-crucial test. | Bayes Factor difference in time taken between mental states and world group for using model of H1 with an SD of the raw difference in TMS scores between interventions divided by slope of regression of TMS on time taken to complete an intervention. | As above | *B* > 3, time taken non-equivalent, *B* < 1/3, time taken equivalent. | Any effect in outcome variables may be due to time taken to complete intervention (non-crucial manipulation check). |
| Has metacognitive task performance been equalised between conditions? | Mindfulness of Mental States will have ‘equivalent’ d’ scores to Mindfulness of the World. | Non-crucial test. | Bayes Factor of mean difference in d’ between groups, with H1 modelled as a half-normal with an SD of the difference in meta-d’ between groups | As above | *B* > 3, task performance non-equivalent, *B* < 1/3, task performance equivalent. | Any effect in meta-d’ may be due to task performance (non-crucial manipulation check). |
| Is mindfulness a metacognitive practice? | Mindfulness of Mental States will increase d’ adjusted meta-d’ scores over Mindfulness of the World. | Estimated 160 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | Bayes Factor of interaction contrast between mental states group and world group by pre vs post, using model of H1 with SD =.5 meta-d’ units difference. | As above | *B* > 3, metacognition training increases mindfulness. *B* < 1/3, the extra metacognitive training is not useful for a short mindfulness intervention in order to increase mindfulness. | Metacognitive mindfulness training enhances adjusted metacognitive sensitivity (manipulation check). |
| Does training in mindfulness of mental states rather than the world promote more mindfulness of mental states? | Mindfulness of Mental States will increase TMS-D (decentring) scores over Mindfulness of the World. | Estimated 220 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | Bayes Factor of interaction contrast between mental states group and world group by pre vs post, using model of H1 with SD =.2 Likert units difference. | As above | *B* > 3, metacognition training increases mindfulness. *B* < 1/3, the extra metacognitive training is not useful for a short mindfulness intervention in order to increase mindfulness. | Metacognitive mindfulness training enhances the facilitation of mindfulness of mental states in the short-term (manipulation check). |
| Does a metacognitive component of mindfulness account for its positive effects on mental health, specifically in reducing depression? | Mindfulness of Mental States will decrease PHQ-8 (depression), scores over Mindfulness of the World. | Estimated 180 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | As above | As above | *B* > 3, metacognitive training is an important component of the effectiveness of mindfulness on depression in the short term. *B* < 1/3, metacognitive training is not an important component of short-term mindfulness interventions on depression. | Metacognitive training is key to the beneficial effects of short-term mindfulness interventions on depression. |
| Does a metacognitive component of mindfulness account for its positive effects on mental health, specifically in reducing anxiety? | Mindfulness of Mental States will decrease GAD-7 (anxiety), scores over Mindfulness of the World. | Estimated 220 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | As above | As above | *B* > 3, metacognitive training is an important component of the effectiveness of mindfulness on mental health in the short term. *B* < 1/3, metacognitive training is not an important component of short-term mindfulness interventions on anxiety. | Metacognitive training is key to the beneficial effects of short-term mindfulness interventions on anxiety. |
| Is the Mindfulness of the World an effective mindfulness intervention?  | TMS-D scores will increase in The Mindfulness of the World group over Waitlist controls | Estimated 180 participants needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | As above, except between World and Waitlist Group | As above | *B* > 3, Mindfulness of the World training increases mindfulness (TMS-D) scores, *B* < 1/3, the Mindfulness of the World group was not successful in increasing mindfulness scores. | Mindfulness of the world is an effective part of mindfulness training that can be targeted (manipulation check). |
| Mindfulness of the world has positive effects on mental health, specifically in reducing depression | Mindfulness of the World will decrease, and PHQ-8 (depression) scores compared to the Waitlist control. | Estimated 150 participants for PHQ-8 needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | As above | As above | *B* > 3, mindfulness of the world is an important component of the effectiveness of mindfulness on depression in the short term. *B* < 1/3, mindfulness of the world is not an important component of short-term mindfulness interventions on depression. | Mindfulness of the world is a component of the beneficial effects of short-term mindfulness interventions on depression. |
| Mindfulness of the world has positive effects on mental health, specifically in reducing anxiety | Mindfulness of the World will decrease, and GAD-7 (anxiety) scores compared to the Waitlist control. | Estimated 180 participants for GAD-7 needed. Sample until one of: i) *B* > 3; ii) *B* < 1/3; or iii) N = 300 | As above | As above | *B* > 3, mindfulness of the world is an important component of the effectiveness of mindfulness on mental health in the short term. *B* < 1/3, mindfulness of the world is not an important component of short-term mindfulness interventions on anxiety. | Mindfulness of the world is a component of the beneficial effects of short-term mindfulness interventions on anxiety. |

# References

1. Van Dam NT, van Vugt MK, Vago DR, Schmalzl L, Saron CD, Olendzki A, et al. Mind the Hype: A Critical Evaluation and Prescriptive Agenda for Research on Mindfulness and Meditation. Perspect Psychol Sci. 2018 Jan;131:36–61.

