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Effects of Current and Long-Term Yoga Practice on Explicit and Implicit Emotion Regulation

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Os Efeitos da Prática de Yoga Atual e a Longo-Prazo Sobre a Regulação Emocional Explícita e Implícita

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Because of the torment of threefold suffering, arises the desire to know the means of counteracting it. If it is said that this inquiry is useless because perceptible means of removal are available, we say no, since perceptible means are not final or abiding.

—Ishvarakrishna, *Samkhya Karika*, Verse 1

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Abstract

Yoga-based practices are proposed to affect explicit and implicit emotion regulation. This work presents two studies that investigated this proposition. Study 1 tested whether long-term and current weekly hours of yoga practice predicted self-reported cognitive reappraisal, expressive suppression, attentional focusing, and attentional shifting (as indices of explicit emotion regulation), and performance in a verbal emotional go/no-go task (as implicit emotion regulation), in a pre-registered, online, and cross-sectional design. Out of 368 respondents (gender: 79.3% female, 20.1% male, 0.6% non-binary; mean age: 33.85±7.28 years; mean yoga experience: 6.9±5.73 years), 225 completed explicit measures, and 143 completed all of them. Among explicit measures, long-term and current yoga practice predicted greater attentional focusing only. Comparing response patterns of happy vs. sad stimuli in the go/no-go task, long-term yoga experience predicted less commission errors in sad blocks, whilst current yoga practice predicted less valence differences in mean reaction times. Study 2 followed up on these findings, testing the feasibility of combining heart rate variability and emotional spatial cueing paradigms to disentangle top-down and bottom-up effects of yoga on emotion regulation. As a pilot study, it tested whether long-term and current yoga practice predicted greater heart rate variability across measurement conditions (baseline, mild stress, and recovery), and whether they predicted less emotional bias in spatial cueing tasks under exogenous and endogenous orienting, using fearful and neutral facial stimuli of high, low, and broad spatial frequencies. Out of 27 participants, 20 were included due to clinical conditions or technical difficulties in data collection (gender: 60% feminine, 35% masculine, 5% non-binary; age: 46.60±12.37 years, on average; yoga experience: 16.40±13.02 years, on average; yoga/meditation teachers: 70%). HRVs differed as expected, suggesting an effective manipulation of measurement conditions.

When controlling for yoga experience, all effects disappeared, what might suggest a mediational relationship (to be formally tested in future studies). Only long-term yoga experience, and not current hours of practice, interacted with performance in the spatial cueing tasks. Long-term yoga experience was associated with a facilitated attentional disengagement away from fearful faces, specifically under endogenous orienting, which are processes largely based on attentional control and regulatory skills. These results suggest that long-term regular yoga practice primarily modified top-down processes of emotion regulation, although bottom-up effects cannot be discarded, considering methodological limitations of this work. Combined, both studies suggest that the modification of top-down attentional functions constitutes a possible pathway through which yoga affects explicit and implicit emotion regulation, leading to less overall emotional bias. Although encouraging, these findings should be met with caution, and they await further empirical support from different fronts of evidence.

Keywords: emotion regulation, emotional attention, implicit, yoga, mind-body

Resumo Expandido

O yoga tem sido apontado como uma possível intervenção de regulação emocional. Modelos teóricos propõem que a prática promove a integração entre mecanismos *top-down* (como funções inibitórias, de monitoramento executivo e controle atencional) e *bottom-up* (como funções interoceptivas, proprioceptivas e sensório-motoras), o que se traduziria em uma autorregulação mais efetiva em domínios cognitivos, comportamentais e afetivos. A regulação emocional modula a ocorrência, duração e qualidade das emoções, mas apresenta variados níveis de engajamento consciente, gerando suas dimensões explícita e implícita. Quando um objetivo de regulação emocional é ativado e perseguido conscientemente, acionam-se estratégias explícitas de regulação, como a reavaliação cognitiva, a supressão emocional e o controle voluntário atencional. Quando inconscientemente, acionam-se estratégias implícitas, como a aprendizagem por extinção e vieses atencionais automáticos. Este trabalho propôs dois estudos para avaliar se a prática de yoga a longo-prazo e a atual carga horária de prática de yoga estão associadas a mudanças na regulação emocional explícita e implícita. O primeiro estudo investigou se a prática de yoga atual e a longo-prazo se associaria à reavaliação cognitiva, à supressão expressiva, ao foco atencional e à alternância atencional (como medidas explícitas de regulação emocional) e à performance em uma tarefa go/no-go verbal emocional, com estímulos positivos e negativos (como uma medida implícita de regulação emocional). Hipotetizava-se que o tempo de experiência com yoga e a carga atual de prática prediriam maiores índices de reavaliação cognitiva, foco atencional e alternância atencional, e menores índices de supressão emocional. Na tarefa go/no-go, prediriam menores erros por comissão no geral (indicando controle inibitório), menores diferenças entre estímulos positivos vs. negativos em erros de comissão e menores diferenças entre estímulos positivos vs. negativos nas médias de tempos de

resposta (indicando menor viés emocional no controle inibitório). A amostra contou com 368 participantes (gênero: 79.3% feminino, 20.1% masculino, 0.6% não-binário; idade: 33.85±7.28 anos, em média; experiência com yoga: 6.9±5.73 anos, em média), em um estudo pré-registrado, online e transversal. Destes, 225 completaram apenas as medidas explícitas, enquanto 143 completaram todas. Entre as medidas explícitas, os anos de experiência com yoga e a carga atual de prática predisseram maiores índices de foco atencional autorrelatado, apenas. Na tarefa go/no-go, os anos de experiência predisseram melhor controle inibitório geral (menos erros de comissão). Além disso, comparando padrões de resposta para estímulos positivos e negativos, os anos de experiência predisseram menos erros de comissão em blocos negativos, enquanto carga atual de prática predisse menor interferência emocional nas médias de tempo de resposta. Assim, as hipóteses iniciais foram parcialmente corroboradas. Na dimensão explícita, a prática de yoga associou-se apenas ao controle de foco atencional, enquanto na dimensão implícita associou-se tanto a um melhor controle inibitório geral quanto a menos vieses emocionais. O segundo estudo, visando a aprofundar os achados do primeiro, testou a viabilidade da combinação de medidas fisiológicas e comportamentais para melhor discriminar efeitos *top-down* e *bottom-up* das práticas de yoga na regulação emocional. Tratou-se de um estudo piloto que investigou se a prática de yoga atual e a longo prazo prediriam maior variabilidade de frequência cardíaca, (um marcador fisiológico de regulação emocional, que foi mensurado em linha de base, estresse leve e recuperação), e padrões de resposta em duas tarefas de atenção emocional: uma tarefa emocional de pistas espaciais com orientação exógena e uma com orientação endógena (*endogenous and exogenous emotional spatial cueing tasks*). Nas tarefas, foram utilizados estímulos faciais amedrontados e neutros, com diferentes frequências espaciais (alta, baixa e intacta). Com base em estudos prévios, parâmetros das tarefas foram manipulados para melhor distinguir processos *top-down* e *bottom-up* de atenção emocional. Enquanto a atenção emocional *top-down* pode ser mais fortemente evidenciada no desengajamento atencional para longe de estímulos negativos vs. neutros, especialmente para estímulos de frequência espacial alta, na tarefa endógena, a atenção emocional *bottom-up* pode ser mais fortemente evidenciada no engajamento atencional frente a estímulos negativos vs. neutros, especialmente estímulos de frequência espacial baixa, na tarefa exógena. Dos 27 participantes, 20 foram incluídos na amostra final (gênero: 60% feminino, 35% masculino, 5% não-binário; idade: 46.60±12.37 anos, em média; experiência com yoga: 16.40±13.02 anos, em média; professores de yoga/meditação: 70%). A coleta de dados foi presencial, em contexto de laboratório—os dados sociodemográficos e de prática de yoga/meditação foram respondidos em lápis e papel, enquanto as demais tarefas (cardiovasculares e de atenção emocional), foram respondidas no computador através do software PsychoPy. As diferenças entre condições de variabilidade de frequência cardíaca desapareceram ao controlar pelos efeitos da experiência com yoga, o que pode indicar uma relação de mediação (a ser formalmente testada em estudos futuros). Em relação às tarefas comportamentais, apenas a experiência a longo-prazo com yoga (e não a carga atual de prática) interagiu com padrões nos tempos de resposta. As respostas frente a estímulos de diferentes frequências espaciais não se diferenciaram como esperado. Mesmo assim, houve evidências de que a experiência a longo-prazo facilitou o desengajamento atencional para longe de estímulos negativos, especificamente sob orientação endógena, o que indica habilidades voluntárias de controle atencional e regulação. Tais resultados apontam que a prática de yoga regular se associou primariamente a mudanças em processos *top-down* de regulação emocional, embora efeitos *bottom-up* não possam ser descartados, considerando limitações metodológicas deste trabalho (em especial o pequeno tamanho de amostra, poder estatístico limitado e maior

necessidade de controle experimental). Em conjunto, ambos os estudos sugerem que a modificação de funções atencionais de maneira *top-down* constitui um possível mecanismo pelo qual a prática de yoga afeta a regulação emocional explícita e implícita, levando a menores vieses emocionais. Apesar de encorajantes, os resultados aqui apresentados devem ser considerados com cautela, à espera de suporte empírico mais robusto de diversas frentes de evidência.

Palavras-Chave: regulação emocional, atenção emocional, processos implícitos, yoga, corpo-mente

General Introduction

Yoga is often presented as one of the six classical schools of Indian Philosophy as systematized in the Yoga Sutras of Patañjali (~4th century CE), but this tradition has been marked by a diverse landscape of conceptions through time—many historical texts deliver yoga teachings, from the early Upanishads to the eighteenth century *haṭhayoga* writings. Most definitions frame yoga as a goal achieved by meditative efforts, such as to suppress all mental activities, experience non-dual states, or connect with a particular deity (Harimoto, 2020; Mallinson & Singleton, 2017).

Patañjali presented the eight-limb yoga system as a method to reach the yogic goal. The eight limbs include ethical behaviors (*yamas* and *niyamas*), physical postures (*asana*), breath control (*pranayama*), sensory withdrawal (*pratyahara*), and various stages of meditation (*dharana*, *dhyana,* and *samadhi* (Bryant, 2015)). Importantly, traditional accounts of yoga emphasized meditation, breath-control, asceticism, and devotional practices—this is not to point modern yoga as flawed or inauthentic, but to acknowledge the mutability of what has been named "yoga" through time, taking more and more physical and secularized shapes (De Michelis, 2005; Newcombe, 2009; Singleton, 2010).

Modern yoga tends to include sequences of postures, breathing exercises, and meditation. Across components, practitioners are often encouraged to focus and sustain attention on an object (e.g., breath, body, thoughts, or visual focal point). Generally, postural training synchronizes breath and movement in a slow and controlled way while creating moderate physical and/or mental stress. Different yoga styles can be more dynamic, steadier, or not include physical training at all. Most breathing exercises also carry slow and controlled qualities (e.g., *nadi sodhana*: alternate nostril breathing), but there are vigorous ones (e.g., *kapalabhati*: fast effortful exhalations). Meanwhile, meditation practice is thought to change over time, moving from focused attention (on the breath, body, or mantras) to also encompass open monitoring (i.e., non-reactive awareness with no specific object) in more advanced stages (Gard et al., 2014; Schmalzl et al., 2015).

Theoretical frameworks propose that yoga facilitates the integration of top-down and bottom-up processes, especially in long-term practitioners (Gard et al., 2014; Schmalzl et al., 2015). Such integration would translate into more efficient bidirectional feedback between high-level brain networks (e.g. frontoparietal control network, linked to behavioral inhibition and executive monitoring; and central executive network, linked to attentional control), low-level brain networks (e.g., striatopallidal-thalamocortical network, linked to extinction learning; and dorsal attention network, linked to attentional orienting), and interoceptive processes (e.g., sensorimotor, cardiovascular, respiratory, and visceral systems), inhibiting maladaptive patterns of response (Gard et al., 2014; Pascoe et al., 2021; Schmalzl et al., 2015; Sullivan et al., 2018).

The neurovisceral integration model also helps to elucidate potential mechanisms of yoga-based practices (Thayer & Lane, 2000). It describes how autonomic inhibitory processes, fostered by the parasympathetic nervous system and indexed by vagally-mediated heart rate variability, regulate attentional and emotional functions. Smith et al. (2017) further developed the model, describing eight levels of hierarchical implementation of vagal control: from the low-level intrinsic cardiac ganglia and cardiovascular reflex arcs, to the mid-level brainstem nuclei, hypothalamus, and amygdala, to the high-level cortical networks. Thus, improvements in top-down/bottom-up integration, while strengthening parasympathetic tonus, are thought to translate into more efficient self-regulation in cognitive, behavioral, and affective domains (Gard et al., 2014; Thayer & Lane, 2000).

Accordingly, yoga practice is proposed to promote emotion regulation (Balasubramaniam et al., 2013; Menezes, Dalpiaz, Kiesow et al., 2015). Emotion regulation modulates the onset, offset, duration, and quality of one's emotions (Gross, 1998). Regulatory goals (i.e., targeted emotional states) are not necessarily activated and implemented in an effortful and conscious manner since they can also be evoked and achieved unconsciously (Custers & Aarts, 2010). These varying levels of conscious engagement create a continuum between explicit and implicit forms of emotion regulation. The explicit-implicit dimension has been conceptualized in many ways, but it refers here to the nature of an emotion regulation goal, while the automatic-controlled dimension refers to the nature of a regulation process—both dimensions are orthogonally related, creating implicit-automatic, implicit-controlled, explicit-automatic, and explicit-controlled classes (Braunstein et al., 2017).

