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Introduction

How often do you experience moments in which you feel relaxed, completely with yourself and completely in the moment? Moments in which you concentrate on yourself and what is important to you right now? And how often, in contrast, do you experience moments or times where you are rushing from one thing to the next, feeling stressed, drained, maybe even full of anxiety? Where everything seems too much? How do you deal with those latter moments and times? Especially the COVID-19 pandemic has confronted us with new challenges, which often lead or add to experiences of stress and anxiety. Since the outbreak of the COVID-19 pandemic in March 2020, acute stress and anxiety levels have been rising in the worldwide population in comparison to before the pandemic, resulting in a prevalence of 25.2 % and 29.6 %, respectively (Salari et al., 2020). While the prevalence of stress in the student population is even higher, with a prevalence of 31 % for stress symptoms, the prevalence of anxiety symptoms is about similar at 28 % (Fang et al., 2022). Both stress and anxiety play a decisive role in the development of various physical diseases as well as mental disorders and contribute to reduced life quality (Mendlowicz & Stein, 2000; Ribeiro et al., 2018). This underlines the urgency for evaluated interventions addressing stress and anxiety as well as their consequences for not only the clinical but the general population. The good news is that there are strategies to help you and others to deal with times of stress: So-called *mindfulness-based interventions* (MBIs). However, while studies show the effectiveness of MBIs for stress and anxiety reduction (e.g., Breedvelt et al., 2019; Fjorback et al., 2011), it remains understudied which specific components of MBIs work and for whom. In this study, we examined the effects of *Hatha Yoga*, as a specific component of MBIs, on individuals' stress, anxiety, and trait mindfulness levels after the intervention (postTM). Further, we investigated how these effects are influenced by individuals' trait mindfulness levels before the intervention (preTM), that is, whether people with low and high levels of trait mindfulness respond to the intervention differently. Thus, in the future, specific components of MBIs can be assigned to specific target groups, leading to optimized MBI application.

Mindfulness-Based Interventions – Hatha Yoga

Interventions aimed at learning and deepening mindfulness are increasingly researched as stress treatments (Park et al., 2021). Mindfulness can be defined as "moment to moment, non-judgmental awareness, cultivated by paying attention in a specific way" (Kabat-Zinn, 2015, p. 1481). *Trait mindfulness* refers to attention and general awareness to current events and experiences (Brown et al., 2007), while *state mindfulness* describes mindfulness at specific timepoints and is thus less stable (Mesmer-Magnus et al., 2017). Positive effects of MBIs on trait and state mindfulness, stress and anxiety reduction, as well as general well-being have been found in both clinical and healthy populations (Fjorback et al., 2011; Kiken et al., 2015; Pascoe & Bauer, 2015; Robins et al., 2011). Despite this growing interest in MBIs, there is a research gap regarding investigation of effects of their individual components (Mesmer-Magnus et al., 2017; Park et al., 2021), since multiple components are often used together. For example, the Mindfulness-Based Stress Reduction Program (Kabat-Zinn, 1990) consists of various interrelated components, ranging from psychoeducation to meditation and yoga practice. However, the different components do not seem to be equally effective: In nine different Mindfulness-Based Stress Reduction courses for clinical populations, yoga not only led to higher levels of mindfulness but also to greater reduction of reported stress levels than meditation did (Carmody & Baer, 2008). Yoga in general can be described as a group of physical, spiritual, and mental practices of Indian origin (Büssing et al., 2012).

Studies focusing on yoga as a specific component of MBIs show great variety in the application of it: Interventions differ in the extent of mindfulness elements being included, physical engagement, and frequency, resulting in varying outcomes depending on the type of intervention (Cramer et al., 2018; Matko et al., 2021; Pascoe & Bauer, 2015). Additionally, many studies including yoga show methodological weaknesses, such as missing control groups, lack of randomization, or insufficient intervention descriptions (Csala et al., 2021; Elwy et al., 2014; Gothe & McAuley, 2015; Li & Goldsmith, 2012). In our randomized controlled trial, we address these shortcomings by using the most widely practiced form of yoga, Hatha Yoga, and characterizing it with the Essential Properties of Yoga Questionnaire (EPYQ; Grössl et al., 2015), a tool allowing specific intervention characterization. Hatha Yoga includes stretching exercises, postures, and mindful breathing (Shapiro et al., 1998). We decided to specifically investigate Hatha Yoga and not any other MBI due to manifold reasons: First, due to its physically oriented nature, it provides reliable separation from other mindfulness-based practices, which is important for our aim to delineate the effects of individual components of MBIs. Second, Hatha Yoga is of high popularity among the population and of good feasibility for many people. Finally, while there are studies providing a solid base for further investigations of Hatha Yoga, there are still various research gaps regarding the effects of Hatha Yoga on different outcomes. These research gaps will be pointed out during this introduction.

Anxiety and Stress – Psychological and Physiological Stress Responses

Anxiety, an aversive motivational state, is experienced when individuals perceive high levels of threat (Eysenck, 1992). While *trait anxiety* describes a rather stable tendency to experience anxiety, *state anxiety* is defined by an individuals' trait anxiety and situational stress (Leal et al., 2017). Stress occurs, when individuals experience inability to cope with the demands or threats that they are confronted with (Lambert & Lazarus, 1970).

Psychological stress responses are increased perceived arousal (*stress reactivity*) and psychological pressure (*perceived stress*; Park et al., 2021). They differ in their impact on individual's experiences (Flett et al., 2016) and optimal treatment approaches (Iglesias et al., 2012). Despite their differences, they have often not been differentiated in research on the effects of yoga on stress (Park et al., 2021). Consequently, it remains unclear which type of stress should be addressed with which type of yoga. It has been suggested that more physically oriented forms of yoga, such as Hatha Yoga, might be more suitable for individuals with higher stress reactivity (Park et al., 2021). We tested this theory by investigating how each type of stress reacts to Hatha Yoga.

Physiological stress responses occur through two main pathways: the autonomic nervous system and the hypothalamic-pituitary-adrenal axis (García-Sesnich et al., 2017). After a situation is assessed as stressing in the limbic system, which is the central unit of the autonomic nervous system, signals to the hypothalamus lead to activation of the sympathetic nervous system. A protein that indexes increased sympathetic nervous system activity is the digestive enzyme *alpha-amylase*. Additionally, the hypothalamic-pituitary-adrenal axis gets activated and fulfils two main functions: First, it further activates the sympathetic nervous system through the corticotropin-releasing hormone, thereby mediating and amplifying the stress response; second, it triggers the release of other hormones with various functions. These hormones include the *glucocorticoid cortisol* (Malysheva et al., 2010; Smyth et al., 2013). Both alpha-amylase and the glucocorticoid cortisol are reliable physiological markers of stress experience and can be measured in saliva (Malysheva et al., 2010; Nater et al., 2006; Smyth et al., 2013). A review by Li and Goldsmith (2012) revealed that while some studies show reduced cortisol levels following yoga interventions, several studies did not find such effects. This might be due to differentiating yoga interventions but also due to insufficient considerations of the circadian rhythm of cortisol and its dependence on the menstrual cycle (Aguilar-Raab et al., 2021). In this study, saliva samples are taken at five time points during the day for three consecutive days while controlling for menstrual cycles, a procedure suggested by Matousek et al. (2010). However, some argue that cortisol is not a sufficient physiological marker for stress, claiming alpha-amylase as the better index due to its stronger and more rapid reaction to stressors (Takai et al., 2004). While there have been studies showing an effect of MBIs and yoga in general on alpha-amylase (Aguilar-Raab et al., 2021; García-Sesnich et al., 2017), to the best of our knowledge there is no study existing today that has investigated the effect of Hatha Yoga on this specific physiological stress marker in healthy populations. By not only using cortisol but also alpha-amylase as physiological stress marker, we conducted the first study assessing effects of Hatha Yoga on both.

Trait Mindfulness

It has often been argued that it is especially the explicit addressing and increasing of mindfulness (through meditation, psychoeducation, etc.) that accounts for the effectiveness of MBIs (Greeson et al., 2015). Looking at the current literature, this assumption seems plausible: High trait mindfulness (TM) is related to lower stress levels (Lu et al., 2019), lower anxiety levels, and higher life satisfaction (Mesmer-Magnus et al., 2017). But how about an intervention such as Hatha Yoga that does not explicitly address mindfulness? Can an increase in TM still be found? The few studies investigating this subject leave us with promising results: A study by Saksena et al. (2020) shows that levels of TM are not only higher after interventions including meditation, but that increased TM can also be found in Hatha Yoga only involving body postures. These findings are in line with those of Shelov et al. (2009) showing that an eight-week Hatha Yoga course increased TM. However, how Hatha Yoga effects TM remains understudied.

It further remains unclear, how preTM influences the effect of yoga on anxiety and stress. Can everyone benefit from Hatha Yoga or is it mainly people with low/high levels of preTM? There are both reasons to believe that individuals with high preTM and low preTM would primarily benefit from yoga. On the one hand, TM has often been suggested as a mechanism through which yoga has an effect on various outcomes, such as stress or anxiety (Park et al., 2021). Therefore, individuals with high preTM could benefit less from the intervention, since their TM is at a level, where further TM increase and associated stress decrease is limited. Such ceiling effects have been reported in other MBIs research areas, for example, regarding the benefit of MBIs for emotion regulation (Kittler et al., 2018) and partnership satisfaction (Kappen et al., 2019). However, ceiling effects have not yet been investigated regarding TM and its influence on the effects of yoga.

On the other hand, individuals with high preTM could benefit more from Hatha Yoga: By not having to focus much on controlling the mind and staying aware (Kabat-Zinn, 2015), they could get into a stress-releasing state more easily, therefore showing greater stress and anxiety reduction. Since individuals with low TM have fewer attentional regulation strategies (Schmertz et al., 2008), it could further be that yoga novices with low preTM experience more frustration, counteracting stress and anxiety reduction. These theories find support in a study demonstrating that only individuals with high preTM benefitted of a yoga intervention in terms of increased self-compassion and social connectedness, while those with low preTM did not (Kishida et al., 2018). However, no studies investigating how preTM influences the effects of yoga on stress and anxiety could be found. It is of importance to find out whether yoga is equally suitable for individuals with low and high preTM, or whether individuals with a certain mindfulness level should receive another kind of intervention. Therefore, the moderating role of preTM was investigated exploratively.

Cognitive Performance

While the focus of the current thesis was to examine the effects of Hatha Yoga on stress and anxiety as well as the moderating role of TM, research has also shown effects of MBIs on different cognitive aspects (e.g., Lippelt et al., 2014; Tang et al., 2015), which will be described in more detail throughout this section. Due to its nature, yoga seems especially suitable for improving cognitive performance, since it involves intense self-perception and requires the control of one's attention regarding body sensations, feelings, and thoughts (Mendelson et al., 2010). However, effects of yoga in particular on various cognitive aspects remain understudied. Since there are interesting relationships between stress, anxiety, and cognitive performance (for a review on the topic, see Gard et al., 2014), investigation of the effects of yoga on cognitive performance might also be of interest for readers of this thesis. Therefore, we want to provide at least basic information about the investigation of the effects of yoga on cognitive performance in the overall study that the current thesis was part of. We focus on presenting the most central aspects of the investigation of the effects of Hatha Yoga on cognitive aspects: What concrete cognitive aspects have been investigated and what are central constructs for understanding these cognitive aspects? How can these cognitive aspects be measured? Why should yoga have an effect on these cognitive aspects? And finally, how can stress and anxiety as the central concepts of this thesis be linked to the different cognitive aspects? For detailed information about the investigation of the effects of Hatha Yoga on cognitive performance, data analysis, and results of this investigation see the master thesis of Laiber (currently in progress) and the paper by Szaszkó et al. (currently in progress).

Inhibition

We start by introducing the *inhibition function* as a central aspect of cognitive performance. The inhibition function is one of the three main functions of the *central executive* (Miyake et al., 2000), next to the *shifting function* (which we will take a closer look at in the next section), and the *updating function*. The central executive, in turn, is essential for controlling attention processes (Baddeley, 1996). Since effects on the updating function could not be confirmed in a recent meta-analysis, only the inhibition and shifting functions were investigated in the overall study as there is evidence that they can be influenced by MBIs (Yakobi et al., 2021). To understand the inhibition function as well as the other functions that are closely linked to attention processes, it is important to know the two different ways in which attention works: While *top-down attention* allows individuals to volitionally focus their attention on certain stimuli, *bottom-up attention* refers to the perception of stimuli regardless of their relevance for someone's intentions. Therefore, top-down attention is an endogenous and strategically controlled process, which is based on the intention to focus on specific features of the environment (Schoeberl & Ansorge, 2017). In contrast, bottom-up attention is an automatic process, which is mainly controlled by features of the environment and focuses on stimuli as soon as they occur (Posner, 1980; Theeuwes, 2010).

Inhibition, as a form of top-down control of attention, can be defined as the ability to minimize or completely block interference of stimuli that are not of importance for a demanded task (task-irrelevant stimuli; Coombes et al., 2009). Hence, through the inhibitory function the central executive is enabled to suppress the use of resources that are not of use for current (search) goals. This is where the possible link between regular yoga practice and the inhibition function can be found: In yoga, it is of central importance to focus attention only on specific yoga postures or on one's own breath and to ignore all distractions, such as noises, thoughts, or body sensations (Mendelson et al., 2010)[1]. This, in turn, can be seen as a selective attention to a specific goal, such as holding a certain yoga posture, and a suppression of everything that is not useful for reaching or conducting that specific goal (Gard et al., 2014). The volitional focus of attention on certain sensations or tasks while blocking irrelevant sensations presents a central component of inhibitory control. Accordingly, it is plausible to assume that someone who regularly practices focusing attention on certain sensations while blocking out others during yoga sessions acquires an improved inhibition function, hence, an improved active suppression of distractors. This leads us directly to the next question: How can this improvement of the inhibition function be measured?