2. Zawidzki TW. What Is Meta-Cognitive Skill? Kindling a Conversation Between Culadasa and Contemporary Philosophy of Psychology. Contemporary Buddhism. 2018 Jul 3;192:476–92.

3. Anālayo B. Satipạṭthāna: The direct path to realization. Cambridge, United Kingdom: Windhorse. 2003;

4. Jankowski T, Holas P. Metacognitive model of mindfulness. Consciousness and Cognition: An International Journal. 2014 Aug;28:64–80.

5. Teasdale JD, Moore RG, Hayhurst H, Pope M, Williams SM, Segal ZV. Metacognitive awareness and prevention of relapse in depression: empirical evidence. Journal of consulting and clinical psychology. 2002;702:275–87.

6. Vago DR, Silbersweig DA. Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. Frontiers in Human Neuroscience. 2012 Oct 25;6:30.

7. Dreyfus G. Is mindfulness present-centred and non-judgmental? A discussion of the cognitive dimensions of mindfulness. Contemporary Buddhism. 2011 May 1;121:41–54.

8. Bodhi B. What does mindfulness really mean? A canonical perspective. Contemporary Buddhism. 2011 May 1;121:19–39.

9. Shapiro SL, Carlson LE, Astin JA, Freedman B. Mechanisms of mindfulness. Journal of Clinical Psychology. 2006;623:373–86.

10. Bernstein A, Hadash Y, Lichtash Y, Tanay G, Shepherd K, Fresco DM. Decentering and Related Constructs: A Critical Review and Metacognitive Processes Model. Perspectives on Psychological Science [Internet]. 2015 Sep 17 [cited 2020 Feb 9]; Available from: https://journals.sagepub.com/doi/10.1177/1745691615594577

11. Bernstein A, Hadash Y, Fresco DM. Metacognitive processes model of decentering: emerging methods and insights. Current Opinion in Psychology. 2019 Aug 1;28:245–51.

12. Hargus E, Crane C, Barnhofer T, Williams JMG. Effects of mindfulness on meta-awareness and specificity of describing prodromal symptoms in suicidal depression. Emotion. 2010;101:34.

13. Hoge EA, Bui E, Goetter E, Robinaugh DJ, Ojserkis RA, Fresco DM, et al. Change in Decentering Mediates Improvement in Anxiety in Mindfulness-Based Stress Reduction for Generalized Anxiety Disorder. Cognit Ther Res. 2015 Apr;392:228–35.

14. Orzech KM, Shapiro SL, Brown KW, McKay M. Intensive mindfulness training-related changes in cognitive and emotional experience. The Journal of Positive Psychology. 2009 May;43:212–22.

15. Carmody J, Baer RA, Lykins ELB, Olendzki N. An empirical study of the mechanisms of mindfulness in a mindfulness-based stress reduction program. Journal of Clinical Psychology. 2009;656:613–26.

16. Tanay G, Lotan G, Bernstein A. Salutary Proximal Processes and Distal Mood and Anxiety Vulnerability Outcomes of Mindfulness Training: A Pilot Preventive Intervention. Behavior Therapy. 2012 Sep 1;433:492–505.

17. Feldman G, Greeson J, Senville J. Differential effects of mindful breathing, progressive muscle relaxation, and loving-kindness meditation on decentering and negative reactions to repetitive thoughts. Behaviour Research and Therapy. 2010 Oct 1;4810:1002–11.

18. Gayner B, Esplen MJ, DeRoche P, Wong J, Bishop S, Kavanagh L, et al. A randomized controlled trial of mindfulness-based stress reduction to manage affective symptoms and improve quality of life in gay men living with HIV. J Behav Med. 2012 Jun 1;353:272–85.

19. Haggard P, Clark S, Kalogeras J. Voluntary action and conscious awareness. Nat Neurosci. 2002 Apr;54:382–5.

20. Wolpe N, Rowe JB. Beyond the “urge to move”: objective measures for the study of agency in the post-Libet era. Front Hum Neurosci [Internet]. 2014 [cited 2020 Apr 24];8. Available from: https://www.frontiersin.org/articles/10.3389/fnhum.2014.00450/full

21. Suzuki K, Lush P, Seth AK, Roseboom W. Intentional Binding Without Intentional Action. Psychol Sci. 2019 Jun 1;306:842–53.

22. Jo H-G, Hinterberger T, Wittmann M, Schmidt S. Do meditators have higher awareness of their intentions to act? Cortex. 2015 Apr 1;65:149–58.

23. Lush P, Naish P, Dienes Z. Metacognition of intentions in mindfulness and hypnosis. Neuroscience of consciousness. 2016;20161:1.