In adults, yoga-based practices have been linked to improved positive affect and behavioral inhibition (Bilderbeck et al., 2013), reduced stress, anxiety, and depression symptoms (Rocha et al., 2012; Schmalzl et al., 2018), decreased emotional reactivity (Mocanu et al., 2018), less emotional interference under attentional load (Menezes, Dalpiaz, Rossi et al., 2015), and healthier use of emotion regulation strategies (Kobylinska et al., 2018; Sahni et al., 2021). In adolescents, a randomized trial of yoga vs. physical education led to improved emotion regulation (Daly et al., 2015), and in older adults, another randomized trial of yoga vs. stretching led to decreased levels of stress and anxiety (Gothe et al., 2016), but the empirical scenario is far from complete. In a recent study, no systematic or meta-analytic reviews of yoga-based interventions and emotion regulation were found (Pascoe et al., 2021).

In an attempt to elucidate how yoga-based practices impact explicit and implicit forms of emotion regulation, two studies are presented. The first study investigated whether long-term and current weekly hours of yoga practice were associated with explicit emotion regulation, using cognitive reappraisal, expressive suppression, attentional focusing, and attentional shifting measures, and with implicit emotion regulation, using a verbal emotional go/no-go task, in adult practitioners. The second study followed up on the main findings of study 1, trying to disentangle top-down and bottom-up effects of yoga on emotion regulation combining cardiovascular and emotional attention measures. As a pilot study, it tested whether long-term and current yoga practice were linked to increased heart rate variability and decreased emotional bias in spatial cueing paradigms. Thus, traditional and novel methods to investigate emotion regulation were evaluated in less- and more-experienced yoga practitioners, aiming to fill substantial gaps in the field.

Study 1

Long-Term and Current Yoga Practice Predict Explicit and Implicit Emotion Regulation Outcomes: A Cross-Sectional Study

The ability to regulate emotions in face of environmental demands is essential for physical, psychological, and social well-being. Emotions have the power to recruit physiological, cognitive, behavioral, and psychological systems, modulated by evaluative processes (Norman et al., 2014). Our desired emotional states can be activated and pursued consciously or unconsciously, giving rise to explicit and implicit forms of emotion regulation (Braunstein et al., 2017; Custers & Aarts, 2010).

Most studies of emotion regulation have focused on explicit strategies, especially cognitive reappraisal—reinterpreting an event to modulate an emotional response (Gross, 1998)—, and expressive suppression—attempting to subdue an emotional response (Gross & Levenson, 1993). Cognitive reappraisal has been consistently associated with healthier cognitive, emotional, and social outcomes than expressive suppression, which has been linked to increased negative emotion and physiological activation (Cutuli, 2014; Dryman & Heimberg, 2018; but see Ford & Mauss, 2015 for cultural differences; and Gross, 2015 for a nuanced discussion).

Yoga and Explicit Emotion Regulation

There are mixed findings in regard to yoga's effects on cognitive reappraisal and expressive suppression. Kobylinska et al. (2018) found higher self-reported reappraisal in long- vs. short-term practitioners but no effects for suppression, and Sahni et al. (2021) found this same pattern comparing practitioners with yoga-naïve adults. Gootjes et al. (2011) found sustained attenuation of event-related potentials while practitioners reappraised aversive pictures, which suggests a more effective use of this strategy. Meanwhile, Dick et al. (2014) showed decreased self-reported suppression but no changes in reappraisal after a 12-week yoga intervention for women with posttraumatic stress disorder symptoms, while Cunningham (2020) found no differences between practitioners and non-practitioners on self-reported reappraisal nor suppression in healthy adults. Therefore, the field requires further evidence, drawing from different populations and measures.

Attentional control is another prominent explicit strategy (Braunstein et al., 2017; Ochsner & Gross, 2005; Wadlinger & Isaacovitz, 2011), inasmuch as attention is a key emotion-generating system that can be voluntarily modulated (Koole, 2009). Attentional control has been associated with greater spontaneous downregulation of negative emotions (Morillas-Romero et al., 2015), fewer specific emotion regulation difficulties (O'Bryan et al., 2017), as well as diminished symptoms of anxiety and depression (Ólafsson et al., 2011). A meta-analysis indicated moderate improvements in attention after both acute and continued yoga training (Gothe & McAuley, 2015), and attentional control skills might be more sensitive to breath-focused training (Schmalzl et al., 2018) and long-term practice (Menezes, Dalpiaz, Rossi et al., 2015).

Yoga and Implicit Emotion Regulation

Implicit emotion regulation, the modulation of emotional responses without the conscious goal of doing so (Braunstein et al., 2017), encompasses a wide range of regulatory strategies, such as extinction learning (Quirk & Mueller, 2008), affect labeling (Torre & Lieberman, 2018), and affect-biased attention (Todd et al., 2012). Yoga is proposed to benefit implicit emotion regulation, by working with the body and the breath in a way that facilitates vagal control (Gerritsen & Band, 2018; Zhang et al., 2019; Zou et al., 2018). According to the neurovisceral integration model, vagal control is implemented by hierarchical levels of organization (including cardiovascular, viscerosomatic, low-order, and high-order cognitive systems) which rely especially on inhibitory processes to optimize self-regulation (Thayer & Lane, 2000; Smith et al., 2017). The multiple components of yoga seem to place it in an advantageous position to impact several of these hierarchical levels (e.g., postural training: sensorimotor/viscerosomatic functions; breath control: cardiovascular/autonomic functions; meditation/attentional training: low- and high-level cognitive networks (Gard et al., 2014; Schmalzl et al., 2015; Schmalzl et al., 2020)).

The emotional go/no-go task measures emotional biases in behavioral inhibition (Schulz et al., 2007), and can help to provide a more complete scenario of yoga's implicit effects. A high number of commission errors (to respond in no-go trials) indexes low behavioral inhibition, with a possible stronger detection in shift blocks, i.e. when the present block requires the participant to change their behavior compared to the previous one (Meule, 2017). Furthermore, commission errors towards positive *vs.* negative targets measure emotional biases in behavioral inhibition, while mean reaction times (RTs) in go trials of positive *vs.* negative targets can indicate an approach tendency for specific valences (Murphy et al., 1999; Schulz et al., 2007; but see Meule, 2017 for a word of caution about mean RTs).

Categorization tasks of emotional words present mixed findings, but adults show a general tendency of positivity over negativity biases (Kauschke et al., 2019). Negativity biases seem to underlie emotion dysregulation (Bardeen et al., 2017), thus, positively-biased or balanced word processing styles are more desirable. Emotional biases are modifiable (Browning et al., 2010; Wadlinger & Isaacowitz, 2011), and it is possible that yoga practice attenuates affective biases irrespective of valence, especially in the long run (Davis & Thompson, 2015; Mocanu et al., 2018), but this hypothesis needs further empirical support.

Present Study

This cross-sectional study investigated whether yoga experience time and current weekly hours of yoga practice were associated with measures of explicit and implicit emotion regulation. It was hypothesized that years and current weekly hours of practice would predict higher self-reported cognitive reappraisal, lower self-reported expressive suppression, higher self-reported attentional control, and less emotional biases in a verbal emotional go/no-go task. Considering previously reported influences of general physical exercise (Giles et al., 2018) and mental health (Hu et al., 2014) on emotion regulation, these variables were treated as covariates when appropriate. This study was registered prior to data collection (osf.io/mhty6), approved by the local ethics committee, and financially supported by the Brazilian National Council for Scientific and Technological Development (CNPq).

Method

Participants

Recruitment and data collection were online, during the COVID-19 pandemic. Potential participants were reached out via social media and e-mail lists of yoga communities. Inclusion criteria were: practicing yoga for at least three months, twice a week, and being 18 years old. While self-report measures could be completed from mobile phones, the go/no-go task required access to a computer or laptop. Responses with slow framerates (< 55 Hz) were excluded from data analyses based on PsychoPy developers' recommendations (Peirce & MacAskill, 2018).

A few participants were excluded due to no report of yoga experience (n=5); no yoga practice for at least three months or twice a week (n=9); during the go/no-go task, framerates were < 55 Hz (n=10); or omission errors were > 15% of go trials, suggesting task abandonment (n=8). Included participants were 368 Brazilian adults (gender: 79.3% female, 20.1% male, 0.6%

non-binary). On average, they were 33.85 years old (±7.28; range: 18-50) and practiced yoga for 6.90 years (±5.73; range: 0.39-42.13). They practiced 22 different styles, and the most frequent were: Hatha (29.6%); Mixed (20.4%); Hatha Vinyasa (10.9%); Ashtanga (8.2%); Vinyasa (6.3%); Swasthya (4.1%); and Iyengar (2.7%). Out of the 368 participants, 225 completed self-report measures only, and 143 completed self-report measures and the emotional go/no-go task. Table 1 contains detailed sociodemographic, and yoga practice data.

Table 1

Participants' Sociodemographic and Yoga Practice Characteristics

	Participants				Group Comparisons
	All	Self-report	HSSH Order	SHHS Order	
N	368	225	77	66	
Age	33.85(±7.28)	33.67(±7.28)	34.52(±6.99)	33.68(±7.67)	$F(2,365)=0.41$, $p=.66$
Gender:					$X^2(6)= 7.62$, $p=.27$
Feminine	79.3%	79.6%	77.9%	80.3%	
Masculine	20.1%	20.4%	19.5%	19.7%	
Non-binary	0.6%	-	2.6%	-	
Education Level (attained):					$X^2(10)=8.98$, $p=.53$
Lower secondary	0.3%	0.4%	-	-	
Upper secondary	20.9%	23.6%	18.2%	15.1%	
Bachelor's	39.4%	40.9%	33.8%	40.9%	
Postgraduate	39.4%	35.1%	48.1%	43.9%	
Yoga Experience (years)	6.90(±5.73)	7.20(±6.18)	6.03(±4.69)	6.85(±5.19)	$F(2,365)=1.22$, $p=.30$
Yoga Experience (y/age)	.196(±.140)	.205(±.149)	.169(± .119)	.199(±.125)	$F(2,365)=1.84$, $p=.16$
Yoga Practice (h/week):					
Postures	3.38(±2.33)	3.28(±2.47)	3.77(±2.22)	3.28(±1.91)	$F(2,365)=1.31$, $p=.27$
Pranayamas	1.08(±1.46)	1.11(±1.58)	1.13(±1.46)	0.94(±1.03)	$F(2,365)=0.38$, $p=.69$
Seated meditation	1.22(±1.66)	1.31(±1.78)	1.21(±1.78)	0.94(±0.89)	$F(2,365)=1.26$, $p=.28$
Total	5.69(±4.33)	5.70(±4.86)	6.11(±3.69)	5.17(±2.84)	$F(2,365)=0.84$, $p=.43$
MHI-5	79.15(±11.16)	80.96(±9.68)	76.21(±12.21)	76.39(±13.25)	$F(2,365)=4.00$, $p=.02$
GSLTPAQ	40.17(±26.29)	41.98(±26.40)	32.71(±23.95)	42.70(±27.32)	$F(2,365)=7.94$, $p<.001$

Note. Means and standard deviations as M(±SD). Group comparisons were ANOVAs or chi-square tests. HSSH = go/no-go in happy-sad-sad-happy order; SHHS = go/no-go in sad-happy-happy-sad order; y/age = years of yoga experience/age; h/week = hours/week; MHI-5 = Mental Health Index; GSLTPAQ = Godin-Shepard Leisure Time Physical Activity Questionnaire.

Measures

Yoga and Meditation Practice Questionnaire

An 11-item questionnaire, developed for this study, assessed yoga practice (Appendix A). Participants reported their yoga style/tradition, approximate initial date of regular practice, and weekly hours of yoga practice for the past three months (i.e., mean frequency and duration of postural practice, breathing exercises, and seated meditation in a regular week). They were also asked about behavioral modifications linked to their yoga practice, and which ones were those from a list of behaviors/habits (i.e., diet, alcohol/cigarette/other substances' consumption, differences in interpersonal relationships, places they choose to go to, consumption of yoga-related content on the internet, social engagement with other practitioners, yoga philosophy studies, and devotional practices).

Emotion Regulation Questionnaire (ERQ)

The bifactorial 10-item ERQ assesses the use of cognitive reappraisal (α=.83; e.g., "I control my emotions by changing the way I think about the situation I'm in") and emotional suppression (α=.76; e.g., "I control my emotions by not expressing them") when facing positive, negative, or general emotions (Gross & John, 2003; Brazilian version: Batistoni et al., 2013).

Attentional Control Scale (ACS)

The ACS is a bifactorial 20-item scale of voluntary attentional focusing (α=.76; e.g., "It is hard for me to concentrate on a difficult task when there are noises around") and shifting (α =.64; e.g., "I can become interested in a new topic very quickly when I need to") in varied daily contexts (Derryberry & Reed, 2002; Ólafsson et al., 2011; Brazilian version: Filgueiras et al., 2015).

