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Critical Investigations of Two Meditation-Based Stress Reduction Programs and of Mindfulness as a Predictor of Mental Health in the Population

PH.D. DISSERTATION

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Ph.D.-Dissertation
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List of abbreviations

Abbreviation	*Explicated term*
5-HTTLPR	Serotonin Transporter-Linked Polymorphic Region
AAQ-II	Acceptance and Action Questionnaire-II
ALT	Allostatic Load Theory
ANOVA	Analysis of Variance
ASC	Altered State of Consciousness
AUC_G	Area Under the Curve with respect to Ground
AUC_I	Area Under the Curve with respect to Increase
BMI	Body-Mass Index
BSI-18	Brief Symptom Inventory-18
BSI-18 GSI	Brief Symptom Inventory-18 General Severity Index
BSI-53	Brief Symptom Inventory-53
BSI-53 GSI	Brief Symptom Inventory-53 General Severity Index
CAR	Cortisol Awakening Response
CBT	Cognitive Behavioral Therapy
CFA	Confirmatory Factor Analysis
CFF	Critical Flicker Fusion
CFI	Bentler Comparative Fit Index
CI	Confidence Interval
CICO	Collapsed Inactive Controls
CR	Composite Reliability
CTI	Cue-Target Interval
CV	Coefficient of Variation
FF	Fight-and-flight
FFMQ	Five Factor Mindfulness Questionnaire
HAM-D	Hamilton Depression Rating Scale – 17 items
HPA	Hypothalamic–Pituitary–Adrenal
ICC	Intraclass Correlation Coefficient
ICD-10	International Classification of Diseases-10
INCO	Incentive Controls
ISCO-88	International Standard Classification of Occupations-88
ITT	Intent-To-Treat
MAAS	Mindfulness Attention Awareness Scale
MANOVA	Multivariate Analysis of Variance
MANCOVA	Multivariate Analysis of Covariance
MBI	Meditation-Based Intervention
MBSR	Mindfulness-Based Stress Reduction
MCSD	Marlow-Crowne Social Desirability Index

Abbreviation	*Explicated term*
MDI	Major Depression Inventory
MM	Mindfulness Meditation
MMN	Mismatch Negativity
NMSR	Non-Mindfulness Stress Reduction
NOCO	Non-incentive Controls
OECD	Organisation for Economic Co-operation and Development
PCR	Polymerase Chain Reaction
PSQI	Pittsburgh Sleep Quality Index
PSS	Perceived Stress Scale (10-item version)
PSS-4	Perceived Stress Scale—4-item version
QOL	Quality of Life
RMSEA	Root Mean Square Error of Approximation
SCL-90-R-GSI	Symptom Checklist 90 – Revised General Severity Index
SD	Standard Deviation
SEM	Structural Equation Modeling
SES	Socioeconomic Status
SF-36	Short-Form health survey-36
SF-36-MCS	Short-Form health survey-36 – Mental Component Summary Score
SF-36-PCS	Short-Form health survey-36 – Physical Component Summary Score
SD	Standard Deviation
SLE	Stressful Life Events
SPSS	Statistical software Package for the Social Sciences
TAU	Treatment As Usual
TCI-HA	Temperament and Character Inventory – Harm Avoidance
TCI-SD	Temperament and Character Inventory – Self Directedness
T_1	Baseline (Time 1)
T_2	Post-treatment (Time 2)
T_3	Follow-up (Time 3)
TM	Transcendental Meditation
TMMS	Trait Meta-Mood Scale
TLI	Tucker-Lewis fit Index
TVA(-test)	Theory of Visual Attention (-based test)
t_0	Threshold of conscious perception within the TVA framework
C	Speed of processing within the TVA framework
K	Visual short term memory storage capacity within the TVA framework
UNDP	United Nations Development Programme
WHO	World Health Organization
WLSMV	Weighted Least Square Means and Variance adjusted estimator

Thesis summary

The thesis comprises three studies in an overall effort to investigate interplays between meditation-based interventions (MBIs), attentional functions, and psychological and physical markers of health. Study 1 was a randomized controlled trial (RCT) including healthy students and tested attentional, stress-physiological (cortisol), and self-reported outcome changes after Mindfulness-Based Stress Reduction (MBSR) compared with two active and one inactive control group. Study 2 represented the first validation of a Danish translation of the Mindful Awareness Attention Scale (MAAS) and extended previous research by testing the MAAS scores' long-term test-retest reliability as well as the MAAS scores' ability to predict scores of mental health and psychological distress, respectively, after controlling statistically for the influence of socioeconomic status (SES) and other potential confounders in an adult healthy community sample. Study 3 was an RCT including adults with prolonged stress and examined attentional, stress-physiological, and self-reported outcome changes after the meditation-based stress reduction and mental health promotion program "Open and Calm" (OC) in individual format and group format, respectively, compared with a Treatment As Usual (TAU) control group. Study 1—3 used several similar or identical outcomes and methods, enabling a broader discussion of MBIs, attention, and health.

Main conclusions

MBSR may specifically benefit the threshold for visual perception and sustained selective attention, but more studies are needed since most reaction-time (RT)-based attentional outcomes were improved to a similar degree by non-specific stress reduction or an experimentally increased task incentive, respectively. The Danish translation of the MAAS scale yielded scores of general inattentiveness that confirm to theoretical and psychometric predictions and the scores are reliable over a period of six months. MAAS scores predict mental health scores and psychological distress scores, respectively, after controlling for potential confounders. The OC program participants showed significantly larger improvements than the TAU controls on self-reported, stress-physiological, and perceptual outcomes and a low dropout rate. The consistent, promising results warrant further studies of potential benefits of implementing the OC program in the public health sector for stress reduction and mental health promotion.

Resumé af Ph.D. afhandlingen

Afhandlingen omfatter tre studier som tilsigtede at undersøge samspil mellem meditation-baserede interventioner, opmærksomhedsfunktioner samt psykologiske og fysiologiske sundhedsmarkører. Studium 1 var en randomiseret kontrolleret trial som inkluderede raske universitetsstuderende og testede opmærksomhedsmæssige, stress-fysiologiske (kortisol), samt selv-rapporterede effektmåls-forandringer efter Mindfulness-Baseret Stress Reduktion (MBSR) sammenlignet med to aktive samt en inaktiv kontrolgruppe. Studium 2 var den første validering af en dansk oversættelse af Mindful Attention Awareness Scale (MAAS) og udvidede tidligere forskning ved at undersøge MAAS-scorernes test-retest reliabilitet over et langt tidsinterval samt MAAS-scorernes evne til at forudsige scores for henholdsvis mental sundhed samt psykologisk distress efter statistisk kontrol for socioøkonomisk status (SES) og andre potentielle confounders i et befolkningssample af raske voksne. Studium 3 var en RCT som inkluderede voksne med langvarig stress og undersøgte opmærksomhedsmæssige, stress-fysiologiske (kortisol), og selvrapporterede effektmåls-forandringer efter det meditationsbaserede program "Åben og Rolig" (ÅR) udviklet specifikt til offentlig implementering som et borgerforløb til stressreduktion og mental sundhedsfremme. Åben og Rolig undersøgtes i henholdsvis individuelt- samt gruppebaseret format og sammenlignedes med en sædvanlige behandling (treatment as usual; TAU) af stress i den københavnske sundhedssektor. Studium 1—3 anvendte flere ensartede eller identiske effektmål og metoder, hvilket muliggjorde en bredere diskussion af meditations-baserede interventioner, opmærksomhedsfunktioner og sundhed.

Hovedkonklusioner

MBSR forbedrer muligvis specifikt tærskelværdien for visuel perception samt vedholdt, selektiv opmærksomhed, men yderligere studier er nødvendige da de fleste reaktionstidsbaserede opmærksomhedsmål forbedredes i ligeså høj grad af henholdsvis non-specifik stress reduktion eller et eksperimentelt forøget opgaveincitament. Den danske oversættelse af MAAS skalaen udmunder i scores for generel uopmærksomhed som bekræfter teoretiske og psykometriske forudsigelser og som er reliable over en periode på seks måneder. MAAS scores forudsiger scores for henholdsvist mental sundhed samt psykologisk distress efter statistisk kontrol for potentielle confounders. Deltagere i ÅR programmet viste signifikant større forbedringer end deltagere i TAU forløb på selv-rapporterede, stress-fysiologiske, samt perceptuelle effektmål samt en lav frafaldsrate. De konsistente, lovende resultater støtter relevansen af videre undersøgelser af mulige nytteværdier af at implementere ÅR som et offentligt tilbud til stressreduktion og mental sundhedsfremme.

Chapter 1

Background

Chapter 1. Background

Meditation-Based Interventions (MBIs) are gaining public momentum and academic respect as treatments for stress reduction in modernized[1] countries. Concurrently, researchers in many fields are encouraging more critical and methodologically thorough studies of MBIs and of potential mechanisms of change, such as the "real-life" centrality of attentiveness towards the present moment for health parameters in the general population. In the present studies, I therefore aimed to direct a critical looking glass at potential joints between MBIs, attentional functions, and health.

In this chapter, I first review the evidence on beneficial effects of MBIs and define the present use of the central term *meditation*. Second, I briefly describe the growing reports of *stress* in modernized countries and the present understanding of this term. Third, I outline theories and predictions of attentional improvements as mechanisms of change in MBIs. Fourth, I present two major problems in meditation research to which I hope the present studies may contribute, namely the lack of control for potential confounders, including the paucity of active control group studies, and the lack of theory-driven research.

1.1 Literature Review: The Efficacy of Meditation-Based Interventions

The evidence for moderate, beneficial effects of MBIs for stress-reduction in healthy samples is quite consistent. Reviews agree that MBIs improve symptoms of stress in healthy adults (Chiesa & Serretti, 2009a; Conley, Travers & Bryant, 2013; Orme-Johnson & Dillbeck, 2014; Regehr, Glancy, Pitts, & LeBlanc, 2014; Sedlmeier et al., 2012; Virgili, 2013), cognitive abilities in stressed, healthy adults (Chiesa, Calati, & Serretti, 2011) and stress in adolescents (Black, Milam, & Sussman, 2009). Reviews have documented beneficial effects on markers of hypertension by systematically trained transcendental meditation (TM) (Anderson, Liu, & Kryscio, 2008; Rainforth et al., 2007), yoga (Chu, Gotnik, Yeh, Goldie, & Hunink, 2014; Ospina et al., 2007), relaxation response (RR) meditation (Park et al., 2013), and across mindfulness meditation (MM), TM, and other MBIs (Younge, Gotink, Baena, Roos-Hesselink, & Hunink, 2015). Pioneering studies have shown improvement of stress-related immune function variables after MM (Davidson et al., 2003; Schutte & Malouff, 2014) and loving-kindness meditation (Pace et al., 2009, 2010) in healthy adults. A full genome study showed genomic stress resiliency improvements in healthy adults after 8 weeks of

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[1] I prefer the term "modernized", rather than e.g., "Western", since new MBIs are also gaining popularity in China (e.g., *Integrative Mind-Body Training*: Fan et al., 2010; Tang et al., 2007, 2012), in Japan, (e.g.,

RR meditation (Dusek et al., 2008).

Interestingly, a systematic review of effects of MBIs for healthy samples found no substantial differences between MM (46 studies, mean Cohen's *d* = 0.52), TM (36 studies, mean *d* = 0.54), and other types of MBIs (43 studies, mean *d* = 0.52; Sedlmeier et al., 2012, p. 1153)[2]. This is confirmed by other reviews of this field (Ospina et al., 2007; Virgili, 2013), although one review disputed the methods in Sedlmeier et al. (2012), arguing that the evidence slightly favored TM when also including non-peer-reviewed studies in the data set (Orme-Johnson & Dilbeck, 2014; and see Sedlmeier, Eberth, Schwarz, & Hinshaw, 2014). Nonetheless, stress management programs *without* meditative training have also been found to have a mean effect size of *d* = 0.54 in a meta-analytic review (Richardson & Rothstein, 2008). On the other hand, MBIs were superior to physical relaxation for healthy adults in a sub-analysis across ten such studies (Sedlmeier et al., 2012). However, mechanisms of change are unclear at this point and are rarely studied in active control group designs. For example, a recent systematic review of mediating factors for effects of MBIs (Gu, Strauss, Bond, & Cavanagh, 2015) found only one study using mediation analyses to study mechanism of change in Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1994) compared to an active control group and only two mediation studies comparing Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002) to active control groups. Many reviews of MBIs emphasize that active-control group studies of are remarkably rare (Goyal et al., 2014; Khoury et al., 2013; Ospina et al., 2007; Sedlmeier et al., 2012). This represents a general problem in meditation research (see Section 1.4).

For stress-physiological outcomes, the evidence for beneficial effects of MBIs is less consistent. One review (Matousek, Dobkin, & Pruessner, 2010) of studies of cortisol changes after MBSR reported that only four out of eight studies found positive cortisol effects. The authors found cortisol to be a promising outcome for MBI studies of physiological stress but criticized previous studies on methodological grounds, e.g., due to the measurement of cortisol only through a single sampling pre- and post-treatment (Matousek et al., 2010). A comprehensive and often cited review (Ospina et al., 2007) reached very critical conclusions. Methodologically, the authors divided meditative practices into five categories[3] and found 253 studies of MBIs and stress-physiological

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[2] For comparability with other reviews, I converted the Pearson correlations reported by Sedlmeier et al. (2012) to Cohen's *d*, using formulas in Rosenthal (1994).

[3] The five categories were: Mantra-based meditation (e.g., TM, RR), MM-based meditation (e.g., MBSR, MBCT), Yoga, Tai Chi, and Qi Gong (Ospina et al., 2007).

parameters (Ospina et al., 2007; p.157). More than 50% of these 253 studies were randomized controlled trials (RCT). However, Ospina et al. included only 28 studies in their meta-analyses of MBIs and physiological effects. Among the remaining 225 studies, less than two studies within each of the five meditation categories investigated the same outcome. Separate meta-analyses were then performed on effects of each meditation type on each outcome. Applying this method, most of the meta-analyses (31/43 analyses) included only two studies (Ospina et al., 2007: table 41). In contrast, the abovementioned meta-analysis showing a significant reduction of blood pressure for high-quality studies of hypertension patients was performed across 11 unique RCTs of different meditative techniques (Younge et al., 2015). Thus, there is evidence that MBIs across different traditions decrease blood pressure significantly for hypertension patients, while potential differences between meditative traditions are unclear due to a low number of studies within each tradition and the use of heterogeneous physiological outcomes.

Clinical reviews, which are relevant here due to the stress related to virtually any illness, have sometimes reported equivocal evidence for MBIs, e.g., across two anxiety disorder trials (Krisanaprakornkit, Sriraj, Piyavhatkul, & Laopaiboon, 2006), three studies of MBSR for low back pain (Cramer, Haller, Lauche, & Dobos, 2012), three RCTs of MBCT for bipolar spectrum disorders (Stratford, Cooper, Di Simplicio, Blackwell, & Holmes, 2015), and four studies on MBCT for recurrence of major depression (Coelho, Canter, & Ernst, 2007). One systematic review (with no meta-analysis due to heterogeneous outcomes between studies) of seven studies of MBSR for sleep disturbances also found the evidence inconclusive (Winbush, Gross, & Kreitzer, 2007). While the number of studies in a review does not determine its quality or relevance, more recent clinical reviews have been larger and have recommended MM-based programs for anxiety disorders (Hofmann et al., 2010; Manzoni, Pagnini, Castelnuovo, & Molinari, 2008; Vøllestad, Sivertsen, & Nielsen, 2011), MBCT for the prevention of relapse in major depression disorder (Piet & Hougaard, 2011), and MM-based programs across different clinical conditions (Keng, Smoski, & Robins, 2011; Khoury et al., 2013; Strauss, Cavanagh, Oliver, & Pettman, 2014). The largest review across different clinical groups found that MM-based programs were superior to active treatments (68 studies, Hedge's $g = 0.33$), and to some psychological treatments (35 studies, $g = 0.22$), but not to cognitive-behavioral therapy (CBT) (nine studies, $g = -0.07$; Khoury et al., 2013). The mean uncontrolled effect of clinical MM-studies (g = 0.53-0.55; Khoury et al., 2013)[4] is similar to the mean effects of MBIs for healthy samples (ds = 0.52-0.54; Sedlmeier et al., 2012). A parallel pattern is seen in reviews of different treatments for anxiety disorders. A systematic review of MBSR for anxiety disorders found a mean effect size on anxiety symptoms of g = 0.55 (95% CI [0.44, 0.66]; Hofmann, Sawyer, Witt, & Oh, 2010). This overlaps the effect estimate for MBCT for anxiety, g = 0.79 (95% CI [0.45, 1.13]; Hofmann et al., 2010). Finally, these estimates are only slightly larger and do overlap the mean effect of active control (so-called *placebo*) treatments for anxiety disorders as demonstrated by another systematic review, mean g = 0.45 (Smits & Hofmann, 2009). In other words, treatment effect sizes of MBIs for healthy and clinical samples are mostly positive, but the evidence for unique or superior effects of MBIs compared to active control groups is at not convincing. Active control group studies are needed for evidence-based and eventually theory-driven intervention development (Section 1.4).

Adverse effects of MBIs are seldom studied. A review of factors predicting dropout of MM-based interventions concluded that too few studies had been conducted to provide empirically based conclusions (Dobkin, Irving, & Amar, 2012). This echoes an early review of adverse effects of MBIs (Shapiro & Walsh, 1984). Outside MBI research, younger age seems to increase the risk for dropout (Groeneveld, Proper, van der Beek, Hildebrandt, & van Mechelen, 2009; Melville, Casey, & Kavanagh, 2010; Pinto-Meza et al., 2011) and dropout rates typically range 15-30% in stress reduction programs (e.g., Ismail et al., 2009; Quartero, Burger, Donker, & de Wit, 2011), including different types of MBIs (Ospina et al., 2007). Nevertheless, the knowledge on strategies for avoiding negative effects and lower dropout in MBIs is very limited (Dobkin et al, 2012).

Finally, when discussing the efficacy of *meditation*-based interventions (MBIs) it seems appropriate to note that compliance with the meditative practices has not been documented to be an important factor for the degree of beneficial changes. Larger numbers of meditation course hours did not at all[5] predict larger effect sizes across 30 MBI studies of mixed samples (Carmody & Baer, 2009). Similarly, only 13/24 studies (54%) of mixed sample types found that increased compliance with MM practices was associated with increased treatment effects (Vettese, Toneatto, Stea, Nguyen, & Wang, 2009). A third review reported that course length (6-12 weeks) was not

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[4] Hedge's g is a more conservative (unbiased) measure than Cohen's d, but they are largely comparable (i.e., both reflect the standardized mean difference).
[5] The non-significant tendency was in the opposite direction, i.e., longer versions of MM-based MBIs tended towards producing smaller effects, r = -.25, p = .18 (Carmody & Baer, 2009, p. 634).

associated with mean effect sizes for MM-based interventions at work places (Virgili, 2013)[6]. A fourth review of 15 clinical studies of MBSR on symptoms of anxiety and depression found no relationships between compliance with MM-practices and treatment effects (Toneatto & Nguyen, 2007). The largest systematic review and meta-analysis of MBIs for healthy samples to date demonstrated that the numbers of treatment days across MBI types were not related to treatment effect sizes (Sedlmeier et al., 2012). Other factors are probably at play (Section 1.4).