One way to assess the inhibition function is through the conduction of experimental tasks, in which certain stimuli should be attended (target stimuli) and others should be ignored (distractors). Distractors can be divided into *salient singleton* or *nonsingleton distractors*. Salience, as we use it here, refers to the visibility of different regions, or in this case stimuli, within a field of view (Itti & Koch, 2000). For calculations of this visibility, a simplified neurophysiological model is assumed without consideration of search goals. Salience can for example be influenced by early visual features such as color, intensity, or orientation. Recent research has shown that certain stimuli, such as singletons, are more salient than others (Gaspelin et al., 2015). The term singleton here refers to a stimulus that is of unique color and/or shape and therefore different from its homogeneous immediate surroundings (Duncan & Humphreys, 1989). Immediate capture of attention by salient singletons can be reduced through practice, if these stimuli are whether

[1] It is of importance to note that yoga is not about actively suppressing certain sensations per se but rather about developing a non-reactive awareness towards body sensations, thoughts, and feelings. This non-reactive attitude should then in turn lead to improvements in removing attention from sensations or thoughts that do not seem relevant to current tasks (Bishop et al., 2004; Kabat-Zinn, 2003).

irrelevant for the task (Folk, et al., 1992, 1994) or can be anticipated (Ludwig et al., 2008; but also see Schreij et al., 2008). Experiments that consist of conditions in which salient singleton distractors next to nonsingleton distractors are presented during visual search tasks provide important information about the ability of inhibition: If individuals improve their inhibition function through regular yoga practice, this should be reflected in a reduction of the rate of false alarms, hence, a higher proportion of correct responses, due to the increased inhibition of salient and target-similar distractors.

Interestingly, the inhibition function is also reflected in electroencephalography (EEG) data: Increased incidences of the event-related potential *distractor positivity (Pd)* indicate improved inhibition of distractors (Gaspelin & Luck, 2018). Additionally, reduction of the event-related potential *N2-posterior-contralateral (N2pc)* on the distractor indicates lower attraction of attention of this distractor (Sawaki & Luck, 2010).

Task/Modality Switching

In the following section we are going to take a closer look at the switching between different tasks or modalities as an important cognitive function. The ability to switch attention from one task to another or, alternatively, from one modality to another, is referred to as *shifting function*. By successfully switching the attention, individuals can respond to changing task demands in a flexible, optimal way (Miyake et al., 2000). If we look at the key aspects of yoga practice, the association between regular yoga practice and an improvement of the shifting function seems reasonable: Individuals are regularly, sometimes even frequently, challenged to switch from one yoga posture to another or to shift attention from one body part to another, or from the body to the breath. Additionally, following the moment-to-moment principle of mindfulness, they are often reminded to pay attention to the current challenge and withdraw attention from preceding or upcoming challenges (Lutz et al., 2008). It seems likely that such active training of cognitive flexibility and switching between different yoga postures or tasks leads to a general improvement of the attentional shifting function. This improvement can be represented through *task-switching paradigms* (Monsell, 2003). Task-switching experiments usually consist of two distinct tasks, for example reporting visual vs. auditory stimuli, between which individuals must shift. If yoga improves the shifting function, individuals, who regularly practice yoga, should show superior performance in task-switching experiments in comparison to those who do not practice yoga. Better performance can be indicated through lower *switching costs*. Here, switching costs refer to longer response times (RTs) and lower hit rates, hence, an overall worse performance, for trials, in which participants must switch between two different tasks/modalities (trial-by-trial switches) compared to RTs and hit rates after repeated responses in the same task/modality (e.g., Monsell, 2003). RTs describe the time participants need to detect and report the target, while hit rates refer to the ratio of correct answers given by the subject to the maximum number of correct answers possibly achieved.

Furthermore, the switching function can be reflected in EEG data in experiments involving the switch between different modalities through measuring oscillatory activity, namely *visually evoked steady-state potentials* (SSVEP) and *auditory steady-state responses* (ASSR; De Jong et al., 2010; Norcia et al., 2015). These endogenous brain oscillations are evoked by the presentation of repetitive auditory and visual stimuli and are entrained by the frequency of the presentation in the respective modality (Saupe et al., 2009). Through presentation of stimuli in the visual and the auditory modality with different frequencies, information in the millisecond range about which modality is currently attended can be obtained.

Switching between Attentional Control Settings

Besides switching between different tasks or modalities one can also switch between different mental presets that are used for successfully performing a task. Usually, when we search for certain objects whose features are known to us, the search is based on representations of those known features. For example, if you are looking for your black dog, these representations are the color (black) and the form (four legs, head, tail, etc.). These mental representations are called *attentional control settings* (ACSs; Folk et al., 1992). Due to ACSs, targets and cues that are consistent with the ACS, meaning they have the same color/shape, capture attention, while cues not matching the attentional template of the observer (nonmatching cues) are ignored (Büsel et al., 2019). Cues generally describe stimuli preceding a to-be-searched-for-target. In a *visual search task*, usually referring to a task in which a target among various distractors must be found (Verghese, 2001), it has been found that participants used different ACSs for different target stimuli (Büsel et al., 2019). Consequently, a switch between different ACSs is necessary, when targets are different between trials. Visual search tasks that aim at assessing the switch between ACSs usually consist of two different blocks and two different targets. While in the one block, participants only must search for one target (e.g., a red circle), in the other block they must look out for two different targets (e.g., a red and a green circle) and thus switch between different ACSs in response to the target if the target color differs between trials. In such dual-color visual search tasks, two behavioral measures are usually used: *switching* and *mixing costs*. *Switching costs* here refer to longer RTs and lower hit rates, hence, an overall worse performance, for trials, in which participants must switch between two different targets, than for trials in which they do not have to switch between different targets (e.g., Monsell, 2003). *Mixing costs* refer to an overall worse performance for trials in which participants must search for two possible target colors instead of one (Los, 1996). Additionally, it has been found that RTs are fastest for trials with *valid top-down-matching cues* (Büsel et al., 2019). Valid top-down-matching cues refer to cues that are shown at the same position as the target (*valid*) and in the same color as the target (*matching*). Due to the need for reactive attentional control in trials, in which target position cannot be anticipated by valid cues, RTs are longer in invalid cueing conditions, with cue and target at different positions (Ort et al., 2017). Faster RTs for valid top-down-matching cues in comparison to RTs for invalid top-down-matching cues (*validity effect*) indicate that a cue's capture of attention seems to be conditional to its match to ACS (Eimer & Kiss, 2008; Folk & Remington, 1998; Folk et al., 1992). In other words, while top-down-matching cues capture attention and can thereby serve as indicators for the position of the target under valid conditions, non-matching cues do not, or at least not to the same extent, capture attention, and can thereby also not serve as indicators for the target position, even under valid conditions.

To explain how regular yoga practice could improve switching between different ACS, it is of help to simply look at the nature of yoga once again: Due to constantly focusing on and switching between different sensations, reminders to focus attention on the task at hand and the establishment of a non-reactive attitude towards potential distractions, participants who regularly practice yoga should be able to better direct their attention to current search targets according to ACSs and to ignore competing stimuli. Hence, volitional shifting of attention should improve for individuals practicing yoga on a regular base, leading to lower switching and mixing costs. In terms of measuring switching between different ACSs, the dual-color visual search task explained earlier, to outline the key constructs of switching between ACSs, provides a well-researched way of measurement (Büsel et al., 2019).

Relationship between Yoga, Emotions, and Cognition: Attentional Control Theory

In this last section of the introduction, we are going to take a brief look at possible connections between the improvement of emotional aspects due to yoga and improvement of cognitive performance. One theory directly aiming at explaining this relationship is the *attentional control theory* (Eysenck et al., 2007). Attentional control theory is based on the assumption that anxiety has a negative effect on the regulation of attention by disturbing the balance between top-down and bottom-up attentional networks, resulting in a shift towards the bottom-up attentional network. Looking at this shift from an evolutionary perspective, it seems quite useful: Since fear serves as an important physiological mechanism to prepare for danger, it is of importance to shift towards a stimulus-driven attentional mechanism when experiencing fear, which allows immediate perception of danger signals (Bar-Haim et al., 2007). Accordingly, it makes sense that anxiety causes a shift to the bottom-down attentional network (Power & Dalgleish, 1997). However, since top-down processing is needed for performing cognitively demanding tasks, in which a focus on essential task elements as well as a suppression of irrelevant stimuli is needed, a shift towards bottom-up processing is not without consequences. Since anxiety impedes the performance of cognitive tasks, making it more difficult to volitionally regulate attention, Eysenck and Calvo (1992) assumed that anxiety is related to changes in attentional mechanisms leading to unawareness of task-relevant information and attendance of task-irrelevant information. Individuals tend to focus less on goal-congruent stimuli due to the stress-induced dominance of the bottom-up system and thereby act less congruent with behavioral goals. Accordingly, attentional control theory assumes that anxiety impairs both inhibition and shifting functions of attention. Hence, individuals with lower (vs. higher) anxiety levels should be able to perform better in tasks demanding inhibition and shifting between modalities/ACSs. The assumed connection between yoga, emotional, and cognitive aspects can be summarized as follows: We expected that regular yoga practice influences the performance of individuals in cognitive tasks in two possible ways. First, as already pointed out, simply through its very own nature, and second, through its anxiety-reducing effects as described in the first section of this thesis. The connection of all three (yoga, anxiety/stress, and inhibition/task switching) will be discussed in detail in the paper by Szaszkó et al. (currently in progress).

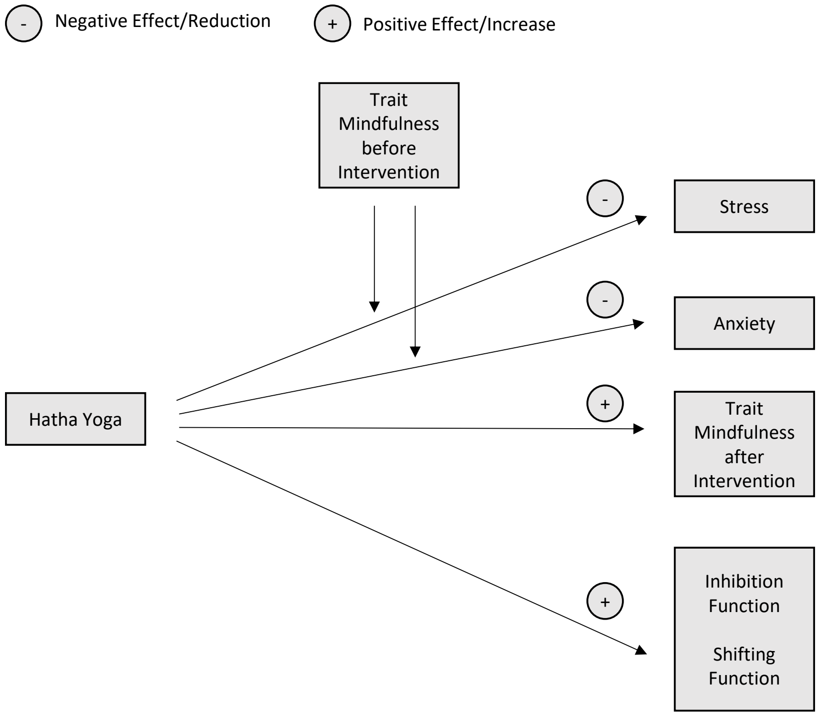
Research Questions

This study addresses the question, how regular Hatha Yoga practice affects individuals' stress, anxiety, and postTM and how these effects are moderated by preTM. We investigated this research question by conducting a randomized controlled trial, in which the intervention group (IG) participated in an eight-week Hatha Yoga course, while the wait list control group (CG) received the course after the IG finished. Cortisol, alpha-amylase, stress, anxiety, and TM levels were measured before and after the intervention. We expected a stronger reduction of cortisol, alpha-amylase, perceived stress, perceived stress reactivity[2], and anxiety levels, and a stronger increase of TM levels from pre- to posttest measurements in the IG than in the CG. We investigated the moderating role of preTM exploratively. Not of central importance for the topic of the current thesis, we also investigated the effect of regular Hatha Yoga practice on individuals' inhibition and shifting function. We expected a stronger improvement of the ability (1) to suppress irrelevant distractors, (2) to switch between tasks/modalities and, (3) to switch between colors during visual search from pre- to posttest measurements in the IG than in the CG. The investigated effects are illustrated in Figure 1.

[2] Note that in our preregistration, which can be checked under the link https://osf.io/cdx96, perceived stress reactivity was not mentioned as a main, but a secondary outcome without specification of associated hypotheses. However, since the focus of this thesis is on stress and anxiety and since there is a reasonable theoretical background, perceived stress reactivity is treated as a main outcome with an associated directional hypothesis in this thesis.

Figure 1

The Effects of Hatha Yoga on Stress, Anxiety, Trait Mindfulness, and Cognition



Note. This figure illustrates the expected effects of Hatha Yoga on certain outcome variables. While Hatha Yoga is expected to reduce stress and anxiety, it is expected to increase trait mindfulness as well as the inhibition and shifting function. The moderating role of trait mindfulness before the intervention is investigated for the effects of Hatha Yoga on stress and anxiety.