Mental Health Index-5 (MHI-5)

The five-item MHI (α=.70) briefly evaluates general mental health, encompassing symptoms of depression (e.g., feeling downhearted and blue), anxiety (e.g., being a very nervous person), and positive affect (e.g., feeling calm and peaceful) in the past month (McHorney & Ware, 1995; Brazilian version: Damásio et al., 2014).

Godin-Shephard Leisure-Time Physical Activity Questionnaire (GSLTPAQ)

The GSLTPAQ (α=.57) is a 3-item questionnaire to quantify physical activity performance in a regular week (Godin, 2011; Brazilian version: São-João et al., 2013). Respondents were asked to indicate how many days per week they practiced vigorous, moderate, and mild physical activity for more than 15 minutes, other than their postural yoga practice, during the past three months.

Verbal Emotional Go/No-Go Task

The emotional go/no-go task was structured based on the studies of Murphy et al. (1999) and Schulz et al. (2007). Verbal stimuli were selected based on valence ratings of a normative study for Brazilian Portuguese words (Oliveira et al., 2013). On a scale of 1-9, happy words had mean valence scores > 7 while sad words had scores < 3. A list of 80 words—40 happy and 40 sad—composed the task, controlled for length and concreteness (Janczura et al., 2007). Stimuli are provided in the Appendix B, in Portuguese and English. The task was built in PsychoPy version 2021.2.3, while data collection happened in Pavlovia, PsychoPy's associated online platform (Peirce et al., 2019). PsychoPy and Pavlovia show good precision for visual stimuli presentation in testing studies (Bridges et al., 2020; Garaizar & Vadillo, 2014).

Procedures

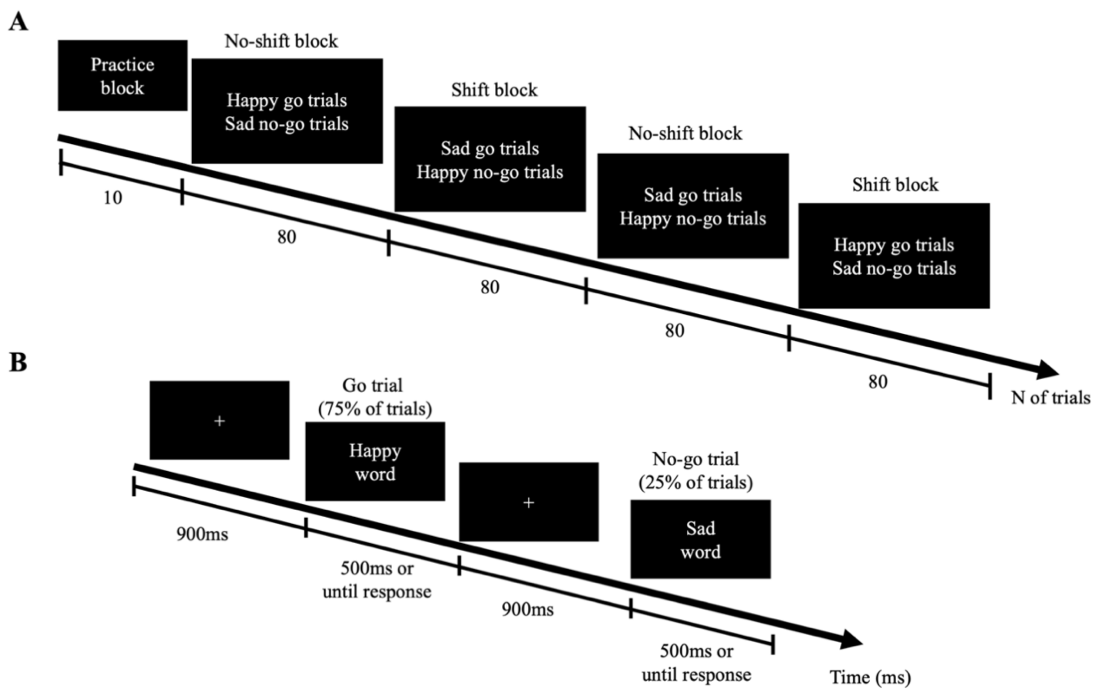
Potential participants were informed about the study's general purpose, duration, and inclusion criteria (practicing yoga for at least three months and twice a week) in the recruitment message. They were also informed that participation was voluntary, anonymous, and unpaid. Those willing to participate completed all self-report measures in the same order (yoga and meditation practice, GSLTPAQ, ACS, MHI-5, ERQ, and sociodemographics) in Google Forms (~15 min), and were subsequently redirected to Pavlovia for the go/no-go task (~10 min), which is detailed below. A personal password connected responses from both platforms while securing anonymity.

Go/No-Go Task

The task contained a practice block with 10 trials, then four blocks with 80 trials each. Participants should press the spacebar as quickly as they could for words of a particular valence (go words) and let words of the opposite valence pass (no-go words). Valence varied systematically across blocks. Some participants completed the four blocks following a happy-sad-sad-happy order (HSSH), while others completed a sad-happy-happy-sad order (SHHS), to counterbalance. Such sequencing allowed all participants to go through two shift blocks and two non-shift blocks along the task (see Figure 1A). In each trial, words were quasi-randomly selected following a proportion of 75% go words (240 trials) and 25% no-go words (80 trials). The selected word appeared at the center of the screen for 500ms or until response, followed by a fixation cross during the interstimulus interval of 900ms. Words appeared in white, letter height of 0.1 (1 unit being the full-screen size), against a dark blue background (see Figure 1B).

Figure 1

Schematic Structure of Blocks and Trials of the Verbal Emotional Go/No-Go Task



Note. (A) Block sequence following a happy-sad-sad-happy order of target stimuli. (B) Two consecutive trials in a block with happy words as targets and sad words as distractors.

Data Analysis

The yoga experience score was calculated as years of yoga experience divided by age, to dissociate age-related confounds (years of yoga experience and age showed a medium to large correlation in this sample, $r=.47$, $p<.001$—the yoga experience score maintained a very high correlation with the original variable of years of yoga experience, $r=.96$, $p<.001$, while dropping the correlation with age, $r=.25$, $p<.001$). Thus, the yoga experience variable refers to the proportion of time someone has practiced yoga in their lifetime.

Current hours of practice were the sum of time for physical postures, breathwork, and meditation in a regular week during the past three months. Hierarchical linear regression models tested whether yoga experience and current practice predicted scores of explicit emotion regulation strategies (cognitive reappraisal, expressive suppression, attentional focusing, and attentional shifting) for the whole sample. MHI-5 and GSLTPAQ scores were entered as second-block predictors.

Hierarchical linear regression models were also used to test whether yoga experience and weekly hours of practice predicted commission errors in all blocks and in shift blocks of the go/no-go task, as indices of general behavioral inhibition. MHI-5 and GSLTPAQ scores were not entered as second-block predictors, given the reduced sample size of go/no-go respondents.

The MEMORE macro for SPSS was used to test for emotional biases in go/no-go responses, as a parsimonious way of testing moderation models of repeated measures (Montoya & Hayes, 2016; Montoya, 2019). Commission errors and mean RTs in happy *vs.* sad blocks were evaluated using MEMORE's model 2, entering yoga experience and current weekly hours of yoga practice as continuous between-subjects moderators.

Results

All but two participants reported behavior modifications associated with their yoga practice. In order of frequency, they were: behavioral changes in interpersonal relationships (87.1%); study of yoga philosophy (81.8%); consumption of yoga-related content on the internet (79.8%); diet (71.2%); places they go to/avoid (64.4%); use of alcohol/cigarettes/other substances (56.8%); social engagement with other practitioners (55.1%); and devotional practices (46.1%).

Explicit Emotion Regulation Measures

Regression models of cognitive reappraisal, attentional focusing, and attentional shifting showed statistically significant results, but the expressive suppression model did not (see Table 2). Yoga experience and current weekly hours of yoga practice significantly predicted attentional focusing only. Cognitive reappraisal and attentional shifting were predicted by general mental health, but no other variable. Physical activity other than postural yoga did not predict any of the self-report measures.

Table 2

Hierarchical Multiple Linear Regression Models of Yoga Experience, Weekly Hours of Yoga Practice, General Mental Health, and Physical Activity Performance on Explicit Emotion Regulation Measures

	Cognitive Reappraisal							
	Model 1 (R^2=.004, F(2,365)=.81, p=.45)				Model 2 (R^2=.08, F(4,363)=7.37, p<.001)			
	b [95%CI]	*SE*	*t(365)*	*p*	b [95%CI]	*SE*	*t(363)*	*p*
Constant	5.58[5.34, 5.81]	.12	46.73	<.001	3.68[2.88, 4.47]	.40	9.08	<.001
Yoga Experience	-.46[-1.28, .36]	.42	-1.10	.27	-.59[-1.39, .22]	.41	-1.44	.15
Hours/Week of Yoga	.011[-.016, .037]	.014	.79	.43	.003[-.023, .028]	.013	.192	.85
MHI-5	-	-	-	-	.026[.016, .036]	.005	5.18	<.001
GSLTPAQ	-	-	-	-	-.003[-.007, .001]	.002	-1.41	.16
	Expressive Suppression							
	Model 1 (R^2=.007, F(2,365)=1.26, p=.29)				Model 2 (R^2=.02, F(4,363)=2.20, p=.07)			
	b [95%CI]	*SE*	*t(365)*	*p*	b [95%CI]	*SE*	*t(363)*	*p*
Constant	3.26[2.98, 3.53]	.14	23.45	<.001	4.18[3.22, 5.13]	.48	8.61	<.001
Yoga Experience	-.73[-1.69, .23]	.49	-1.50	.14	-.70[-1.65, .26]	.49	-1.43	.16
Hours/Week of Yoga	-.005[-.036, .026]	.016	-.30	.77	-.001[-.032, .030]	.02	-.07	.95
MHI-5	-	-	-	-	-.014[-.026, -.002]	.006	-2.24	.03
GSLTPAQ	-	-	-	-	.003[-.002, .008]	.003	1.29	.20
	Attentional Focusing							
	Model 1 (R^2=.10, F(2,365)=19.69, p<.001)				Model 2 (R^2=.17, F(4,363)=18.84, p<.001)			
Predictors	b [95%CI]	*SE*	*t(365)*	*p*	b [95%CI]	*SE*	*t(363)*	*p*
Constant	24.50[23.69, 25.31]	.41	59.68	<.001	16.91[14.19,19.64]	1.38	12.21	<.001
Yoga Experience	6.79[3.96, 9.62]	1.44	4.71	<.001	6.07[3.33, 8.81]	1.39	4.36	<.001
Hours/Week of Yoga	.16[.07, .25]	.046	3.44	<.001	.13[.036, .214]	.045	2.77	.006
MHI-5	-	-	-	-	.10[.06, .13]	.017	5.66	<.001
GSLTPAQ	-	-	-	-	.003[-.012, .017]	.007	.35	.73
	Attentional Shifting							
	Model 1 (R^2=.01, F(2,365)=2.40, p=.09)				Model 2 (R^2=.07, F(4,363)=6.76, p<.001)			
Predictors	b [95%CI]	*SE*	*t(365)*	*p*	b [95%CI]	*SE*	*t(363)*	*p*
Constant	27.11[26.28, 27.95]	.43	63.58	<.001	20.70[17.83,23.57]	1.46	14.19	<.001
Years of Yoga Experience	2.50[-.44, 5.45]	1.50	1.67	.10	1.77[-1.12, 4.65]	1.47	1.20	.23
Hours/Week of Yoga	.056[-.039, .151]	.048	1.17	.24	.025[-.068,.118]	.047	.53	.60
MHI-5	-	-	-	-	.079[.043, .116]	.018	4.32	<.001
GSLTPAQ	-	-	-	-	.011[-.004,.027]	.008	1.47	.14

Note. MHI-5 = Mental Health Index-5. GSLTPAQ = Godin Shepard Leisure Time Physical Activity Questionnaire.

Emotional Go/No-Go Task

Table 3 shows mean commission errors, omission errors, and RTs in the task, as well as group comparisons for order effects. Independent-samples t-tests showed no statistically significant differences for commission errors nor RTs between participants in HSSH and SHHS subsamples (all p > .05). There were group differences for omission errors in all blocks, sad blocks, and non-shift blocks, suggesting order effects for omission rates. Given that only commission errors and mean RTs are here investigated as indices of behavioral inhibition, the detected differences were not considered a major issue for the following data analyses.