In sum, when discussing the efficacy of standardized MBIs, the evidence consistently supports moderate benefits for healthy samples on stress and mental health-related outcomes. Physiological findings are more inconsistent and such studies have been methodologically flawed. Adverse effects seem seldom, but are also empirically overlooked. Active control group studies are rare and the mechanisms of change are unclear, as reviewed further throughout Chapter 1.

1.1.1 Defining meditation

In this section, I will present the many aspects of the term meditation. I arrive at the conclusion that the term cannot be clearly defined and subsequently define what I presently mean by that term.

People have engaged in meditative activities to improve their mental health, spiritual growth, and for many other purposes in a variety of cultures tracing back at least 2,500 years (Walsh, 1984). The vast array of meditative traditions and techniques have sprouted nearly as many descriptions and thus definitions, and strategies for operationalizing or measuring meditation are not at all clarified to this day (Andresen, 2000; Sedlmeier et al., 2012). Public narratives about meditation have changed dramatically during the past five hundred years (Harrington, 2008). In the 16th century Europe, Asian mind-body practices were ridiculed as primitive, non-sense rituals by Western travelers. From the 1850s and onwards, meditation gradually became popularized in Europe and North America as a technique for rediscovering one's own sources of forgotten wisdom by religious or spiritual writers (e.g., Madame Blavatsky), anti-modernist philosophers (e.g., Henry Thoreau), and even by world-leading psychologists (e.g., William James and Carl Gustav Jung). This romantic turn may have been partly due to a counter-cultural movement to the industrialization and the naturalistic worldviews of man nurtured by e.g., Darwinian evolutionary theories (Harrington, 2008). Meditation was, in that portrait, a mystical path back to the forgotten realms of

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[6] A non-significant tendency was found (course length: mean Hedge's *g* [number of studies]):
6 weeks: $g = 0.64$ [6]; 8 weeks: $g = 0.68$ [11]; 12 weeks: $g = 0.81$ [2] (Virgili, 2013: table 3).

existential wisdom or cosmic insight. I find this story relevant also today, since meditation is still portrayed as an anti-dote to the hectic, multitasking-activities of modern living.

However, an important shift in the narratives surrounding meditation was spurred forward in the 1970s, when prominent stress research groups began reporting benefits of meditative practices on purely physiological stress markers in flagship journals such as *Science* (Hoffman et al., 1982), *The Lancet*, (Benson, Beary, & Carol, 1974; Benson, Alexander, & Feldman, 1975), *Psychosomatic Medicine* (Beary, Benson, & Klemchuk, 1974), and *New England Journal of Medicine* (Benson, 1977). Ever since, the orange smoke of Eastern religion, ancient wisdom, and mysticism has been busily whiffed away by expert proponents and pro-meditation scientists within all main meditative traditions. Meditation researchers (including me!) have repeatedly explicated how their type of meditation or MBI is simply a set of mental or mind-body techniques, which can be defined in terms of e.g., attentional and emotional-attitudinal coping strategies that are trained systematically (Horan, 2009; Lutz, Slagter, Dunne & Davidson, 2008; Sedlmeier et al., 2012). Technical definitions and program manuals in hand, researchers have sought to free the word “meditation” from religious beliefs, to domesticate meditative training and make it fit for scientific investigations and integration with a secular (i.e., non-religious) worldview. Secularized, technical portraits have been forwarded for MBSR (Kabat-Zinn, 1990, 2013), which was investigated in Study 1, and for RR meditation (Benson & Proctor, 1984, 2010), which was investigated in Study 3.

But does a technical description of a meditation type untie the conceptual knot? Meditative practices certainly comprise colorful panoply. Meditation may involve sitting quietly to produce a state of restful quiescence (e.g., RR, MM) – but also sitting quietly to produce a state of excitement and arousal (tantric meditation). Other types of meditation involve series of active movements to induce either relaxation (tai chi, hatha yoga) or arousal and excitement (Sufi whirling dervish; Shapiro, 1980). Other meditation types focus on the use of holy or meaningful words to invoke substantially different effects, such as the inspiration of divine, transformative energies (e.g., TM, catholic psalm recitation). Meditations may also focus on training personal growth or situational balance through sustaining and internalizing visualizations of a saint or a symbol (e.g., Buddhist visualizations of the Buddha or a mandala). Finally, some meditative techniques focus on building and strengthening strong emotions (e.g., loving-kindness meditation), while other types aim to invoke clear-headed rationality and independence from emotions (e.g., Stoic meditations; Aurelius, 2003). The conclusion is simple: Even when applying technical definitions, it is very difficult, in my opinion impossible, to pinpoint one coherent set of techniques, which may be described as the essence of meditation. The etymological core of the term is to *mediate*[7], but this does not solve the knot either. To the point, the word meditation should be defined in each specific context with respect to the techniques or mental strategies being investigated. Importantly, it is not a weakness of meditation research that the central term cannot be precisely defined. In a similar fashion, no universal definitions of *psychotherapy*, *exercise*, or *behavioral training* exist. Therefore, these interventional elements are also required to be defined in each local research context.

As an alternative to focusing on techniques, one might try to define meditation types according to their intended effects, e.g., relaxation, exaltation, attentiveness to the influx of the breath, the influx of divine inspiration, increased emotionality, or increased rationality. However, defining a meditation type according to the states or results that it is supposed to produce risks circularity, since the independent variable (meditation-as-technique) is then defined in terms of (or at least the technique is confounded by) the dependent variable (e.g., meditation-as-mental-clarity). An important distinction when defining meditation in this way concerns the differences between meditation-as-a-state-of-consciousness versus meditation-as-a-self-regulation-strategy that aims to obtain an outcome, but can be defined independently of this potential outcome.

For the presentation and discussion of the two MBI studies (Study 1 and Study 3), meditation refers to an attempt at using a set of self-regulation strategies, and not to the states these strategies might produce. Below, I outline the advantages of this choice. In addition, the meditative techniques investigated (Study 1: MM; Study 3: RR, MM) are reflected by my present definition:

> *The term meditation here refers to the use of a specified set of self-regulation techniques applied in a conscious attempt to establish and sustain attention towards a personally meaningful focus in an unstrained, receptive, and experiential way, and in an attempt not to engage in, or dwell on, evaluations of one's experiences as positive or negative, and in an attempt to refrain from automatically changing one's experiences, be they pleasant or not.*

This definition involves several important terms and connotations: First, the definition is overall in line with most definitions of the MM applied in Study 1, emphasizing conscious intention, relaxed, receptive awareness, a non-judgmental attitude, and contemplative coping (e.g., Kabat-Zinn, 1990; Shapiro, Carlson, Astin, & Freedman, 2006) or *non-reactivity* (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). These are also core elements in the RR- and MM-inspired MBI investigated in

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[7] Meditation stems from latin: *mediere*, meaning to mediate.

Study 3 (Jensen, 2013; Appendix III). In the present definition, the word "conscious" indicates that meditation is here viewed as a personally intended activity and not, for example, a primarily externally sustained activity, such as hypnosis or guided visualizations.

Second, the definition several times includes the word "attempt" to underline that I focus on meditation-as-strategy, and not meditation-as-state. In other words, the present definition does not require success in producing a specific state of consciousness, but only requires an attempt to use a set of meditative techniques. This may sound controversial, but in fact, the vast majority of meditation studies have (implicitly or explicitly) relied on this definition. For example, virtually all MBI studies today, including the present two, measure intervention *compliance* in terms of the number of times intervention participants have attended the course sessions or attempted to meditate (e.g., the number of guided meditations they have tried to listen to), while the relative success in obtaining a certain state of consciousness is not quantified or studied, although phenomenological descriptions are abundant in the anecdotal literature (Brown & Cordon, 2007). This may be viewed as a serious short-coming for a field studying (in part) self-awareness training, but it is very difficult to train participants who have not previously engaged in meditation to gain conscious access to a clear perception of the degree of success they have had with inducing and sustaining a specific conscious state, and to report this in standardized ways (Tart, 1975). The many challenges of training participants to deliver useful introspective reports have been well known in psychological research since the establishment of the first psychological laboratory by Wilhelm Wundt in Germany in 1879. The problem of standardizing introspective reports is also central today in experimental consciousness research (Overgaard, 2015). Notwithstanding, it should be clearly acknowledged that the present definition therefore poses a central problem, since the quality of the meditative training must be hypothesized to influence the effects. After all, no theories would claim that it is enough to simply sit down and intend to meditate. To the contrary, the ability to produce and sustain a specific type of mental processing is hypothesized to lie at the core of the mechanisms of change in MBIs (for a review, Gu et al., 2015).

Third, the definition is secular. This is appropriate, since the Study 1 and Study 3 investigated secularized MBIs while all three studies applied a secular measure of mindfulness (the Mindful Attention Awareness Scale [MAAS]; Brown & Ryan, 2003, Chapter 4 and Appendix II).

Fourth, the phrase "a meaningful focus" in the definition indicates that a meditative strategy may be applied with many different types of stimuli or experiences. This is in line with the emphasis on applying meditation during everyday activities in both MBSR and the OC program.

Fifth, while meditation-as-state research needs more work to form testable hypotheses on the importance of e.g., success in obtaining and measuring specific elements of conscious states, testable hypotheses have been put forth for studies of MBIs when meditation is defined as a self-regulation strategy (see Chapter 2). Thus, the meditation-as-strategy research field is more ready for control group studies designed to test specific hypotheses. The ability to define the activities in the MBIs was important for the design of the active control intervention in Study 1 and for the two formats of the same MBI paradigm in Study 3. Therefore, a technical meditation-as-strategy definition reflecting the core elements of MM and RR was adequate for the present context.

1.2 The understanding of stress as a growing problem for health

Estimates of the prevalence of stressed individuals depend on the applied definitions of stress. However, reports of severe stress are increasing. In Denmark, a survey by the National Research Center for the Working Environment found that 13-15% of Danish adults reported problematic levels of stress (Jakobsen et al., 2013), an increase compared to 9% in 2005 and 6% in 1987 (Christensen, Ekholm, Davidson, & Juhl, 2012). American Psychological Association carried out a survey termed *Stress in America*, which showed that a fourth of North American adults experienced high stress levels regularly and that about half of the survey respondents felt their stress levels had increased during the past five years (Anderson et al., 2012).

Prolonged stress is alerting for many reasons. Much evidence has been purely correlational, but even low levels of prolonged stress seem to perpetuate or worsen illnesses by impairing the cardiovascular, immune, and metabolic functions, and decrease the functionality of nervous systems (Fernandez-Mendoza & Vgontzas, 2013; McEwen, 2006; Palagini et al., 2013). Stress increases neuropathological inflammatory processes (Blix, Perski, Berglund, & Savic, 2013; Lucassen et al., 2014), which play a role in the neuropathophysiology of mood disorders (Holsboer, 2001; Ising et al., 2005; Mannie, Harmer, & Cowen, 2007) and stress is regarded as a notable risk factor for depression (Anisman & Zacharko, 1982; Grippo & Johnson, 2009; Hill, Hellemans, Verma, Gorzalka, & Weinberg, 2012; Kahn, Sheppes, & Sadeh, 2013).

For these reasons, health agencies worldwide have underlined a need for research into evidence-based programs targeting psychosocial stress and promoting stress resiliency, both to ease human suffering and to lower the growing economic pressure that stress is imposing on public health sectors (Campion, Bhui, & Bhugra, 2012; National Research Council & Institute of Medicine, 2009a, b; Roy & Campbell, 2013; Smith, Soubhi, Fortin, Hudon, & O'Dowd, 2012; World Health Organization, 2005). This was also reinforced in a Danish white paper on the nation's mental health (Borg, Nexø, Kolte, & Andersen, 2010). Public health research is generally needed in Denmark, where only about 5% of health research concerns public health (Gulis, Erikson, & Aro, 2010). As a specific guideline, The European Psychiatric Association recommended systematic research in different formats of the same public mental health promotion paradigm to develop evidence-based health sectorial strategies for implementing specific programs (Kalra et al., 2012).

1.2.1 Theories and understandings of *stress*

The present studies conceptualized *stress* as a bio-psycho-social phenomenon, in line with most current understandings. Reviews have concerned, for example, the multidirectional causal pathways between genetic stress resiliency dispositions, hormonal stress markers, and social cognition (Canli & Lesch, 2007), or between socioeconomic status (SES), coping strategies, personality, and stress resiliency (Matthews, Gallo, & Taylor, 2010). Stress researchers are not trying to pin down "the central component of stress", but to illuminate the complex bio-psycho-social pathways of different human agents' situated abilities to function under different types of bio-psycho-social pressure.

Historically, the complexity of stress models has only increased. In 1914, Walter B. Cannon (Cannon, 1914) proposed the *fight-or-flight* (FF) response as a core physiological response in humans and other animals when faced with adverse stimuli or acute threats. Following this, in the 1930's, biologist Hans Selye coined the term *stressors* for the external sources of stress (e.g., a painful stimulus) and used the term stress for the bodily stress response. Selye (1956/1976) documented that laboratory animals exposed to long-term stressors showed e.g., heightened hypothalamus-pituitary-adrenal (HPA) axis activity, increased levels of glucocorticoid hormones, sleep disturbances, aggressive behaviors, and impaired performance on concentration and memory tasks. Selye termed this the *General Adaptation Syndrome* (GAS) and argued that these negative effects of long-term stress occurred due to the prolonged activation of the FF system's attempts at adaptation (hence the name of the syndrome) to the environmental stressors, with detrimental costs of the continuous HPA-activation over time.

The negative consequences of prolonged HPA-axis activation are still central to research in prolonged stress. Longitudinal studies suggest that a blunted HPA-axis response to stimulation (e.g., to awakening, corresponding to a mild stressor; Fekedulegn et al., 2007) develops with prolonged distress over time (Booij, Bouma, de Jonge, Ormel, & Oldehinkel, 2012). This pattern is in line with the GAS theory, which proposes an HPA *exhaustion phase* with flattened HPA axis responsiveness after long-term stress. Studies have also associated burnout with blunted HPA-axis reactivity, as seen in a flattened cortisol awakening response (CAR; Juster et al., 2011;

Marchand, Juster, Durand, & Lupien, 2014; Moya-Albiol, Serrano, & Salvador, 2010; Preussner, Hellhammer, & Kirschbaum, 1999). HPA-axis dysregulation in prolonged stress is, however, complex and not fully understood (Danhof-Pont, van Veen, & Zitman, 2011). We investigated HPA axis dynamics through patterns of cortisol secretion in Study 1 and Study 3.

Concerning *short-term stress*, the FF response to adverse stimuli or demanding tasks is well-established. The FF response is sympathetically enervated and comprises e.g., elevated blood pressure, higher breathing rates, increased secretion of cortisol and adrenalin, and increased catabolic processes[8]. Conversely, decades of stress research have identified a bodily *relaxation response* (RR; Benson, 1977), involving antagonistic processes to the FF response, e.g., increased parasympathetic activity, decreased pulse, lowered blood pressure, lowered breathing rate, increased oxygen uptake, and anabolic processes[9].

However, the human nervous system seems to include at least two arousal systems with different neurophysiological underpinnings so physiological stress is more complex than a continuum of sympathetic vs. parasympathetic dominance (Boucsein, 2012). Yet, stress researchers still focus on the cost of continuous adaptation, as voiced by Selye in the GAS. Among prominent stress models, the bio-psycho-social Allostatic Load Theory (ALT; McEwen & Stellar, 1993; McEwen & Morrison, 2013) argues that it is the cost of continuous bio-psycho-social adaption processes that leads to negative consequences of prolonged stress. Adaptation processes may be initiated consciously or unconsciously, e.g., by conscious decisions or primarily biological receptors and feedback loops, with the purpose of re-establishing e.g., bodily homeostasis or to complete (adapt to) a task at the work place. The costly process towards adaption is termed *allostasis* and negative consequences of prolonged stress are then caused by the long-term cost of the total sum of allostasis, the *allostatic load*. The ALT therefore proposes that decreasing allostatic processes is essential for stress reduction. The ALT specifies that stress resiliency factors vary over the lifetime, depending on e.g., psychosocial experiences and the biological, material and social environment

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[8] Catabolism refers to chemical processes where complex molecules (polymers, e.g., glycogen) are broken down into more simple molecules (monomers, e.g., glucose) releasing energy the body needs for e.g., cellular and physical activity. This is relevant here, since Study 1 and Study 3 measures cortisol, and cortisol is a catabolic hormone, increasing blood pressure and blood sugar, and reducing the immune response (Chida & Steptoe, 2009; Fekedulegn et al., 2007).

[9] Anabolic processes refer to the synthesis of monomers (e.g., amino acids) into polymers (e.g., proteins), and are necessary for cellular regeneration, maintenance, and growth within all bodily tissues (for a review on anabolic vs. catabolic processes in stress see Theorell, 2008).

(McEwen & Morrison, 2013). The ALT is in this way relevant for the present MBIs, which both focus on training the ability to be attentive while remaining non-reactive or contemplative, i.e., to be consciously aware of a stressor (and of the pleasant parts of existence), but to refrain from initiating the costly allostatic processes automatically, such as automatically participating in a work task or immediately fighting to make a stress response go away.

However, even though the ALT is explicitly bio-psycho-social, it does not focus on psychosocial stress. Lazarus and Folkman argued (1984) that stress depends crucially upon the cognitive appraisal of a situation. Lazarus emphasized that "psychological stress and physiological stress require entirely different levels of analysis" (Lazarus, 1993, p. 4) since psychological stress deals with personal meaning. As an example, a Danish qualitative study showed that stress-related absence from work was also associated with feelings of shame, loss of personal value, or disturbances of personal identity (Andersen, Nielsen, & Brinkmann, 2014). Thus, psychological stress encompasses a wide range of experiences, rendering it difficult to define and to measure.

Stress researches sometimes reduce the complexity of stress by distinguishing between different causes of stress. Lazarus (1966) proposed three main types of stressors, being harm, threat, and challenge. Today, stress research is focused on e.g., family-related stress, illness-related stress, or work-related stress (WRS). For example, the Demand-Control Model proposes that high demands and low control at work are risk factors for WRS (Karasek, 1979; for a review: Häusser et al., 2010) and the Effort-Reward Imbalance Model emphasizes that high work effort in combination with low reward at work are risk factors for WRS (Siegrist, 1996, 2008). Similarly, research is sometimes focused on the duration (e.g., short-term, long-term, chronic), or the severity (e.g., moderate, severe, burn-out) of the stress condition.