24. Dienes Z, Lush P, Palfi B, Roseboom W, Scott R, Parris B, et al. Phenomenological control as cold control. Psychology of Consciousness: Theory, Research, and Practice. 2020;

25. Lush P, Parkinson J, Dienes Z. Illusory Temporal Binding in Meditators. Mindfulness. 2016 Dec;76:1416–22.

26. Semmens-Wheeler R. The contrasting role of higher order awareness in hypnosis and meditation [PhD Thesis]. University of Sussex; 2013.

27. Dienes Z, Perner J. Executive control without conscious awareness: The cold control theory of hypnosis. Hypnosis and conscious states: The cognitive neuroscience perspective. 2007;293–314.

28. Lynn SJ, Rhue JW, Weekes JR. Hypnotic involuntariness: A social cognitive analysis. Psychological Review. 1990;972:169.

29. Dienes Z, Lush P, Semmens-Wheeler R, Parkinson J, Scott R, Naish P. Hypnosis as self-deception; Meditation as self-insight. In: Raz IA, Lifshitz M, editors. Hypnosis and Meditation: Toward an integrative science of conscious planes. Oxford: Oxford University Press; 2016. p. 107–28.

30. Fernandez-Duque D, Baird JA, Posner MI. Executive Attention and Metacognitive Regulation. Consciousness and Cognition. 2000 Jun;92:288–307.

31. Shimamura AP. Toward a Cognitive Neuroscience of Metacognition. Consciousness and Cognition. 2000 Jun;92:313–23.

32. Brefczynski-Lewis JA, Lutz A, Schaefer HS, Levinson DB, Davidson RJ. Neural correlates of attentional expertise in long-term meditation practitioners. Proceedings of the National Academy of Sciences. 2007 Jul 3;10427:11483–8.

33. Newberg A, Alavi A, Baime M, Pourdehnad M, Santanna J, d’Aquili E. The measurement of regional cerebral blood flow during the complex cognitive task of meditation: a preliminary SPECT study. Psychiatry Research: Neuroimaging. 2001 Apr 10;1062:113–22.

34. Tang Y-Y, Tang R. Rethinking future directions of the mindfulness field. Psychological Inquiry. 2015 Oct;264:368–72.

35. Creswell JD, Way BM, Eisenberger NI, Matthew, Lieberman D. Neural correlates of dispositional mindfulness during affect labeling. Psychosomatic Medicine. 2007;

36. Berkovich-Ohana A, Glicksohn J, Goldstein A. Mindfulness-induced changes in gamma band activity – Implications for the default mode network, self-reference and attention. Clinical Neurophysiology. 2012 Apr 1;1234:700–10.

37. Farb NAS, Segal ZV, Mayberg H, Bean J, McKeon D, Fatima Z, et al. Attending to the present: mindfulness meditation reveals distinct neural modes of self-reference. Social cognitive and affective neuroscience. 2007 Dec;24:313–22.

38. Allen M, Dietz M, Blair KS, van Beek M, Rees G, Vestergaard-Poulsen P, et al. Cognitive-affective neural plasticity following active-controlled mindfulness intervention. The Journal of neuroscience : the official journal of the Society for Neuroscience. 2012 Oct 31;3244:15601–10.

39. Tang Y-Y, Lu Q, Geng X, Stein EA, Yang Y, Posner MI. Short-term meditation induces white matter changes in the anterior cingulate. PNAS. 2010 Aug 31;10735:15649–52.

40. Martin JR. The common factor of mindfulness--An expanding discourse: Comment on Horowitz (2002). Journal of Psychotherapy Integration. 2002 Jun;122:139–42.

41. Wells A. Detached mindfulness in cognitive therapy: A metacognitive analysis and ten techniques. Journal of Rational-Emotive & Cognitive-Behavior Therapy. 2005 Dec;234:337–55.

42. Bauer PR, Poletti S, Lutz A, Sabourdy C. Coping with Seizures Through Mindfulness Meditation: a Qualitative Study of a Mindfulness-Based Intervention in Epilepsy. Mindfulness. 2019 Oct 1;1010:2010–25.

43. Goyal M, Singh S, Sibinga E, Gould N, Rowland-Seymour A, Sharma R, et al. Meditation Programs for Psychological Stress and Well-being: A Systematic Review and Meta-analysis. Deutsche Zeitschrift für Akupunktur. 2014;573:26–7.

44. Hofmann SG, Sawyer AT, Witt AA, Oh D. The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. Journal of Consulting and Clinical Psychology. 2010;782:169–83.

45. Wells A, Matthews G. Modelling cognition in emotional disorder: The S-REF model. Behaviour Research and Therapy. 1996 Nov 1;3411:881–8.

46. Wells A. Emotional disorders and metacognition: Innovative cognitive therapy. John Wiley & Sons; 2002.

47. Bodhi B. Dhamma and Non-duality [Internet]. Access to Insight (BCBS Edition); 2011. Available from: http://www.accesstoinsight.org/lib/authors/bodhi/bps-essay\_27.html

48. Kabat‐Zinn J. Mindfulness-Based Interventions in Context: Past, Present, and Future. Clinical Psychology: Science and Practice. 2003;102:144–56.