Table 3

Mean Commission Errors, Omission Errors, and Reaction Times of the Verbal Emotional Go/No-Go Task

	Participants			Group Comparisons	
	All (N=143)	HSSH Order (N=77)	SHHS Order (N=66)	t(141)	p
Commission Errors:					
All Blocks	19.03(±10.72)	19.58(±11.57)	19.45(±9.96)	.07	.94
Happy-Target Blocks	9.24(±5.69)	9.77(±5.79)	9.23(±5.68)	.56	.57
Sad-Target Blocks	9.78(±5.79)	9.82(±6.30)	10.23(±5.34)	-.42	.68
Shift Blocks	9.70(±5.93)	10.27(±6.53)	9.70(±5.29)	.58	.57
Non-Shift Blocks	9.33(±5.48)	9.31(±5.58)	9.76(±5.57)	-.48	.56
Omission Errors:					
All Blocks	4.92(±4.66)	4.26(±4.63)	5.83(±4.63)	-2.03	.05
Happy-Target Blocks	2.27(±2.76)	2.12(±3.04)	2.50(±2.48)	-.81	.41
Sad-Target Blocks	2.65(±2.77)	2.14(±2.41)	3.33(±3.10)	-2.58	.01
Shift Blocks	2.52(±3.08)	2.32(±3.33)	2.83(±2.84)	-.97	.33
Non-Shift Blocks	2.41(±2.45)	1.93(±2.07)	3.00(±2.75)	-2.63	.01
Go Reaction Times (ms):					
All Blocks	.515(±.088)	.506(±.058)	.521(±.061)	-1.55	.12
Happy-Target Blocks	.508(±.086)	.498(±.059)	.514(±.057)	-1.64	.10
Sad-Target Blocks	.522(±.089)	.513(±.060)	.528(±.068)	-1.40	.16
Shift Blocks	.514(±.088)	.507(±.061)	.519(±.063)	-1.16	.25
Non-Shift Blocks	.516(±.088)	.505(±.057)	.524(±.061)	-1.91	.06

Note. HSSH Order = go/no-go task in a happy-sad-sad-happy order. SHHS Order = go/no-go task in sad-happy-happy-sad order. Means and standard deviations are shown as M(±SD). Group comparisons are independent-samples t-tests between HSSH and SHHS subsamples.

General Behavioral Inhibition

A hierarchical linear regression model, R^2=.04, F(2,140)=2.95, p=.06, specified that yoga experience predicted less general commission errors, b=-16.63[-31.31, -1.95], SE=7.42, t(140)=-2.24, p=.03, while weekly hours of yoga practice did not, p=.19. For shift blocks the same pattern was found, R^2=.05, F(2,140)=4.00, p=.02, so that yoga experience significantly predicted less commission errors, b=-11.03[-19.04, -3.03], SE=4.05, t(140)=-2.72, p=.007, while current hours of practice did not, p=.23.

Emotional Modulation of Behavioral Inhibition

Commission Errors in Happy *vs.* Sad Blocks. Using MEMORE, a moderation analysis for repeated measures was performed entering yoga experience and weekly hours of practice as between-subjects moderators of valence differences in commission errors. Valence differences were calculated as commission errors in happy minus sad blocks. The analysis indicated a non-significant model, R=.12, R^2=.02, F(2,140)=1.07, p=.35, so that neither yoga experience, p=.16, nor current hours of practice, p=.52, were significant predictors.

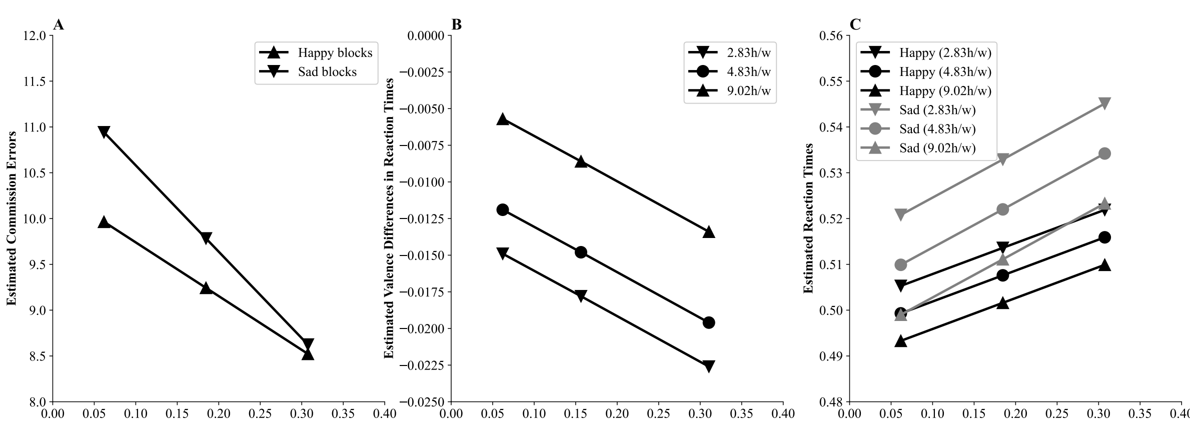
Inspecting each valence separately, the model for commission errors in sad blocks was statistically significant, R=.23, R^2=.05, F(2,140)=3.87, p=.02, so that yoga experience was a significant predictor, b=-10.33 [-18.22, -2.43], SE=3.99, t(140)=-2.58, p=.01, and current weekly hours of practice was not, p=.15. Meanwhile, the model for happy blocks was not significant, R=.15, R^2=.02, F(2,140)=1.53, p=.22. Figure 2A shows conditional effects of yoga experience on happy and sad blocks separately while evaluating current hours of practice at its mean value (5.68h/week).

Mean RTs in Happy *vs.* Sad Blocks. Another MEMORE model indicated a statistically significant effect when entering yoga experience and hours of practice as moderators of valence differences in mean RTs, R=.21, R^2=.04, F(2,140)=3.07, p=.05, so that yoga experience was not a significant predictor, p=.08, but current hours of practice was so, b=.0014[.0000, .0027], SE=.0007, t(140)=2.02, p=.04. Figure 2B shows valence differences in mean RTs by years of yoga experience, at different points of current weekly hours of practice (mean ± one standard deviation: 2.33, 5.68, and 9.02h/week).

Looking at each valence separately, the model for RTs in sad blocks was statistically significant, R=.26, R^2=.07, F(2, 140)=4.93, p=.009. Both years of experience, b=.1128[.0271, .1985], SE=.0433, t(140)=2.60, p=.01, and weekly hours of yoga practice, b=-.0034[-.0066, -.0003], SE=.0016, t(140)=-2.16, p=.03, were significant predictors. Meanwhile, the model for happy blocks was not statistically significant, R=.19, R^2=.04, F(2,140)=2.54, p=.08, but yoga experience was a significant predictor, b=.0801[.0002, .1601], SE=.0404, t(140)=1.98, p=.05, while hours of practice was not, p=.17. Figure 2C shows the effects of yoga experience and hours of practice on happy and sad RTs separately.

Figure 2

Conditional Effects of Valence on Commission Errors and Reaction Times of the Emotional Go/No-Go Task Moderated by Yoga Experience and Current Weekly Hours of Yoga Practice



Note. H/w = hours per week. Valence differences were calculated as happy- minus sad-target blocks (A, C). Weekly hours of yoga practice were evaluated at its mean (A, B), or mean ± one standard deviation (C, D). (A) Markers indicate deciles of yoga experience.

Discussion

In this study, the only explicit emotion regulation strategy associated with years of yoga experience and weekly hours of practice was attentional focusing. Higher self-reported attentional focusing was found as yoga experience and current hours of practice increased, even when controlling for general mental health, and physical activity other than postural yoga. Cognitive reappraisal, expressive suppression, and attentional shifting were not predicted by levels of experience or current yoga practice. This contraposes previous findings for cognitive reappraisal (Kobylinska et al., 2018; Sahni et al., 2021), and at least one past study has also done so (Cunningham, 2020), while previous findings for expressive suppression were also mostly null (Cunningham, 2020; Kobylinska et al., 2018; Sahni et al., 2021), except in a sample of women with post-traumatic stress disorder symptoms (Dick et al., 2014).

Given that yoga instructions often discourage mental elaborations during formal practice in favor of sustained attention on present moment experience, the development of attentional focusing (and not reappraisal, expressive, and attentional shifting skills) makes sense. These results are based on self-report measures in a cross-sectional design, however, so their limitations must be acknowledged. But they point to fruitful future directions in the yoga-emotion regulation intersection, suggesting a particular association between yoga and explicit emotion regulation via attentional training (Browning et al., 2010; Ochsner & Gross, 2005; Wadlinger & Isaacowitz, 2011).

The emotional go/no-go task indicated that long-term yoga experience predicted better overall behavioral inhibition, as indexed by fewer commission errors in all blocks and in shift blocks. Considering the emotional modulation of behavioral inhibition, yoga experience was associated with less commission errors in sad blocks only (Fig. 2A). This could have happened because sad blocks are more challenging: they require responses which go against our natural approach/avoidance tendencies, and are possibly better able to discriminate emotion regulation capacities.

Furthermore, current hours of yoga practice predicted valence differences in RTs. Those who practiced more hours per week tended to show valence differences significantly closer to zero than those who practiced fewer hours (Fig. 2B). This indicates that current practice was associated with less emotional bias in the task. Looking at each valence separately, yoga experience predicted slower RTs for both happy and sad stimuli, while current practice predicted faster RTs specifically for sad stimuli (Fig. 2C).

Why would yoga experience and current practice show differential effects? One possible explanation is based on speed-accuracy tradeoffs (Mueller et al., 2020). More-experienced practitioners could be tuned to prioritize being accurate over fast, while current practice could be optimizing speed performance. Speed-accuracy tradeoffs are often conceived as thresholds of evidence accumulation—the more evidence is accumulated before responding, the slower one's responses will be. Speed/accuracy response thresholds have been linked to brain connectivity patterns, especially in cortico-basal ganglia circuits (Bogacz et al., 2010). The striatum seems to play an important role in facilitating faster responses, by disinhibiting motor networks (Forstmann et al., 2010), and decreased cortico-striatal activity has been previously described in long-term yoga practitioners (Kjaer et al., 2002; van Aalst, Ceccarini, Schramm, et al., 2020).

Villemure et al. (2015) also reported differential findings for yoga experience and current hours of practice. Years of yoga experience correlated with greater grey matter volume mainly in the insula, frontal operculum, and orbitofrontal cortex of the left hemisphere—the authors interpreted these findings as a progressive tuning towards parasympathetically-driven states. Meanwhile, weekly hours of practice correlated with greater volume in the right primary somatosensory cortex/superior parietal lobule, midline precuneus/posterior cingulate cortex, left hippocampus, and right primary visual cortex—the authors emphasized their role in somatic awareness and stress regulation functions. These structural and functional differences might influence behavioral outcomes and can provide insights for future studies.

In summary, long-term and current yoga practice were specifically linked to attentional focusing, and not to other explicit emotion regulation strategies, i.e., cognitive reappraisal, expressive suppression, and attentional shifting. In this regard, there are mixed findings in the literature which might be accommodated if cultural, sample-specific, or design-specific lenses are applied. Here, it is understood that attentional focusing seems to be more associated with yoga practice, and causal explanations of the yoga-explicit emotion regulation intersection could further explore it.

In a verbal emotional go/no-go task, yoga experience predicted greater general behavioral inhibition, as indexed by commission errors in all blocks and in shift blocks. Yoga experience and current weekly hours of practice also predicted decreased emotional effects in the task—while yoga experience was linked to less commission errors in sad blocks, current yoga practice was linked to decreased valence differences in mean RTs. Thus, long-term and current yoga practice were associated with more balanced behavioral responses towards affective stimuli, indicating enhanced implicit emotion regulation. Specific processes involved in long-term and current yoga practice still need to be detailed, since they seem to affect neural, physiological, and behavioral functions differentially (Villemure et al., 2015; Mocanu et al., 2018). Behavioral studies on the effects of yoga are still scarce, and ideally these findings will be further tested and developed as the field unfolds.

Study 2

Disentangling Top-down and Bottom-up Emotion Regulation in Long-term Yoga Practitioners: A Pilot Study of Heart Rate Variability and Emotional Attention Tasks

Emotion regulation goals can be activated and pursued at various degrees of conscious engagement, giving rise to its explicit and implicit dimensions (Braunstein et al., 2017). Attentional processes are involved in both explicit and implicit emotion regulation (Wadlinger & Isaacowitz, 2011). As an explicit strategy, selective attention can consciously move cognitive resources towards, or away from, aspects of an emotional event (Ochsner & Gross, 2005). Attentional control has been linked to greater task persistence under stress (Johnson, 2009), fewer difficulties in emotion regulation (O'Bryan et al., 2017), decreased use of dysfunctional emotion regulation strategies (Tortella-Feliu et al., 2014), and enhanced downregulation of negative emotions (Dolcos et al., 2020; Morillas-Romero et al., 2015).

In an implicit level, attentional biases act as filters for initial and subsequent emotional processing (Todd et al., 2012). The presence and direction of such attentional biases vary depending on several factors, such as developmental stage (Kauschke et al., 2019), experimental paradigms (Kauschke et al., 2019; Yiend, 2010; McNally, 2019), and psychopathological conditions (Bar-Haim et al., 2007; Browning et al., 2010). For example, a tendency to attend to positive vs. neutral stimuli has been described in non-clinical populations (Pool et al., 2016; Kauschke et al., 2019), and positivity biases have been associated with trait stress resilience (Thoern et al., 2016). Meanwhile, attentional bias for threatening vs. neutral stimuli is often found in anxious, but not in nonanxious populations (Bar-Haim et al., 2007).

Both controlled and biased attention are modifiable, and can help to create new emotion regulation patterns (Derryberry & Reed, 2002; Browning et al., 2010; Wadlinger & Isaacowitz, 2011). A central component of yoga-based practices is attentional training—across yoga components (i.e., postural practice, breathing exercises, and meditation), practitioners often train to place and sustain attention on internal (e.g., interoceptive, proprioceptive signals) or external information (e.g., sounds or visual focal points). There is considerable empirical support for yoga's benefits to non-emotional attention (Chobe et al., 2020; Gothe & McAuley, 2015; Schmalzl et al., 2018; Singh & Mutreja, 2020), and initial evidence for yoga's impacts on emotional attention, such as less susceptibility to emotion interference (Froeliger et al., 2012; Menezes, Dalpiaz, Rossi et al., 2015; Mocanu et al., 2018), and greater emotion discrimination (Herbert, 2021).