In the present studies, we did not distinguish between different causes of stress. However, in Study 3, we applied an analytical distinction between normal and flattened HPA-axis responsiveness to awakening (present or absent CAR) to investigate specific cortisol changes for individuals with or without this indication of physiological burnout, respectively. We evaluated stress broadly, with two physiological stress markers related to cortisol and with Cohen's perceived stress scale (PSS; Cohen & Williamson, 1988; see Chapter 4). A broad understanding of stress was the focus, since participants (see Chapter 3) came from diverse backgrounds and experienced many different types of, causes of, and degrees of stress. Thus, overall markers of stress were selected to investigate stress an important aspect of mental and physical health alongside with other health markers, such as attentional functions, quality of life, and symptoms of depression.

1.3 Meditation and attention

Attentional training is a core element in most types of meditation, which are often defined according to their attentional strategies (Lutz et al., 2008; Travis & Shear, 2010). Unsurprisingly then, theories of mechanisms of change in MBIs generally view improvements in attentional functions as mediators of beneficial changes. However, no theoretical model of mechanisms of change in MBIs has received substantial empirical documentation (Andresen, 2000; Ospina et al., 2007; Sedlmeier et al., 2012). The most recent review of mediators of change in MBIs (Gu et al., 2015) discussed how six theoretical models suggested a very wide range of potential mechanisms:

> "Taken together…possible mechanisms connecting MBSR and MBCT with their beneficial effects include improvements in a number of variables including mindfulness, repetitive negative thinking, AMS [autobiographical memory specificity], re-perceiving, reactivity, nonattachment, nonaversion, self-awareness, self-regulation, self-transcendence, psychological flexibility, clarification of inner values, exposure, attentional control and regulation, body awareness, mind-body and integrated functioning, emotion regulation, self-compassion, compassion, insight, acceptance, relaxation and ethical practices" (Gu et al., 2015, p. 5).

However, attentional training is at the heart of meditation. Many reviews and theories of MBIs focus explicitly on attentional changes (Bedford, 2012; Bishop et al., 2004; Bushell, 2009; Davidson Goleman, & Schwartz, 1984; Horan, 2009; Shapiro et al., 2006). A large, systematic review of neuroimaging studies of meditation stated: "The primary psychological domain mediating and affected by meditative practice is attention" (Cahn & Polich, 2006, p. 200). Similarly, other neurobiological reviews or models of the effects of meditation focus on attentional improvements (Chiesa & Serretti, 2009b; Hölzel et al., 2011; Lutz et al., 2007; Newberg & Iversen, 2003; Rubia, 2009). Gu et al. (2015) also concluded that the most consistent mediator of change in MBIs was *mindfulness*, which demonstrated a significant moderate mediation effect across 16 studies. Mindfulness in these studies was always measured with scales that included attentional functions (for references to these studies, see Gu et al., 2015, p. 13).

But attention appears at many levels of information processing, from a consciously directed attentional "spotlight" (Posner, 1994) to the subconscious awareness of a personal point of view in one's experiences (Taylor & Rogers, 2002). Attentional changes in MBIs may be highly complex. One model of mechanisms of change in MM hypothesized that mindful attention is closely interwoven with the non-judgmental attitude of MM, as well as the purposefulness, or intention with which mindful attention is sustained: "Intention, Attention, and Attitude, are not separate stages [of mindfulness]. They are interwoven aspects of a *single* cyclic process" (Shapiro et al., 2006, p. 375, italics added). Another model suggested that attentional improvements after MM "include alerting and orienting toward an intended object of interest, engaging with the object, sustaining attentional focus, executive monitoring and detecting distraction, disengaging from the source of distraction, and re-engaging on the intended object" (Vago & Silbersweig, 2012, p. 16). This wide range of functions encompasses most of the cross-modal components of primarily top-down driven attention in cognitive models (Posner & Petersen, 1990; Corbetta & Shulman, 2002; Raz & Buhle, 2006; Posner & Rothbart, 2009). More specific predictions are therefore needed. In addition to these functions, theories have also predicted that meditation should result in perceptual improvements, i.e., in improvements of the most primary levels of attention pathways from sensory stimulation to conscious registration. One theory stated that MBIs should lead to "greater than usual attention to exact perceptual stimulation over space and time that comes through any sense modality" (Bedford, 2012, p. 27). This line of thinking has been present in theories on both TM (Lindsay & Norman, 1977) and MM (Brown et al., 2007; Lutz et al., 2006; Vago & Silbergsveig, 2012) and has been supported by a few studies showing improved basic functions in visual perception after MBIs (Brown et al., 1984; Dilbeck, 1982; MacLean et al., 2010; Vani et al., 1997) and in proprioceptive perception after MBSR (Naranjo et al., 2012), although none of these studies used active control groups. In conclusion, no *short* list of the theoretically most central attentional functions improved by MBIs can be derived from existing theories. As a result, the present studies examined a range of attentional functions in relation to MBIs and mental and physical health.

Specifically, Study 1 tested several explicit hypotheses (Bishop et al., 2004; Grabovac, Lau, & Willett, 2011; Hölzel et al., 2011; Shapiro et al., 2006) stating that MM is effective due to improvements in the abilities to maintain a stable focus over time (sustained attention), to switch the focus between objects or mindsets (attentional [set] shifting), to execute top-down control by sustaining a selective focus during stressful tasks (selective attention), and due to improvements in basic functions in (here visual) perception. Study 2 examined self-reported instability of attention as measured by the MAAS. More knowledge on self-reported attention is important to meditation research since it represents an important part of most mindfulness scales, such as the Five Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006) and other scales (e.g., Bodner & Langer, 2001; Greco et al., 2011; Haigh, Moore, Kashdan, & Fresco, 2011; Tharaldsen & Blu, 2011; Walach, Buchheld, Buttenmüller, Kleinknecht, & Schmidt, 2006).

1.4 Methodological problems in meditation research

Meditation research has been hampered by methodological problems throughout history (Andresen, 2000), including studies on meditation and attention (Cahn & Polich, 2006) and MBIs and stress (Ospina et al., 2007; Sedlmeier et al., 2012). Criticism has centered on inadequate control for confounders and a paucity of theory-driven research and MBIs. The present studies aimed to test new control group designs (Study 1, Study 3), more thorough control for confounders (Study 2), more detailed analyses of physiological markers of long-term stress (Study 3), and to evaluate a new, theory-driven MBI (Study 3), and thus to inspire or forward the field methodologically.

1.4.1 Control for confounders

A primary purpose of science is to reveal causal relationships between variables of interest [10]. In any study of bio-psycho-social human health, this is extremely complex, since so many variables are potentially at play. Thus, controlling for relevant confounders becomes important. Confounding means to "pour together" (latin: *confundere*; Glare, 1982) and refers to the mixing of the role of two or more predictor variables for an outcome.

In cross-sectional studies (as in Study 2) it is commonly investigated whether a hypothesized predictor (e.g., inattentiveness as measured by MAAS scores) independently predicts or mediates variance within an outcome (e.g., psychological distress scores). It is basic knowledge that unadjusted correlations (or unadjusted regression coefficients) are not indications of causal relationships. Variables that may affect the association between a theoretical predictor and an outcome should therefore be controlled for (Hull, Tedlie, & Lehn, 1992; MacKinnon, Fairchild, & Frtiz, 2007). Causation may be impossible to establish by statistical methods alone (Hernan, Hernandez-Diaz, Werler, & Mitchell, 2002), but by assessing the influence of relevant confounders on our primary relationships, we may develop a better causal theory. This is especially important in observational studies without randomization or pre-post analyses of changes in exposed versus non-exposed groups, where the specificity of the primary associations is a cardinal point. There are two principal reasons for including a potential confounder as a covariate in statistical models in cross-sectional studies: power and adjustment. Power is improved when the covariate is related to the dependent variable and not to the independent variable (Yzerbyt, Muller, & Judd, 2004).

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[10] *Variables* may refer to a principally unlimited number of phenomena, from proton spin to public spin-doctors, or any other measurable variables within e.g., physics, biology, psychology, or culture.

Conversely, if the covariate is related to the predictor, the inclusion of the covariate reduces or adjusts the (inflated) effect estimate (Yzerbyt et al., 2004).

In intervention studies, even in RCTs such as Study 1 and Study 3, confounding is crucial to consider. Many types of psychotherapeutic interventions may reduce stress and benefit parameters of mental health, as denoted by the term *non-specific* therapeutic effects. Thus, if a meditation method is to be investigated as the theoretically central part of an MBI, this can ideally be done by within-study comparisons of the MBI with a similarly designed intervention that does not include the (definable) meditation method. Active control interventions could in this way – ideally – be designed to "filter out" pre-specified factors and thus to promote understanding of specific "active ingredient[s]" in the target MBI intervention (Chiesa & Serretti, 2009a, p. 598). However, the precise delineation of specific elements is very difficult and non-specific effects are equally difficult to account for in real-life studies. For example, the inter-personal contact with the course instructor may (should!) always increase awareness or attentiveness to one's own situation. This is thus a non-specific effect. The meditation expert instructing an MBI will therefore represent a mix of non-specific as well as method-specific self-awareness influences. Similarly, social support and normalization of experienced symptoms is a common and non-specific factor, but the social support in MBIs may differ from that of other groups due to the shared experiences with meditation and dialogues and psychoeducation on meditation. Thus, social support also partly represents a specific factor. The potentially specific effects of MBI-based social support are thus difficult to evaluate but may (for a start) be addressed by within-study comparisons of the same MBI paradigm lead by the same instructor in group-based versus individual format, as in Study 3.

Furthermore, the use of active control groups is relevant for research focused on attentional effects of MBIs, since a century of research has demonstrated that many attentional test paradigms are heavily affected by the participants' task effort at the test session, their so-called attentional effort (Sarter, Gehring, & Kozak, 2006). Yet, only one meditation study prior to the present Study 1 actively manipulated attentional effort in a control group. This elegant study found that a small financial incentive induced significantly larger blood flow in nearly all neural regions of interest for sustained attention tasks (Brefzynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). This is important, since MBI participants may be more motivated to perform well on attentional tasks after the intervention period. The need to distinguish the influence of participants' attentional effort from genuine effects of meditative training is of obvious relevance for meditation research (Shapiro & Walsh, 1984; Valentine & Sweet, 1999), but is virtually unexplored.

Equally important, meditation studies have seldom controlled for non-specific effects of stress reduction on attention and working memory functions. It is well known that concentration and working memory problems are strongly impaired by any type of long-term stress, perhaps due to neurotoxic effects on the hippocampus (Blix et al., 2013) and prefrontal cortex (Arnsten, 2009). For these reasons, any type of stress reduction may benefit attention (McEwen & Morrison, 2013). Yet, a large review of 813 studies found that about one-third of MBI studies have not included any control groups (Ospina et al., 2007). Even worse, a systematic review of MBIs for healthy samples (Sedlmeier et al., 2012) found that only 18 out of 163 (11%) included studies involved active control groups such as exercise or relaxation[11]. As mentioned, reviews often emphasize that active control groups are seldom in MBI studies (Gu et al., 2015; Keng et al., 2011; Khoury et al., 2013).

But life is full of potentially relevant covariates, and we cannot control for all of them. In the statistically central discipline of variable selection, *causal relevance* is the primary criterion for including a variable as a covariate. The causal relevance of potential confounders should ideally be explicitly discussed. It can also be helpful to visualize the assumed directed, causal pathways to argue why, or why not, a variable should be controlled for (Glymour, Weuve, & Chen, 2008). For example, if a variable (e.g., the degree of rumination) lies on the theorized pathway between the predictor (e.g., mindfulness) and an outcome (psychological distress), it may not be appropriate to use it (i.e., rumination) as a covariate predictor, since it may be a mediator rather than a confounder (VanderWeele & Vansteeland, 2009). In fact, this was hypothesized for rumination and mindfulness (Bishop et al., 2004; Shapiro et al., 2006). Later mediation studies supported this hypothesis since increased mindfulness decreased distress partly through decreasing rumination (Borders, Earleywine, & Jajodia, 2010; Coffey & Hartmann, 2008) and consistent evidence supports that MBIs work partly through decreasing rumination or repetitive negative thinking (Gu et al., 2015). Oppositely, if a variable lies before a theoretical predictor of mindfulness or attentiveness, associations between e.g., attentiveness and the outcome should be controlled for the influence of this variable. For example, age is related to biological, psychological and social health parameters, including attentional functions. Age cannot be placed on the causal pathway between e.g., attention and health (after all, people do not grow older as a function of their attention). Rather, age affects a multitude of parameters, including aspects of attention and mental health (for a review on MBIs and

[11] This unflattering statistic was even calculated *after* excluding 432 studies of MBIs for healthy samples with no control group or too poor methodology to be reviewed (Sedlmeier et al., 2012).

aging: Gard, Hölzel, & Lazar, 2014). Thus, aging may be a common cause for variations in both attention and health variables. In this case, the confounding role of age should thus be examined.

1.4.2 A paucity of theory-driven research

A major challenge for the evidence-based development of MBIs has been the paucity of theory-driven research and interventions. Non-specific factors are an Achilles' heel for MBI research to the same degree that researchers are unable to explain or define the methods being applied, e.g., the theoretical rationale, the specific techniques trained in an MBI, and the consequential predictions. The most thorough available review of effects of MBIs for healthy participants summarized that:

> "The vast majority of the studies reviewed below say little or nothing about why and how meditation should work. In short, meditation research has been conducted in a more or less atheoretical manner" (Sedlmeier et al., 2012, p. 1140).

This critique has been voiced for four decades. Leading meditation researcher Deane Shapiro stated in a speech in 1976 before the American Association for the Advancement of Science:

> "One of the primary weaknesses in meditation studies thus far has been the lack of a clear theoretical rationale between the independent variable [meditation] and the selection of the dependent variable [the study outcomes]. " (Shapiro & Giber, 1984, p. 66).

As mentioned, anecdotal "theories" are abundant, since the majority of MBIs are based on religious traditions encompassing enormous amounts of literature, subjective accounts, and different schools of ideas from millennia of writings (Harvey, Watkins, Mansell, & Shafran, 2004; Klostermaier, 2006; Sedlmeier et al., 2012). It is then difficult to form a coherent theory, which is in cohesion with the meditative "tradition" – since there *is* no single, theoretical tradition. To solve this, some researchers advocate for a stronger collaboration between academic meditation researchers and meditative-religious experts (Grabovac et al., 2011; Loizzo, 2014).

All in all, the fields of meditation research and mental health research require more thorough investigations of MBIs to make real progress (Sedlmeier et al., 2012). It is beyond the aim of the present thesis to develop a theory of mechanisms of change for MBIs. However, I aimed for methodological rigorousness to potentially add new knowledge and contribute to future theories.

Chapter 2

The Present Studies

Chapter 2. The Present Studies

In this chapter, I depict the designs, main aims and hypotheses, participants, and procedures of the studies. Methods, including the interventions, the outcomes, and the analyses, are outlined in Chapter 3. All these aspects of the studies are described in more detail in Appendices I-III.

2.1 Study designs

2.1.1 Design of Study 1

Study 1 was an RCT comparing attentional, stress-physiological, and self-report effects of MBSR with such effects of a non-mindfulness stress reduction program (NMSR), an inactive control group financially motivated at the post-treatment attentional test session, termed the incentive control group (INCO), and an inactive control group receiving no intervention, termed the non-incentive control group (NOCO). Before randomization, the four groups were balanced on age, gender, and scores on five major personality trait scales. I was blinded to participants' group status and collected all data within three weeks prior to and two weeks after the intervention period. The design including three such control groups had not previously been applied in meditation research.

2.1.2 Design of Study 2

Study 2 involved two cross-sectional surveys, both including a follow-up, and aimed to validate the Danish translation of the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). Part 1 of the study examined psychometric properties of MAAS scores in a randomly invited community sample. Part 2 investigated the short-term retest reliability of MAAS scores in healthy psychology students using a test-retest interval of two weeks. Part 3 re-invited the initial community sample for a follow-up study of the long-term test-retest reliability of MAAS scores after a six-month interval.

2.1.3 Design of Study 3

Study 3 was an RCT evaluating attentional, stress-physiological, and self-report effects of the Open and Calm (OC) MBI designed for adults with prolonged psychosocial stress. The RCT compared the following three age- and gender-matched groups: OC in group-format (OC-G), OC in individual format (OC-I), and a treatment-as-usual (TAU) control group. Baseline data were collected before randomization under double-blind conditions and post-treatment data were collected within 2 weeks after the intervention period by researchers blinded to participant status. Follow-up 3 months after the intervention included online self-report questionnaires completed by participants at home. Participants were not contacted during the follow-up period itself.

2.2 Main aims and hypotheses

The evidence-based or theoretical background for the aims and hypotheses is described in Appendices I-III. A full list of abbreviations is found on page 9—10 of the present thesis.

2.2.1 Main aims of Study 1

1) *Specificity of attentional effects of an MBI.* We aimed to test whether MBSR improved theoretically relevant attentional functions to a significantly larger degree than NMSR, INCO, and NOCO, respectively.
2) *Specificity of stress reduction effects.* We aimed to evaluate the specificity of MBI-related stress reduction effects by comparing MBSR, NMSR, and the collapsed inactive controls (CICO)[12] on physiological stress reduction (CAR) and reduction of perceived stress (PSS).
3) *Inattentiveness and compliance as mechanisms of change.* On exploratory grounds, we aimed to examine whether outcome changes in the MBSR group were related to pre-post changes in perceived inattentiveness (MAAS) or with compliance with the MBSR practices.

2.2.2 Main aims of Study 2

1) *Psychometric validation of the Danish translation of the MAAS.* We overall set out to validate the Danish translation of the MAAS with respect to the MAAS scores' factor structure, internal reliability and consistency, convergent validity, incremental validity, and short-term as well as long-term test-retest reliability.
2) *General inattentiveness as a psychological trait.* We aimed to investigate whether general inattentiveness, as measured by MAAS scores, might be interpreted as a reflection of a relatively stable psychological trait or disposition over long periods of time. This has been hypothesized for scores on the MAAS when reported outside attentional training contexts, but this had not previously been investigated for MAAS scores produced by adults.
3) *The MAAS as a predictor for mental health variables.* We aimed to test whether the MAAS scores predicted psychological distress scores and mental health scores, respectively, after control for SES indicators (education, income, occupational SES), and other relevant confounders. Previous MAAS studies have seldom controlled for validated SES indicators.

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[12] We aimed to compare the intervention groups to CICO (rather than NOCO and INCO) since the financial incentive was only theoretically relevant for the attentional performance scores. The financial incentive was therefore given after collecting self-report data and saliva cortisol, and therefore did not affect these data.