49. Dreeben SJ, Mamberg MH, Salmon P. The MBSR Body Scan in Clinical Practice. Mindfulness. 2013 Dec 1;44:394–401.

50. Sharf R. Mindfulness and Mindlessness in Early Chan. Philosophy East and West. 2014;644:933–64.

51. Laukkonen RE, Slagter HA. From many to (n)one:Meditation and the plasticity of the predictive mind. Neuroscience & Biobehavioral Reviews [Internet]. 2021 Jun 14 [cited 2021 Jun 19]; Available from: https://www.sciencedirect.com/science/article/pii/S014976342100261X

52. Anālayo. Mindfulness of breathing: A practice guide and translations. Cambridge: Windhorse Publications; 2019.

53. Rosenthal DM. Consciousness and mind. Oxford ; New York: Oxford University Press; 2005. 378 p.

54. Coseru C. Buddhism, Comparative Neurophilosophy, and Flourishing. Zygon®. 2014;491:208–19.

55. Garfield JL. Engaging Buddhism: Why it matters to philosophy. Oxford University Press; 2014. Ch. 5.5-5.7.

56. Yao Z. The Buddhist theory of self-cognition. Routledge; 2012. p. 159.

57. Upatissa A, Thera S, Thera K, Ehara NRM. The Path of Freedom (Vimuttimagga). Kandy, Ceylon (Sri Lanka): Buddhist Publication Society; 1961.

58. Nanamoli B, Bodhi B. The middle length discourses of the Buddha. A Translation of the Majjhima Nikaya, Wisdom Publication, Somerville, MA. 1995;

59. Santorelli SF, Meleo-Meyer F, Koerbel L, Kabat-Zinn J. Mindfulness-Based Stress Reduction (MBSR) Authorized Curriculum Guide. 2017;65.

60. Baer RA, editor. Mindfulness-based treatment approaches: clinician’s guide to evidence base and applications. Second edition. London, UK ; Waltham, MA: Elsevier Academic Press; 2014. 391 p.

61. Segal ZV, Williams JMG, Teasdale JD. Mindfulness-based Cognitive Therapy for Depression. 2nd ed. New York, NY, US: The Guilford Press; 2013.

62. Ospina MB, Bond K, Karkhaneh M, Buscemi N, Dryden DM, Barnes V, et al. Clinical Trials of Meditation Practices in Health Care: Characteristics and Quality. The Journal of Alternative and Complementary Medicine. 2008 Dec 1;1410:1199–213.

63. Baer R, Gu J, Cavanagh K, Strauss C. Differential sensitivity of mindfulness questionnaires to change with treatment: A systematic review and meta-analysis. Psychological Assessment. 2019 Oct;3110:1247–63.

64. Goldberg SB, Tucker RP, Greene PA, Simpson TL, Hoyt WT, Kearney DJ, et al. What Can We Learn from Randomized Clinical Trials About the Construct Validity of Self-Report Measures of Mindfulness? A Meta-Analysis. Mindfulness. 2019 May;105:775–85.

65. Khoury B, Lecomte T, Fortin G, Masse M, Therien P, Bouchard V, et al. Mindfulness-based therapy: A comprehensive meta-analysis. Clinical Psychology Review. 2013 Aug;336:763–71.

66. Quaglia JT, Braun SE, Freeman SP, McDaniel MA, Brown KW. Meta-analytic evidence for effects of mindfulness training on dimensions of self-reported dispositional mindfulness. Psychological Assessment. 2016;287:803–18.

67. Visted E, Vøllestad J, Nielsen MB, Nielsen GH. The Impact of Group-Based Mindfulness Training on Self-Reported Mindfulness: a Systematic Review and Meta-analysis. Mindfulness. 2015 Jun 1;63:501–22.

68. Martin JR. Mindfulness: A proposed common factor. Journal of Psychotherapy Integration. 1997 Dec;74:291–312.

69. Holowka DW. Experiential awareness and psychological well -being: Preliminary investigation of a proposed common factor [Internet] [Ph.D.]. [United States -- Massachusetts]: University of Massachusetts Boston; 2008 [cited 2020 Feb 21]. Available from: http://search.proquest.com/docview/304800706/abstract/5F8A299811424352PQ/1

70. Zeidan F, Johnson SK, Gordon NS, Goolkasian P. Effects of Brief and Sham Mindfulness Meditation on Mood and Cardiovascular Variables. The Journal of Alternative and Complementary Medicine. 2010 Aug;168:867–73.

71. Smith JC. Psychotherapeutic effects of transcendental meditation with controls for expectation of relief and daily sitting. Journal of Consulting and Clinical Psychology. 1976 Aug;444:630–7.

72. Johnson S, Gur RM, David Z, Currier E. One-Session Mindfulness Meditation: A Randomized Controlled Study of Effects on Cognition and Mood. Mindfulness. 2015 Feb 1;61:88–98.