Method

Participants

A power analysis with G*Power (Erdfelder et al., 1996) yielded a sample size of 102 participants, with $d = 0.5$, 80 % power, and alpha error probability of .05, based on a one-tailed *t* test. However, it should be noted that due to the diversity and heterogeneity of the applied methodology (including EEG, behavioral, and questionnaire measures), the here used single estimated power value only provides us with power information about the worst case, namely questionnaires, where we only obtained two measurements per participant (pretest and posttest). Behavioral experiments using thousands of trials per participant tend to have much higher power due to reliable within-subject effects. This is especially the case for EEG recorded data, where the number of trials per cell often exceeds 100. Thus, power in our behavioral experiments (and even in the saliva measures with 30 measurements for each participant) was significantly higher than in the case of the questionnaires, even after the unexpectedly high rate of data that had to be excluded from analyses, which will be discussed in detail later (see section “Limitations”, p. 43). The expected effect size was based on previous studies on the effects of yoga on stress and anxiety (Della Valle et al., 2020; Pascoe et al., 2017). Accounting for an estimated dropout rate of 20 %, we aimed to recruit 122 participants through the study platform Laboratory Administration for Behavioral Sciences of the University of Vienna (UoV), the Vienna CogSciHub: Study Participant Platform, and social media advertisement. 105 participants (83 female; M_{Age} = 25.03 years; SD_{Age} = 4.18 years; range 18-40 years) completed both pretest sessions and were still part of the study as the intervention started. Before participation, subjects had to perform a shortened online version of the Diagnostic Interview for Mental Disorders (Mini-DIPS; Margraf et al., 2017), a screening instrument for mental disorders with a high reliability of Cronbach's alpha between .84 and .90 for the different disorders (Margraf, 1994). Besides current mental disorders other exclusion criteria were age under 18 or over 40 years, German level under C1, previous yoga practice exceeding twice a month in the past year, uncorrected visual or hearing impairment, skull fractures or concussions within the past six weeks, and non-provision of a recovery or vaccination COVID-19 certificate. A one-time sample characterization, assessing age and gender[3], was obtained at baseline using the Patient Health Questionnaire (PHQ-D; Löwe et al., 2002). All participants signed written informed consent and received detailed debriefing. Ethical approval of the Ethics Committee of the UoV was obtained.

Study Design

Participants were divided into two equally sized cohorts with different start dates. Each cohort followed the same procedure. Pretest and posttest measurements were divided into two sessions each. In the first pretest session, participants signed informed consent and performed an experimental task aiming at assessing switching between different ACS. In the second pretest session, participants were trained in saliva sample collection (SSC), received equipment for SSC, and performed two experimental tasks, with the first one aiming at assessing their inhibition function and the second one aiming at assessing their ability to switch between different modalities. After this session, participants were randomly assigned to a group: the IG (n = 54) or the CG (n = 51). SSC and performance of online questionnaires, assessing stress, anxiety, and TM, took place in the week after the second pretest session. The IG then received an eight-week Hatha Yoga course, while the CG did not receive an intervention during this time period but after the IG finished the intervention, thereby serving as a wait list control group. The two posttest sessions differed from the pretest sessions in two ways: Firstly, participants received the SSC equipment already in the first session. Secondly, questionnaires, including a post-monitoring intervention questionnaire for the IG, were

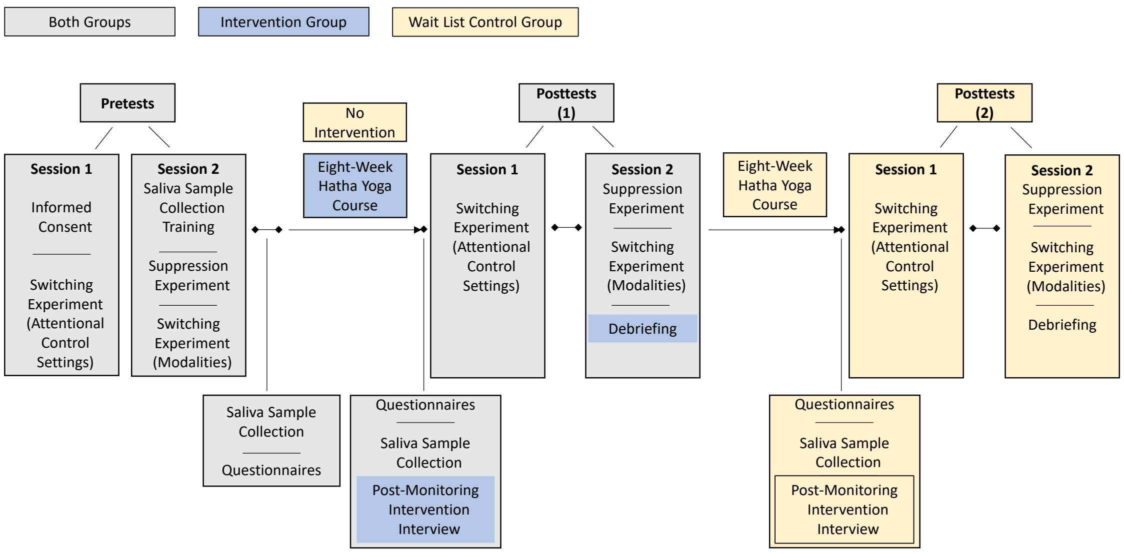
[3] Next to age and gender, other sample characteristics such as educational level and financial income were obtained. Since they are not of relevance to the object of this thesis, they are not further described here.

performed within three days after the end of the intervention. SSC took place one and a half weeks after the end of the intervention. This was done in order to ensure that the distance between the intervention and the pretest/posttest saliva measurements and questionnaires was constant. While the study ended for the IG after the second posttest session, the CG then received the Hatha Yoga course, followed by two posttest sessions with the same procedure as the previous posttests. Study design is illustrated in Figure 2.

Participants received the following financial compensation: Regardless of their group belonging (IG or CG), all participants received an eight-week Hatha Yoga course free of charge. Further, they received 30 EUR for successful completion of pre- and posttests, respectively, if all other requirements were met (course attendance at least three times a week for the IG, completion of questionnaires and saliva testing for both groups). If participants attended four yoga sessions a week on average, they received a bonus of 20 EUR. Accordingly, participants of the IG could receive a financial compensation up to 80 EUR and participants of the CG could receive a financial compensation up to 110 EUR, since they received additional 30 EUR for completion of the second posttests.

Figure 2

Study Design



Note. This figure illustrates the study design dependent on group membership. The intervention group (IG) received the intervention after the pretests, the wait list control group (CG) received no intervention in this time. After posttests 1, the study ended for the IG. The CG then received the intervention, followed by posttests 2.

Intervention

The eight-week Hatha Yoga course was guided by trained instructors at a yoga studio ($M_{\text{Job Experience}}$ = 4.00 years; $SD_{\text{Job Experience}}$ = 1.15 years; range 3-5 years of job experience), with each session being instructed by one of four female instructors (N = 4). To control for biases through different instructions and styles, instructors were briefed together by the experimenters and received a strict program to be followed. Each week, a different focus was set in all the yoga sessions for that week. The different focuses per week as well as exemplary *asanas* (yoga postures) can be seen in Table 1.

Table 1

Focus of Yoga Sessions per Week and Exemplary Asanas (Yoga Postures)

Week	Focus	Exemplary Asanas
1	Sun salutation, breathing exercises	Downward Facing Dog, Cobra Pose, Sprinter Pose
2	Standing positions	Warrior I and II, Triangle Pose, Chair Pose
3	Forward Bends	Different variations of Forward Bends, Pigeon Pose, Butterfly Pose
4	Twists	Waists Turn, Crocodile Pose, twisted Triangle Pose
5	Backbends	Shoulder Bridge, Locust Pose, Bow Pose
6	Sitting poses	Different variations of Lotus positions, Boat Pose, Child Pose
7	Balance	Tree Pose, Warrior III, Crow Pose, Half Moon Pose
8	Combining focuses 1-7	Combinations of the previous exemplary asanas

Note. In each week of the Hatha Yoga intervention, comprising a total of eight weeks, a different focus was set, which determined the practiced *asanas* (yoga postures) of that week. This focus had to be maintained by all yoga teachers when leading their yoga sessions.

Each 60 min session consisted of 5-10 min warm-up exercises, 40-50 min *asanas*, and 5-10 min *savasana* (relaxing while lying flat on the back). The Essential Properties of Yoga Questionnaire

(EPYQ; Grössl et al., 2015), consisting of 62 items and with an acceptable to good reliability of Cronbach's alpha between .70 and .90 for the fourteen different subscales (Park et al., 2018), was used to characterize the yoga intervention. All items of the EPQY are introduced with "How much did the instructor mention or include…" and rated from 1 (not at all) to 5 (a very large amount), with higher scores indicating a higher level of mentioning/inclusion of the regarding yoga element. Since it is impractical to expect all fourteen different components to be addressed in a yoga intervention, and different yoga styles vary on the focus and inclusion of components (Park et al., 2018), we decided to include the following five subscales in our analyses: Acceptance/compassion (e.g., "… acceptance of things as they are?"), breathwork (e.g., "… linking breathing with movement?"), physicality (e.g., "… physical balance?"), body awareness (e.g., "…asking students to concentrate on bodily sensations [such as tightness, softness, and muscle awareness]?"), and meditation/mindfulness (e.g., "…mindfulness [non-judgmental awareness of one's thoughts, feelings, or movements]?"). While we assessed acceptance/compassion, and meditation/mindfulness as classic components of MBIs in general (Kabat-Zinn, 2015; Park et al., 2021), we also assessed breathwork, physicality, and body awareness, since they are more specific for Hatha Yoga (Shapiro et al., 1998).

Participants were instructed to attend at least three and maximum five yoga sessions per week. They had to sign an attendance list at the yoga studio before each attended yoga session. Each week, three to four early sessions (8 am), and five late sessions (5 or 7 pm) were offered. The yoga course feasibility was assessed by each participant at the end of the intervention using a specially constructed post-monitoring interview for this purpose. However, since the analysis of the post-monitoring interview is conducted in a time-consuming qualitative manner by a collaborative group of the study, results of the post-monitoring interview have not yet been finalized. Therefore, they will be reported in the paper by Szaszkó et al. (currently in progress).

Measures

In this chapter we present the measures for perceived stress, stress reactivity, trait anxiety, state anxiety, TM, cortisol-, and alpha-amylase levels.

Stress

The German version of the Perceived Stress Scale (PSS-10; Schneider et al., 2020) was used to assess subjective stress levels within the past month. It includes ten items and has an acceptable to good reliability of Cronbach's alpha of .78 (Klein et al., 2016). Items are rated from 0 (never) to 4 (very often), adding up to a range of final scores from 0 to 40 with higher scores indicating higher levels of perceived stress. They are phrased in a general manner, thereby being relatively independent from content specific to certain individuals and aim to assess feelings as well as thoughts connected to stress. A sample item is “In the last month, how often have you found that you could not cope with all the things you had to do?”.

Stress reactivity was assessed using a German-translated version by the UoV of the Perceived Stress Reactivity Scale (PSRS; Schlotz et al., 2011), a 23-item questionnaire scale with an acceptable to excellent reliability of Cronbach’s alpha between .71 to .91 for different subscales (Schulz et al., 2005). Range of final score is 0 to 46 with higher scores indicating higher levels of perceived stress reactivity. Each item, rated from 0 (indicating a rather weak reaction to a potential stressor) to 2 (indicating a rather strong reaction), consists of the description of a potentially stressful situation and three typical ways of responding to this certain stressor. The five scales of the PSRS comprise reactivity to work overload (e.g., “When tasks and duties build up to the extent that they are hard to manage, I am generally untroubled/ usually feel a little uneasy/ normally get quite nervous”), reactivity to social evaluation (e.g., “When I am unsure what to do or say in a social situation, I generally stay cool/ often feel warm/ often begin to sweat”), reactivity to social conflicts (e.g., “When I argue with other people, I usually calm down quickly/ stay upset for some time/ it takes me a long time until I calm down”), reactivity to failure (e.g., “When I fail at a task, I usually feel very uncomfortable/ feel somewhat uncomfortable/ in general, I don’t mind”), and prolonged reactivity (e.g., “When tasks and duties accumulate to the extent that they are hard to cope with, my sleep is unaffected/ slightly disturbed/ very disturbed”).

To assess physiological stress markers, five saliva samples were taken per day (immediately upon waking up, 30 min thereafter, 11 am, 2 pm, and 7 pm) by participants on three consecutive days (Tuesday, Wednesday, and Thursday) before and after the intervention. For each SSC, participants had to document the exact time of extraction, their perceived stress level and various variables affecting cortisol and alpha-amylase levels (food and drink intake, smoking, current activity; Aguilar-Raab et al., 2021). Participants received SMS reminders for every required SSC, with the first reminder being sent at 6 am, including a reminder for the SSC taking place 30 min after waking up, and the other reminders being sent 10 min before each required SSC time point. Participants were asked to store saliva samples in their freezer and bring them to the Psychological Department of the UoV after the SSC period, where samples were stored in a freezer until laboratory examination. Cortisol and alpha-amylase levels from saliva samples were supposed to be analyzed in the Biochemical Laboratory of the UoV, located at the Campus Vienna Biocenter. However, due to unforeseen events, the analysis of saliva samples is not expected to be completed until mid of 2023 and will therefore be reported in the paper by Szaszkó et al. (currently in progress).

Anxiety

Trait and state anxiety were measured with the German version of the 20-items State-Trait-Anxiety-Inventory (STAI) – Form Y (Grimm, 2009), with ten items assessing trait anxiety and ten items assessing state anxiety. Items, rated from 1 (almost never) to 7 (almost always), adding up to a range of final scores from 10 to 70 (trait/state anxiety) with higher scores indicating higher levels of anxiety. A sample item for the trait anxiety scale is "Unimportant thoughts run through my head and weigh me down" and for the state anxiety scale "I am concerned". Different short versions of the STAI- Form Y have been shown to validly distinguish anxiety from depression and to have a good reliability of Cronbach's alpha > .8 for both trait and state anxiety (e.g., De Vries & Van Heck, 2013; Tluczek et al., 2009). As suggested by Grimm (2009), raw values were converted to a scale ranging from 0 to 100 with the following formula to ensure comparability to other test values:

Comparable $\text{value}_{\text{Trait/StateAnxiety}}$ = (Raw $\text{value}_{\text{Trait/State Anxiety}}$ – 10) x 100/ 70.