2.2.3 Main aims of Study 3

1) *Program formats*. We aimed to evaluate whether OC in individual format (OC-I) was as effective as OC in group-format (OC-G). This was important for any future public implementation. In addition, it would add knowledge on effects of social support in MBIs.
2) *Program efficacy.* We aimed to evaluate whether OC (or one of its formats) was recommendable for public implementation by comparing OC to a group of healthy adults with prolonged stress receiving treatment as usual (TAU) in the local public health sector.
3) *Visual perception and MBIs.* We aimed to re-examine promising findings from Study 1 on seemingly MBSR-specific improvements of the threshold for visual perception (TVA t_0) in a more stressed and demographically broader sample, and using a different MBI paradigm.
4) *Program applicability for a broad demographic group.* Since we aimed to develop an evidence-based, standardized MBI for implementation in the public health sector, we finally aimed to evaluate whether OC showed a broad demographic applicability.

2.2.4 Main hypotheses of Study 1

1) *Specificity of attentional effects of an MBI.* Due to theoretical predictions and empirical studies, we hypothesized that the MBSR group would improve sustained attention. We did not predict that MBSR would improve more than the NMSR or INCO groups, since this had not been studied, but hypothesized that MBSR would improve more than the NOCO group. We also hypothesized that MBSR might specifically improve the perceptual threshold (t_0), based on anecdotal evidence and a few empirical studies. Finally, we expected that perceptual outcomes not based on RTs might be less confounded by attentional effort.
2) *Specificity of stress reduction effects.* Since previous evidence on MBIs and active control groups was mixed, we did not state hypotheses on the comparison of stress outcomes (PSS, CAR) in MBSR versus NMSR groups. However, we expected the intervention groups to show significantly larger stress reduction effects than the inactive control group (CICO).

2.2.5 Main hypotheses of Study 2

1) *Psychometric properties of the Danish version of the MAAS.* We expected that the Danish translation of the MAAS, in line with other translations, would demonstrate a unifactorial structure and satisfactory internal reliability and consistency. For the convergent validity tests, we predicted on empirical grounds that the MAAS scores would be negatively related to scores reflecting psychological distress (BSI-53-GSI), avoidance (AAQ-II; TCI-HA),

symptoms of depression (MDI), and perceived stress (PSS), and, conversely, that MAAS scores would be positively related to scores reflecting mindfulness (FFMQ), emotional intelligence (TMMS), self-regulation abilities (TCI-SD), and physical health (SF-36-PCS)[13].

2) *General inattentiveness as a psychological trait.* We hypothesized on theoretical grounds that the MAAS scores would show satisfactory (*rho* > .70) long-term test-retest reliability over a six-month interval, but this had not been tested in adults. On similar grounds, we expected that MAAS scores would show a significantly stronger long-term test-retest reliability coefficient than for distress scores (BSI-18-GSI), but this had also not been tested.
3) *The MAAS as a predictor for mental health variables.* Due to previous studies, we expected that MAAS scores would continue to predict psychological distress scores (BSI-53-GSI), and mental health scores (SF-36-MCS) after controlling for potential confounders.

2.2.6 Main hypotheses of Study 3

1) *Program formats*. Since many types of MBIs seem equally effective, we predicted that OC-I and OC-G would not show significantly different treatment effects.
2) *Program efficacy.* For our primary outcome analyses, we expected a decrease in PSS scores and in the magnitude of cortisol secretion (AUC_G) of significantly larger magnitudes in the OC intervention group than in the TAU control group. Concerning secondary effect measures, we predicted that the OC participants would show significantly larger improvements than the TAU controls on depression scores (MDI), sleep disturbances scores (PSQI), quality of life scores (QOL-5), and mental health scores (SF-36-MCS).
3) *Visual perception and MBIs.* Based on Study 1, anecdotal and limited empirical evidence, we predicted that the OC group would show significantly larger improvement on the threshold for conscious visual perception (t_0) than the TAU control group.
4) *Program applicability for a broad demographic group.* Due to the careful design of OC for a broad demographic group (Appendix III), we presumed that age, gender, and education would not systematically influence long-term (baseline-follow-up) self-report changes.

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[13] AAQ-II = Acceptance and Action Questionnaire-II (Bond et al., 2011); BSI-53-GSI = Brief Symptom Inventory-53 General Severity Index (Derogatis & Melisaratos, 1983); MDI = Major Depression Inventory (Beck et al., 2001); SF-36-PCS/MCS = Short-Form Health Survey-36 Physical Component Summary/Mental Component Summary (Bjørner et al., 1997; Ware & Sherbourne, 1992); TCI-HA/SD = Temperament and Character Inventory-Harm Avoidance/Self-Directedness (Cloninger, Przybeck, & Svrakic, 1994); TMMS = Trait Meta-Mood Scale (Salovey et al., 1995).

Chapter 3

Participants

Chapter 3. Participants

I here describe recruitment and participants. All studies were approved by the Danish Ethics Committee and the Data Protection Agency. Participants always signed informed consent.

3.1 Recruitment and participants in Study 1

Participants were recruited through oral presentations and posters at the University of Copenhagen. Figure 1 illustrates the participant flow. Table 1 displays demographic data. Screening for age, health, and experience with meditation (regular meditation experience was not allowed) resulted in 60 eligible persons. All men (n = 18) were included, and the inclusion of 30 women was randomized. Three additional women were randomly selected, baseline tested, and included on a waitlist for quick inclusion in the case of early dropouts. Three groups of n = 16 balanced for age, sex, marital status, education, and perceived stress (PSS), and all five subscales on the NEO Personality Inventory–Revised (Costa & McCrae, 1992) were created and randomly assigned to one of three groups: collapsed inactive controls (CICO), NMSR, or MBSR. Groups were randomized with a ratio of 1:1:1 using www.random.org. CICO was randomly split before the posttest by a researcher with no participant contact (S. G. Hasselbalch). *Incentive controls* (INCO; n = 8) were offered a financial bonus of ≈ $50 (300 Danish Crowns) if they could "improve" (not defined to them) compared with baseline. I collected all data blinded to participants' group status within three weeks prior to and two weeks after the intervention period.

3.2. Recruitment and participants in Study 2

Statistics Denmark randomly selected a sample of 3025 persons balanced for gender, year of birth, and zip code within the City of Copenhagen. Three consecutive letters were sent (102 addresses proved outdated), inviting citizens fluent in Danish and not currently diagnosed or treated for psychiatric illness to participate during the month of May 2012 in the *Copenhagen Health Survey* at the Copenhagen University Hospital. A total of 572 citizens (19.6%) completed a 70-item screening questionnaire on a secure website. Among these, we excluded n = 22 due to problematic alcohol use (Alcohol Use Disorders Identification Test score > 20) or recreational drug use (> 24 times per year). We also excluded persons who did not complete all questionnaires (n = 60), which did not change results significantly. The final sample comprised 490 healthy participants. Table 1 summarizes descriptive characteristics. Highly educated (professional educations >4 years) and high-income citizens were overrepresented while citizens with shorter educations or low income were underrepresented compared to the local population at the time (Statistics Denmark, 2011a, b).

3.3. Recruitment and participants in Study 3

We recruited participants through 20 General Practitioners (GP) and an online medical recruitment company (Medicollect). Figure 2 shows participant flow and retest rates. Participants were stressed, but otherwise healthy. Table 1 shows demographic data. Participants were well educated compared with the Copenhagen adult population at the time (see Appendix III; Statistics Denmark, 2014). The majority (92%) had never meditated regularly (defined as > 2 times / week for > 1 month). The primary inclusion criteria were the age 18 – 59 years, fluency in Danish, and subjective report of reduced daily functioning due to prolonged (> 1 month) stress, which I evaluated qualitatively in a 1-hr personal interview with each person. Main exclusion criteria were current treatment for any illness; >1 diagnosed or treated ICD-10 mood disorder (F30-39) or somatoform (F45) disorder within three years; Hamilton Depression Rating Scale score > 20 at the inclusion interview (these and other criteria ensured that participants experienced stress-related problems, but were not suffering from psychiatric disorders); recreational drug use > 24 times per year or > 50 times in the lifetime, and medication use that might markedly affect the brain or cortisol. Inclusion or exclusion decisions were in complex cases discussed by a research team (V. Frokjaer, S. G. Hasselbalch, and C. G. Jensen). Stratifying for age and gender, a researcher with no participant contact (S. G. Hasselbalch) block-randomized three consecutively enrolled cohorts of $n = 24$ to intervention in individual format (OC-I), group-format (OC-G), or treatment as usual (TAU), involving e.g., extra GP visits, or stress leave. Groups were randomized with a ratio of 1:1:1 using www.random.org. An *a priori* power calculation in G-power (Faul, Erdfelder, Lang, & Buchner, 2007) revealed a required $N = 54$ (power = .95, three groups, three measurements [pre, post, follow-up], expected effect $f = 0.25$, sphericity correction = 1). Expecting 15-30% dropout (Ospina et al., 2007), $N = 72$ were recruited.

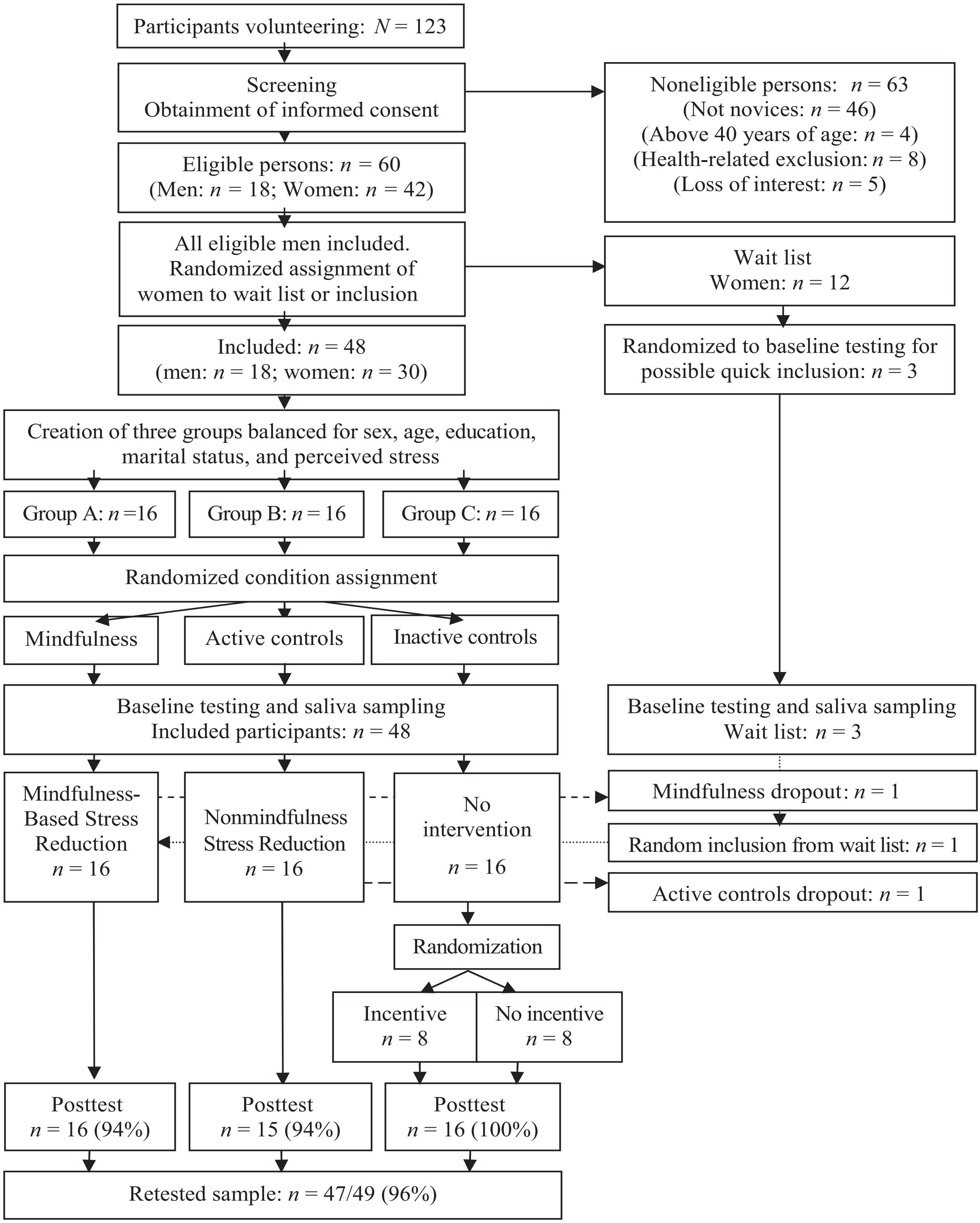

Figure 1. Participant flow in Study 1. One MBSR participant was hospitalized after 8 days, so a random participant was included from the wait list. After 22 days, one person from NMSR left the study due to illness, but no replacement was included this late in the study.

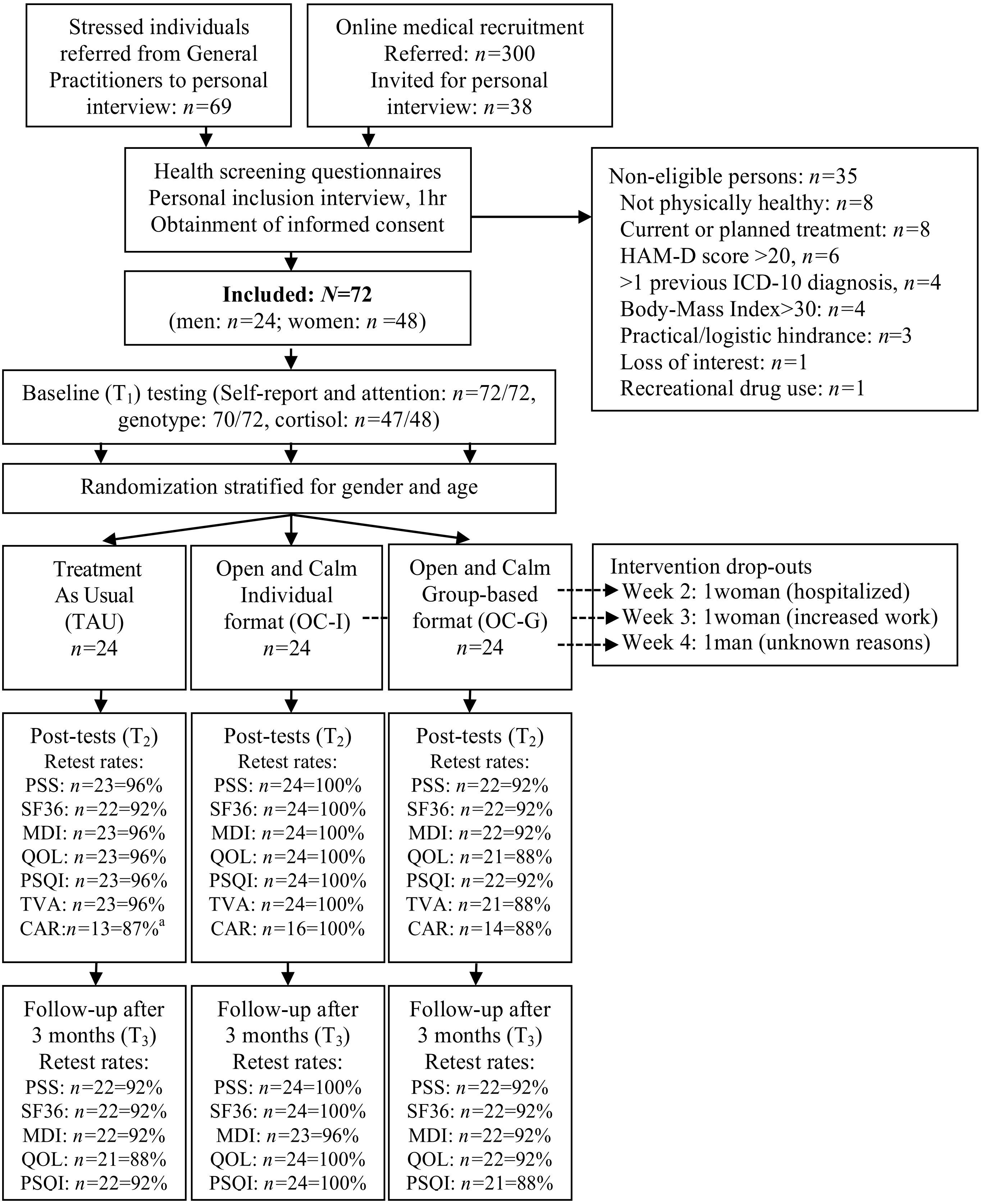

Figure 2. Participant flow in Study 3.[a].The retest ratio is 87% (n = 13/15) since only 15 cortisol sets from TAU participants were received before randomization. For an explanation of abbreviations: see the initial "List of abbreviations" on page 10 in the present thesis.

3.4. Participants across the three studies

The present studies involved seven samples of healthy adults. Age means spanned 22—42 years and age ranges spanned 18—59 years (Table 1). Participants in Study 1 and Study 2 were highly educated, while participants in Study 3 were more representative of the Danish population with respect to professional education. All samples included an overweight of women (63—87%).

The present findings should therefore not be generalized to the total population. For example, the elderly population was not investigated. Similarly, citizens with no professional education were heavily underrepresented (e.g., Study 1: 0.0%; Study 2/community baseline sample: 2.7%; Study 2/student baseline sample: 0.0%; Study 3: 8.3%). Scores on the perceived stress scale (PSS) were similar to the Danish mean (M) in Study 1 (M = 13.05) and Study 2 (M = 12.45) (Danish population [N>21,000] M = 11.0; Stigsdotter et al., 2010). As intended, the PSS mean was substantially higher in Study 3 (M = 18.57). A post hoc test revealed a large difference between the PSS mean score in Study 3 compared with and the Danish norm, Cohen's d=1.28 (Table 1). The mean PSS in Study 3 was also above the 80th percentile on the Copenhagen distribution of PSS scores (80th PSS percentile in Copenhagen [N >35,000] = 16.0; Hilding-Nørkjær, 2009).

Table 1. Participants in the three studies.