73. Austin JH. Zen and the brain: Toward an understanding of meditation and consciousness. MIT Press; 1999.

74. Siff J. Unlearning meditation: What to do when the instructions get in the way. Shambhala Publications; 2010.

75. Yen S. The method of no-method: The Chan practice of silent illumination. Shambhala Publications; 2008.

76. Zeidan F, Emerson NM, Farris SR, Ray JN, Jung Y, McHaffie JG, et al. Mindfulness Meditation-Based Pain Relief Employs Different Neural Mechanisms Than Placebo and Sham Mindfulness Meditation-Induced Analgesia. J Neurosci. 2015 Nov 18;3546:15307–25.

77. Noone C, Hogan MJ. A randomised active-controlled trial to examine the effects of an online mindfulness intervention on executive control, critical thinking and key thinking dispositions in a university student sample. BMC Psychol. 2018 Dec;61:13.

78. Lieberman MD, Inagaki TK, Tabibnia G, Crockett MJ. Subjective responses to emotional stimuli during labeling, reappraisal, and distraction. Emotion. 2011;113:468.

79. Kiken LG, Shook NJ. Looking Up: Mindfulness Increases Positive Judgments and Reduces Negativity Bias. Social Psychological and Personality Science. 2011 Jul 1;24:425–31.

80. Kiken LG, Shook NJ. Does mindfulness attenuate thoughts emphasizing negativity, but not positivity? Journal of Research in Personality. 2014 Dec;53:22–30.

81. Hafenbrack AC, Kinias Z, Barsade SG. Debiasing the Mind Through Meditation: Mindfulness and the Sunk-Cost Bias. Psychol Sci. 2014 Feb 1;252:369–76.

82. Wilson BM, Mickes L, Stolarz-Fantino S, Evrard M, Fantino E. Increased False-Memory Susceptibility After Mindfulness Meditation. Psychol Sci. 2015 Oct 1;2610:1567–73.

83. McEvoy PM, Graville R, Hayes S, Kane RT, Foster JK. Mechanisms of change during attention training and mindfulness in high trait-anxious individuals: A randomized controlled study. Behavior Therapy. 2017 Sep;485:678–94.

84. Upton SR, Renshaw TL. Immediate Effects of the Mindful Body Scan Practice on Risk-Taking Behavior. Mindfulness. 2019 Jan 1;101:78–88.

85. McHugh L, Simpson A, Reed P. Mindfulness as a potential intervention for stimulus over-selectivity in older adults. Research in Developmental Disabilities. 2010 Jan 1;311:178–84.

86. Arch JJ, Craske MG. Mechanisms of mindfulness: emotion regulation following a focused breathing induction. Behaviour research and therapy. 2006 Dec;4412:1849–58.

87. Lutz A, Dunne JD, Davidson RJ, others. Meditation and the neuroscience of consciousness. Cambridge handbook of consciousness. 2007;499–555.

88. Lutz A, Slagter HA, Dunne JD, Davidson RJ. Attention regulation and monitoring in meditation. Trends Cogn Sci. 2008 Apr;124:163–9.

89. Kabat-Zinn J. A Meditation on Observing Thoughts, Non-Judgmentally - Mindful [Internet]. 2019 [cited 2020 Jan 6]. Available from: https://www.mindful.org/a-meditation-on-observing-thoughts-non-judgmentally/

90. Mirgain S. A Mindful Breathing Script [Internet]. VHA / Office of Patient Centered Care & Cultural Transformation; 2016 [cited 2019 Dec 4]. Available from: http://projects.hsl.wisc.edu/SERVICE/courses/whole-health-for-pain-and-suffering/Script-Mindful-Breathing.pdf

91. Bishop SR. What Do We Really Know About Mindfulness-Based Stress Reduction? Psychosomatic Medicine. 2002 Feb;641:71.

92. James M. Broadway. A Very Short Tour of the Mind-Wandering Brain. The American Journal of Psychology. 2017;1303:389.

93. Schooler JW, Mrazek MD, Franklin MS, Baird B, Mooneyham BW, Zedelius C, et al. The Middle Way. In: Psychology of Learning and Motivation [Internet]. Elsevier; 2014 [cited 2019 Nov 22]. p. 1–33. Available from: https://linkinghub.elsevier.com/retrieve/pii/B9780128000908000019

94. Schmidt C, Reyes G, Barrientos M, Langer ÁI, Sackur J. Meditation focused on self-observation of the body impairs metacognitive efficiency. Consciousness and Cognition. 2019 Apr 1;70:116–25.

95. Fleming SM, Lau HC. How to measure metacognition. Front Hum Neurosci [Internet]. 2014 [cited 2020 Apr 27];8. Available from: https://www.frontiersin.org/articles/10.3389/fnhum.2014.00443/full

96. Cavanagh K, Strauss C, Cicconi F, Griffiths N, Wyper A, Jones F. A randomised controlled trial of a brief online mindfulness-based intervention. Behaviour Research and Therapy. 2013 Sep;519:573–8.