Yoga's general focus on cultivating equanimity informs about the possible direction of emotional attention training—equanimity is characterized by even-mindedness across different kinds of experience, regardless of valence (Desbordes et al., 2015). From this perspective, yoga-based practices could act to decrease both positivity and negativity biases and preferences (Davis & Thompson, 2015). From another point of view, yoga practice often focuses on well-being, self-care, and positive embodiment, so that it could actually facilitate positivity biases and still benefit emotion regulation (Cox & Tylka, 2020; Ivtzan & Papantoniou, 2014). Thus, the expected direction of yoga's impacts on emotional attention remains unclear, and it might change depending on practice motivation.

Yoga and Cardiac Vagal Tone

Effective emotion regulation depends on the coordinated recruitment of systems in the organism, to adaptively respond to environmental situations. The neurovisceral integration model describes how hierarchical levels of organization, which underlie affective regulation, are coordinated by vagal functions. These levels go from low-level intra-cardiac ganglia, cardiovascular reflex arcs, and brainstem nuclei, to mid-level hypothalamus, amygdala, and basal forebrain structures, to high-level insular, somatosensory, and prefrontal cortices (Thayer & Lane, 2000; Smith et al., 2017).

Vagal control can be measured by vagally-mediated heart rate variability (HRV), which indicates the degree of parasympathetic modulation of cardiac responses based on changes between inter-beat intervals (Thomas et al., 2019). A growing body of evidence has placed HRV as a potential biomarker of emotion regulation (Appelhans & Luecken, 2006; Balzarotti et al., 2017; Mather & Thayer, 2018; Mulcahy et al., 2019), and top-down self-regulation (Holzman & Bridgett, 2017). Resting, reactivity, and recovery vagal functions provide unique information on self-regulation patterns. While greater resting and recovery vagal control signal a more adaptive emotional functioning, both higher and lower vagal reactivity can facilitate one's ability to meet situational demands (Laborde et al., 2018).

There are inconclusive findings for yoga's effects on vagal tone. On the one hand, yoga's multiple components seem to recruit and modify several of the hierarchical levels implicated in vagal control, especially in the long run (Gard et al., 2014; Schamlzl et al., 2020; Sullivan et al., 2018; van Aalst, Ceccarini, Demyttenaere, et al., 2020). For example, long-term yoga experience has been associated with greater gray matter volume in several regions of the left hemisphere (i.e., insula, frontal operculum, and orbitofrontal cortex), what the authors interpreted as an enhanced parasympathetic tuning (Villemure et al., 2015). Increases in GABA levels, which are promoted by the parasympathetic system, have also been found after yoga practice (Streeter et al., 2007; Streeter et al., 2010; Streeter et al., 2012). Furthermore, several studies that directly measured HRV report positive effects of yoga-based practices (Pascoe et al., 2017; Sharpe et al., 2021; Tyagi & Cohen, 2016; Zou et al., 2018).

On the other hand, the field needs to overcome several methodological issues, such as small sample sizes, short intervention periods, lack of experimental control, and insufficient statistical reports, which impair clear conclusions (Pascoe et al., 2017; Posadzki et al., 2015; Tyagi & Cohen, 2016; Zou et al., 2018). Besides, HRV indices are often misinterpreted—not only in yoga-related studies, but also in the wider literature (e.g., taking low-frequency HRV to be a sympathetic marker, or using low-/high-frequency ratios as indices of sympathovagal balance: see Laborde et al., 2017, and Thomas et al., 2019).

Considering the intricate link between autonomic, cognitive, and emotional functioning (Critchley et al., 2013; Pinna & Edwards, 2020), the combined use of affective behavioral paradigms and HRV measures might help to qualify whether and how yoga influences emotion regulatory processes. For instance, cardiac vagal tone seems to modulate attentional patterns toward affective stimuli, such as the attentional engagement to, and disengagement away from, emotional faces (Cocia et al., 2012; Forte et al., 2021; Koster, 2006; Park et al., 2012; Park et al., 2013; Park & Thayer, 2014). Thus, this pilot cross-sectional study used HRV and emotional spatial cueing tasks to evaluate vagal function and emotional attention in long-term yoga practitioners.

Emotional Spatial Cueing Task

The emotional spatial cueing task (ESCT) is derived from Posner's spatial cueing paradigm (Posner, 1980; Posner, 2014). It is a single cueing paradigm (Yiend, 2010), where a target appears on either left or right side of the screen, preceded by an emotional cue which can validly or invalidly indicate the target's location. Several cue parameters can be adjusted in the ESCT. Next, four cue parameters which are relevant for this study are discussed: validity, timing, emotion, and spatial frequency.

Validity

The cue can indicate the target's location correctly, constituting a valid trial, or incorrectly, in an invalid trial. Under high cue predictiveness (> 75%), valid trials facilitate responses towards the cue's side, speeding up reaction times (RTs), while invalid trials require the inhibition of such a facilitated response, slowing down RTs (Bartolomeo et al., 2001; Coull et al., 2000; Posner & Petersen, 1990).

Timing

Stimulus onset asynchrony (SOA), the period of time that separates cue and target onset, can be manipulated to elicit exogenous or endogenous attentional orienting. Orienting is the allocation of attention to a particular location, so that processing of events there are amplified—this can happen in a goal-directed, internal, endogenous manner or in a stimulus-driven, external, exogenous manner (Chica et al., 2013; Corbetta & Shulman, 2002; Posner, 2014). Under high cue predictiveness, short SOAs (100-150ms) elicit bottom-up, stimulus-driven responses, so they are used to manipulate exogenous orienting. Meanwhile, long SOAs (>300ms) enable top-down, goal-directed responses, which are related to endogenous orienting (Bartolomeo et al., 2001; Berger et al., 2005; Müller & Findlay, 1988).

Emotion

Emotional stimuli amplify neural responses of sensory processing, through either exogenous or endogenous orienting (Brosch et al., 2011; Pourtois et al., 2013). Stimuli that signal danger or threat, compared to neutral, tend to increase processing efficiency and gain control over attentional mechanisms. Fearful faces were used in this study, given their evolutionary significance, and adequacy to investigate bottom-up and top-down emotion regulation processes (Kauschke et al., 2019; Pourtois et al., 2013; Whalen et al., 2013).

Attentional engagement towards fearful faces can be quantified by comparing fearful vs. neutral valid trials, while attentional disengagement from fearful faces can be measured by comparing fearful vs. neutral invalid trials. Faster engagement towards fearful faces can indicate hypervigilance to threatening information, while delayed disengagement away from fearful faces can indicate impaired inhibition of attention from them (Koster et al., 2004; Koster et al., 2006; Park et al., 2013).

Spatial Frequency

Emotional stimuli of high vs. low spatial frequencies are processed through different pathways. High-spatial-frequency faces seem to be processed via parvocellular channels mainly in cortical regions, such as the fusiform, and medial prefrontal cortices. Meanwhile, low-spatial-frequency faces seem to engage subcortical regions, especially the amygdala, via magnocellular channels (Johnson, 2005; Méndez-Bértolo et al., 2016; Vuilleumier et al., 2003). Thus, presenting broad, high-, and low-spatial frequency faces can help to further isolate top-down and bottom-up effects in emotional attention (Azevedo et al., 2018; Park & Thayer, 2014).

Top-down and bottom-up modes of emotional attention

Combined, the above-mentioned parameters allow the spatial cueing task to detail top-down and bottom-up emotional attention (as previously done by Park et al., 2013). Bottom-up emotional attention should be mainly found when measuring attentional engagement to low-spatial-frequency fearful faces under exogenous attention, given that these parameters are related to stimulus-driven subcortical pathways. In turn, top-down emotional attention should be primarily found in attentional disengagement from high-spatial-frequency fearful faces under endogenous attention, given that these parameters are associated with goal-directed cortical mechanisms (Park & Thayer, 2014).

Present Study

The emotional spatial cueing task can help to disentangle top-down and bottom-up impacts of yoga-based practices on emotional attention. Besides, vagal functions might be causally implicated in such bottom-up/top-down modifications (Mather & Thayer, 2018), so their joint investigation can further elucidate how long-term practice affects explicit and implicit emotion regulation. These are new measurement strategies in yoga-related studies, so a pilot cross-sectional study is here presented, to assess their feasibility and potential relevance to the field.

This study tested whether long-term yoga experience and weekly hours of practice (1) were associated with changes in vagal control during rest, reactivity, spontaneous recovery, and guided breathing recovery, in long-term yoga practitioners. It was hypothesized that greater yoga experience and practice would be linked to increased vagal control across situations. This study also investigated whether yoga experience and practice (2) were related to bottom-up emotional attention (in an exogenous ESCT: ESCT-exo), and top-down emotional attention (in an endogenous ESCT: ESCT-endo). It was hypothesized that greater experience and practice would delay attentional engagement to low-spatial frequency fearful faces under exogenous orienting, and accelerate attentional disengagement away from high-spatial frequency fearful faces under endogenous orienting. General mental health and physical activity performance were measured to better describe the sample and provide comparability with participants from Study 1. This study was approved by the local ethics committee, and received financial support from the Brazilian National Council for Scientific and Technological Development (CNPq).

Method

Participants

Yoga studios, meditation centers, and yoga-related social media groups were contacted for recruitment. Regular practitioners with at least 6 months of experience were invited to visit the lab for 1h, to participate in a study of the cognitive and emotional effects of yoga and meditation. They were aware that participation was voluntary, unpaid, and anonymous. Those who were willing to participate scheduled their data collection. Exclusion criteria were any cardiovascular, respiratory, motor, or mental health clinical conditions.

Twenty-seven yoga and meditation practitioners participated. Participants with diverse practice profiles were welcomed (i.e., mostly postural, mixed, and mostly meditative). Five were excluded due to self-reported clinical conditions, and two due to technical difficulties. The final sample had 20 participants (gender: 60% female, 35% male, 5% non-binary), who were 46.60 years old ± 12.37, on average (range: 28-75). They practiced for 16.40 ± 13.02 years (range: .83-48), and those who were yoga/meditation teachers (70%) had been teaching for 8.36 ± 5.68 years (range: 1-18).

MHI-5 scores were similar to those found in another Brazilian sample and in a British normative study, indicating good mental health levels (Damásio et al., 2014; Kelly et al., 2008). GSLTPAQ scores indicated that this sample was physically active, on average, according to specified cutpoints (insufficiently active: < 14; moderately active: 14-23; active: >= 24 (Godin, 2011)). A few participants, however, were insufficiently active (n=2). Table 4 presents detailed sample characteristics.

Table 4

Participants' Sociodemographic and Yoga Practice Data

N	20	Yoga Experience (years)	16.40±13.02 (range: 0.83-48)
Age (years)	46.60±12.37 (range: 28-75)	Yoga Experience (y/age)	0.34±0.21 (range: 0.02-0.73)
Gender:		Yoga/Meditation Teaching:	
Feminine	60%	Yes	70%
Masculine	35%	No	30%
Non-binary	5%	Teaching Experience (years)	8.36±5.68 (range:1-18)
Education Level (highest attained):		Confounding Variables:	
		Regular smoking	5%
		Substance use (medication)	15%
Upper secondary	15%	Substance use (caffeine)	25%
Bachelor's	35%	Poor sleep	5%
Postgraduate	50%	Intense exercise	0%
Practice Hours (h/week):			
Physical postures	2.54±2.91 (range: 0-12)	MHI-5	76.75±8.77(range:60-90)
Breathing exercises	0.31±0.37 (range: 0-1.2)	GSLTPAQ	39.75±20.4(range:11-105)
Seated meditation	4.56±5.39 (range: 0.2-20.5)		
Total	7.39±5.60 (range: 1.2-21.8)		

Note. *Means and standard deviations are presented as M±SD. h/week = hours per week; y/age = years of yoga experience divided by age; MHI-5 = Five-item Mental Health Index; GSLTPAQ = Godin-Shepard Leisure Time Physical Activity Questionnaire.*

Measures

Sociodemographic and Eligibility Questionnaire

Participants reported their sociodemographic data (gender, age, and education level), and provided information on variables that might influence cardiovascular measurements: smoking habits; substance use on that day (caffeine, alcohol, stimulants, psychotropic medications); food intake in the past 2h; sleep quality on the previous night; and intense physical exercise in the past 12h. They also indicated any diagnosed cardiovascular, respiratory, motor, or mental health conditions (Appendix C).

Yoga and Meditation Practice Questionnaire

An 18-item questionnaire was developed to assess yoga and meditation practice, with open-ended and Likert-scale items (Appendix C). Practitioners reported their approximate initial date of regular practice, currently practiced school/style/tradition, changes in practice style over time, and experience as yoga or meditation teachers. They also reported their routine of practice during the last year: how many times per week and for how long they practiced physical postures (*asana*), breathing exercises (*pranayama*), focused-attention meditation, open-monitoring meditation, lying-down meditation/relaxation, and walking meditation, on average.