Study	Sample type	*N*	Gender	Age (years)			Education[a]		PSS		MAAS	
			% women	mean	(*SD*)	range	mean	(*SD*)	mean	(*SD*)	mean	(*SD*)
Study 1	University students	48	62.50	24.08	(3.94)	20—36	4.18	(0.28)	13.05	(6.07)	4.01[b]	(0.68)[b]
Study 2	Community sample	490	66.67	35.44	(9.89)	18—53	4.46	(1.05)	12.45	(5.75)	4.28	(0.68)
	Retest community	407	65.60	36.29	(9.55)	18—53	4.52	(0.93)	12.11	(6.04)	4.34	(0.70)
	University students	119	84.03	22.34	(3.73)	19—43	4.06	(0.24)	9.00[c]	(2.82)	4.15	(0.65)
	Retest students	100	87.00	22.25	(3.84)	19—43	4.04	(0.20)	9.01[c]	(2.79)	4.16	(0.66)
Study 3	Healthy stressed adults	72	65.28	42.24	(8.91)	18—59	3.44	(1.36)	18.57	(2.83)	3.76	(0.67)

Notes. [a]. Professional education on a scale from 1—5 (1: no professional education; 2: 0—1.99 years; 3: 2—2.99 years; 4: 3—3.99 years; 5: ≥ 4 years), where ongoing educations were scored as completed (e.g., bachelor students in Study 2 were scored as “4”). [b]. The MAAS scale used in Study 1 was not the final, validated version used in Study 2 and Study 3, since several adjustments were made in the translation and back-translation process in collaboration with Kirk Brown in Study 2. Thus, MAAS scores from Study 1 should be interpreted with caution. [c]. A 4-item version of Cohen’s Perceived Stress Scale (PSS; Cohen & Williamson, 1988) was applied, so the university students’ PSS scores are not comparable to the full 10-item scale. *SD* = Standard Deviation. MAAS = Mindful Attention Awareness Scale (Brown & Ryan, 2003).

Chapter 4

Methods

Chapter 4. Methods

4.1 Applied interventions

Mindfulness-Based Stress Reduction (MBSR). In Study 1, a licensed psychologist and experienced mindfulness instructor (Tine Norup) implemented a standard MBSR program as described by Jon Kabat-Zinn (1990). MBSR is an 8-week program involving weekly meetings of 2.5 hrs. to develop mindfulness skills and stress coping, as well as formal meditations (45 min /day) following CDs with guided meditation practices, and informal mindfulness practices (15 min/day) to be carried out during other, daily activities. An intensive 7-hr meditation retreat was held during the sixth week.

Non-Mindfulness Stress Reduction (NMSR). In Study 1, a licensed psychomotrician (Bodil Hjorth) implemented a Non-Mindfulness Stress Reduction (NMSR) program designed to resemble MBSR, but without MM practices and training in a non-judgmental attitude. Guided bodily relaxations were carried out, but instructions were deliberately based on suggestions, such as "Imagine how the muscles in your calves are relaxing…". This is contrary to MBSR, in which the instructions are more open and generally non-suggestive, such as "Notice how your legs are in this moment—whether they are heavy or light. Just notice how they are, and let it be okay". The NMSR course was structurally similar to MBSR with eight 2.5-hr weekly courses and equal amounts of formal (following a CD) and informal assignments.

The Open and Calm Program. The OC program is inspired by the Relaxation Response Resiliency-program (Park et al., 2013), and by mindfulness meditation (Wallace, 2010), and is formally termed Relaxation Response-based Mental Health Promotion (RR-MHP). OC practices focused on training *Open* (defined as "relaxed and receptive") *attention* and *Calm* (defined as "allowing" or "non-intervening") processing". This was theoretically inspired by the two main technical elements across many meditative traditions, often referred to as *focused attention* and *open monitoring*, respectively (Lutz et al., 2008; Benson & Proctor, 2010), which are paralleled by two main types of yogic techniques termed *dharana* and *dhyana*, respectively (Telles, Naveen, & Balkrishna, 2010). The course structure was modeled on a bio-psycho-social theory of stress, focusing each week on the body, the mind (thoughts and emotions), or social relationships. Two standardized 9-week OC programs were offered: A group format (OC-G) involving weekly 2.5-hr group sessions and two optional 1.5-hr personal sessions; and an individual format (OC-I) involving personal, weekly 1.5-

hr sessions. Formats involved identical course materials (Jensen, 2013) and home assignments (e.g., 1—2 daily meditations of 10—20 min following audio files, frequent daily *mini-meditations* of 1-3 min, and a few daily written notes on e.g., bodily sensations). I instructed all OC groups as well as individual courses.

4.2 Outcomes of the studies

I here present attentional, self-reported, and physiological outcomes. Table 2 provides an overview of the application of these variables as outcomes or covariates across the three studies.

4.2.1 Cognitive tasks

Study 1 applied five attention tasks (DART, STAN, Stroop, the d2 Test, and a TVA-based test) in randomized order. Study 3 applied a modified TVA-test and two tasks under validation (the Verbal Affective Memory Task [VAMT; Jensen et al., *in press*); and the Affective Priming Task [APT] in a fixed order (VAMT, TVA, APT). We pre-specified in the trial protocol[14] that the TVA-t_0 parameter would be analyzed, while the VAMT and APT tests were included to develop these tests[15]. Hence, APT and VAMT results are not reported upon here.

4.2.1.1 Dual Attention to Response Task (DART)

DART (Dockree et al., 2006) is developed from the Sustained Attention to Response Task (Robertson et al., 1997). DART measures sustained attention and attentional set shifting. Both of these attentional functions were predicted to improve after MM (Bishop et al., 2004). DART displays white and grey digits from 1—9 and participants were instructed to monitor the digit color, pressing *1* after white digits and *2* after gray digits but to always withhold the response after the digit *3*. Our first outcome was the *RT coefficient of variation* (CV) *for white digits* (white digits standard deviation [*SD*]/white digits mean RT), an indicator of overall DART performance (Dockree et al., 2006). The second outcome was *RT on gray digits*, a measure of attentional set shifting (Dockree et al., 2006). Since response speed variability presents many advantages to raw RT (Van Breukelen et al., 1995), such as reduced confounding by practice effects (Flehmig,

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[14] ClinicalTrials.gov ID: NCT02140307.

[15] The APT was based on the APT constructed by Bem (2011). The tests were developed in collaboration between Neurobiology Research Unit, Copenhagen University Hospital, the Cognitive Neuroscience Research Unit, Århus University, and the Centre for Visual Cognition, Copenhagen University.

Steinborn, Langner, Anja, & Westhoff, 2007), we also analyzed the gray-digit RT after transforming them into a *gray-digit CV*.

4.2.1.2 The d2 Test of Attention (d2 Test)

The d2 Test (Brickenkamp, 2002; Brickenkamp & Zillmer, 1998) is a paper-and-pencil cancelation task measuring sustained and selective attention. These attentional abilities were predicted to be improved by MM (Bishop et al., 2004). The d2 Test also showed superior selective attention in meditators compared with controls (Moore & Malinowski, 2009). The psychometric properties of the d2 Test have been well supported (Bates & Lemay, 2004).

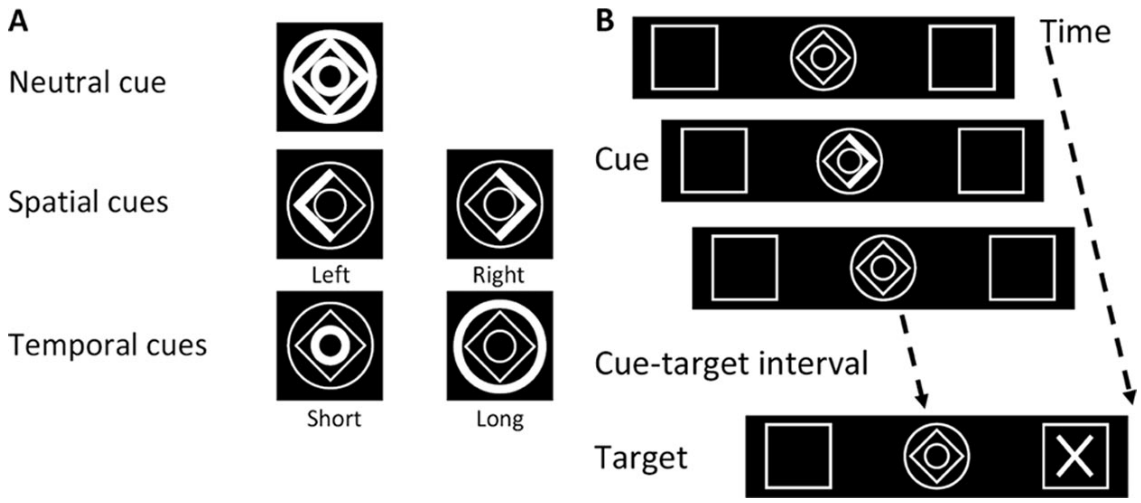
The d2 sheet contains 14 lines of letters. The task is to cross out target *d*s with two dashes in their proximity, which are interspaced with distractor *d*s. The time limit per line is 20 s. Based on the d2 manual, we chose three outcomes which we hypothesized to be most sensitive in this young, healthy sample: (1) the *total error rate* (E; commissions and omissions); (2) the *error percentage* (E%, calculated as E/TN×100, where TN represents the total number of processed items); and, (3) the *error distribution* (ED), defined as the error sums for three test sections (lines 1–5, lines 5–10, and lines 11–14, respectively).

4.2.1.3 Spatial and Temporal Attention Network task (STAN)

STAN (Coull & Nobre, 1998) is modeled on the classic "flanker task" (Posner, Snyder, & Davidson, 1980) used for testing spatial orienting. STAN has been validated in health adults (Coull, 2009). Centrally, while other orienting tasks measures only spatial orienting (i.e., spatial orientation and control of attention), STAN also measures *temporal* attentional orientation. Temporal orienting is recruited "particularly [when] directing attention toward a particular moment in time" (Coull & Nobre, 1998, p. 7434). In MBSR, returning attention to the present moment is a cardinal point.

We defined two primary outcomes. The first was *RT after invalidly cued short temporal trials*. This represented the RT in trials where a temporal cue indicated a long (1,500 ms) cue–target interval (CTI), when the target in fact appeared after a short (750 ms) CTI. This outcome indicated how quickly a participant was able to return attention to the present moment and react at an unexpected point in time. The second outcome was the *RTs after uninformative cues* (neutral cues, Figure 3). This RT mean reflected the ability to stay alert in the absence of information and is a common baseline or control condition in sustained attention tasks. To expand our investigation of the resistance of CV-based outcomes to attentional effort, we also analyzed the *neutral trials CV*. We tested the functionality of the STAN task by examining, across groups, the disadvantage of invalid cues compared with neutral cues, and the advantage of valid cues compared with neutral cues and invalid cues, respectively, as in the original studies (Coull, 2009; Coull & Nobre, 1998).

Figure 3. Cue types and a trial type in the Spatial and Temporal Attention Network task



A. Cue types used in the spatial and temporal attention network task (STAN) to direct attention to a particular location or stimulus-onset time. The neutral cue does not provide spatial or temporal information. Spatial cues direct attention to the left or right. Temporal cues direct attention to a short or long cue–target interval (CTI). *B*. A valid spatial trial, directing the participant's attention to the right location, with no information about the CTI. Adapted from Coull & Nobre (1998, p. 7427). Copyright 1998 by the Society for Neuroscience (permission to reprint was obtained for Study 3 [Appendix III] of the present thesis).

4.2.1.4 Stroop Color–Word Task

Stroop Color-Word tasks (Stroop, 1935) exist in many varieties, representing a widely used test paradigm regarded as a measure of selective attention, cognitive flexibility and control (MacLeod, 1991, 2005). Since these are central abilities in mindfulness, Stroop paradigms were specifically proposed as relevant for measuring specific effects of MM (Bishop et al., 2004). The applied version of the Stroop paradigm presented two blocks of 100 color words (*red, blue, yellow,* or *green*, in Danish) printed in red, blue, yellow, or green ink and arranged in a 10 × 10 word matrix on two separate pieces of paper. The first block presented congruent color-words (e.g., "*green*" in green ink) whereas the second block presented incongruent color-words (e.g., "*red*" in green ink).

Participants were asked to state the ink color as fast as possible while avoiding mistakes. Our primary outcome was the *incongruent block error rate*. This outcome was chosen because it is difficult to detect changes in Stroop response speed in healthy samples due to floor effects (MacLeod, 2005), and because MM had been proposed to improve especially the inhibition process in the incongruent Stroop condition (Bishop et al., 2004). We corroborated the test's functionality by examining block RTs (in s), predicting significantly slower completion of incongruent blocks than congruent blocks, the well-known Stroop interference effect.

4.2.1.5 Theory of Visual Attention-based tests

The computational Theory of Visual Attention (TVA; Bundesen, 1990) quantifies functions of visual attention using accuracy-based testing and is thus unspeeded and unconfounded by motor components. This particular advantage of TVA-based tests was important since RTs are heavily influenced by the task incentive, or the attentional effort (Sarter et al., 2006).

The TVA-test applied in Study 1 was based on the paradigm described by Vangkilde, Bundesen, & Coull (2011) and comprised nine test blocks of 36 trials and took 40 min to complete. Trials were initiated by a fixation cross and the stimulus display presented six letters chosen randomly without replacement from a set of 20 letters on a black background with six possible locations on an imaginary circle (r = 7.5 degrees of visual angle). The participant could then type in the letter(s) that he or she had seen. In whole report trials, either two or six red target letters were presented, while partial report trials contained two red target letters and four blue letters. Displays with six red target letters were shown for each of six stimulus durations (10, 20, 50, 80, 140, or 200 ms). Other displays were shown for 80 ms. Participants were to make an unspeeded report of all red letters they were "fairly certain" of having seen (they were instructed to use all available information but refrain from pure guessing and aim for an accuracy of 80—90%). The number of correctly reported letters in each trial constituted the main dependent variable based on which the TVA-outcomes were calculated. The TVA-performance was computationally modeled using a maximum likelihood fitting procedure (Kyllingsbæk, 2006, Dyrholm, Kyllingsbæk, Espeseth, & Bundesen, 2011) to derive estimates of four attentional parameters: First is t_0, the threshold of conscious perception, defined as the longest ineffective exposure duration measured in milliseconds below which the participant has not consciously perceived, and therefore cannot report, any letters. Second is K, the maximum capacity of visual working memory measured in number of letters. Third is C, the speed of visual processing measured in letters processed per second. Fourth is alpha, α, the top-down controlled selectivity, defined as the ratio between the attentional weight of a target (correctly reported red letters) and the attentional weight of a distractor (blue letters).

In Study 3, we used a different TVA-based test. This test was still based on the methods described by Vangkilde et al. (2011), but comprised two (rather than one) practice blocks and three (rather than nine) test blocks of 30 (rather than 36) trials presenting six red letters on a black background. The letter display durations were varied systematically (10 – 200 ms), and terminated by pattern masks (500 ms) before participants made an unspeeded report using identical methods as in Study 1. Parameters α and W were not supported as meditation-specific in Study 1. In addition, the test did not allow for a calculation of α since we used a full-report test including only red letters. Thus, three parameters were extracted by mathematical modeling (Dyrholm et al., 2011): K, C, and t_0. We pre-specified in the trial protocol that t_0 was our only TVA-based outcome.

4.2.2 Primary self-report outcomes

4.2.2.1 Mindful Attention Awareness Scale (MAAS)

The MAAS (Brown & Ryan, 2003) is widely used as a reversed indicator of mindfulness, since it quantifies the degree of mindfulness through 15 items inquiring about the estimated[16] frequency of experiences of being inattentive towards ongoing activities, emotions, bodily sensations, thoughts, and other persons. The MAAS was chosen as a measure of mindfulness in Study 1 since everyday attentional instability was an interesting parallel to the attention tests. Study 2 represented the first Danish validation studies of the MAAS (hence, Appendix II thoroughly presents the MAAS). Study 3 examined whether baseline MAAS scores were related to treatment effects. The focus on (in)attentiveness is important for meditation research (see Section 1.3). The Scores on the MAAS were internally consistent in all studies, all Cronbach's alphas (αs*)* ≥ .83.

4.2.2.2 Cohen's Perceived Stress Scale (PSS)

A 10-item version of the PSS (Cohen & Williamson, 1988) was used in all studies to evaluate perceived stress. Based on the past two weeks, participants evaluate to which degree environmental demands exceeded their resources, affected their thoughts or emotions, their abilities to relax or to

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[16] It is somewhat paradoxical to ask participants to report upon the frequency of small periods of time during which they did *not* pay attention. See Appendix II as well as Van Dam, Earleywine, & Borders, (2010) for a discussion of this inherent issue with the MAAS.

concentrate, or to cope with their situation. Thus, PSS generally measures stress indirectly based on experiences of different stress symptoms[17]. PSS scores were always internally consistent, $\alpha s \geq .82$.[18]

4.2.2.3 Brief Symptom Inventory-53 (BSI-53)

The BSI-53 (Derogatis & Melisaratos, 1983; Olsen, Mortensen & Bech, 2004, 2006) was applied in Study 2 to measure a broad range of psychological symptoms through 53 items. Items were rated on a 5-point Likert scale from 0 (*none*) to 4 (*extreme*), based on the recollection of the last week (e.g., to what degree have you been affected by "Trouble falling asleep" or "Fear of leaving your home alone"). We investigated the *Brief-Symptom Inventory-53-Global Severity Index* (BSI-53-GSI), which indexes the global severity of mental distress as a mean of all items. The well-validated BSI-53-GSI scores were internally highly consistent, $\alpha = .96$. In Part 3 of Study 2, we also applied the Brief Symptom Inventory-18 (BSI-18, Derogatis, 2001), a short version of BSI-53 incorporating 18 items. We again investigated the General Severity Index (BSI-18-GSI), which is comparable to the BSI-53-GSI in absolute values (since the GSI is a mean score), and the two are strongly correlated ($r > .90$; Derogatis, 2001). BSI-18-GSI scores were internally consistent, $\alpha = .89$.

4.2.2.4 Short-Form Health Survey-36 Mental Component Summary (SF-36-MCS)

The SF-36 was used in Study 2 and Study 3 in the standard 4-week recall version (SF-36; Ware & Sherbourne, 1992; Ware et al., 1993). SF-36 has been validated for Danish use (Bjorner, Damsgaard, Watt, & Groenvold, 1998; Bjorner, Thunedborg, Kristensen, Modvig, & Bech, 1998) and measures eight health dimensions: 1) physical function, 2) physical role limitations, 3) bodily pain, 4) general health, 5) emotional function, 6) vitality, 7) emotional role limitations, and 8) mental health. Each dimension is scored from 0 (*poor health*) to 100 (*best possible health*). The *Mental Component Summary* score (SF-36-MCS) was the main outcome in both studies and was based on weighting of all dimensions (Bjørner et al., 1997). The internal consistency estimates (Cronbach's alpha) of SF-36-MCS scores were calculated after item recalibration as specified in the Danish manual (Bjørner et al., 1997) and were always satisfactory, $\alpha s \geq .71$.