97. Trautwein F-M, Kanske P, Böckler A, Singer T. Differential benefits of mental training types for attention, compassion, and theory of mind. Cognition. 2020 Jan 1;194:104039.

98. Carpenter J, Sherman MT, Kievit RA, Seth AK, Lau H, Fleming SM. Domain-general enhancements of metacognitive ability through adaptive training. J Exp Psychol Gen. 2019 Jan;1481:51–64.

99. Baird B, Mrazek MD, Phillips DT, Schooler JW. Domain-specific enhancement of metacognitive ability following meditation training. Journal of Experimental Psychology: General. 2014 Oct;1435:1972–9.

100. Mazancieux A, Fleming SM, Souchay C, Moulin CJA. Is there a G factor for metacognition? Correlations in retrospective metacognitive sensitivity across tasks. Journal of Experimental Psychology: General. 20200319;1499:1788.

101. Baer RA, Smith GT, Hopkins J, Krietemeyer J, Toney L. Using Self-Report Assessment Methods to Explore Facets of Mindfulness. Assessment. 2006 Mar;131:27–45.

102. Baer RA, Smith GT, Lykins E, Button D, Krietemeyer J, Sauer S, et al. Construct Validity of the Five Facet Mindfulness Questionnaire in Meditating and Nonmeditating Samples. Assessment. 2008 Sep;153:329–42.

103. Baer RA, Samuel DB, Lykins ELB. Differential Item Functioning on the Five Facet Mindfulness Questionnaire Is Minimal in Demographically Matched Meditators and Nonmeditators. Assessment. 2011 Mar;181:3–10.

104. Gu J, Strauss C, Crane C, Barnhofer T, Karl A, Cavanagh K, et al. Examining the factor structure of the 39-item and 15-item versions of the Five Facet Mindfulness Questionnaire before and after mindfulness-based cognitive therapy for people with recurrent depression. Psychological Assessment. 2016 Jul;287:791–802.

105. Lilja J, Lundh L-G, Josefsson T, Falkenström F. Observing as an Essential Facet of Mindfulness: A Comparison of FFMQ Patterns in Meditating and Non-Meditating Individuals. Mindfulness. 2012 Sep 1;4:1–10.

106. Bruin E, Topper M, Muskens J, Bögels S, Kamphuis J. Psychometric Properties of the Five Facets Mindfulness Questionnaire (FFMQ) in a Meditating and a Non-meditating Sample. Assessment. 2012 Jun 1;19:187–97.

107. Mattes J. Systematic Review and Meta-Analysis of Correlates of FFMQ Mindfulness Facets. Front Psychol [Internet]. 2019 [cited 2020 Dec 2];10. Available from: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02684/full

108. Bohlmeijer E, ten Klooster PM, Fledderus M, Veehof M, Baer R. Psychometric Properties of the Five Facet Mindfulness Questionnaire in Depressed Adults and Development of a Short Form. Assessment. 2011 Sep;183:308–20.

109. Rudkin E, Medvedev ON, Siegert RJ. The Five-Facet Mindfulness Questionnaire: Why the Observing Subscale Does Not Predict Psychological Symptoms. Mindfulness. 2018 Feb;91:230–42.

110. Cardaciotto L, Herbert JD, Forman EM, Moitra E, Farrow V. The Assessment of Present-Moment Awareness and Acceptance: The Philadelphia Mindfulness Scale. Assessment. 2008 Jun;152:204–23.

111. Wells A, Cartwright-Hatton S. A short form of the metacognitions questionnaire: properties of the MCQ-30. Behaviour Research and Therapy. 2004 Apr;424:385–96.

112. Fresco DM, Moore MT, van Dulmen MH, Segal ZV, Ma SH, Teasdale JD, et al. Initial psychometric properties of the experiences questionnaire: validation of a self-report measure of decentering. Behavior therapy. 2007;383:234–46.

113. Lau MA, Bishop SR, Segal ZV, Buis T, Anderson ND, Carlson L, et al. The toronto mindfulness scale: Development and validation. Journal of Clinical Psychology. 2006;6212:1445–67.

114. Kroenke K, Spitzer RL, Williams JBW, Löwe B. The Patient Health Questionnaire Somatic, Anxiety, and Depressive Symptom Scales: a systematic review. General Hospital Psychiatry. 2010 Jul 1;324:345–59.

115. Kroenke K, Spitzer RL. The PHQ-9: A New Depression Diagnostic and Severity Measure. Psychiatric Annals. 2002 Sep;329:509–15.

116. Papageorgiou C, Wells A. An Empirical Test of a Clinical Metacognitive Model of Rumination and Depression. Cognitive Therapy and Research. 2003;13.

117. Alsubaie M, Abbott R, Dunn B, Dickens C, Keil TF, Henley W, et al. Mechanisms of action in mindfulness-based cognitive therapy (MBCT) and mindfulness-based stress reduction (MBSR) in people with physical and/or psychological conditions: A systematic review. Clinical Psychology Review. 2017 Jul 1;55:74–91.