Mental Health Index-5 (MHI)

The 5-item MHI briefly evaluates symptoms of anxiety (e.g., feeling nervous), depression (e.g., feeling blue and downhearted), and positive affect (e.g., feeling calm) in the past month (McHorney & Ware, 1995; Brazilian version: Damásio et al., 2014). Final scores range from 0 to 100, and a normative study in a British sample indicated cutpoints of 76, 68, or 60 for adequate mental health levels using different calculation methods (Kelly et al., 2008).

Godin-Shepard Leisure Time Physical Activity Questionnaire (GSLTPAQ)

This 3-item measure assesses frequency and intensity of physical activity during a regular week in the past 3 months (Godin, 2011; Brazilian version: São-João et al, 2013). Final scores range from 0 to 119. The questionnaire's author, based on medical guidelines, categorized respondents as insufficiently active: < 14; moderately active: 14-23; or active: >= 24 (Godin, 2011).

Heart Rate Variability

A Polar H10 heart rate sensor and the Elite HRV mobile app were used to monitor inter-beat intervals. Previous studies in lab settings provided evidence of validity for both tools, compared to electrocardiograms (Polar H10: Schaffarczyk et al., 2022; Gilgen-Ammann et al., 2019; and Elite HRV app: Stone et al., 2021; Moya-Ramon et al., 2022). HRV was assessed in four different tasks, which are described below. All of them were built and run on PsychoPy, version 2021.2.3 (Peirce et al., 2019), which presents visual stimuli with good precision (Garaizar & Vadillo, 2014; Bridges et al., 2020).

Vanilla task (baseline). Participants should mentally count how many yellow rectangles appeared on the laptop screen (Jennings et al., 1992). For 5 minutes, one colorful rectangle appeared on the laptop screen every 10 seconds, and 5 of them were yellow. This simple and standardized procedure requires some sustained attention under low cognitive load, and it was chosen to avoid possible confounders in passive rest, such as measurement anxiety, mind wandering, or spontaneous meditation (Quintana & Heathers, 2014).

Cognitive stress. A 5-min HRV recording was extracted during the ESCT-exo, as a condition of mild cognitive stress. The ESCT-exo was chosen given its faster rhythm and, thus, greater potential to create vagal reactivity.

Vanilla task (recovery). A 4-minute vanilla task was repeated after both ESCTs, to assess HRV during spontaneous recovery. This slightly shorter period of time is sufficient for accurate RMSSD recordings (Camm et al., 1996; Munoz et al., 2015), and helped to make data collection more viable.

Guided Breathing. HRV was recorded as participants inhaled for 6s, and exhaled for 6s, during 4 minutes. Instructions ("inhale" or "exhale") and counts (in seconds) appeared on the screen during the whole time. Before starting, participants were told that they could go to their natural breath if any discomfort was experienced.

Emotional Spatial Cueing Tasks (ESCTs)

The ESCTs were created based on previous studies (Bartolomeo et al., 2001; Koster et al., 2006; Park et al., 2013). Neutral and fearful facial stimuli were the same used by Park et al. (2013)—see Fig. 3A. Both tasks were also built and presented on PsychoPy, version 2021.2.3.

Short (150 ms) and long SOAs (900 ms) were used to differentiate the Exogenous ESCT (ESCT-Exo) and the Endogenous ESCT (ESCT-Endo), which are detailed below.

Procedures

One day before data collection, participants were asked to abstain from caffeine, alcohol, or any other stimulants; to have a light meal 2h before the scheduled time; to avoid intense physical exercise; and to wear loose, comfortable clothes for the data collection morning. They were offered a chance to go to the bathroom just before data collection. In a laboratory setting, the researcher explained the study's purposes, ethical guidelines, and asked for written consent.

Participants were asked to wear the chest strap, and complete all self-report measures in paper-and-pencil format (~15 min). Then, they sat comfortably at approximately 60 cm from the laptop screen (macOS), and completed the vanilla baseline task (5 min), ESCT-exo (~8 min), ESCT-endo (~10 min), vanilla recovery task (4 min), and controlled breathing task (4 min) on PsychoPy, in this order. The experimenter remained in the same room answering questions, coordinating task transitions, and recording RR intervals at the specified occasions.

After data collection, participants were fully debriefed about the study's hypotheses and potential applications. They were also offered the opportunity to receive the aggregated results after the study's completion. COVID-19 prevention protocols were followed throughout the experiment (i.e., use of mask, social distancing, hygiene of hands, space and materials).

Exogenous Emotional Spatial Cueing Task (ESCT-exo)

The ESCT-exo had a 24-trial practice block, where facial stimuli of different spatial frequencies were presented. Then, the task contained 3 blocks of 88 trials: one block for each cue spatial frequency (i.e., broad, high, and low), which was randomly selected (see Fig. 3B). Each trial began with a fixation cross at the center of the screen, plus a left- and a right-side frame

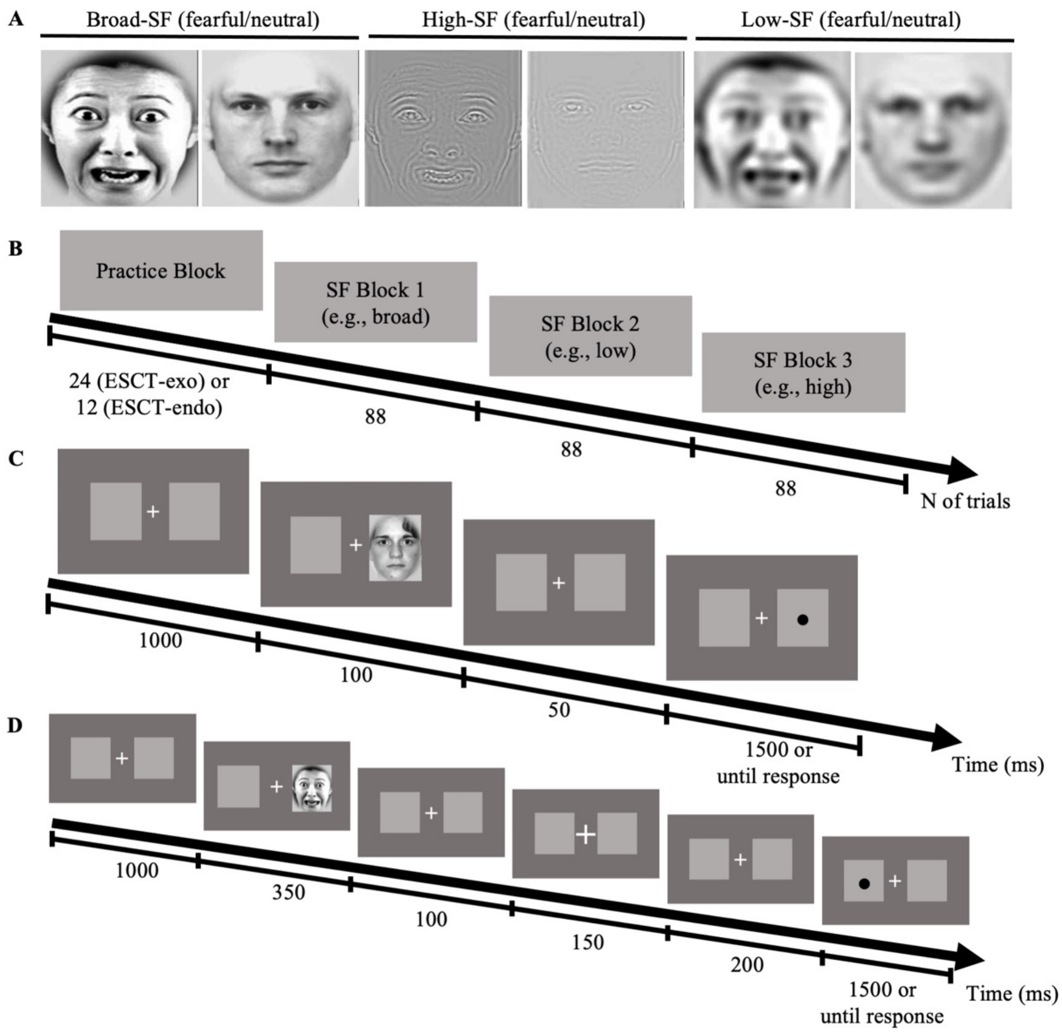
(1000ms). Then, the cue appeared on the left or the right (100ms), and could be valid (80%) or invalid (20%). The cue disappeared, and after 50ms the target appeared on the left or the right (for 1500ms or until response). Thus, the ESCT-exo had a 150-ms SOA (see Fig. 3C).

Endogenous Emotional Spatial Cueing Task (ESCT-endo)

The ESCT-endo had a shorter practice block (12 trials), given its similarity to the ESCT-exo. The structure of three blocks of 88 trials was maintained—the only difference between them was a longer SOA in the ESCT-endo. Again, each trial started with a fixation cross at the center, plus a left- and a right-side frame (1000ms). Then, the cue appeared on the left or the right (350ms), and could be valid (80%) or invalid (20%). The cue disappeared, and the fixation cross augmented then went back to normal (450ms), followed by the target on the left or the right (for 1500ms or until response). Thus, the ESCT-endo had a 900-ms SOA (Fig. 3D).

Figure 3

Illustration of Facial Stimuli, Blocks and Trials of the Emotional Spatial Cueing Tasks



Note. *SF=Spatial frequency; (A) Fearful and neutral faces of broad-, high-, and low-spatial frequencies; (B) Sequence of blocks, and number of trials in the ESCTs; (C) Schema of a broad, neutral, and valid trial in the ESCT of exogenous attention; (D) Schema of a broad, fearful, and invalid trial in the ESCT of endogenous attention.*

Data Analysis

Self-report Measures

Yoga experience was calculated as the years of regular yoga practice divided by age (i.e., the proportion of time that someone has practiced yoga in their lifetime). In this way, age-related confounds were disentangled from yoga experience measurement. Weekly hours of yoga practice were calculated as the sum of hours spent in postural, breathing, and meditative practices in a regular week for the past year. MHI-5 and GSLTPAQ scores were measured to better describe the sample and provide comparability between Study 1 and Study 2 samples, so they did not enter any statistical analysis.

HRV Pre-processing and Analysis

HRV data was pre-processed using the "hrv" open-source Python package (Bartels & Peçanha, 2020). Using package functions, each recording was trimmed in 5- or 4-min durations, depending on HRV condition. Then, artifact correction was applied in all recordings, using a threshold filter (each inter-beat interval was compared to its local median of 5 adjacent intervals: if the difference was greater than the medium-strength threshold of 250ms, the interval was automatically replaced with cubic spline interpolation). After that, RMSSDs of filtered inter-beat intervals (i.e., square root of the mean of the sum of squares of differences between adjacent inter-beat intervals) were calculated. Among HRV measures, RMSSDs were chosen because they index vagal modulation of cardiac activity, and are appropriate for short recordings (Camm et al., 1996). RMSSDs were then exported for data analysis in SPSS version 23.

For data analysis, HRV measurement conditions (i.e., vanilla baseline, cognitive task, vanilla recovery, and guided breathing) were first compared in a repeated-measures GLM. Then, each predictor was individually assessed, because of the small sample size and associated lack of statistical power (yoga experience and current hours of practice). Two mixed GLMs were performed, comparing HRV conditions (within-subjects) while entering a given predictor (between-subjects continuous variable).

Emotional Spatial Cueing Tasks

The same data analysis strategy was followed for both ESCTs. First, a 2 (emotion: fearful, neutral) x 3 (spatial frequency: broad, high, low) x 2 (validity: valid, invalid) repeated-measures GLM was performed, to look solely at task parameters. Then, each predictor (yoga experience and current hours of practice) was also individually evaluated. Two mixed GLMs were performed, one for each predictor, while entering the same within-subjects variables (emotion, spatial frequency, and validity).

Results

HRV

A repeated-measures GLM revealed significant within-subjects effects of measurement condition on RMSSDs, $F(3,51)=7.53$, $p < .001$, $\eta_p^2 = .31$. Contrasts revealed significant differences between baseline (M=33.62, SD=20.03) and recovery (M=29.58, SD=15.72), $F(1,17)=4.57$, $p=.047$, $\eta_p^2=.21$; between cognitive task (M=29.26, SD=15.97) and guided breathing (M=39.40, SD=18.43), $F(1,17)=16.51$, $p=.001$, $\eta_p^2=.49$; and between recovery and guided breathing, $F(1,17)=18.98$, $p < .001$, $\eta_p^2=.53$.

Yoga Experience and HRV

A mixed GLM compared RMSSD conditions while entering yoga experience as a continuous predictor. The first-order HRV effect disappeared, p=.42, and the HRV-yoga experience interaction was not significant, p=.78, holding yoga experience at its mean (.33). There were no between-subjects effects of yoga experience, p=.44.

Weekly Practice Hours and HRV

A mixed GLM compared RMSSDs considering weekly practice hours as a continuous predictor. While holding practice hours at its mean (6.68), there was a significant first-order HRV effect, $F(3,48)=3.56$, $p=.02$, $\eta_p^2=.18$. Contrasts showed a significant difference between recovery and guided breathing only, $F(1,16)=10.47$, $p < .005$, $\eta_p^2=.40$. The HRV * practice hours interaction was not statistically significant, $p=.11$.