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[17] Item 3 in the 10-item PSS asks participants directly how often they have felt 'nervous or stressed'. Item 3 loaded satisfactorily on the PSS total score ($r \geq .48$; Cohen & Williamson, 1988, p. 45).
[18] Study 2 also used a 4-item PSS (PSS-4; Cohen & Williamson, 1988). PSS-4 scores yielded αs of .55—.65. However, α is decreased by a lower number of items and PSS-4 was not a central measure in Study 2.

4.2.3 Secondary self-report outcomes

In Study 3, we applied three secondary self-report outcomes in validated Danish versions. First, we used the 5-items *Quality of Life* (QOL-5) developed by the World Health Organization (WHO) to assess quality of life through positive affect and vitality. On the Danish QOL-5, scores < 50 indicate risk for depression (Folker & Folker, 2008). QOL-5 scores were internally consistent, αs > .81.

Major Depression Inventory (MDI; Bech et al., 2001) applies 12 items to generate self-reported ratings of the frequency of the ten ICD-10 depressive symptoms during the past two weeks (0 = *not at all*; 5 = *all of the time*). The total MDI score was investigated. Scores on the MDI were always internally consistent, αs > .83.

Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) indexes sleep disturbances during the past month via 19 items. On the examined "PSQI Global", scores > 5 indicate increased risk for depression (Buysse et al., 1989). PSQI scores showed slightly low internal consistency at baseline (T_1; α = .61), while the internal consistency was satisfactory at post-treatment (T_2; α = .77) and nearly satisfactory at follow-up (T_3), α = .69.

4.2.4 Physiological outcomes

In Study 1 and Study 3, we measured two stress-physiological outcomes related to the cortisol awakening response (CAR), which reflects hypothalamic–pituitary–adrenal (HPA) axis activity (Fekedulegn et al., 2007). We used identical data collection methods in the two studies. After written and verbal instructions and training, participants performed home-samplings of saliva in Salivette tubes (Sarstedt, Neubringen, Germany). Sample 1 was taken immediately upon awakening, and samples 2–5 every 15 min for the subsequent hour. Participants registered the time of awakening and of each sampling. Samples were centrifuged and stored within 48 hrs. at –80 degrees Celsius. The entire batch of samples for each study was analyzed in one step using electrochemiluminescent immunoassay (Cobas equipment, Roche, Germany). Our two outcomes were the *Area Under the Curve with respect to ground* (AUC_G)[19], representing the total magnitude of cortisol secretion; and the *Area Under the Curve with respect to increase from awakening levels* (AUC_I), reflecting the HPA axis' cortisol response to awakening (Fekedulegn et al., 2007).

[19] AUC_G (and not AUC_I) was specified as the primary outcome in the Study 3 protocol (Table 2).

Table 2. Main outcomes in the three studies.

Test	Measure(s)	Study 1[1]	Study 2	Study 3
Attention tests				
DART	*CV* for white digits	Outcome	-	-
	Mean RT on gray digits	Outcome		
	CV for gray digits	Outcome		
The d2-test	Error_rate	Outcome	-	-
STAN	Mean RT after invalid cues	Outcome	-	-
	RT after neutral cues	Outcome		
Stroop Color-Word test	Incongruent error_rate	Outcome	-	-
TVA-based test	Visual threshold, t_0	Outcome	-	Secondary outcome
	Short-term memory capacity, *K*	Outcome	-	Exploratory outcome
	Speed of processing, *C*	Outcome	-	Exploratory outcome
	Selectivity, α	Outcome	-	-
Self-report scales				
MAAS	Mean of all items	Outcome	Central measure for validation; Predictor	Baseline covariate
PSS	Total sum of all items	Outcome	Convergent validity variable	Primary outcome
MDI	Total sum of all items	-	Convergent validity variable	Secondary outcome
SF-36	SF-36-MCS	-	Dependent variable in SEM	Secondary outcome
BSI-53	General Severity Index	-	Dependent variable in SEM	-
PSQI	Total sum of all items	-	-	Secondary outcome
Physiology				
CAR	AUG_G	Outcome	-	Primary outcome
	AUC_I	Outcome	-	Secondary outcome

Notes. AUC_G = Area Under Curve with respect to Ground. AUC_I = Area Under Curve with respect to Increase. BSI-53 = Brief Symptom Inventory-53. CAR = Cortisol Awakening Response. *CV* = Coefficient of Variation. DART = Dual Attention to Response Task. MAAS = Mindful Attention Awareness Scale. MDI = Major Depression Inventory. PSQI = Pittsburgh Sleep Quality Index. PSS = Perceived Stress Scale. RT = Reaction Time. SEM = Structural Equation Modeling. SF-36(-MCS) = Short Form health survey-36(-Mental Component Summary). STAN = Spatial and Temporal Attention Network task. TVA = Theory of Visual Attention. [1]. We did not specify primary and secondary outcomes in Study 1, since so few active control group studies of MBIs and attention had been conducted.

4.3 Statistical methods

4.3.1 Statistical methods in Study 1

We used a predefined series of comparisons: On attention tests, MBSR was first compared with NOCO and INCO, respectively. If this did not yield significant group differences, MBSR was compared to the collapsed inactive controls (CICO). Finally, MBSR was compared with NMSR. Although orthogonal comparisons are preferable, they are no longer considered as crucial as once was the case (Howell, 2007). Group differences in changes on single outcomes were evaluated in mixed model analyses of variance (ANOVAs) using Time (pre/post) as the within-subject variable and Group (e.g., MBSR/NMSR) as the between-subjects variable. We applied Bonferroni-correction for the total number of tests carried out on each outcome. Effect sizes for Time × Group interactions were estimated with omega squared, Ω^2. We were able to calculate cortisol scores for 162/188 potential scores (86%; 47 × 2 time points × 2 CAR outcomes). Statistical analyses were carried out in SPSS (*vs*. 18.0), and effect sizes were calculated in Microsoft Excel 2007.

4.3.2 Statistical methods Study 2

Study 2 contained three parts. Part 1 was a cross-sectional survey including 490 healthy adults. Part 2 was a short-term test-retest reliability study with 119 healthy students. Part 3 was a six-month follow-up on Part 1 to examine the long-term test-retest reliability of the MAAS scores and included 407 healthy adults.

In Part 1, the unifactorial model fit of the MAAS scores was examined with confirmatory factor analysis (CFA). We treated data categorically and applied the weighted least square means and variance adjusted (WLSMV) estimator, as recommended with the present sample size (Brown, 2006). We evaluated model fits with four metrics: the chi square test (χ^2), the Steiger-Lind root mean square error of approximation (RMSEA; < 0.08 = acceptable fit, < 0.05 = good fit), the Bentler Comparative Fit Index (CFI), and the Tucker-Lewis fit Index (TFI) (for CFI and TFI values > 0.90 indicated acceptable fits, while values > 0.95 indicated good fits; Schreiber, Nora, Stage, Barlow, & King, 2006).

The internal consistency of the MAAS scores was evaluated with the composite reliability (CR), Cronbach's alpha (α), and corrected item-total correlations. The CR (in contrast to Cronbach's α) takes item-scale complexity into account since it estimates the internal reliability as the composite of the items while adjusting for the standardized loadings and the measurement errors of each item (α and CR values > 0.70 were deemed satisfactory).

The incremental validity of the MAAS scores was tested in two structural equation models (SEM) with psychological distress (BSI-53-GSI) and mental health (SF-36-MCS) scores as outcomes. We screened for demographic, socioeconomic, and life style covariates (Appendix II[20]) in marginal correlations using bootstrapping (10,000 samplings) and $p < .05$ as a variable inclusion criterion (using $p < .01$ and fewer samplings yielded similar results) and adjusted the two SEM analyses accordingly. We report effect sizes with beta and β (standardized beta). Convergent validity was examined in eight Bonferroni-corrected correlations. CFA and SEM models were computed in MPlus (version 7); other analyses in SPSS (version 20). All data points were included.

In Part 2 of Study 2, we examined Cronbach's α for scores on the MAAS and a 4-item PSS-scale (PSS-4) at T_1 and T_2. The test-retest reliability of the MAAS scores was evaluated primarily with the intraclass correlation coefficient (ICC) using two two-way random models for group means and individual scores, respectively. Absolute test-retest reliability is more important than correlational test-retest reliability when investigating a hypothesized trait, but for comparison with other studies, we also conducted a zero-order Spearman's ϱ test-retest correlation bootstrapped with 10,000 samplings (ICC and $\varrho \geq .70$ = satisfactory, > .80 = good, and > .90 = excellent).

In Part 3 of Study 2, we evaluated the MAAS scores' absolute long-term test-retest reliability. We again applied the ICC in two two-way random absolute agreement models for means and individual participants' MAAS scores, respectively, as well as a secondary test-retest correlation (ϱ) bootstrapped with 10,000 permutations. Furthermore, we cross-validated test-retest reliability estimates within genders and median-split groups of age, professional education (≤ 4 years, > 4 years), income (50% highest, 50% lowest), and ISCO-88 (≤ 4, > 4). Most importantly, to investigate if the degree of general inattentiveness was a more reliable trait than psychological distress, we calculated BSI-18-GSI for the T_1 (May) data (results were similar when using the full BSI-53-GSI as T_1 data) and examined whether bootstrapped test-retest correlations for scores on the MAAS and the BSI-18-GSI scores, respectively, differed significantly according to Steiger's z-test (Steiger, 1980) using peer-reviewed SPSS syntax for this purpose (Weaver & Wuensch, 2013).

[20] For example: age, gender, income, marital status, body-mass index, perceived culture, Severe Life Events (SLE; Kendler et al., 1995), Marlowe-Crowne Social Desirability index (MCSD; Crowne & Marlowe, 1960) and occupational SES according to the International Standard Classification of Occupations-88 (ISCO-88; Statistics Denmark, 1996) scored by two independent raters (inter-rater reliability, ϱ = .90).

4.3.3 Statistical methods Study 3

We always used Intent-To-Treat (ITT) analyses, replacing missing T_2 or T_3 scores with T_1 or T_2 scores, respectively. Treatment effect analyses were adjusted for covariates (age, gender, education, TCI-SD, TCI-HA, T_1-MAAS score, 5-HTTLPR-type) related to ($p < .05$) outcome changes within groups (using $p < .01$ as a criterion for selecting covariates did not change any results significantly). All *p*-values were Bonferroni-Holm-corrected for the number of tests within each outcome type (self-report/cortisol/attention). OC format was not expected to affect intervention effects (Brown, Cochrane, Mack, Leung, & Hancox, 1998; Main, Elliot, & Brown, 2005; Virgili, 2013), but this was investigated in an initial OC-I *vs*. OC-G comparison. If formats did not differ ($p < .05$), the collapsed OC was compared to controls. If formats *did* differ, each format was to be compared to TAU in turn. Group differences in outcome changes were investigated in two-way repeated measures ANCOVAs using Time ($T_1/T_2/T_3$) and Group (e.g., OC/TAU) as independent variables. A multivariate analysis of variance (MANOVA) examined whether gender, age (median split), or education (3 *df*) affected long-term (T_1—T_3) changes across self-report scales in OC. Effects were expressed with Cohen's *d* (group differences and pre-post within group effects were adjusted ad modum Morris & Deshon, 2002; formula 8), Pearson's *r* or Spearman's *rho* (ϱ) (variable associations), or partial eta-squared, η_p^2, (Time × Group effects). Excluding scores > 3.0 *SD* from group means (< 2% in all analyses) yielded similar results. MDI and PSQI data were skewed and $\log^{10}$-transformed, yielding normal distributions. AUC_G and PSS were primary outcomes. AUC_G, SF-36-MCS, MDI, QOL, PSQI, and t_0 were secondary outcomes. Analyses were carried out in SPSS (version 20.0) and Microsoft Excel 2011.

Chapter 5

Results

Chapter 5. Results

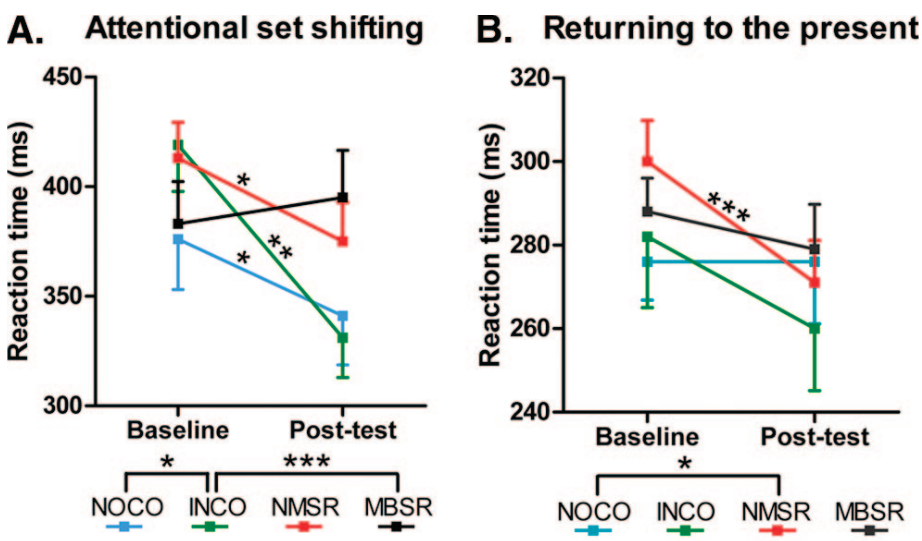
This chapter outlines the main findings of the studies. Additional results, figures, tables, and explanatory text, are presented in the original papers (Appendices I—III).

5.1 Main findings – Study 1

5.1.1 Reaction-time based results

The MBSR group did not show any improvements that differed significantly from improvements within NMSR or INCO on RT-based outcomes in the DART and STAN tasks. In fact, the incentive control group, INCO, showed significantly larger RT improvements than the MBSR participants on gray digit trials in DART, indicating that increasing the test motivation had a significantly larger beneficial effect than MBSR in trials requiring participants to respond according to a new set of rules (perform a mental set shift and react accordingly). Effects of MBSR on RT-based measures of sustained, spatial, and temporal attention could thus not be distinguished from non-specific stress reduction effects (NMSR) or effects of an increased task incentive (INCO), as illustrated in Figure 4.

Figure 4. Attentional outcomes confounded by attentional effort and non-specific stress reduction.



Notes. * $p < .05$. ** $p < .01$.*** $p < .001$ (two-tailed, uncorrected). Time × Group interactions are indicated below each panel. ***A.*** Gray-digit trials in the DART task, measuring attentional set shifts. INCO improved significantly more than MBSR. *B*. Invalidly cued, short temporal trials in the STAN task, measuring the ability to reorient attention to the present moment. NMSR (not MBSR) improved significantly, and significantly more than NOCO. Error bars indicate one standard error of the mean.

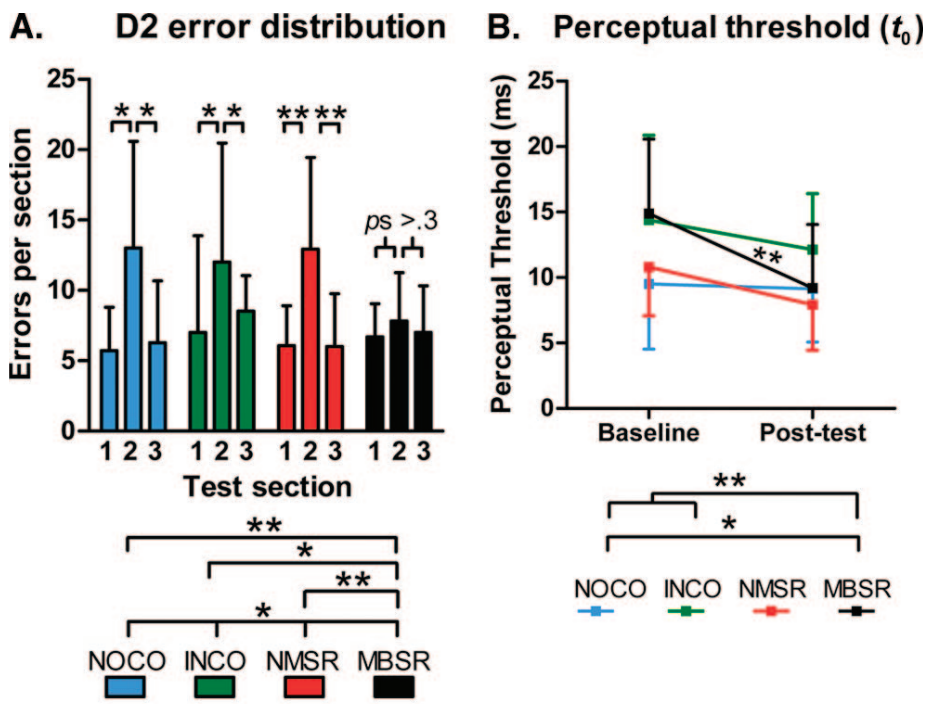
5.1.2 Lowered error rates during sustained selective attention

In the d2 Test of Attention, the post-treatment error distribution for MBSR differed significantly from that in all other groups, since MBSR did not show increased error rates during the middle section of the d2 Test, but actually approached a significant decrease, $p = .07$. Importantly, the error increment in the middle section of the d2 Test was present in all groups at baseline, especially in the MBSR group, $p < .01$. Whereas the NOCO, INCO, and NMSR groups all increased the error rate from the first to the second section (ps < .02) and decreased from the second to the third test section (ps < 05), MBSR did not change between any sections at T_2, ps ≥ .32. We interpret this as an MBSR-induced attenuation of a tiring effect evident in all the other groups. The d2 results therefore support that sustained, selective attention may be specifically improved after MBSR independent of non-specific effects of stress reduction and also independent from the perceived task incentive of the participants. To our knowledge, this has never been shown before. However, d2 changes were not related to MBSR compliance. Figure 5 displays seemingly MBSR-specific attentional changes.

5.1.3 Lowered threshold for conscious visual perception

As the only group in Study 1, MBSR showed a significant improvement of the TVA-based measure of the threshold for conscious visual perception, t_0. This indicated faster encoding of visual information into conscious, short-term memory, i.e., an ability to identify material presented for shorter durations. Further, the perceptual degree of improvement within MBSR was related to self-reported improvement in mindfulness as measured by the MAAS, indicating that stronger perceptual improvements were related to larger decreases in self-reported inattentiveness. The latter finding was strengthened by a post hoc test revealing a significant association between higher levels of mindfulness (lower degrees of inattentiveness on the MAAS) and lower perceptual thresholds across groups at T_1, $r = -.40$, $p = .005$. This indicated that faster visual perception was related to fewer experiences of inattentiveness in everyday life. However, while the t_0 improvement in MBSR was significantly larger than t_0-changes in the non-incentive controls (NOCO), and also, as revealed by an exploratory test, from the collapsed inactive controls (CICO) – it did not differ significantly from t_0-changes in INCO or from changes in the active stress reduction group, NMSR, ps > .15. Similarly, t_0-changes in MBSR were not related to MBSR compliance.