Trait Mindfulness

TM was assessed by the German version of the Freiburg Mindfulness Inventory (FMI; Buchheld & Walach, 2002), using the 14-item short form with items rated from 1 (rarely) to 4 (almost always). Within a range of final scores from 14 to 46, higher scores indicated higher levels of TM. A sample item is "I am open to the experience of the present moment". The decision to use the short form is first based on its good reliability of a Cronbach's alpha of .86, which is reasonably close to that of the 30-items long form (Cronbach's alpha = .93), and second on its high economy in comparison to that of the long form. Additionally, important criteria for the choice of the short form of the FMI are its sensitivity to changes in TM as well as its applicability for mindfulness novices (Walach et al., 2006).

Suppression

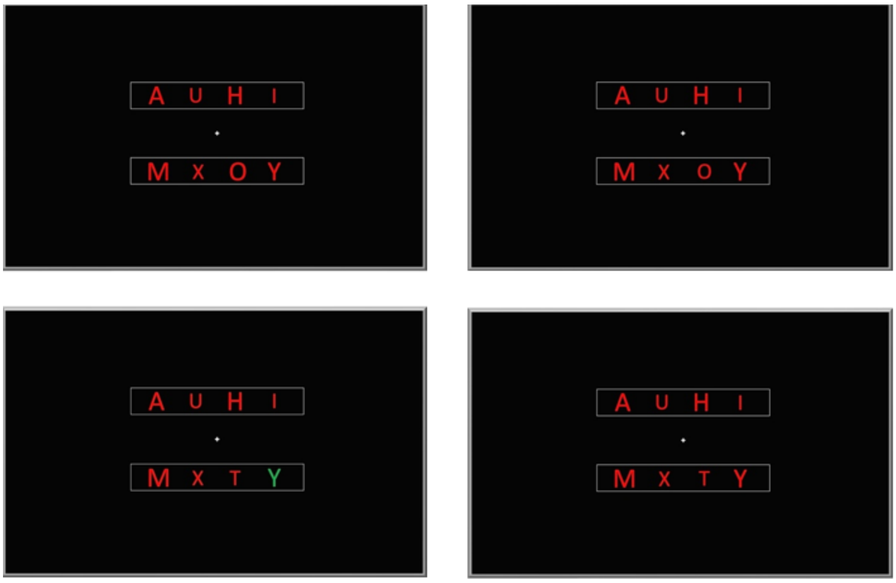
Suppression was measured using an experiment aiming at representing the ability to suppress irrelevant distractors. Participants were instructed to search for a shape- and size-defined target letter among seven distractor letters presented on a display and press a key if the target was present. Instructions stressed both speed and accuracy. While target and distractor letters varied in shape (letter identity, e.g., A), size (small/big), and color (red/green), participants were instructed to only pay attention to target shape and size, while color was considered irrelevant. Target letter shape and target letter size was varied randomly across trials and each stimulus was presented randomly, therefore unforeseeably at one out of eight potential target positions. Stimulus displays always included four small and four big letters. Each trial was with a chance of 50 % whether a red-standard trial, meaning all items were red, except the salient distractor, which was green, or a green-standard trial, meaning all items were green, expect the red salient distractor. Red- and green-standard trials occurred in random order.

As illustrated in Figure 3, the experiment comprised four different conditions. The target condition consisted of 576 trials that included a target stimulus. In the target-similar distractor condition, all 576 trials showed a target-similar distractor, which had a target-similar shape, hence, was the same letter as the target, but of different size. In the salient distractor condition, all 576 trials involved a salient distractor, that is, a letter different from the target letter in a color different from all other stimuli presented. To the fourth condition belonged 288 trials that did not meet any of the mentioned conditions, hence, the fourth condition served as a control condition. The experiment consisted of 36 blocks with 56 trials each, with each block lasting for approximately 1 min (2016 trials total). Including 72 practice trials, the experiment lasted approximately 45 min, including self-paced breaks between the blocks.

We expected a stronger increase of inhibition of salient task-irrelevant singleton distractors (e.g., green distractors among red stimuli) in the salient distractor condition and stronger reduction of attraction of attention by distractors in the target-similar distractor condition during visual search from pre- to posttest measurements in the IG in comparison to the CG. Both inhibition and attraction of attention were measured by the two already mentioned event-related potential components: Inhibition was indexed by an increased mean amplitude of distractor positivity (Pd; Gaspelin & Luck, 2018) on the distractor and lower attraction of attention was indexed by a reduced mean amplitude of N2-posterior-contralateral (N2pc; Sawaki & Luck, 2010) on the distractor. Additionally, we expected a stronger reduction in the rate of false alarms from pre- to posttest measurements in the IG than in the CG, due to the increased inhibition of salient and target-similar distractors in the IG, resulting in a higher proportion of correct responses (as non-responses are counted as correct in those conditions).

Figure 3

Suppression Experiment



Note. In this figure, the four conditions of the suppression experiment are presented. In this example, participants had to look for a big O and press a key when the target was present. The target condition (upper left corner) always included a target stimulus, hence, a big O was presented. In the target-similar distractor condition (upper right corner), a target-similar distractor was shown, as to be seen by presentation of a small o. In the salient distractor condition (lower left corner), a salient distractor in a different color from all other stimuli was presented, here a green Y among seven red letters. The control condition (lower right corner) included trials that did not meet criteria of conditions 1 to 3.

Task/Modality Switching

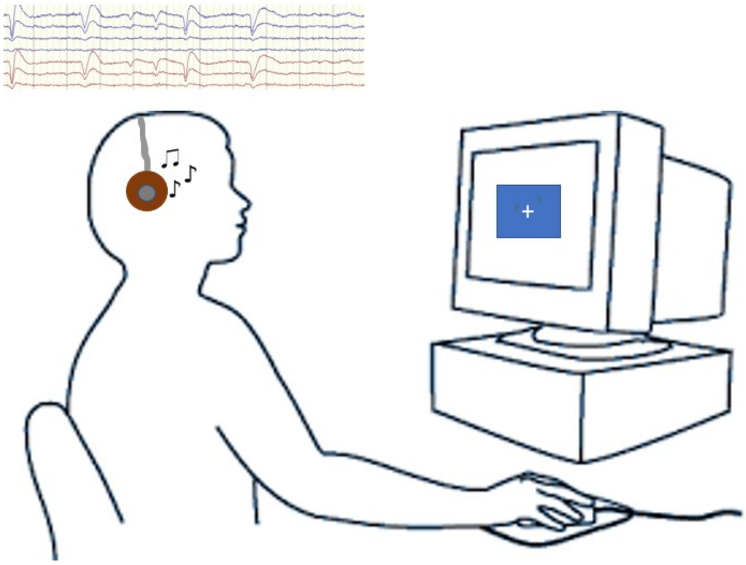
Another experimental task was performed by the participants to assess the ability to switch between different modalities. To assess the shifting function, a so-called 2-back task (e.g., Kane et al., 2007) was used: Participants were instructed to switch between searching for stimuli in the visual and in the auditory domain when indicated by a bimodal cue. Therefore, they were introduced to the targeted stimuli in the beginning of the experiment, which was a blue-colored rectangle presented in the display in the visual domain and a certain tone presented through headphones in the auditory domain. Stimuli in the visual domain differed in four possible colors and stimuli in the auditory domain in four possible audio frequencies. Both stimuli of the visual and the auditory domain appeared in different frequencies. Participants were instructed to indicate when stimulus n-2 matched stimulus n (with a stimulus gap in between). To give an example of the visual domain: When a blue rectangle was followed by an orange rectangle and the orange rectangle was followed by a blue rectangle again, participants had to press a key as fast and accurate as possible when the second blue rectangle appeared. The stimuli were played simultaneously in both modalities. A distinct bimodal cue gave an indication for participants which modality they should pay attention to.

There were no distinct trials in the experiment, but stimuli were presented continuously for 180 sec. A total of 15 blocks of stimuli presentation were included. Before and after these 15 blocks, there was both one visual and one auditory baseline block, each of which lasted 60 sec. In these baseline blocks, only visual/auditory stimuli were presented, and participants did not have to switch between the two modalities. Hence, these baseline blocks allowed the comparison between switching and non-switching conditions. After each period of stimuli presentation participants received a break, of which the duration could be determined by participants themselves. Including a practice block of 180 sec at the beginning, the experiment lasted approximately 65 min.

During the whole experiment visually evoked steady-state potential (SSVEP) and auditory steady-state response (ASSR; De Jong et al., 2010; Norcia et al., 2015) were measured by means of EEG. Switching speed was analyzed by using the SSVEP and the ASSR with tagged frequencies. For participants of the IG, we expected an earlier onset latency of the SSVEP and the ASSR measured after a modality switch, entrained by the distinctive presentation frequencies of stimuli in the respective modalities, after the intervention in comparison to before the intervention. Furthermore, we expected a stronger reduction of switching costs, hence, a better performance (i.e., lower RTs and higher hit rates) in passage wise alternation vs. repetition of visual-/auditory target-focused trials from pre- to posttest measurements in the IG in comparison to the CG. Figure 4 illustrates the core elements of the experimental setup of the 2-back task.

Figure 4

Switching between Modalities Experiment



Note. This figure illustrates the experimental setup of the experiment aiming at assessing switching between different modalities. Participants were placed in front of a computer and connected to an electroencephalography (EEG) devise. They were simultaneously presented with stimuli of both visual and auditory modality but only had to attend to one modality at any given time point. If they had to switch from the visual to the auditory modality or vice versa, the demanded switch was indicated by a cue presented in both modalities.

Switching between Attentional Control Settings

The third experiment aimed at assessing the ability to switch between different ACSs during a visual search task. In each trial of this task, participants were instructed to search for a color-defined target among four distractors presented on a display. They had to indicate as fast and accurate as possible in which direction the T within the target was directed by pressing a key. Each stimulus was presented randomly, therefore unforeseeably at one out four potential target positions. The visual search task was divided in single-color (A) and two-color (B) search blocks, which were balanced across subjects in one of the following orders: A-B-A-B or B-A-B-A.

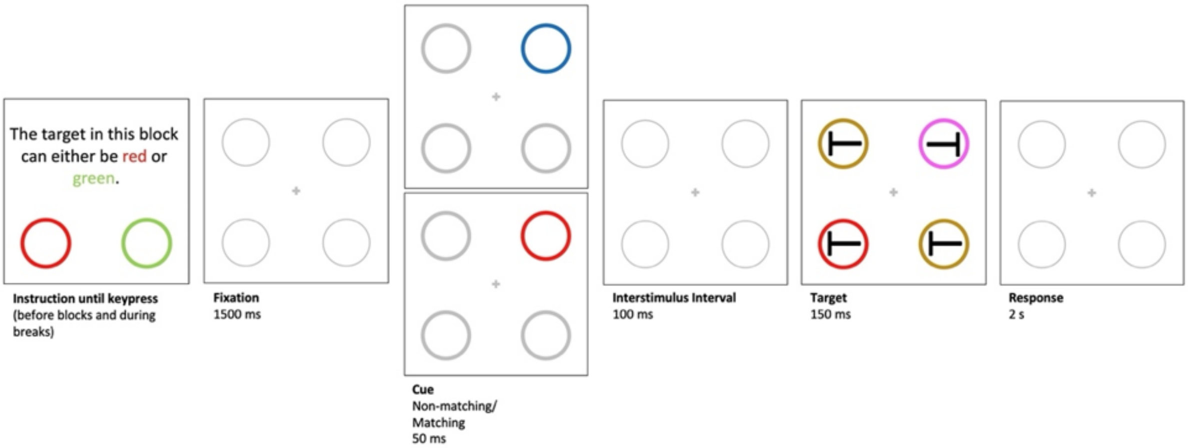
In the single-color search blocks, participants were instructed to search for a single-color target (e.g., the red stimulus per each target display). Immediately before the target display, a cueing display was presented containing a salient (i.e., color-singleton) cue at one out of the four potential target positions among nonsingleton (i.e., gray) distractors at the remaining three target positions. Cues could vary in two dimensions: They could be matching or nonmatching cues, and valid or invalid. As a quick reminder, cues with a similar color to the target are called *top-down* *matching cues* since they match a top-down control setting to search for the target colors. Accordingly, cues with a dissimilar color to the target are called *nonmatching cues*. In valid conditions, cues appeared at the target position and in invalid conditions they appeared at a position different to the target position. However, since cues were not predictive of target positions across trials, there was no incentive for participants to search for peripheral cues themselves. It was expected that top-down matching cues would capture attention, due to their fit to the top-down control settings, hence, allowing facilitated target search under valid as compared to invalid conditions. In contrast, nonmatching cues are expected to capture lesser or no attention, hence, there should be no or small performance differences between valid and invalid conditions in nonmatching-cue trials. Here, it is interesting to see if participants in the IG and in the CG show similar performance patterns. Performance differences between valid and invalid conditions could be used to test if participants followed the instructions, as indicated by appearing of cueing effects if they followed instructions and non-appearance of cueing effects if they did not follow them.

In the dual-color search blocks, participants were instructed to pay attention to two potential target colors: red and green. Accordingly, per each trial the target could either be red or green. Like in the single-color blocks, cues could whether appear as top-down matching cues or nonmatching cues and under valid or invalid conditions. An exemplary trial of a dual-color block is illustrated in Figure 5. Including dual-color blocks enabled us to look at switching and mixing costs. Switching costs were calculated as the difference in performance (i.e., RTs and hit rates) between conditions in which the target color switched from a preceding trial n-1 to the current trial n and conditions in which the target color repeated from a preceding trial n-1 to a current trial n. We expected switching costs and, if regular Hatha Yoga practice improved the ability to switch between ACSs, a stronger reduction of switching costs from pre- to posttest measurements in the IG than in the CG. Mixing costs were calculated as the difference in average performance across the two-color search trials and across the single-color search trials. Note that only trial-by-trial color repetitions of the two-color search trials were included to avoid a contamination of mixing costs with switching costs. We expected a stronger reduction of mixing costs from pre- to posttest measurements in the IG than in the CG, if regular Hatha Yoga practice improved the performance in color search tasks. However, since switching abilities are not taxed by the mixing costs, the intervention effect might be absent regarding this mixing-cost measure.