ESCT-exo

Mean RTs in the ESCT-exo were evaluated in a 2 (emotion) x 3 (spatial frequency) x 2 (validity) repeated-measures GLM. There was a significant main effect of validity, $F(1,19)=134.55$, $p < .001$, $\eta_p^2=.88$, so that valid trials (M=.424, SD=.138) were faster than invalid ones (M=.498, SD=.131). There were no other significant main or interaction effects, all $p > .05$.

Yoga Experience and ESCT-exo

A mixed GLM was performed, adding yoga experience as a continuous predictor. When evaluating yoga experience at its mean, there were first-order effects of validity, $F(1,18)=39.88$, $p < .001$, $\eta_p^2=.69$, and spatial frequency, $F(2,36)=6.27$, $p=.005$, $\eta_p^2=.26$, due to faster RTs in low- (estimated mean=.455 [95% CI: .386, .523]) than high-spatial-frequency trials (estimated mean=.465 [95% CI: .402, .528]), $F(1)=8.37$, $p=.01$, $\eta_p^2=.32$, but broad- did not differ from high- or low-spatial-frequency trials, $p > .05$. There were a few significant second-order interactions (spatial frequency * yoga experience, emotion * spatial frequency, and emotion * validity), which are not central to this study's purposes.

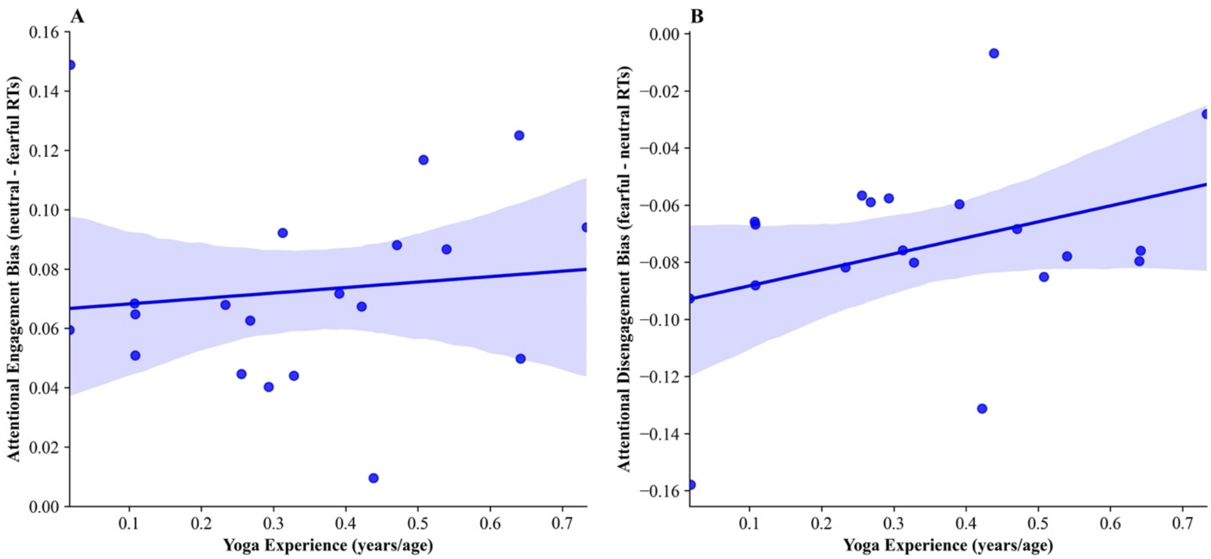
In turn, there was a significant third-order effect of emotion * validity * yoga experience, $F(1,18)=5.29$, $p=.03$, $\eta_p^2=.23$. To decompose the three-way interaction, attentional engagement

(Mean $RT_{neutral\ valid}$ – Mean $RT_{fearful\ valid}$), and attentional disengagement scores (Mean $RT_{fearful\ invalid}$ – Mean $RT_{neutral\ invalid}$) were computed, following previous studies (Koster et al., 2004; Koster et al., 2006; Park et al., 2013). Since spatial frequency was not included in the interaction, attentional engagement and disengagement scores were computed combining RTs from all spatial frequencies. Here, positive attentional engagement scores indicate a faster attentional engagement by fearful cues, while positive attentional disengagement scores indicate a delayed attentional disengagement away from fearful cues.

A linear regression model showed that yoga experience was not significantly associated with attentional engagement scores, p=.62. Another model for attentional disengagement scores indicated a non-significant trend, with a moderate effect size, R^2=.14, F=2.91, b=.056 [95%CI: -.013, .125], SE=.033, t(18)=-1.71, p=.10. Figure 4 shows attentional engagement (3A) and disengagement scores (3B) by yoga experience—as yoga experience increased, attentional engagement scores were more stable, while attentional disengagement scores were less extreme. These results should be taken with caution, as suggestive but inconclusive, considering its non-significant statistical results.

Figure 4

Attentional Engagement and Disengagement Scores by Yoga Experience in the Exogenous Spatial Cueing Task



Note. years/age = years of yoga experience divided by age.

Weekly Practice Hours and ESCT-exo

A mixed GLM was performed, taking yoga practice hours as a continuous predictor. The first-order validity effect was maintained, $F(1,18)=81.11$, $p < .001$, $\eta_p^2=.82$, and there was a marginally significant validity/practice hours interaction, $F(1,18)=3.95$, $p=.06$, $\eta_p^2=.18$, so that RT differences between valid and invalid trials seemed to decrease as hours of practice increased. No other effects were present, all $p > .05$.

ESCT-endo

Mean RTs in the ESCT-endo were evaluated in a 2 (emotion) x 3 (spatial frequency) x 2 (validity) repeated-measures GLM. There were significant main effects of validity, $F(1,18)=17.45$, $p=.001$, $\eta_p^2=.49$, due to faster valid ($M=.409$, $SD=.072$) than invalid trials ($M=.434$, $SD=.081$), and spatial frequency, $F(2,36)=3.41$, $p=.044$, $\eta_p^2=.16$, due to faster RTs in low- (M=.408, SD=.078), and broad- (M=.409, SD=.072), than in high-spatial-frequency trials (M=.424, SD=.074). There were no other significant effects, all $p > .05$.

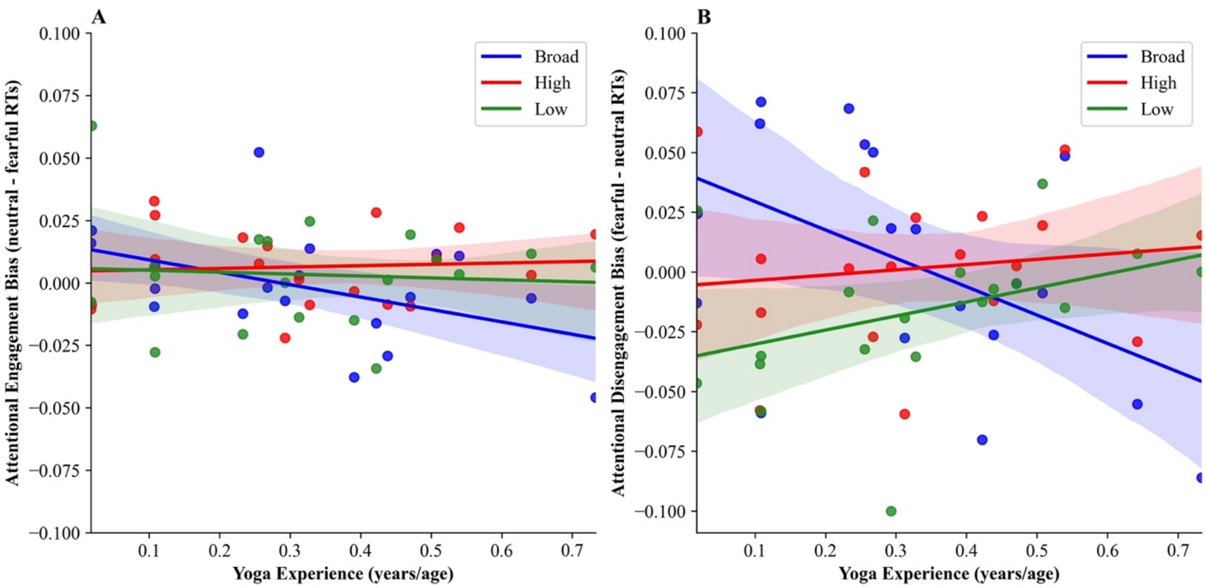
Yoga Experience and ESCT-endo

When entering yoga experience as a continuous predictor, the first order effects disappeared, $p > .05$. There was a significant second-order effect of emotion * spatial frequency, and a third-order effect of emotion * spatial frequency * validity, which can be placed under a fourth-order emotion * spatial frequency * validity * yoga experience interaction, $F(2,34)=6.50$, $p=.004$, $\eta_p^{2}=.28$. To decompose the four-way interaction, attentional engagement (Mean $RT_{neutral\ valid}$ – Mean $RT_{fearful\ valid}$), and disengagement scores (Mean $RT_{fearful\ invalid}$ – Mean $RT_{neutral\ invalid}$) were computed for each spatial frequency (Park et al., 2013).

A mixed GLM of attentional engagement scores was performed, entering spatial frequency as a within-subjects variable and yoga experience as a predictor. There were no main or interaction effects, all $p > .05$. Another mixed GLM evaluated attentional disengagement scores, which showed a significant spatial frequency effect, $F(2,34)=6.33$, $p=.005$, $\eta_p^{2}=.27$, and a significant spatial frequency * yoga experience interaction, $F(2,34)=5.31$, $p=.01$, $\eta_p^{2}=.24$. Contrasts pointed that yoga experience interacted with RTs in broad- vs. high-, $F(1,17)=5.45$, $p=.032$, $\eta_p^{2}=.24$, and broad- vs. low-, $F(1,17)= 7.91$, $p=.01$, $\eta_p^{2}=.32$, but not in high- vs. low-spatial-frequency trials, $p=.14$. Parameter estimates point that, as yoga experience increased, broad cues elicited lower attentional disengagement bias, indicating faster disengagement away from fearful cues, $b=.-119$ [95% CI: -.226, -.011], $SE=.051$, $t(17)=-2.33$, $p=.03$, $\eta_p^{2}=.24$, while there were non-significant results for high- and low-spatial-frequency trials (see Fig. 5).

Figure 5

Attentional Engagement and Disengagement by Yoga Experience for Broad-, High-, and Low-Spatial-Frequency Stimuli in the Endogenous Emotional Spatial Cueing Task



Note. years/age = years of yoga experience divided by age.

Weekly Practice Hours and ESCT-endo

When entering weekly yoga practice hours as a continuous predictor in another mixed GLM, there was a significant validity effect, $F(1,17)=6.11$, $p=.02$, $\eta_p^2=.26$, but no other significant main or interaction effects, all $p>.05$.

Discussion

This pilot study investigated whether yoga experience and practice were related to HRV, bottom-up, and top-down emotional attention, as indices of emotion regulation. In general, HRV conditions (i.e., resting, reactivity, spontaneous recovery, and guided breathing recovery) modified vagal responses as expected, in yoga practitioners. However, there were no significant differences between baseline and cognitive-task RMSSDs—it could be that the baseline task created some stress or measurement anxiety (what was informally reported by some practitioners, who were not used to lab settings), that the ESCT-exo was not sufficiently stressful for this sample, or both. HRV measurements could be refined, to capture clearer recordings from practitioners (e.g., using non-performative procedures for baseline/recovery conditions; adding longer stabilization periods before baseline; recording HRV continuously or with no previous announcement; using more demanding tasks for stress conditions; having the experimenter in a separate room; and asking participants to wear ear plugs to minimize external disturbances). When considering yoga experience constant at its mean, all HRV effects disappeared. This might indicate a mediational role of long-term yoga experience in HRV differences, for this sample. Such a conclusion cannot be fully drawn from this data, however, and future studies should formally test it.

This study also investigated whether yoga experience and practice were related to bottom-up and top-down emotional attention, as measured by emotional spatial cueing paradigms. It was hypothesized that greater experience and practice would delay attentional engagement to fearful faces, especially with exogenous orienting and low-spatial-frequency stimuli, and accelerate attentional disengagement away from fearful faces, especially with endogenous orienting and high-spatial-frequency stimuli.

In the ESCT-exo, a three-way interaction was found (emotion * validity * yoga experience). Spatial frequency effects were not detected in the higher-order interaction, so the hypothesized slower engagement towards low-spatial-frequency fearful faces, as yoga experience/practice increased, could not be tested. Decomposing the three-way interaction, neither attentional engagement nor disengagement scores were significantly predicted by yoga experience. Nonetheless, there was a tendency for attentional disengagement away from fearful vs. neutral faces to be more balanced, among the more experienced practitioners (Fig. 5). Importantly, their estimated disengagement scores were less extreme but still below zero, so it does not look like experienced practitioners had difficulties to inhibit attention from fearful faces, compared to neutral faces—it looks like they responded with less overall emotional bias, but were still able to effectively inhibit attention from negative stimuli.