Figure 5. Attentional outcomes affected especially by MBSR.



Notes. Section × Group interactions at the post-treatment test session (A) or Time × Group interactions (B) *A*. Distribution of errors in the d2 Test. MBSR did not show a significant error increase during the middle test section. *B*. Pre–post changes in the perceptual threshold, t_0. Only MBSR participants improved significantly, and to a significantly larger degree than the combined inactive control group. * $p < .05$. ** $p < .01$ (two-tailed, uncorrected). Error bars indicate one standard error of the mean.

5.2 Main findings – Study 2

5.2.1 Factor structure and internal reliability of the MAAS

The unifactorial model of the MAAS scores with one first-order latent factor was supported in our factor analyses, as evidenced by good CFI and TLI, and borderline acceptable RMSEA (Table 3). The internal composite reliability was excellent, $CR = 0.91$. The internal consistency was good and nearly excellent, $\alpha = .88$. The unifactorial structure, the internal consistency, and the internal reliability of participants' MAAS scores on the present Danish translation were therefore supported.

Table 3. Unifactorial model fit indexes of the Danish version of the Mindful Attention Awareness Scale (MAAS)

	Chi Square (df)	RMSEA	(90% CI)	CFI	TLI
CFA model without modifications	433 (90)	0.088	(0.080-0.097)	0.959	0.952
CFA model with modifications[a]	332 (89)	0.075	(0.066-0.083)	0.971	0.966
SEM model on BSI-53-GSI	392 (193)	0.046	(0.039-0.052)	0.978	0.976
SEM model on SF-36-MH	419 (208)	0.045	(0.039-0.052)	0.977	0.974

Notes. CFI=Bentler comparative fit index. RMSEA= Root mean square error of approximation. TLI= Tucker-Lewis fit index. [a]. This model allowed for a cross-loading between items 7 and 8.

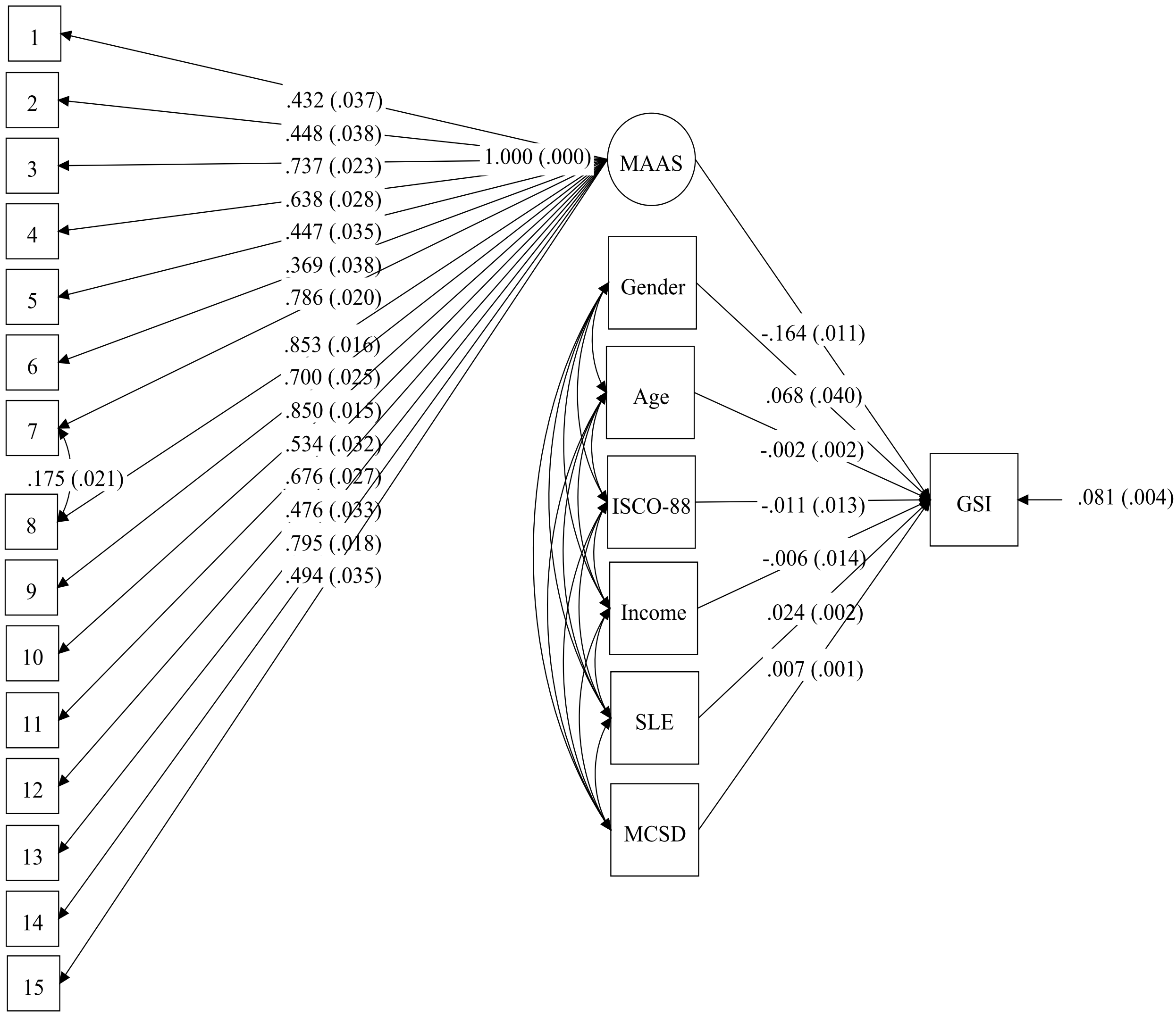
5.2.2 Convergent validity

All our predictions concerning positive and negative correlations between scores on the MAAS and on other self-report scales were supported. The MAAS scores were negatively associated with scores of perceived stress (PSS), depressive symptoms (MDI), avoidant personality (TCI-HA), and experiential avoidance (AAQ-II). Conversely, MAAS scores were positively related with scores reflecting a broader conceptualization of mindfulness (FFMQ), emotional intelligence (TMMS), personality self-directedness (TCI-SD), and physical health (SF-36-PCS). The convergent validity of the MAAS scores in the present Danish translation was therefore supported (Appendix II).

5.2.2 Incremental validity

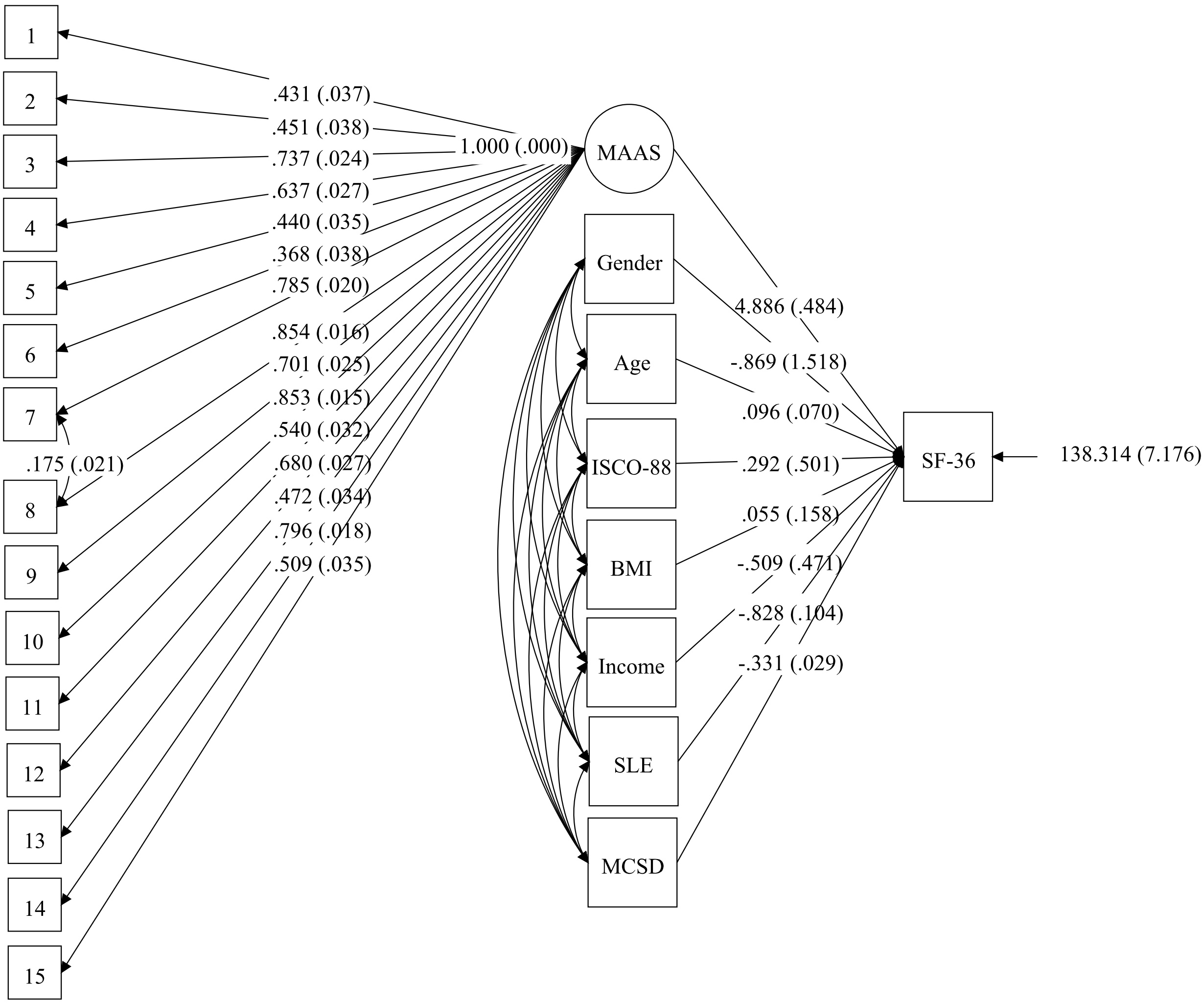
After controlling for effects of gender, age, occupational SES (ISCO-88), SLE, and MSCD, scores on the MAAS still predicted significant variance in psychological distress as quantified by BSI-53-GSI scores, *beta* = -.16 (95% CI [-.19, -.143], $\beta = -.42$, $p < .001$. The SEM model investigating MAAS scores as a predictor of psychological health scores included the same covariates and also BMI, and similarly showed that the MAAS scores contributed independently to predicting SF-36-MCS scores, *beta* = 4.89 (95% CI [3.94, 5.84]) $\beta = 0.32$, $p < .001$. Both SEM results were replicated separately for men and women (data not shown). Exploratory models also controlling for the personality factors TCI-HA and TCI-SD showed similar results although effect sizes were attenuated (Appendix II). Higher inattentiveness, as measured by the MAAS scores, was thus supported as a significant, independent predictor of higher psychological distress as well as an independent predictor of lower psychological health. Figures 6 and 7 display the SEM results.

Figure 6. Structural equation modeling of MAAS scores as a predictor for psychological distress scores



Notes. GSI = Brief Symptom Inventory-53-General Severity Index. ISCO-88 = International Standard Classification of Occupations-88; Income = self-reported income during the previous year; MAAS = Mindful Attention Awareness Scale; MCSD = Marlowe-Crowne Social Desirability; SLE = stressful life events. A cross-loading between item 7 and item 8 was allowed for in the model (see text). The final model revealed that the MAAS scores predicted significant variance in BSI-53-GSI scores after controlling for the six potential confounders, beta = -.16 (95% CI [-.19, -.14], β = -.42, p < .001.

Figure 7. Structural equation modeling of MAAS scores as a predictor for mental health scores



Notes. SF-36 = Short Form Health Survey-36 Mental Component Summary score (in the text referred to as SF-36-MCS); ISCO-88 = International Standard Classification of Occupations-88; Income = self-reported income during the previous year; MAAS = Mindful Attention Awareness Scale; MCSD = Marlowe-Crowne Social Desirability; SLE = stressful life events. A cross-loading between item 7 and item 8 was allowed for in the model (see text). The final model revealed that the MAAS scores predicted significant variance in SF-36-MCS scores after controlling for the seven potential confounders, beta = 4.89 (95% CI [3.94, 5.84]) $\beta = 0.32$, $p < .001$.

5.3 Main findings – Study 3

5.3.1 Compliance and professional contact hours

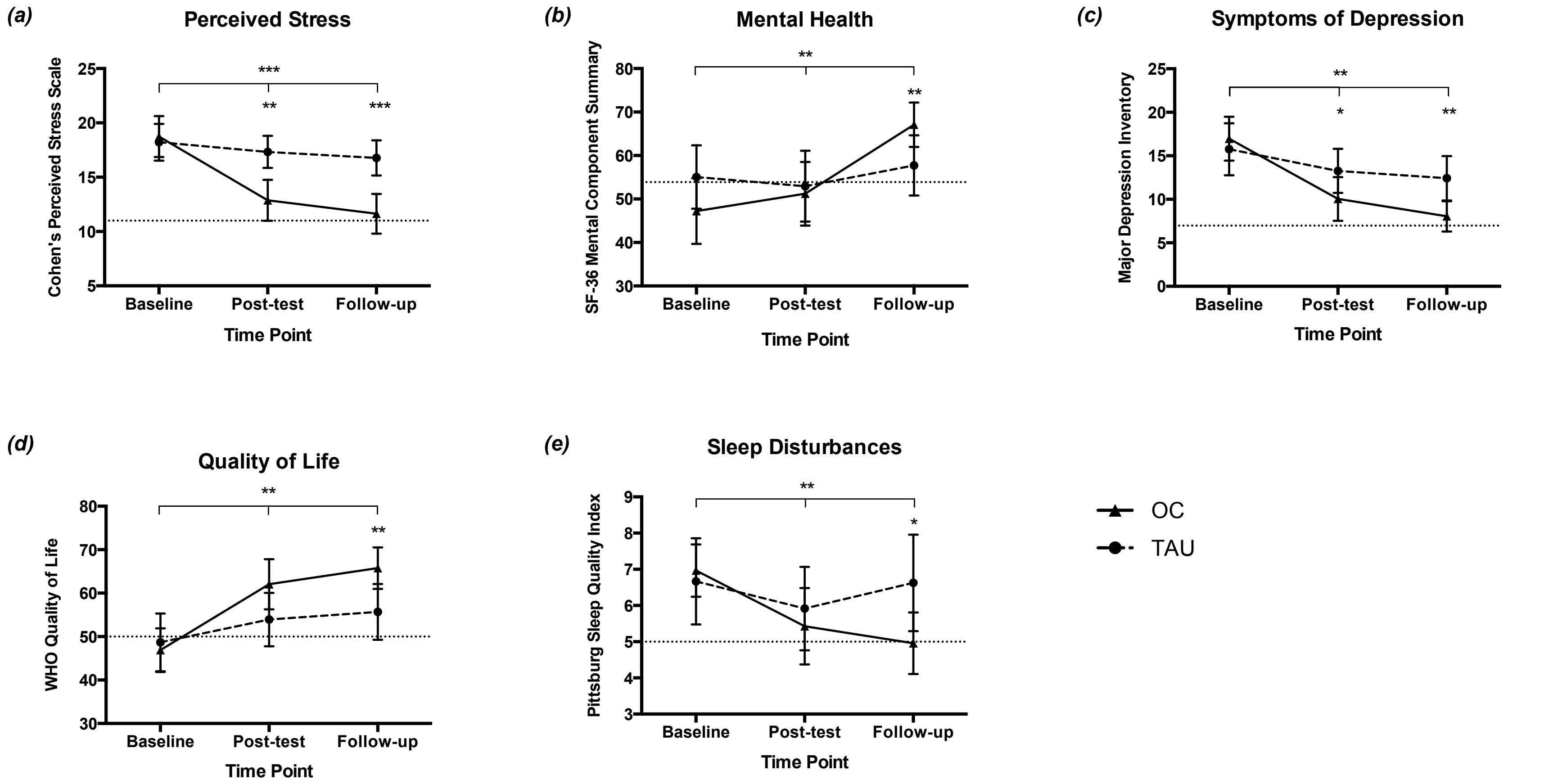
OC had a 94% (n = 45/48) completion rate, i.e., only a 6% dropout rate. Group participants (OC-G) attended significantly more sessions (M = 8.3, SD = 2.7) than participants in the individual program format (OC-I: M = 6.7, SD = 2.0), p = .020. OC-I involved on average 2.6 times more professional contact hours per participant (M = 10.0 hrs., SD = 3.0) than OC-G (M = 3.9 hrs., SD = 1.7). Session attendance rates were unrelated to outcome change scores unless otherwise is stated.

5.3.2 Self-report outcomes

As hypothesized, the two OC formats displayed similar changes on all self-report outcomes, ps > .1 (uncorrected; see Supplementary panel 1 in Appendix III). This indicated that the two formats of OC were equally effective, although the OC-I format involved more contact hours, as mentioned. The total intervention group (OC) improved significantly more on all self-report outcomes than the TAU control group, ps < .01 (Bonferroni-Holm corrected and adjusted for relevant covariates). Figure 8 displays group comparisons on changes in self-report outcomes. As seen, the OC group decreased to the Danish population mean on perceived stress (PSS), while the TAU group continued to report higher PSS scores throughout the six-month study period. (Table 1 of Appendix III displays the full self-report data and group comparisons at T_1, T_2, and T_3.

Importantly, all self-report effects were sustained or significantly improved during the 3-month follow-up period. Further, OC differed significantly from TAU controls on all scales at follow-up, corrected ps < .02. The MANOVA showed no effect of age, gender, or education across T_1-T_3 self-report effects among OC participants, p > .24. This indicated that these demographic variables did not systematically influence long-term self-report changes within the OC group.

Figure 8. Group comparisons on self-report outcomes in Study 3.



Notes. *p < .05. **p < .01. ***p < .001. p-values are two-tailed, corrected for ten comparisons (Bonferroni-Holm), and based on intent-to-treat-analyses (Open and Calm [OC] $N = 48$. Treatment As Usual [TAU] $N = 24$) after adjustment for relevant biological, socioeconomic, and psychological trait variables. Asterisks (*) above horizontal lines represent p-values of Time × Group effects, while asterisks or p-values above error bars represent p-values of between-group comparisons (Appendix III). Error bars represent 95% CI of the mean. (*a*). The dotted line represent the mean among a national region-stratified random sample of >21,000 Danish adults (Stigsdotter et al., 2010). (*b)* The dotted line represents the age-adjusted Danish norm for the SF36-Mental Health Component (Bjørner et al., 1997) (*c*). The dotted line represents the Danish norm (Olsen et al., 2004). *(d)* Scores below the dotted line represent a risk marker for depression (Folker & Folker, 2008). As seen, the 95%CI still contains this cut-off for TAU, but not for OC. *(e)* Scores above the dotted line represent a risk marker for depression (Buysse et al., 1989). TAU remains at increased risk at all time points. Specifically, 67% of OC and 63% of TAU were at increased risk at baseline. At follow-up, this was still found for 63% of TAU, but only 35% of OC.