Each of the four blocks comprised 240 trials and lasted for approximately 10 min. In between each block (after 5 min) and after each block, there was a break, which duration could be determined by participants themselves. Together with a brief training phase, comprising 24 trials, at the start of the visual search task, the whole experiment took approximately 75 min.

Figure 5

Switching between Attentional Control Settings Experiment



Note. This figure illustrates an exemplary trial of the experiment aiming to assess switching between different Attentional Control Sets. In the first display, participants got informed about the possible target color(s). These could either be red, green or both, as it is the case in this trial (dual-color block). After a fixation display, a cueing display was shown with either a non-matching cue, hence, a cue in a different color from the target (here blue), or a matching cue of the same color as the target (here red). Additionally, the cue could appear under valid conditions, hence, at the same position as the subsequent target, or under invalid conditions, hence, at a different position as the subsequent target, as shown in this exemplary trial. After an interstimulus interval, the target display was presented (here, the target is presented in the lower left corner of the display). Finally, a response display was presented, during which participants had to indicate as quick and accurate as possible in which direction the T within the target was directed (here left).

Data Analysis

A significance level of p <.05 was used for determining if our results significantly differ from those expected if the null hypotheses were correct. In cases of multiple testing and when additional tests/comparisons were not mandatory or indicated in our preregistered hypotheses, *p*-values were corrected using the Holm-Bonferroni method (Holm, 1979). Data was analyzed using the free software environment "R" (Version 3.6.3; R Core Team, 2018) and the free software "JASP" (Version 0.16; JASP Team, 2021).

To assess the effects of the intervention on perceived stress (PSS score), perceived stress reactivity (PSRS score), trait anxiety (STAI-Y-TR score), state anxiety (STAI-Y-ST score), and postTM (FMI score), we conducted five two-way (2 x 2) mixed Analyses of Variance (ANOVAs), with the repeated within-subject factor "measurement" (pretest/posttest), between-subjects factor "group" (IG/CG) and the dependent variables "PSS score", "PSRS score", "STAI-Y trait anxiety score", "STAI-Y state anxiety score", and "FMI score". Using one-sided *t*-tests for independent samples, we conducted planned comparisons for all significant interaction terms, testing if there were a) significant greater reductions of perceived stress, perceived stress reactivity, trait anxiety, and state anxiety, and b) a significant greater increase of TM from pre- to posttest measurements in the IG in comparison to the CG. Partial eta quadrat (η_p^2) was used for the two-way mixed ANOVAs to determine the size of effects, with .01 indicating a small, .06 indicating a medium, and .14 indicating a large effect (Cohen, 1988).

To account for recent research developments challenging the traditional use of *p*-values, the Bayes Factors for both ANOVAs (BF_{10}) and *t*-tests (BF_{+0}) were reported (Van de Schoot & Depaoli, 2014). The here reported Bayes Factors (e.g., 3) indicate that our data is x (in our example 3) times more likely if our alternative hypotheses are true, hence, if significant interactions between measurement and group (ANOVAs) as well as greater differences in changes from pre- to posttest measurements in the IG than in the CG (*t*-tests) exist. However, the Bayesian analyses were not reported in detail. Bayes Factors larger than 3 generally indicate moderate evidence for the alternative hypothesis, values larger than 10 strong evidence, and values larger than 30 very strong evidence (e.g., Rouder et al., 2009). It should be noted that the Bayes Factors reported for ANOVAs are from Bayesian ANOVAs, which, like all other ANOVAs, test undirected hypotheses, whereas all our hypotheses were directed hypotheses. Therefore, a lowered power of the Bayesian ANOVAs might have contributed to rather indeterminate Bayesian Factors for ANOVAs (Schönbrodt & Wagenmakers, 2018).

To investigate the moderating role of preTM, multiple regression analyses were performed for each significant effect of Hatha Yoga on the regarding outcome variable revealed through the two-way mixed ANOVAs. Each of the regression models comprised the pretest measurement, preTM, and the interaction between both as possible predictors for the posttest measurement. It was tested if adding preTM as a moderator could add a significant advantage for explaining the outcome variable of interest, as indicated by a significant interaction term (Hayes, 2018). Using the Johnson-Neyman technique (Johnson & Neyman, 1936), simple slopes at low (defined as -1 standard deviation; *SD*), average and high (+1 *SD*) preTM values were computed for significant or marginally significant interactions and regions of significance were calculated by identification of those points on our continuous moderator preTM, at which the relationship between dependent and independent variables was statistically significant (Hayes & Matthes, 2009; Johnson & Fay, 1950). Beta coefficients were used for determining effect sizes, with a size of > 0.1 indicating a small, > 0.3 indicating a medium, and > 0.5 indicating a large effect (Cohen, 1988).

Missing Data Analysis

Data of participants who did not complete entire pre-, or posttest measurements were excluded from the analysis. If participants did not participate in yoga sessions at least two times per week over a time period of three consecutive weeks, their data were excluded. Data of 74 participants (64 female; M_{Age} = 24.95 years; SD_{Age} = 4.48 years; range 18-40 years), of which 34 belonged to the IG (30 female; M_{Age} = 24.74 years; SD_{Age} = 3.95 years; range 18-40 years), and 40 belonged to the CG (34 female; M_{Age} = 25.13 years; SD_{Age} = 4.93 years; range 19-40 years), were analyzed after excluding participants from analyses, e.g., due to prematurely termination of study participation. Data of participants that did not participate in single experiments or failed to provide answers to single questionnaires were not excluded and each experiment/index was treated independently from each other in this regard. For missing data analysis, it was first checked if data were missing completely at random, using the Little's test (Little, 1988). None of the Little's tests for the different questionnaires got significant, suggesting that data were missing completely at random, with all p values > .50. Second, a deterministic regression imputation was performed, fitting a statistical model based on the observed data on variables with missing values (e.g, De Waal et al., 2011; Zhang, 2016). Predictions of this regression models were then used to substitute the missing values in these variables. The predicted values thus served as missing data estimates.

Detection and Exclusion of Outliers

For all data sets, outliers were detected and excluded from the data analyses by inspection of boxplots, displaying a) the median (Q2, 50th percentile), as the middle value of the data set, b) the first quartile (Q1, 25th percentile), as the middle number between the smallest number and the median of the dataset, c) the third quartile (Q3, 75th percentile), as the middle value between the median and the highest value of the data set, d) the interquartile range (IQR, 25th to 75th quartile), telling us how spread the middle values are, e) the maximum (Q3 + 1.5*IQR), and d) the minimum (Q1 – 1.5*IQR). Data points, that were outside the minimum or maximum, were treated as outliers (e.g., Sim et al., 2005).

Results

Before reporting the statistical results of the ANOVAs, we present Table 2 for a descriptive overview of the questionnaire outcomes in the IG and the CG at pre- and posttest measurements. A greater reduction of stress and anxiety measures, and a greater increase of the TM measure from pre- to posttest measurements, as indicators of the effectiveness of our Hatha Yoga intervention, were expected in the IG in comparison to the CG.

Table 2

Questionnaire Outcomes at Pre- and Posttest Measurements

Questionnaire	Measurement	Group	*M [CIs]*	*SD*
Perceived Stress Scale (PSS)	Pretest	IG	17.56 [16.02, 19.10]	6.17
		CG	14.79 [13.72, 15.86]	5.90
	Posttest	IG	**15.21* [13.67, 16.75]**	5.80
		CG	14.84 [13.77, 15.91]	4.50
Perceived Stress Reactivity Scale (PSRS)	Pretest	IG	23.50 [22.41, 24.59]	6.78
		CG	23.68 [22.60, 24.76]	7.08
	Posttest	IG	**20.94** [19.85, 22.03]**	6.72
		CG	23.63 [22.55, 24.71]	7.25
Trait Anxiety (STAI-Y-TR)	Pretest	IG	40.83 [36.89, 44.77]	16.86
		CG	40.41 [38.24, 42.58]	16.84
	Posttest	IG	36.28 [32.24, 40.22]	17.48
		CG	39.26 [37.09, 41.43]	17.06
State Anxiety (STAI-Y-ST)	Pretest	IG	40.20 [36.21, 44.19]	16.31
		CG	39.92 [36.14, 43.70]	16.21
	Posttest	IG	37.55 [33.56, 41.54]	19.15
		CG	37.83 [34.05, 41.61]	15.99
Freiburg Mindfulness Inventory (FMI)	Pretest	IG	38.28 [37.02, 39.54]	5.21
		CG	38.33 [37.45, 39.21]	4.76
	Posttest	IG	**40.34* [39.08, 41.60]**	4.37
		CG	38.44 [37.56, 39.32]	3.85

Note. *M* = Mean, *CIs* = 95 % confidence intervals, *SD* = Standard deviation, IG = Intervention group, CG = Wait list control group. $N = 74$, approximately equal split through the two groups. Participant number within the groups varied between $n = 32$ and $n = 40$ in dependence on excluded outliers.

** = The posttest measurement was significantly lower than the pretest measurement with a *p*-value < .01.

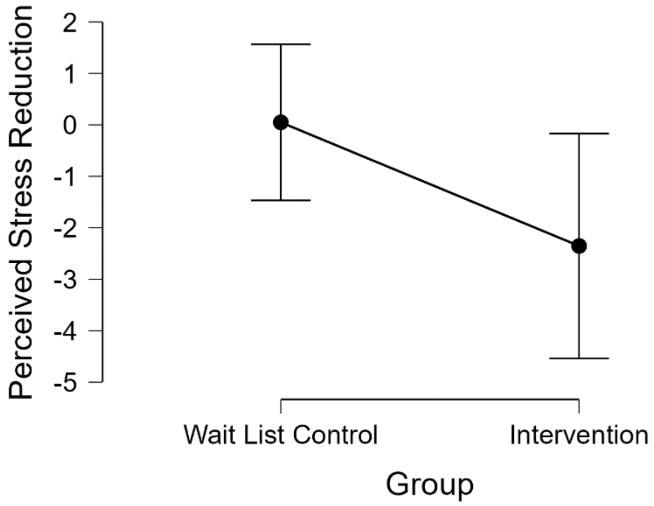
* = The posttest measurement was significantly lower than the pretest measurement with a *p*-value < .02.

Perceived Stress

To test the hypothesis that regular Hatha Yoga practice reduces perceived stress levels, a two-way mixed ANOVA was performed with the within-subject factor measurement (pretest/posttest), the between-subjects factor group (IG/CG), and the dependent variable PSS score. Outliers' analyzation led to exclusion of two data points. Hence, data from 72 participants were analyzed of which 34 belonged to the IG and 38 belonged to the CG (62 female; M_{Age} = 24.95 years; SD_{Age} = 4.48 years; range 18-40 years). The Levene's test (Levene, 1960) revealed that there was heterogeneity in variances of our groups for posttest perceived stress data, F = 4.86, p = .031. We accounted for heterogeneity of variances by conducting a robust two-way mixed ANOVA using the R package WRS2 (Mair & Wilcox, 2020). The robust two-way mixed ANOVA does not assume homogeneity of variances. There was neither a significant main effect of measurement on perceived stress, $F(1, 39.71) = 1.51$, $p = .226$, $\eta_p^2 = .04$, $BF_{\text{inc}} = 0.76$, nor a significant main effect of group on perceived stress, $F(1, 41.51) = 2.12$, $p = .153$, $\eta_p^2 = .05$, $BF_{\text{inc}} = 0.58$. We found a marginally significant interaction between measurement and group, $F(1, 39.71) = 3.48$, $p = .070$, $\eta_p^2 = .08$, $BF_{\text{inc}} = 1.63$. We accounted for heterogeneity of variances in our planned comparisons analyses by using the Welch's *t*-test, which does not assume homogeneity of variances (Welch, 1947). As illustrated in Figure 6, planned comparisons revealed a significant greater reduction of perceived stress from pre- to posttest measurements in the IG (M = –2.35, *SD* = 0.94, 95 % CI [–3.91, Inf]) than in the CG (M = 0.05, *SD* = 0.89, 95 % CI [–1.43, Inf]), t(60.20) = 1.84, p = .036, d_{unb} = 0.43, BF_{+0} = 2.04.

Figure 6

Reduction of Perceived Stress in the Wait List Control and Intervention Group



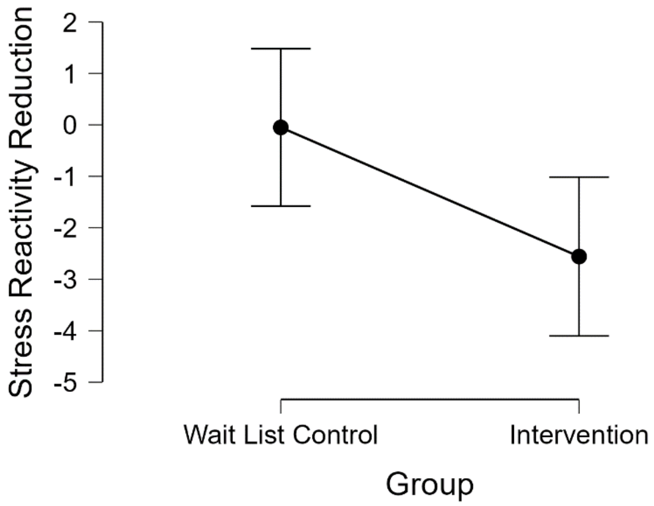
Note. Number of wait list control group participants = 38, number of intervention group participants = 38, total N = 72. Mean of the perceived stress reduction from pre- to posttest measurements in the wait list control and the intervention group (error bars represent 95 % confidence intervals). Perceived stress reduction refers to posttest values minus pretest values (difference values) in the wait list control and the intervention group, respectively. Note that the difference between the two groups was significant.