118. Höping W, de Jong-Meyer R. Differentiating unwanted intrusive thoughts from thought suppression: what does the White Bear Suppression Inventory measure? Personality and Individual Differences. 2003 Apr;346:1049–55.

119. Cavanagh K, Churchard A, O’Hanlon P, Mundy T, Votolato P, Jones F, et al. A Randomised Controlled Trial of a Brief Online Mindfulness-Based Intervention in a Non-clinical Population: Replication and Extension. Mindfulness. 2018 Aug;94:1191–205.

120. Frỳba M. The art of happiness: Teachings of Buddhist psychology. Shambhala Publ.; 1989.

121. Rouault M, Seow T, Gillan CM, Fleming SM. Psychiatric Symptom Dimensions Are Associated With Dissociable Shifts in Metacognition but Not Task Performance. Biological Psychiatry. 2018 Sep 15;846:443–51.

122. Plas E van der, Mason D, Livingston LA, Craigie J, Happe F, Fleming S. Computations of confidence are modulated by mentalizing ability [Internet]. PsyArXiv; 2021 [cited 2021 Oct 19]. Available from: https://psyarxiv.com/c4pzj/

123. Rollwage M, Dolan RJ, Fleming SM. Metacognitive Failure as a Feature of Those Holding Radical Beliefs. Current Biology. 2018 Dec;2824:4014-4021.e8.

124. Schulz L, Rollwage M, Dolan RJ, Fleming SM. Dogmatism manifests in lowered information search under uncertainty. Proc Natl Acad Sci USA. 2020 Dec 8;11749:31527–34.

125. Moses-Payne ME, Rollwage M, Fleming SM, Roiser JP. Postdecision Evidence Integration and Depressive Symptoms. Frontiers in Psychiatry [Internet]. 2019 [cited 2022 Jan 18];10. Available from: https://www.frontiersin.org/article/10.3389/fpsyt.2019.00639

126. Garcı́a-Pérez MA. Forced-choice staircases with fixed step sizes: asymptotic and small-sample properties. Vision Research. 1998 Jun;3812:1861–81.

127. de Leeuw JR, Motz BA. Psychophysics in a Web browser? Comparing response times collected with JavaScript and Psychophysics Toolbox in a visual search task. Behav Res. 2016 Mar 1;481:1–12.

128. Davis KM, Lau MA, Cairns DR. Development and Preliminary Validation of a Trait Version of the Toronto Mindfulness Scale. Journal of Cognitive Psychotherapy. 2009 Aug 1;233:185–97.

129. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A Brief Measure for Assessing Generalized Anxiety Disorder: The GAD-7. Arch Intern Med. 2006 May 22;16610:1092.

130. Treynor W, Gonzalez R, Nolen-Hoeksema S. Rumination Reconsidered: A Psychometric Analysis. Cognitive Therapy and Research. 2003;13.

131. Liu G, Gould AL. COMPARISON OF ALTERNATIVE STRATEGIES FOR ANALYSIS OF LONGITUDINAL TRIALS WITH DROPOUTS. Journal of Biopharmaceutical Statistics. 2002 Jan 1;122:207–26.

132. Gottschall AC, West SG, Enders CK. A Comparison of Item-Level and Scale-Level Multiple Imputation for Questionnaire Batteries. Multivariate Behavioral Research. 2012 Feb 8;471:1–25.

133. Collins L, Schafer J, Kam C-M. A Comparison of Restrictive Strategies in Modern Missing Data Procedures. Psychological methods. 2002 Jan 1;6:330–51.

134. van Buuren S. Flexible Imputation of Missing Data. 2nd ed. CRC Press; 2018. 259–271 p.

135. Plumpton CO, Morris T, Hughes DA, White IR. Multiple imputation of multiple multi-item scales when a full imputation model is infeasible. BMC Research Notes. 2016 Jan 26;91:45.

136. Simons CL, Rivero-Arias O, Yu L-M, Simon J. Multiple imputation to deal with missing EQ-5D-3L data: Should we impute individual domains or the actual index? Quality of Life Research. 2015;244:805–15.

137. Van Buuren S. Flexible imputation of missing data. CRC press; 2018.

138. Van Buuren S, Brand JPL, Groothuis-Oudshoorn CGM, Rubin DB. Fully conditional specification in multivariate imputation. Journal of Statistical Computation and Simulation. 2006 Dec;7612:1049–64.

139. Chhabra G, Amity School of Institute Technology, Amity University, Noida – 201313, Uttar Pradesh, India, Vashisht V, Department of Computer Science and Engineering, Amity School of Engineering, Amity University, Noida – 201313, Uttar Pradesh, India, Ranjan J, Institute of Management Technology, Ghaziabad – 201001, Uttar Pradesh, India. A Comparison of Multiple Imputation Methods for Data with Missing Values. Indian Journal of Science and Technology. 2017 Jun 29;1019:1–7.