In the ESCT-endo, there was a four-way interaction between emotion, spatial frequency, validity, and yoga experience. Attentional engagement towards fearful faces did not seem to be influenced by yoga experience, while attentional disengagement away from fearful faces was faster for broad cues, and not significantly affected in other spatial frequencies. Interestingly, estimated disengagement scores of broad stimuli went from negative, among the less experienced, to positive, among the more experienced practitioners (Fig. 6)—this suggests a healthier pattern of emotional attention as experience increased, because delayed inhibition of attention from negative information can be maladaptive (Grafton & MacLeod, 2014). Therefore, while there was preliminary evidence for a faster attentional disengagement away from fearful faces, this effect was not specific to high-spatial-frequency cues, as hypothesized. Still, it does suggest that yoga experience is associated with top-down modulation of emotional attention.

There was suggestive (but inconclusive) evidence that yoga experience is associated with less emotional bias under exogenous orienting, and some supportive evidence that yoga experience is associated with less emotional bias under endogenous emotional attention—yoga might affect them through a facilitated attentional disengagement from negative stimuli, more strongly found in endogenous orienting, which is largely based on attentional control and regulatory skills (Cocia et al., 2012; Fukuda & Vogel, 2011; Sheppes et al., 2013). Although it is possible that attentional engagement is not impacted by yoga experience, it is also possible that more potent stimuli or other behavioral measurements are necessary to detect changes in attentional engagement among regular yoga practitioners (Grafton & MacLeod, 2014; Koster et al., 2004).

There were several limitations in this study: the small sample size, low statistical power, and single-group design compromise present findings and interpretations. The specific combination of ESCT parameters that theoretically allowed for a clearer dissociation between bottom-up (engagement bias towards low-spatial-frequency fearful faces under exogenous orienting) and top-down emotional attention (disengagement bias away from high-spatial-frequency fearful faces under endogenous orienting) could only be tested for top-down emotional attention, what could be due to low statistical power, or a real absence of effects in this sample. Besides, HRV and behavioral measurements could be refined to gain more experimental control.

Still, these findings indicate that the combination of physiological and behavioral methods, like HRV and emotional attention tasks, can help to detail how yoga-based practices modulate emotion regulation, possibly via attentional training. The aforementioned shortcomings and limitations were likely to happen, given the preliminary and novel nature of this work, but even with a limited statistical power some interesting patterns already emerged, especially concerning top-down modulations of yoga practice on emotional attention. This seems to be a promising line for future investigations.

General Discussion

The first study investigated whether long-term and current weekly hours of yoga practice were associated with explicit emotion regulation, specifically cognitive reappraisal, expressive suppression, attentional focusing, and attentional shifting, and with implicit emotion regulation, using a verbal emotional go/no-go task. Long-term and current yoga practice predicted increased self-reported levels of attentional focusing only, among explicit measures. Also, they were linked to a better general behavioral inhibition, and less emotional bias in behavioral inhibition, what indicates improved implicit emotion regulation.

Despite counterposing previous studies in regard to explicit emotion regulation (Kobylinska et al., 2018; Sahni et al., 2021), these are encouraging results which can help to narrow yoga's main pathways of action on emotion regulation. The present findings make sense when considering the centrality of attentional training across yoga components, and the proposed impact of yoga-based practices toward a more balanced processing of positive and negative stimuli (Davis & Thompson, 2015; Desbordes et al., 2015). These results favor an interpretation of decreased emotional bias regardless of valence, over a positivity bias, as a result of yoga practice, but future studies could use different stimuli and paradigms, to test its generalizability.

The second study followed up on the first one, looking at a physiological marker of emotion regulation, vagally-mediated HRV, and at emotional attention tasks. As a preliminary study with a small sample size and low statistical power, its interpretations should leave room for uncertainty. However, both long-term and current practice interacted with the dependent variables in meaningful ways to guide future research. The HRV results suggest that differences between measurement conditions might be mediated by long-term yoga experience, but this proposition needs to be formally tested.

The ESCTs were designed based on previous studies (Bartolomeo et al., 2001; Koster et al., 2006; Park et al., 2013) to differentiate bottom-up and top-down emotional attention mechanisms. Only long-term yoga experience, and not current hours of practice, interacted significantly with performance in the tasks. It is possible that the effects of yoga on emotional attention depend on continued regular practice: such an extended temporal dynamic is a major obstacle in yoga studies, especially when planning randomized interventions.

Most yoga-based interventions are relatively short. Gothe and McAuley (2015) systematically reviewed acute and chronic effects of yoga on attention, processing speed, executive function, and memory. In their work, acute effects refer to single sessions, while chronic effects refer to randomized trials that lasted between 5 weeks and 6 months. Other reviews reported trials from 3 days to 8 weeks, assessing yoga for anxiety (Cramer et al., 2018), from 3 days to 12 weeks, assessing yoga for depression (Brinsley et al., 2021; Cramer et al., 2013), from 2 weeks to 6 months, for several neuropsychiatric conditions (Balasubramaniam et al., 2013), and from 10 days to 24 weeks, for inflammatory biomarkers (Djalilova et al., 2018). Longer trials, although challenging, might be necessary to detail how yoga shapes emotional functioning more precisely.

The ESCT-exo provided suggestive but inconclusive evidence that yoga experience was linked to attenuated bias in emotional attention of fearful vs. neutral stimuli. While yoga experience was not significantly associated with attentional engagement scores, it showed a non-significant trend of decreased attentional disengagement bias, with a medium effect size. In parallel, the ESCT-endo showed that long-term yoga practice was not significantly linked to attentional engagement, but significantly linked to an attenuated attentional disengagement bias.

The effects of yoga on emotional attention were found only for attentional disengagement, and especially under endogenous orienting, which draw from attentional control and regulatory abilities (Cocia et al., 2012; Fukuda & Vogel, 2011; Sheppes et al., 2013)—these results suggest that continued practice primarily modified top-down processes of emotion regulation, although bottom-up effects cannot be discarded, considering methodological limitations of this work. Combined, both studies provide initial evidence that the modification of top-down attentional functions might be an important pathway through which yoga affects explicit and implicit emotion regulation, leading to less overall bias. These results should be taken with caution and wait for further empirical support from different fronts of evidence.

Yoga-based practices have been adopted by diverse populations: children (Ferreira-Vorkapic et al., 2015; Galantino et al., 2008), adolescents (Daly et al., 2015), younger and older adults (Afonso et al., 2017; Chobe et al., 2020; Park et al., 2015; Santaella et al., 2019); clinical and non-clinical (Balasubramaniam et al., 2013); for physical, mental, and spiritual reasons (Mocanu et al., 2018; Park et al., 2015). A better understanding of how yoga-based practices impact emotion regulation can help to inform health professionals, refine scientific investigations, and benefit the wider society. Importantly, yoga studies are embedded in complex cultural, political, historical, and social dynamics (Newcombe, 2009; Newcombe, 2020)—researchers should always strive to build respectful dialogues with past and present yogic traditions.

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Appendices

Appendix A

Yoga/Meditation Practice Questionnaire of Study 1

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1. **Qual(is) estilo(s) de yoga você pratica regularmente? [ ] Hatha yoga [ ] Ashtanga yoga**

   [ ] Vinyasa/Flow yoga [ ] Iyengar yoga [ ] Sivananda yoga [ ] Yin/Yoga restaurativa [ ] Outros

2. **Quando você começou a praticar com regularidade, aproximadamente?** Mês: ______ Ano: _______

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3. <u>No último ano</u>, em média, quantas vezes por semana você praticou...	**Vezes por Semana**							
Asanas	0	1	2	3	4	5	6	7
Pranayamas	0	1	2	3	4	5	6	7
Meditação sentada com foco em um objeto (respiração, mantra, sons, etc.)	0	1	2	3	4	5	6	7
Meditação sentada sem objeto específico (atenção aberta)	0	1	2	3	4	5	6	7
Meditação Deitada/Relaxamento	0	1	2	3	4	5	6	7
Meditação Caminhando	0	1	2	3	4	5	6	7
Outro conjunto de práticas (qual?): ______________________________	0	1	2	3	4	5	6	7

4. <u>No último ano</u>, em média, quanto tempo durou cada sessão de...	**Duração:**
Asanas	________________________
Pranayamas	________________________
Meditação sentada com foco em um objeto (respiração, mantra, sons, etc.)	________________________
Meditação sentada sem objeto específico (atenção aberta)	________________________
Meditação Deitada/Relaxamento	________________________
Meditação Caminhando	________________________
Outro conjunto de práticas (qual?): ________________________________	________________________

Appendix B

List of Verbal Stimuli used in the Emotional Go/No-Go Task in Brazilian Portuguese and English (Study 1)

Negative Words				
Acidente (Accident)	Agressão (Aggression)	Angústia (Anguish)	Briga (Fight)	Catástrofe (Catastrophe)
Crime (Crime)	Culpa (Guilt)	Decepção (Disappointment)	Desespero (Despair)	Desonesto (Dishonest)
Desperdício (Waste)	Doença (Disease)	Dor (Pain)	Fracasso (Failure)	Frustração (Frustration)
Fúria (Rage)	Grosseria (Rudeness)	Guerra (War)	Horrível (Terrible)	Injustiça (Injustice)
Irritação (Irritation)	Machucado (Injury)	Mal (Evil)	Mal-estar (Ill-being)	Medo (Fear)
Mentira (Lie)	Morte (Death)	Nojo (Disgust)	Ódio (Hate)	Perigo (Danger)
Problema (Problem)	Raiva (Anger)	Roubo (Theft)	Ruim (Bad)	Sofrimento (Suffering)
Trauma (Trauma)	Triste (Sad)	Tristeza (Sadness)	Vingança (Revenge)	Violência (Violence)
Positive Words				
Afeto (Affection)	Agradável (Pleasant)	Alegria (Joy)	Amigo (Friend)	Amizade (Friendship)
Amor (Love)	Apoio (Support)	Beleza (Beauty)	Belo (Beautiful)	Bem-estar (Well-being)
Bom (Good)	Bondade (Goodness)	Bonito (Pretty)	Confiança (Trust)	Conquista (Achievement)
Contente (Glad)	Coração (Heart)	Cura (Cure)	Diversão (Fun)	Elogio (Compliment)
Felicidade (Happiness)	Feliz (Happy)	Gentileza (Kindness)	Harmonia (Harmony)	Honestidade (Honesty)
Liberdade (Freedom)	Paz (Peace)	Respeito (Respect)	Sabedoria (Wisdom)	Satisfação (Satisfaction)
Saudável (Healthy)	Saúde (Health)	Segurança (Safety)	Serenidade (Serenity)	Simpatia (Sympathy)
Sorriso (Smile)	Sucesso (Success)	Tranquilidade (Tranquility)	Virtude (Virtue)	Vitória (Victory)

Appendix C

Eligibility and Yoga/ Meditation Practice Questionnaire of Study 2

Sobre seu Estado Físico e Mental (marque um X na opção adequada e escreva se necessário)

	Sim	Não
Você ingeriu café, algum chá com cafeína (chá preto/chá verde/chá mate), álcool, energéticos ou outros estimulantes hoje?	Qual/quais? ____________________	
Sua última refeição foi há mais de 2h?		
Você utilizou alguma medicação hoje? (remédios de uso contínuo, fitoterápicos, etc.)	Qual/quais? ____________________	
*Você dormiu bem n***est***a noite anterior?*		
Você realizou exercício físico intenso ontem à tarde ou hoje de manhã?		

Por favor, indique se você apresenta...	**Sim (qual?)**	**Não**
Alguma condição cardiovascular (hipertensão, arritmia, angina, inflamações, usa marcapasso, etc.)		
Alguma condição respiratória (asma, bronquite, rinite/sinusite crônica, etc.)		
Algum diagnóstico cognitivo/emocional (e.g., TDAH, transtorno de ansiedade, depressivo, bipolar, etc.)		
Algum diagnóstico que afete seu funcionamento motor (e.g., doença de Parkinson)		

Sobre a sua prática de Yoga

1. **Quando você começou a praticar com regularidade, aproximadamente?** Mês: ______ Ano: _______

2. **Você segue alguma escola, tradição ou estilo de prática? (Se for mais de um, descreva por favor)**

____

____

   a. **Seu estilo de prática se modificou ao longo do tempo? Se sim, quais estilos já praticou e por quanto tempo?**

   ____

   ____

   ____

3. **Você dá aulas de Yoga?** [ ] Sim [ ] Não Se sim, há quanto tempo? ________________________

<u>No último ano</u>, em média, quantas vezes por semana você praticou...	**Vezes por Semana**							
Asanas	0	1	2	3	4	5	6	7
Pranayamas	0	1	2	3	4	5	6	7
Meditação sentada com foco em um objeto (respiração, mantra, sons, etc.)	0	1	2	3	4	5	6	7
Meditação sentada sem objeto específico (atenção aberta)	0	1	2	3	4	5	6	7
Meditação Deitada/Relaxamento	0	1	2	3	4	5	6	7
Meditação Caminhando	0	1	2	3	4	5	6	7
Outro conjunto de práticas (qual?): ______________________________	0	1	2	3	4	5	6	7

<u>No último ano</u>, em média, quanto tempo durou cada sessão de...	**Duração:**
Asanas	________________________
Pranayamas	________________________
Meditação sentada com foco em um objeto (respiração, mantra, sons, etc.)	________________________
Meditação sentada sem objeto específico (atenção aberta)	________________________
Meditação Deitada/Relaxamento	________________________
Meditação Caminhando	________________________
Outro conjunto de práticas (qual?): _______________________________	________________________