Perceived Stress Reactivity

A two-way mixed ANOVA with the within-subject factor measurement (pretest/posttest), the between-subjects factor group (IG/CG), and the dependent variable PSRS score, was performed to test if regular Hatha Yoga practice reduces perceived stress reactivity levels. No outliers were detected for perceived stress reactivity levels. Hence, data from all 74 participants were analyzed, as characterized at the beginning of the section “Results”. There was a significant main effect of measurement on perceived stress reactivity, *F*(1, 72) = 5.85, *p* = .018, η_p^2 = .08, BF_{inc} = 1.47, but no significant main effect of group on perceived stress reactivity, *F*(1, 72) = 0.88, *p* = .353, η_p^2 = .01, BF_{inc} = 0.52. We found a significant interaction between measurement and group, *F*(1, 72) = 5.42, *p* = .023, η_p^2 = .07, BF_{inc} = 2.34. Planned comparisons revealed a significant greater reduction of perceived stress reactivity from pre- to posttest measurements in the IG (M = –2.56, *SD* = 4.43, 95 % CI [–3.88, Inf]) than in the CG (M = –0.05, *SD* = 4.78, 95 % CI [–1.27, Inf]), t(72) = 2.33, *p* = .011, d_{unb} = 0.54, BF_{+0} = 4.67. Figure 7 illustrates the reduction of perceived stress reactivity in the IG in comparison to that of the CG.

Figure 7

Reduction of Perceived Stress Reactivity in the Wait List Control and Intervention Group



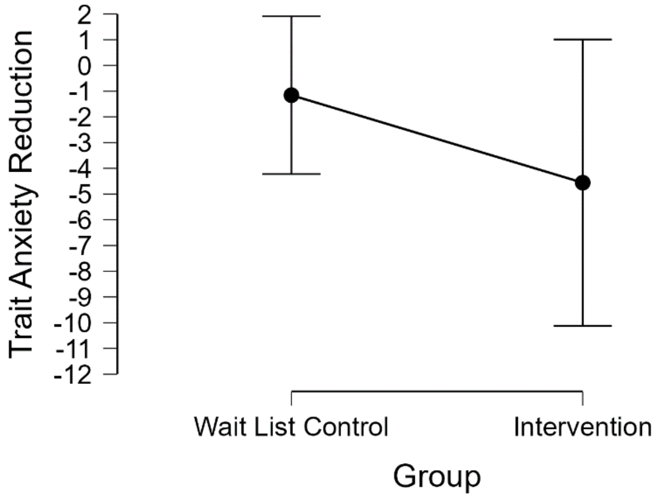
Note. Number of wait list control group participants = 40, number of intervention group participants = 34, total N = 74. Mean of the perceived stress reactivity reduction from pre- to posttest measurements in the wait list control and the intervention group (error bars represent 95 % confidence intervals). Perceived stress reactivity reduction refers to posttest values minus pretest values (difference values) in the wait list control and the intervention group, respectively. Note that the difference between the two groups was significant.

Trait Anxiety

A two-way repeated measures ANOVA with the within-subject factor measurement (pretest/posttest), the between-subjects factor group (IG/CG), and the dependent variable STAI-Y-TR score was used to test the hypothesis that regular Hatha Yoga practice reduces trait anxiety levels. No outliers for TA data were detected. Hence, data from all 74 participants were analyzed. We found a marginally significant main effect of measurement on trait anxiety, $F(1, 72) = 3.29$, $p = .062$, $\eta_p^2 = .05$, $BF_{inc} = 0.78$, but no significant main effect of group on trait anxiety, $F(1, 72) = 0.12$, $p = .730$, $\eta_p^2 < .01$, $BF_{inc} = 0.39$. There was no significant interaction between measurement and group, $F(1, 72) = 1.28$, $p = .262$, $\eta_p^2 = .02$, $BF_{inc} = 0.38$. However, since the descriptive data suggested a stronger reduction of trait anxiety in the IG in comparison to the CG (as can be inspected in Table 2), we still conducted our planned comparisons. The planned comparisons revealed a trend of a stronger reduction of trait anxiety levels in the IG (M = –4.56, *SD* = 15.96, 95 % CI [–4.56, Inf]) than in the CG (M = –1.16, *SD* = 9.59, 95 % CI [–8.25, Inf]), t(72) = 1.3, $p = .131$, $d_{unb} = 0.26$, $BF_{+0} = 0.71$. This nonsignificant difference in trait anxiety reduction between the IG and the CG is illustrated in Figure 8.

Figure 8

Reduction of Trait Anxiety in the Wait List Control and Intervention Group



Note. Number of wait list control group participants = 40, number of intervention group participants = 34, total N = 74. Mean of the trait anxiety reduction from pre- to posttest measurements in the wait list control and the intervention group (error bars represent 95 % confidence intervals). Trait anxiety reduction refers to posttest values minus pretest values (difference values) in the wait list control and the intervention group, respectively. Note that the difference between the two groups was not significant.

State Anxiety

To test the hypothesis that regular Hatha Yoga practice reduces state anxiety levels, a two-way repeated measures ANOVA was performed with the within-subject factor measurement (pretest/posttest), the between-subjects factor group (IG/CG), and the dependent variable STAI-Y-SA score. No outliers for state anxiety data were detected. Hence, data from all 74 participants were analyzed. There was neither a significant main effect of measurement on state anxiety, $F(1, 72) = 1.52$, $p = .222$, $\eta_p^2 = .02$, $BF_{inc} = 0.35$, nor a significant main effect of group on state anxiety, $F(1, 72) < 0.01$, $p > .999$, $\eta_p^2 < .01$, $BF_{inc} = 0.29$. There was no significant interaction between measurement and group, $F(1, 72) = 0.02$, $p = .885$, $\eta_p^2 < .01$, $BF_{inc} = 0.24$.

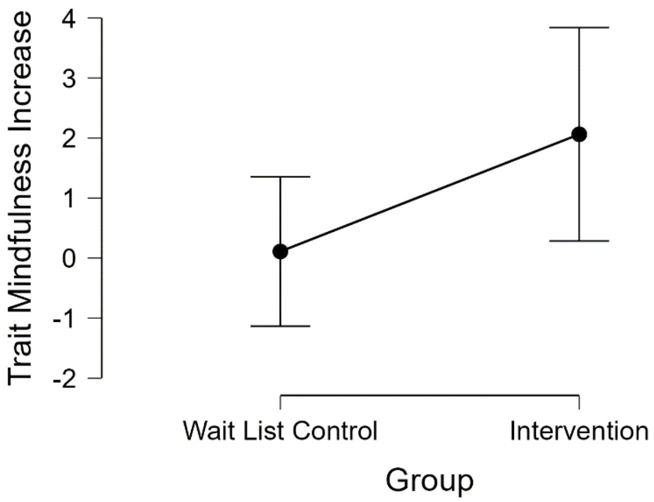
Trait Mindfulness

A two-way repeated measures ANOVA with the within-subject factor measurement (pretest/posttest), the between-subjects factor group (IG/CG), and the dependent variable FMI score was used to test the hypothesis that regular Hatha Yoga practice improves TM levels. Outliers' analyzation led to exclusion of five data points. Hence, data from 69 participants were analyzed of which 32 belonged to the IG and 37 belonged to the CG (59 female; $M_{Age} = 25.1$ years; $SD_{Age} = 4.6$

years; range 18-40 years). We found a significant main effect of measurement on TM, $F(1, 67) = 4.32$, $p = .041$, $\eta_p^2 = .06$, $BF_{inc} = 0.93$. There was no significant main effect of group on TM, $F(1, 67) = 0.93$, $p = .339$, $\eta_p^2 = .01$, $BF_{inc} = 0.43$. Furthermore, we found a marginally significant interaction between measurement and group, $F(1, 67) = 3.49$, $p = .066$, $\eta_p^2 = .05$, $BF_{inc} = 1.09$. As illustrated in Figure 9, planned comparisons revealed a significant greater improvement of TM from pre- to posttest measurements in the IG (M = 2.06, *SD* = 4.93, 95 % CI [0.79, Inf]) than in the CG (M = 0.11, *SD* = 3.73, 95 % CI [–1.08, Inf]), $t(67) = -1.87$, $p = .033$, $d_{unb} = -0.45$, $BF_{-0} = 2.07$.

Figure 9

Increase of Trait Mindfulness in the Wait List Control and Intervention Group



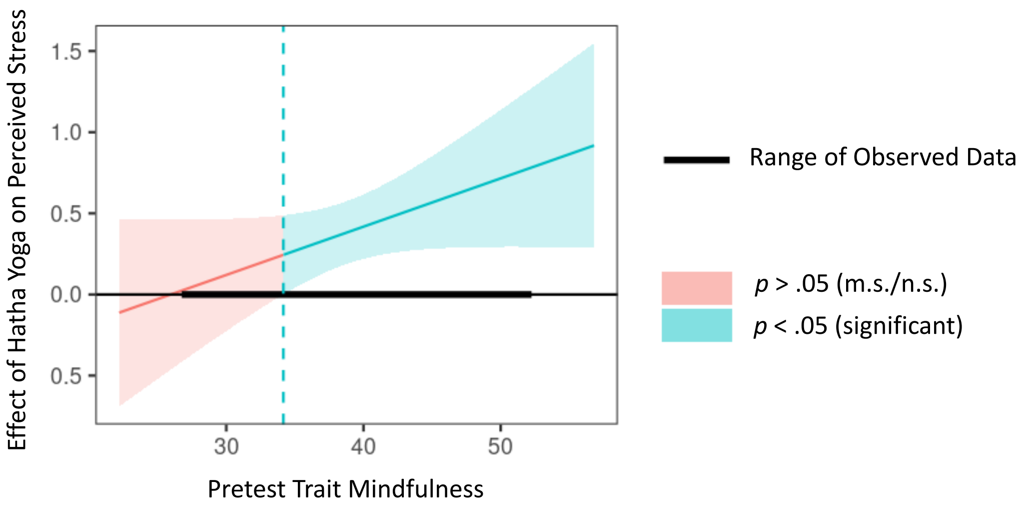
Note. Number of wait list control group participants = 37, number of intervention group participants = 32, total N = 69. Mean of the increase in trait mindfulness from pre- to posttest measurements in the wait list control and the intervention group (error bars represent 95 % confidence intervals). Increased trait mindfulness refers to posttest values minus pretest values (difference values) in the wait list control and the intervention group, respectively. Note that the difference between the two groups was significant.

Moderating Role of Trait Mindfulness for Perceived Stress

To test if preTM has a moderating effect on the effect of Hatha Yoga on perceived stress, a multiple regression analysis was performed, with posttest perceived stress (postPS) as the outcome variable, pretest perceived stress (prePS) as the predictor variable and preTM as the moderator variable. Results indicated that postPS was not associated with prePS ($\beta = 1.43$, *SD* = 5.10, $p = .153$) but marginally significant associated with preTM ($\beta = -.66$, *SD* = 2.36, $p = .091$). The interaction between prePS and preTM was marginally significant ($\beta = 1.58$, *SD* = 0.13, $p = .064$). Before including the interaction effect between prePS and preTM, the individual effects of prePS and preTM on postPS together explained approximately 19 % of the variance in postPS, $R^2 = .19$, $F(1,31) = 3.37$, $p = .048$. Adding the interaction term between prePS and preTM could explain additional 10 % of the variance in postPS, R^2 *Change* = .10, $R^2 = .28$, $F(1,31) = 3.70$, $p = .023$. Since a marginally significant interaction was found, simple slopes for the association between prePS and postPS were tested for low (–1 *SD* below the mean), moderate (mean), and high (+ 1 *SD* above the mean) levels of preTM, using the Johnson-Neyman technique. As illustrated in Figure 10, two of the simple slope tests revealed a significant positive association between prePS and postPS. While prePS was strongly related to postPS for high levels of preTM (β = .51, *SD* = 0.76, $p < .001$), it was moderately related to postPS for moderate levels of preTM (β = .37, *SD* = 0.58, $p < .001$). There was a small marginally significant association between prePS and postPS for low levels of preTM (β = .23, *SD* = 0.70, $p = .070$).

Figure 10

The Effect of Hatha Yoga on Perceived Stress moderated by Pretest Trait Mindfulness



Note. Illustrated is the effect of Hatha Yoga on perceived stress depending on pretest trait mindfulness levels (preTM). In the blue area, the 95 % confident interval does not include zero, indicating that for participants of high preTM (+1 standard deviation) and moderate trait mindfulness (Mean) the effect of Hatha Yoga on perceived stress is significant. The effect appears to be stronger for participants with high levels of preTM than with moderate levels of preTM. In the red area, the 95 % confidence interval includes zero, meaning that the effect of Hatha Yoga on perceived stress is only marginally/not significant (m.s./n.s.) anymore for participants with low levels of preTM (–1 standard deviation or lower).

Moderating Role of Trait Mindfulness for Perceived Stress Reactivity

To test if the effect of Hatha Yoga on perceived stress reactivity levels is moderated by preTM levels, a multiple regression analysis was performed, with posttest perceived stress reactivity (postSR) as the outcome variable, pretest perceived stress reactivity (preSR) as the predictor variable and preTM as the moderator variable. No significant association between postSR with preSR ($\beta = 0.27$, $SD = 4.80$, $p = .824$) nor between preTM and postSR ($\beta = –0.22$, $SD = 2.83$, $p = .590$) was found. The interaction between preSR and preTM was not significant ($\beta = 0.43$, $SE = 0.12$, $p = .559$). Since no significant interaction was found, no further analyses were conducted.