140. Van Buuren S, Groothuis-Oudshoorn K. mice: Multivariate imputation by chained equations in R. Journal of statistical software. 2011;45:1–67.

141. von Hippel PT. Should a Normal Imputation Model be Modified to Impute Skewed Variables? Sociological Methods & Research. 2013 Feb 1;421:105–38.

142. Rodwell L, Lee KJ, Romaniuk H, Carlin JB. Comparison of methods for imputing limited-range variables: a simulation study. BMC Medical Research Methodology. 2014 Apr 26;141:57.

143. Graham JW, Olchowski AE, Gilreath TD. How Many Imputations are Really Needed? Some Practical Clarifications of Multiple Imputation Theory. Prev Sci. 2007 Aug 28;83:206–13.

144. Stata A, Publication P, Lp S. STATA MULTIPLE-IMPUTATION REFERENCE MANUAL RELEASE 13.

145. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. Statistics in Medicine. 2011;304:377–99.

146. Bodner TE. What Improves with Increased Missing Data Imputations? Structural Equation Modeling: A Multidisciplinary Journal. 2008 Oct 22;154:651–75.

147. Maniscalco B. A signal detection theoretic approach for estimating metacognitive sensitivity from confidence ratings. Consciousness and Cognition. 2012;9.

148. Fleming SM, Daw ND. Self-evaluation of decision-making: A general Bayesian framework for metacognitive computation. Psychological Review. 20161222;1241:91.

149. Fleming SM. HMeta-d: hierarchical Bayesian estimation of metacognitive efficiency from confidence ratings. Neuroscience of Consciousness [Internet]. 2017 Jan 1 [cited 2021 Nov 17];20171. Available from: https://academic.oup.com/nc/article/doi/10.1093/nc/nix007/3748261

150. MATLAB. version 7.10.0 (R2010a). Natick, Massachusetts: The MathWorks Inc.; 2010.

151. Dienes Z, Mclatchie N. Four reasons to prefer Bayesian analyses over significance testing. Psychon Bull Rev. 2018 Feb 1;251:207–18.

152. Halsey LG. The reign of the p-value is over: what alternative analyses could we employ to fill the power vacuum? Biology Letters. 2019 May 31;155:20190174.

153. Jeffreys H. The Theory of Probability [Internet]. OUP Oxford; 1998. Oxford Classic Texts in the Physical Sciences. Available from: https://books.google.co.uk/books?id=vh9Act9rtzQC

154. Lee M, Wagenmakers E-J. Bayesian data analysis for cognitive science: A practical course. New York, NY: Cambridge University Press; 2013.

155. Dienes Z. Testing theories with Bayes factors [Internet]. PsyArXiv; 2021 [cited 2022 Jan 18]. Available from: https://psyarxiv.com/pxhd2/

156. Dienes Z. Using Bayes to get the most out of non-significant results. Front Psychol [Internet]. 2014 [cited 2020 Feb 13];5. Available from: https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00781/full

157. Dienes Z. How do I know what my theory predicts? [Internet]. PsyArXiv; 2019 Feb [cited 2020 Mar 5]. Available from: https://osf.io/yqaj4

158. Gu J, Cavanagh K, Strauss C. Investigating the Specific Effects of an Online Mindfulness-Based Self-Help Intervention on Stress and Underlying Mechanisms. Mindfulness. 2018 Aug;94:1245–57.

159. Shore R, Strauss C, Cavanagh K, Hayward M, Ellett L. A Randomised Controlled Trial of a Brief Online Mindfulness-Based Intervention on Paranoia in a Non-Clinical Sample. Mindfulness. 2018 Feb;91:294–302.

160. Economides M, Martman J, Bell MJ, Sanderson B. Improvements in Stress, Affect, and Irritability Following Brief Use of a Mindfulness-based Smartphone App: A Randomized Controlled Trial. Mindfulness. 2018 Oct 1;95:1584–93.

161. Howells A, Ivtzan I, Eiroa-Orosa FJ. Putting the ‘app’ in Happiness: A Randomised Controlled Trial of a Smartphone-Based Mindfulness Intervention to Enhance Wellbeing. J Happiness Stud. 2016 Feb 1;171:163–85.

162. Flett JAM, Hayne H, Riordan BC, Thompson LM, Conner TS. Mobile Mindfulness Meditation: a Randomised Controlled Trial of the Effect of Two Popular Apps on Mental Health. Mindfulness. 2019 May;105:863–76.

163. Palfi B, Dienes Z. The role of Bayes factors in testing interactions. (Version 3). 2019 May 30; Available from: https://doi.org/10.31234/osf.io/qjrg4https://doi.org/10.1089/acm.2008.0307

164. Lovell M. Mindfulness-of-Mental-States R code. 2020; Available from: https://github.com/Max-Lovell/Mindfulness-of-Mental-States