Essential Properties of Yoga Questionnaire

We calculated means and standard deviations of the five included subscales (acceptance/compassion, breathwork, physicality, body awareness, mindfulness/meditation) to compare the amount to which components were included. Values between 1 and 2 indicated a small amount of inclusion of this component, values between 2 and 3 a small to moderate inclusion amount, values between 3 and 4 a moderate to large inclusion amount, and values between 4 and 5 a large inclusion amount (e.g., Park et al., 2018). While Table 3 gives a descriptive overview of the EPYQ outcomes for each included subscale, Figure 11 presents a graphic illustration of the proportion of elements included in our Hatha Yoga intervention.

Table 3

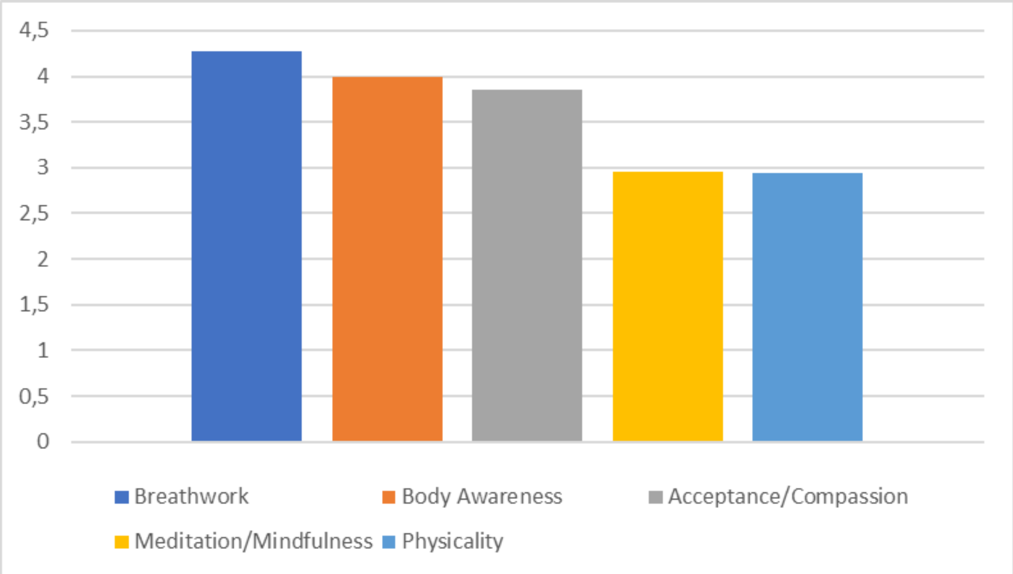
Essential Properties of Yoga Questionnaire Outcomes divided by Subscales

Subscale	*M [CIs]*	*SD*
Acceptance/Compassion	3.85 [1.85, 4.15]	0.72
Breathwork	4.28 [3.03, 4.97]	0.61
Physicality	2.94 [1.17, 2.83]	0.52
Body Awareness	4.00 [3.25, 4.75]	0.47
Meditation and Mindfulness	2.96 [1.00, 1.88]	0.95

Note. M = Mean, *CIs* = 95 % confidence intervals, *SD* = Standard deviation. *N* = 4.

Figure 11

Proportion of Elements Included in the Hatha Yoga Intervention



Note. This figure shows that breathwork and body awareness were the most involved components in the intervention, closely followed by acceptance/compassion. The least included components were physicality and meditation/mindfulness.

Discussion

The purpose of this study was to investigate if regular Hatha Yoga practice can help reduce individuals‘ stress and anxiety levels and to increase trait mindfulness levels. To contribute to an improved application of MBIs, we further analyzed, if effects of yoga can only be found for certain individuals, namely those of low, medium, or high TM or if such effects can be found regardless of individuals' TM. Our hypothesis that Hatha Yoga leads to reduced levels of perceived stress was supported by our findings showing a significantly greater reduction of perceived stress in the IG than the CG from before to after the yoga intervention. The effect of Hatha Yoga on perceived stress was of medium to large size (η_p^2 = 0.08). We also found a marginal significant moderation effect of individuals' TM levels for the effect of Hatha Yoga on perceived stress: Our results suggest that Hatha Yoga reduced perceived stress most effectively for individuals of high TM levels, followed by individuals of moderate TM, while the effect was weakest and only of marginal significance for those of low TM levels. Furthermore, our results supported the hypothesis that regular Hatha yoga practice reduces individuals‘ perceived stress reactivity: The average reduction of perceived stress reactivity levels from before to after the yoga intervention was significantly greater for participants of the IG than the CG. This effect of Hatha Yoga on perceived stress reactivity was of medium to large size (η_p^2 = 0.07). The comparable effect sizes for the effects of

Hatha Yoga on perceived stress and perceived stress reactivity, respectively, are in contrast to our assumption that Hatha Yoga as a more physically oriented form of yoga might be more effective in reducing perceived stress reactivity than perceived stress (Park et al., 2021). However, we will discuss the varying suitability of Hatha Yoga for individuals suffering from perceived stress and/or perceived stress reactivity in detail later, under consideration of the moderating role of preTM (see section "Hatha Yoga and Trait Mindfulness", p. 41). No moderation effect of preTM for the effect of Hatha Yoga on perceived stress reactivity was found.

Our hypothesis that regular Hatha Yoga practice improves individuals' levels of TM was supported by our results indicating that the average improvement of TM was significantly greater in the IG than the CG. This effect of Hatha Yoga on TM was of small to medium size (η_p^2 = 0.05). Regarding our hypothesis that Hatha Yoga reduces anxiety levels, results indicated a stronger reduction of trait anxiety levels in the IG than in the CG from before to after the yoga intervention, however, this difference was not significant.

Analyses of the EPYQ (Grössl et al., 2015) revealed that our Hatha Yoga intervention was characterized by a large amount of included breathwork and body awareness, followed by acceptance/compassion. Instructors placed fewer focus on physicality and mindfulness/meditation.

Hatha Yoga, Stress, and Anxiety

While our results show a significant effect of Hatha Yoga on stress but not on anxiety, most previous studies show similar effects of MBIs on stress and anxiety. For example, in the review by Breedvelt et al. (2019), the authors found similar effect sizes for the effects of meditation, yoga, and mindfulness training on anxiety (g = 0.46) and stress (g = 0.42) in students. These moderate effect sizes shrank to small effect sizes (g = 0.13), when the intervention groups were compared to active control groups. There were no significant differences in the effectiveness of meditation, yoga, and other mindfulness interventions. In line with these findings, another review found that in several studies the Mindfulness-Based Stress Reduction program led to reduction of both stress and anxiety symptoms (Fjorback et al., 2011). One might argue that our study results are to some extent in contrast to the mentioned previous studies, since we found a significant influence of Hatha Yoga on both stress parameters (perceived stress, perceived stress reactivity), but on neither of the two anxiety parameters (trait and state anxiety) included in our study. However, a nonsignificant difference between the IG and the CG in trait anxiety was observed, suggesting that there was an overall stronger trait anxiety reduction in the IG than in the CG. One possible reason that this difference might not have become significant is the great variability in our trait anxiety data, indexed by a standard deviation ranging from 16.84 to 17.48, with an average standard deviation of 17.06. In comparison, in other studies including yoga that used the STAI-Y as a measure for anxiety, standard deviation ranged between 5.40 and 12.56, with an average standard deviation of 7.55 (e.g., Field et al., 2010; Marshall et al., 2020; Rinella et al., 2017). Since great variability in the observed data is one of the factors leading to decreased power, thereby making it more difficult to detect an effect, if the effect exists (Norton & Strube, 2001), the great variability in our anxiety data could have accounted for the nonsignificant findings regarding the effect of Hatha Yoga on trait anxiety. Since our relatively small sample size as well as the transformation of our anxiety data to a better comparable but broader scale could in turn have accounted for this great variability (Lee et al., 2015), future research should investigate the effect of Hatha Yoga on trait anxiety using bigger sample sizes and various measures of anxiety.

Another interesting point of discussion refers to the fact that while we found a nonsignificant trend for trait anxiety reduction through Hatha Yoga, we did not find an effect of Hatha Yoga on state anxiety. This appears counterintuitive in some way, since changes in state anxiety should occur more readily due to its rather situational (instead of stable) nature, and since it is defined through trait anxiety, which decreased, and situational stress (Leal et al., 2017). However, since the exact relationship between trait and state anxiety is not clear, it might not necessarily be the case that state anxiety decreases, when trait anxiety does. Still, it does appear odd, as a review by Sharma and Haider (2013), found that most studies show similar effects of yoga on state and trait anxiety. According to our descriptive data of the STAI-Y-ST scores, there was indeed a reduction of state anxiety in the IG, but a similar reduction could also be observed in the CG. A possible explanation for our findings would be that while trait anxiety was lower, situational stress was higher in the IG during the posttest measurements, which would have counteracted the positive effects of Hatha Yoga on state anxiety. However, to our knowledge, there are no plausible reasons as to why this would be the case. Finally, it should be noted that in most reviews on the effect of MBIs in general and yoga in specific on anxiety, most studies included were not conducted on healthy but rather on clinical populations (e.g., Cramer et al., 2018; Fjorback et al., 2011; Gonzalez et al., 2021; Kirkwood et al., 2005; Sharma & Haider, 2013; Vollbehr et al., 2018). Since we excluded individuals with current psychiatric disorders, ranges of stress and anxiety levels may have been limited in our sample, which in turn could have accounted for our nonsignificant findings regarding the effect of Hatha Yoga on anxiety (e.g., Bland & Altman, 2011). From this perspective, it could also be argued that the medium to large effect of Hatha Yoga on stress found in our study would be even stronger in populations that include individuals with current psychiatric disorders.

The results regarding the characterization of our Hatha Yoga intervention are contrary to our expectations, as we treated Hatha Yoga as a more physically oriented form of MBI, whereas the results of the EPYQ indicated that the intervention was characterized by a rather low to moderate focus on physicality. These results could be explained by the characterization of our sample as yoga novices: The items assessing physicality are divided into items assessing the inclusion of physical elements at a more basic level (e.g., "How much did the teacher include or mention physical balance?") and items assessing challenges related to physical elements (e.g., "How much did the teacher include or mention the challenge of one's physical balance ["finding one's limits" in relation to physical balance]?"). Accordingly, it could be argued that while the yoga teachers focused on incorporating physical elements in general, as it is typical for Hatha Yoga (Shapiro et al., 1998), they avoided challenging physical aspects too much, as our participants were yoga novices. Furthermore, the strong focus on body awareness and breathwork supports the assumption that our intervention was of a more physically oriented nature than other MBIs. Additionally, the rather low to moderate focus on meditation/mindfulness suggests that the differentiation of Hatha Yoga from other MBIs is reasonable, even if there was a moderate to high focus on acceptance/compassion, as it is typical for MBIs (Kabat-Zinn, 2015; Park et al., 2021). Future studies might consider dividing items assessing physicality into two categories (involvement of physicality in general vs. physical challenges), especially if interventions are conducted with yoga novices. In general, research including yoga practices might benefit from linking certain components of yoga interventions (e.g., physicality) directly to certain desirable outcomes, so different forms of yoga interventions can be applied to different target groups.

Consideration of Physiological Stress Markers

Regarding the found effects of Hatha Yoga on perceived stress and perceived stress reactivity, it should be mentioned that we planned to not only report subjective but also objective stress parameters, namely cortisol and alpha-amylase. However, the analysis of these objective stress parameters is not expected to be completed until mid of 2023. Our investigation of the effect of Hatha Yoga on cortisol and alpha-amylase could help understanding the mixed findings of previous research regarding yoga and cortisol: While it could be the case that studies not finding an effect of yoga on cortisol did not pay sufficient attention to the circadian rhythm of cortisol or simply varied in basic elements (Aguilar-Raab et al., 2021; Li & Goldsmith, 2012), nonsignificant findings regarding cortisol could also speak for cortisol not being a sufficient physiological marker of stress in the context of yoga (Takai et al., 2004). The latter assumption would find support in significant effects of Hatha Yoga on alpha-amylase as a physiological marker of stress and nonsignificant findings regarding the effect of Hatha Yoga on cortisol. If we would find both reduced alpha-amylase and reduced cortisol levels after the intervention, this would be an indicator for the effectiveness of Hatha Yoga for reducing physiological markers of stress, provided studies and the interventions are conducted in a high-quality manner.

Hatha Yoga and Trait Mindfulness

In line with recent studies showing positive effects of Hatha Yoga on TM (Saksena et al., 2020; Shelov et al., 2009), Hatha Yoga had a significant effect on individuals' levels of TM in our study. Effects of Hatha Yoga on TM have previously been found for Hatha Yoga interventions with a focus on body postures (Saksena et al., 2020), as it was the case in our study, and for interventions that combined the physical components of Hatha Yoga with explicit mindfulness elements (Shelov et al., 2009). Since there are few studies investigating how the physical components of MBIs influence TM, our study deepens the understanding of strategies to change TM levels by showing that practicing physically oriented Hatha Yoga indeed leads to increased TM levels after the intervention. Hence, practicing Hatha Yoga might provide the benefits of increased TM (e.g., Lu et al., 2019; Mesmer-Magnus et al., 2017) also to individuals who are not interested in practicing and rising Mindfulness in particular but rather practice yoga as a form of exercise or for different purposes.

Further, we showed that TM, on top of being a desirable outcome of yoga practice, also plays a moderating role for the effect of Hatha Yoga on other outcomes, such as perceived stress. Our study revealed that it is mainly individuals of high preTM levels, followed by individuals of moderate preTM levels, that benefit from the yoga intervention in terms of perceived stress. While there are studies showing ceiling effects for individuals with high levels of preTM in terms of their benefit from different MBIs (Kappen et al., 2019; Kittler et al., 2018), our study results indicate a higher effectiveness of Hatha Yoga interventions for individuals with high levels of preTM. Referring to Schmertz et al. (2008), these findings could be explained by fewer attentional regulation strategies of individuals with low levels of preTM that lead to more experiences of frustration during the yoga sessions and therefore less experiences of stress and anxiety relief. Similar results were found in a study by Kishida et al. (2018), in which the authors found positive effects of yoga on self-compassion and social connectedness for individuals of high preTM levels but not for those of low preTM levels. Consequently, one might argue that individuals with low preTM levels should receive a different intervention than Hatha Yoga but there are two reasons against such an argument: First, it should be noticed that the moderating effect of TM for the effect of Hatha Yoga on perceived stress was only marginally significant, hence, results should be interpreted with caution. However, moderated regression analyses often are of low power since the effect size of the interaction term is reduced by the main effects, which could explain our only marginally significant findings (Aiken & West, 1991). Further research is needed to support our preliminary evidence for the moderating role of TM before final conclusions about the effectiveness of Hatha Yoga for individuals with different levels of TM can be drawn. Second, although our results suggest superior efficacy of Hatha Yoga in reducing perceived stress for individuals of high preTM levels, such effects could not be detected in terms of perceived stress reactivity. We found no moderation effect of preTM for the effect of Hatha Yoga on perceived stress reactivity, hence, Hatha Yoga significantly reduced perceived stress reactivity regardless of individuals' TM levels. This might be explained by perceived stress reactivity being the more physical oriented stress response than perceived stress (Park et al., 2021), thereby being addressed through physically oriented Hatha Yoga more independently of individuals' state of mind, hence, more independently of individuals' TM. Consequently, Hatha Yoga might work for enhancing physical relaxation regardless of individuals' TM levels, thereby reducing perceived stress reactivity, while a certain level of TM is needed for Hatha Yoga to also enhance mental relaxation, hence, reduce perceived stress. This assumption is supported by findings showing that changes in mindfulness are more strongly associated with perceived stress than perceived stress reactivity (Park et al., 2021). In future studies it should be investigated, which form of yoga works most efficiently for whom and for which purpose. For example, it could be investigated, if more physical (vs. mental) oriented forms of yoga generally work better for individuals suffering from perceived stress reactivity and if different yoga styles than Hatha Yoga work better for individuals with low TM levels suffering from perceived stress. Finally, since perceived stress and perceived stress reactivity are often related (Park et al., 2021), it would be of benefit to investigate MBIs that are equally effective in reducing both, regardless of individuals' TM.

Trait Mindfulness – A potential Mediator?

As described in the previous section, we found a marginally significant moderation effect of preTM for the effect of Hatha Yoga on perceived stress. However, it has been argued in recent literature that TM could not only play a moderating role but also a mediating role in the context of the effects of yoga. For example, Park et al. (2021) suggested increased mindfulness as one of the potential psychosocial mechanisms through which yoga reduces stress. In their study, perceived stress and stress reactivity were assessed at the beginning, in the middle, and at the end of a 12-week yoga intervention. They further assessed mindfulness, next to interoceptive awareness, spiritual well-being, self-compassion, and self-control, as potential mediators of the effects of yoga on stress. The authors found that increases in each of the potential mechanisms, except for self-control, were strongly correlated with decreases in perceived stress and perceived stress reactivity from the beginning to the middle of the intervention as well as with decreases in perceived stress from the middle to the end of the intervention. However, changes in the different psychosocial mechanisms seemed to happen concurrent with, rather than prior to, changes in the two stress measurements. Therefore, potential mediation effects of mindfulness should be interpreted with caution in the study by Park et al. (2021). Additionally, the yoga intervention being used was based on Kripalu yoga, which comprises a high focus on body awareness, acceptance, self-compassion, breathwork, mental and emotional awareness, and active postures (Park, Elwy, Maiya, Sarkin, Riley, Eisen, Gutierrez, Finkelstein-Fox, et al., 2018). Note that even though our Hatha Yoga intervention was mainly physically oriented, therefore aiming less directly at increasing mindfulness and other aspects of mental and emotional awareness, positive effects of yoga on perceived stress, perceived stress reactivity, and TM could be found in our study. However, since we were mainly interested in the effects of Hatha Yoga on various outcomes and the moderating role of TM, we did not include enough measurement points to also draw conclusions of a potential mediating role of TM for the effects of Hatha Yoga on perceived stress and perceived stress reactivity. Since there was a significant increase in TM as well significant decreases in both stress types from before to after the intervention, it could very well be that the effects of Hatha Yoga on both stress types were mediated by increased TM. To gain comprehensive understanding of both factors influencing the effects of yoga on various outcomes and potential mechanisms through which yoga works future studies should investigate potential mediating as well as moderating influences of TM on the effects of yoga through including enough measurement points to draw valid conclusions in terms of mediation effects of TM.

Limitations

Different limitations to our study could have influenced the study results. While the need for effective stress reduction interventions grew since the outbreak of the COVID-19 pandemic, as described in the introduction of this thesis, the pandemic also had consequences for our study: As already mentioned, the relatively small size of the IG and the CG, respectively, could have accounted for the nonsignificant findings regarding the effect of Hatha Yoga on anxiety. Even though we aimed for a big enough sample size to detect potential effects with a power of 80 %, the amount of useable data shrank to 74 data sets since a relatively high number of participants only completed the measurements partly, for example only pretest measurements, or did not participate in at least two yoga sessions per week for three consecutive weeks if belonging to the IG. While this was partly due to consequences of COVID-19 (non-attendance of measurements, SSC, or yoga sessions due to infection), it could also be due the relatively high commitment character of our study: Since we aimed at avoiding methodological issues of former yoga intervention studies, for example by choosing a time-consuming SSC procedure and a high frequency of yoga sessions, our study could be seen as quite time consuming for participants in general. While we tried to avoid high drop-out rates through detailed briefing of participants and reasonable financial compensation, future studies might consider investigating less time-consuming yoga interventions or higher financial compensations. However, while a review on the effects of yoga in general on stress did not find a relationship between the amount of yoga practice and effect sizes (Breedvelt et al., 2019), a review on the effects of Hatha yoga on anxiety revealed a positive association between intervention efficacy and total number of hours of yoga practice (Hofmann et al., 2016). Such findings should be considered when planning yoga interventions, and it could be of substantial benefit for intervention optimization to investigate at what number of practice hours an intervention leads to positive effects.

Furthermore, we did not include an active control group in our study design to control for intervention-unspecific effects. In a review on the effects of yoga on stress and anxiety it has been found that effect sizes of yoga decrease when the intervention group is compared to an active control group (Breedvelt et al., 2019). Therefore, future studies should investigate the efficacy of Hatha Yoga for stress and anxiety reduction in comparison to other active interventions while following a high-quality methodological design, thereby contributing to an optimal application of different interventions.

Another limitation of our study refers to the nature of our sample: While our study was open to individuals of different educational backgrounds, due to recruitment through university platforms our sample mainly consisted of students, who were further mainly female. Additionally, individuals with a current psychiatric disorder were excluded, what might have reduced ranges of stress and anxiety. This in turn could have affected our findings as described in detail in the end of the section “Hatha Yoga, Stress, and Anxiety” (p. 38). These considerations especially gain importance, when considering that not only anxiety and stress levels are rising in the worldwide population (Salari et al., 2020) but also current mental disorders (Winkler et al., 2020; World Health Organisation, 2022). Therefore, one could question the generalizability of results found in a sample excluding individuals with current mental disorders to the general population. Future studies should investigate the effects of Hatha Yoga on stress, anxiety, and mindfulness in the general population without limiting samples to whether exclusively clinical or exclusively healthy populations to gain a comprehensive understanding of the effectiveness of yoga.

Finally, it must be mentioned that all the results reported in this thesis are based on self-reported measures. Thus, while the previously reported measures have been susceptible to various biases associated with self-reported measures (Paulhus & Vazire, 2007), the analysis of our physiological stress marker will lead to further clarification of the found effects.

Conclusion

Recent developments have led to rising stress and anxiety levels worldwide, underlining the need for efficient strategies to deal with stress and anxiety, such as MBIs. Our study results advance research on MBIs by systematically delineating the effects of individual components of MBIs, namely the effects of Hatha Yoga on stress, anxiety, and trait mindfulness. We successfully demonstrated the effectiveness of Hatha Yoga for increasing mindfulness and decreasing perceived stress as well as perceived stress reactivity. Further, we suggest that individuals with high trait mindfulness at the beginning of the intervention might benefit more from Hatha Yoga in terms of perceived stress reduction, thereby leading to further clarification for whom and for which purpose Hatha Yoga might work. Future research can build on the current evidence base to gain a better understanding of the optimal application of MBIs for stress and anxiety reduction.

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List of Abbreviations

ACS:	Attentional control setting
ANOVA:	Analyses of Variance
ASSR:	Auditory steady-state responses
CG:	Wait list control group
EEG:	Electroencephalography
EPYQ:	Essential Properties of Yoga Questionnaire
FMI:	Freiburg Mindfulness Inventory
IG:	Intervention group
MBI:	Mindfulness-based intervention
N2pc:	N2-posterior-contralateral
Pd:	Distractor positivity
PostPS:	Posttest perceived stress
PostTM:	Posttest trait mindfulness
PrePS:	Pretest perceived stress
PreTM:	Pretest trait mindfulness
PSRS:	Perceived Stress Reactivity Scale
PSS:	Perceived Stress Scale
RT:	Response time
SSC:	Saliva sample collection
SSVEP:	Visually evoked steady-state potentials
STAI-Y:	State-Trait-Anxiety-Inventory, Form Y
STAI-Y-ST:	State-Trait-Anxiety-Inventory, Form Y, state anxiety
STAI-Y-TR:	State-Trait-Anxiety-Inventory, Form Y, trait anxiety
TM:	Trait mindfulness
UoV:	University of Vienna

Appendix

Abstract (English)

Since the outbreak of the COVID-19 pandemic in March 2020, both stress and anxiety levels have increased in the worldwide population. This underlines the need for strategies to deal with stress and anxiety in a constructive way. Mindfulness-based interventions are increasingly found to be effective for stress and anxiety reduction, although it is still unclear which components of these are responsible for their effectiveness and on which factors their effectiveness depends. In our study, we investigated how an eight-week Hatha Yoga intervention affects the stress, anxiety, and mindfulness levels of 74 participants and whether these effects are dependent on the participants' mindfulness levels before the intervention. Our hypotheses were partially confirmed: There was, as expected, a significantly larger reduction of perceived stress and stress reactivity as well as a significantly larger increase of mindfulness levels in the intervention group than in the waiting control group. Unexpectedly, there was a stronger reduction of trait, but not state anxiety levels, in the intervention group, which was further not significant. The effect of Hatha Yoga on stress was strongest for participants with high mindfulness, followed by those with moderate mindfulness. There was a weak, only marginally significant effect for subjects with low levels of mindfulness. These findings can be extended by future research investigating which components of mindfulness-based interventions affect both stress and anxiety, independent of the level of mindfulness prior to the intervention, in order to contribute to an optimized application of mindfulness-based interventions beyond this study.

Keywords: Hatha Yoga, mindfulness, mindfulness-based interventions, perceived stress, state anxiety, stress reactivity, trait anxiety

Zusammenfassung (Deutsch)

Seit dem Ausbruch der COVID-19 Pandemie im März 2020 ist sowohl das Stress- als auch das Angstniveau in der weltweiten Bevölkerung gestiegen. Dies verdeutlicht den Bedarf an Strategien, mit Stress und Angst auf konstruktive Art umzugehen. Als effektive Strategien zur Stress- und Angstreduktion erweisen sich dabei zunehmend achtsamkeitsbasierte Interventionen, wobei noch unklar ist, welche Komponenten dieser für deren Wirksamkeit verantwortlich sind und von welchen Faktoren ihre Wirksamkeit abhängt. In dieser Studie wird untersucht, wie sich eine achtwöchige Hatha Yoga Intervention auf das Stress-, Angst-, und Achtsamkeitsniveau von 74 Versuchspersonen auswirkt und ob diese Auswirkungen vom Achtsamkeitsniveau der Versuchspersonen vor Interventionsbeginn abhängig sind. Dabei wurden unsere Hypothesen nur teilweise bestätigt: Wie erwartet war die Reduktion des wahrgenommenen Stresses und der Stress Reaktivität sowie der Anstieg des Achtsamkeitsniveaus in der Interventionsgruppe signifikant höher als in der Wartekontrollgruppe. Unerwarteterweise zeigte sich zwar eine stärkere Reduktion des Niveaus von Angst als Eigenschaft, jedoch nicht als Zustand, in der Interventionsgruppe, welche zudem nicht signifikant war. Der Effekt von Hatha Yoga auf Stress war am stärksten für Versuchspersonen mit hoher Achtsamkeit, gefolgt von solchen mit moderater Achtsamkeit. Für Personen mit niedrigem Achtsamkeitsniveau zeigte sich ein schwacher, nur geringfügig signifikanter Effekt. Diese Befunde können durch zukünftige Forschung erweitert werden, indem untersucht wird, welche Komponenten achtsamkeitsbasierter Interventionen auch unabhängig vom Achtsamkeitsniveau vor der Intervention sowohl auf Stress als auch auf Angst wirken, um so über diese Studie hinaus zur optimierten Anwendung von achtsamkeitsbasierten Interventionen beizutragen.

Schlüsselwörter: Achtsamkeit, Achtsamkeitsbasierte Interventionen, Eigenschaftsangst, Hatha Yoga, Stress Reaktivität, Wahrgenommener Stress, Zustandsangst