5.3.3 Physiological stress markers

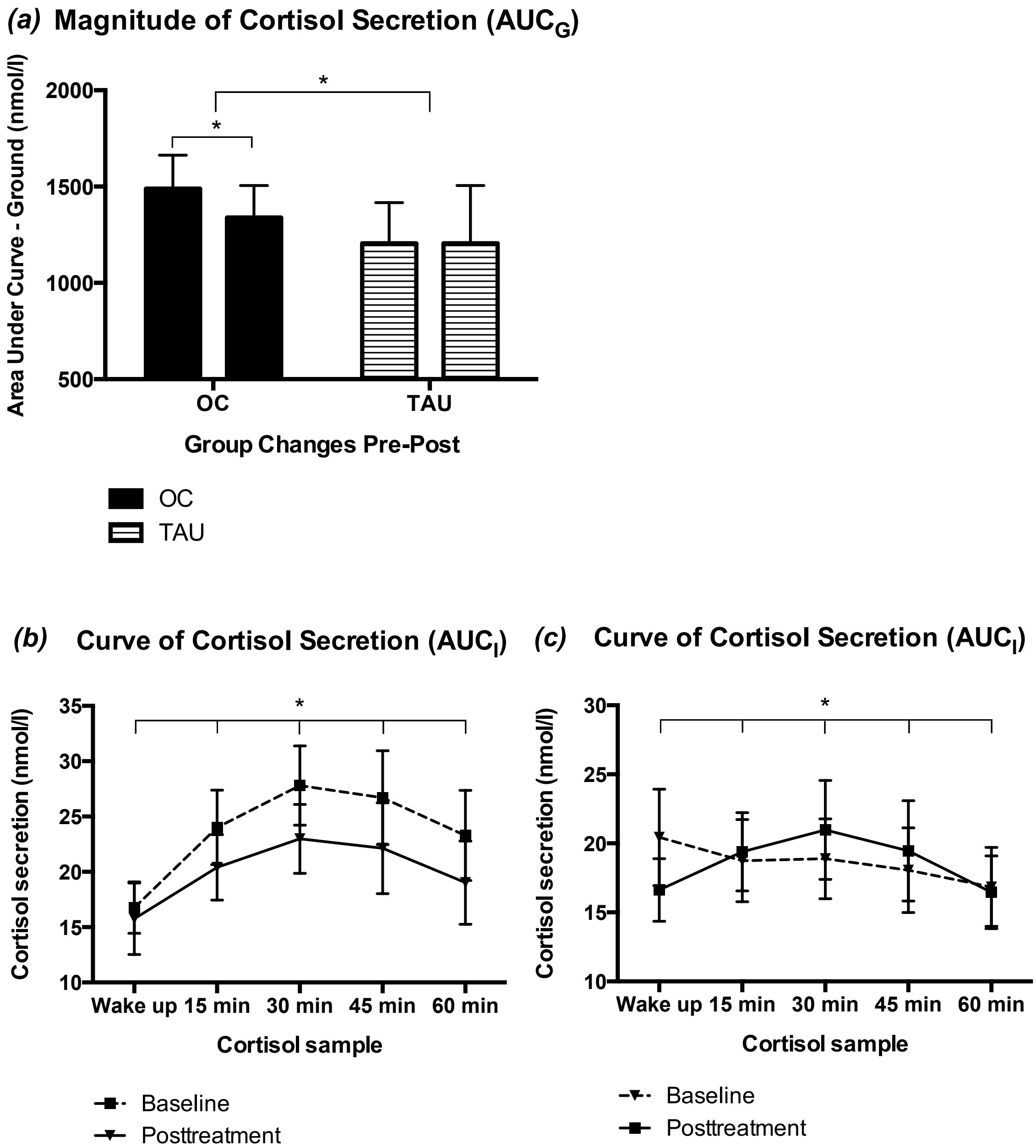
Groups did not differ on cortisol outcomes at baseline (Supplementary Table 2 in Appendix III displays the descriptive data). For participants with a non-blunted T_1 CAR, the OC group decreased significantly more than controls on AUC_G, also after controlling for baseline AUC_G, $F(1,28) = 4.35$, $p < .05$, $\eta^2 = .17$ (Figure 9). Group changes for AUC_I did not differ. Within groups, only OC decreased significantly on AUC_G ($p = .018$, $d = -0.59$) as well as on AUC_I, $p = .018$, $d = -0.76$.

In the visual inspections of individual CAR plots by two independent researchers blinded to participant status, we identified blunted baseline CAR for $n = 18$ in the OC group, but only $n = 2$ in TAU. Group comparisons for participants with blunted baseline AUC_I were therefore not meaningful. As we presumed based on studies showing exhaustion of HPA-axis reactivity to stimulation after long-term stress, CAR-blunted OC participants showed a significantly *increased* AUC_I after the intervention, $p = .015$, $d = 0.88$ (Figure 9). This significant change suggested a healthy reestablishment of HPA-axis reactivity to awakening.

5.3.4 Visual Attention

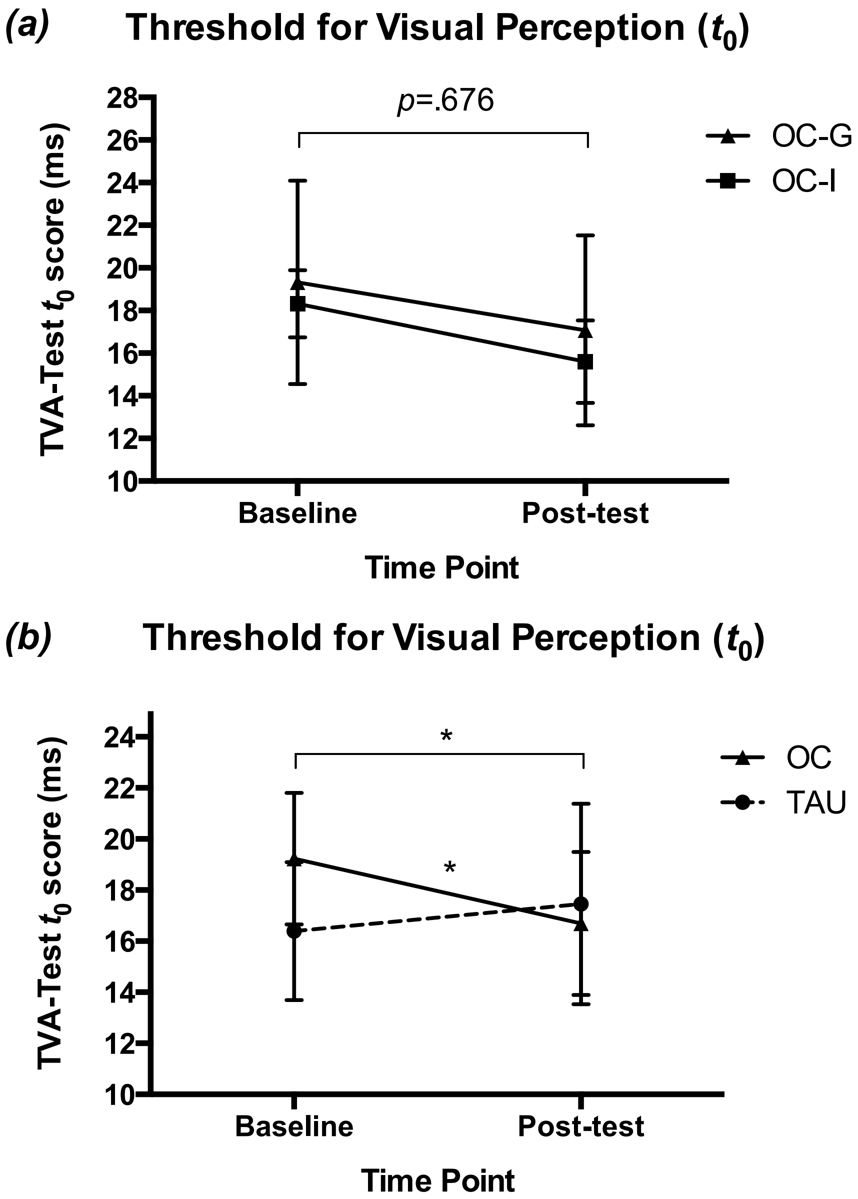
OC format (OC-G/OC-I) did not affect changes in the threshold for conscious visual perception, t_0, $p > .6$. The total OC group improved significantly more than controls on t_0, $p < .05$, $\eta^2 = .056$ (Figure 10). OC improved significantly, TAU controls did not show significant change on t_0 (Supplementary Table 2 in Appendix III displays the descriptive data). A post hoc ANCOVA controlling for t_0 at baseline still supported a significant Time × Group interaction ($p = .054$) with a virtually unchanged effect size, $\eta^2 = .054$. Concerning associations with OC compliance, higher OC attendance rates were indicative of larger t_0 improvement, $\varrho = -.33$, $p = .023$. The exploratory analyses of visual short-term memory capacity, K, and processing speed, C, showed no significant treatment effects, *p*s>.2 (uncorrected). These findings on TVA-based outcomes therefore supported that MBIs may affect especially the threshold for visual perception and that this effect is independent of the MBI format (Figure 10a).

Figure 9. Group comparisons on changes in cortisol secretion upon awakening.



Notes. **p* < .05 (two-tailed, based on ITT-analyses, and adjusted for relevant covariates; see Appendix III). Error bars represent 95% CI of the mean. *(a)* AUC_G for participants with normal (non-blunted) baseline cortisol awakening response (CAR): Open and Calm (OC) n = 15, Treatment As Usual (TAU) n = 13. (*b)* AUC_I decreased significantly for OC participants with a non-blunted baseline CAR, n = 15. *(c)* AUC_I increased significantly for OC participants with blunted baseline CAR, n = 18.

Figure 10. Group comparisons on changes in the threshold for visual perception



Notes. *.p < .05. Asterisks (*) above horizontal lines represent p-values of Time × Group effects (two-tailed, based on ITT analyses, and adjusted for covariates associated with t_0 change-scores; Appendix III). *(a)*. Pre-post t_0-changes in the two intervention formats (OC-G = Open and Calm - Group format; OC-I = Open and Calm - Individual format) were very similar. *(b)*. The collapsed OC group improved significantly more than the TAU controls. Error bars represent 95% CI of the mean.

Chapter 6

Discussion

Chapter 6. Discussion

The overall endeavor of this thesis was to investigate relations between MBIs for stress reduction for healthy samples, behavioral and self-reported measures of attention, and physiological or self-reported markers of stress and mental health. In this chapter I summarize and discuss the three studies' implications. More detailed discussions of each study are found in Appendices I-III.

6.1 Main implications of Study 1

Findings from Study 1 were provocative. On five different tests of human attention, we overall could not distinguish effects of Mindfulness-Based Stress Reduction (MBSR), a Non-mindfulness Stress Reduction Program (NMSR), and the financially increased task motivation in the Incentive Controls (INCO), while all of these groups improved significantly more than the Non-incentive Controls (NOCO) on one or more attentional outcomes. The take-home message was, therefore, that MBSR did not seem to affect most subsystems of human attention above and beyond effects of non-specific stress reduction or the perceived task incentive. Study 1 thereby raised an important critique of previous studies of MBIs and attention. I will unfold this critique shortly.

However, Study 1 also identified two non-reaction time-based outcomes that did seem to indicate MBSR-specific effects, namely the threshold for conscious visual perception, t_0, and the error distribution (ED) in the d2 Test, reflecting the ability to maintain an effective selective focus over time in a context of distractors. These results warranted further studies. Physiologically, Study 1 showed that MBSR reduced the total magnitude of cortisol secretion (AUC_G) significantly more than the collapsed inactive control group (CICO). MBSR did not improve any cortisol measures (*p*s > .4) or PSS (*p* > .07) more than NMSR. On physiological and perceived stress, we could thus not distinguish effects of MBSR from effects of a non-meditation-based stress reduction program.

6.2 Main implications of Study 2

Study 2 produced four major conclusions: First, the MAAS scores showed satisfactory test-retest reliability across the yearly seasons, even on an individual absolute level. This supports that a general proclivity to be inattentive towards the present moment constitutes a relatively stable psychological disposition or a "trait" outside meditation or attention training, as originally hypothesized for the MAAS (Brown & Ryan, 2003, p. 838). Second, our SEM analyses supported that the MAAS means continued to predict scores on well-established scales of psychological distress and mental health, respectively, after controlling for a range of potential confounders. This implicates that the degree of inattentiveness may explain unique variance in mental health variables. Third, we demonstrated good short-term test-retest reliability for the MAAS scores produced by healthy university students. This is relevant for e.g., experimental meditation research, which is often carried out with students over short time spans. Fourth, scores on the Danish translation of the MAAS confirmed to our psychometric expectations with respect to a unifactorial structure, high internal consistency and reliability, and consistent convergent validity. The psychometric validation of the Danish translation of the MAAS is of course important for interested researchers in Denmark, but also for the international research field, which has needed more thorough studies of the MAAS.

6.3 Main implications of Study 3

The RCT in Study 3 produced several important findings: First, the OC group showed significantly larger improvements than the TAU control group on both primary outcomes (perceived stress and the magnitude of cortisol secretion) as well as on all secondary outcomes (self-reported symptoms of depression, sleep disturbances, quality of life, and mental health; and the threshold for conscious visual perception, t_0). The methodological triangulation of using self-reported, physiological, and perceptual outcomes strengthens the interpretation that OC produced consistent, positive effects. Second, the two OC formats showed similar effects, although OC-I involved 2.6 times more professional contact hours than OC-G. Third, all self-report effects were sustained or significantly improved at follow-up three months after the intervention, at which point the OC group differed significantly from the TAU group on all self-report outcomes. Fourth, long-term effects were not moderated by age, gender, or education, and the dropout rate was only 6%. The OC program seemed applicable to a broad demographic group. We recommended further OC studies.

6.4. General Discussion

6.4.1. The efficacy of MBIs on health and stress

MBSR and OC were both supported as effective for stress reduction. In Study 1, the MBSR group showed a significant decrease on perceived stress with a medium effect size (PSS: d = -0.61). The MBSR group increased significantly more than the inactive controls (CICO) on PSS, but not more than participants in NMSR. This is somewhat contrary to a meta-analysis showing that MBIs were superior to physical relaxation across 10 studies (r_p = 0.21, Sedlmeier et al., 2012). A possible explanation may be that NMSR was a thoroughly designed, multicomponent intervention also involving psycho-education and circulatory training, rather than only physical relaxation. Another explanation may lie in the relatively low levels of stress reported by Study 1 participants (Table 1), since this makes it more difficult to achieve large group differences in stress reduction effects.

Relatedly, in Study 3, where participants reported higher baseline PSS scores (Table 1), the reductions within the OC group on PSS were larger (T_1-T_2: d = -0.92; T_1-T_3: d = -1.30) than within the MBSR group in Study 1. The mean intervention effect size across all self-report outcomes for OC (T_1-T_2: d = 0.70; T_1-T_3 d = 1.10; Table 1 in Appendix III) were similar to or larger than meta-analytic mean effect estimates of different types of MBIs for non-clinical samples (ds = .54-.74; Sedlmeier et al., 2012; d = 0.66; Carmody & Baer, 2009). The slightly larger effects for OC compared to MBSR in Study 1 on perceived stress may be explained by several factors alongside random variation in effect sizes between different studies. Among the most prominent differences, again, Study 3 recruited highly stressed participants (mean T_1 PSS = 18.57) from the Copenhagen community, while Study 1 recruited university students with a baseline PSS level (T_1 mean PSS = 13.05) nearly corresponding to the Danish population (M = 11.0; Stigsdottir et al., 2010). On the other hand, mean effects of OC were, as mentioned, promising compared to reviews of MBIs for non-clinical samples. We thus recommended further studies of OC, including potential benefits of participating in OC over longer time periods than the present six-month study period.

In a broader perspective, mental health promotion or preventive programs have generally been supported as effective (Astin, Shapiro, Eisenberg, & Forys, 2003; Nakao et al., 2001; Pelletier, 2004; Samuelson et al., 2010) and on a health political level, there is a strong case for policy investment in mental health promotion (World Health Organization, 2005; Campion et al., 2012). Cost-benefit analyses have demonstrated socioeconomic advantages of health promotion, such as lowered illness prevalence and use of health care services, freeing societal capital and health care resources for those with the strongest need (Sobel, 2000; Muñoz, Beardslee & Leykin, 2012).

Considering positive benefits from health promotion, rather than only economical savings and risk reduction, healthier citizens may also contribute more to a society. A systematic review and meta-analysis showed that higher scores on subjective wellbeing and positive affect scales were related to more success and resiliency within work life, social relationships, and global health (Lyubomirsky, King, & Diener, 2005). Although the majority of such studies have been cross-sectional, the longitudinal literature on positive health factors “is still impressive in its robustness and the consistency of its results”, supporting that e.g., higher QOL scores predict health and health behaviors in the future (Lyubomirsky et al., 2005, p. 834). Health political agencies have also demanded more attentiveness to positive health factors (OECD, 2011; UNDP, 2013).

For these reasons, we investigated positive mental health markers in Study 2 and Study 3 through the QOL-5 and the SF-36-MCS (Table 2). We found beneficial effects of OC on QOL-5 and the multi-component mental health estimator, the SF-36-MCS. At baseline, the OC-group showed QOL-5 scores below WHO's risk marker for depression (QOL-5 scores < 50) and SF-36-MCS scores below the Danish population average (Figure 8). Six months later, at follow-up, the OC group displayed QOL-5 scores above WHO's risk marker ($M = 65.75$) and reported higher mental health scores than the Danish population on SF-36-MCS[21]. In contrast, the TAU control group did not increase above WHO's risk marker for depression on QOL-5 or show any significant changes on the positive health parameters at any time points. The TAU controls also remained above the risk marker for depression on the measure of sleep disturbances (PSQI scores > 5; Buysse et al., 1989) throughout the six-months study period, and they remained above the population averages on perceived stress (PSS) and symptoms of depression (MDI) (Figure 8). These findings for the TAU control group indicate that the unsystematic range of stress reduction initiatives offered by Danish GPs is not effectively helping sleep quality or building positive health factors.

Physiologically, we measured the cortisol awakening response (CAR; Fekedulegn et al., 2007) using identical methods in Study 1 and Study 3. Pre-post effect sizes were similar for MBSR and OC on AUC_G (MBSR: $d = 0.68$, $p = .054$; OC: $d = .59$, $p < .05$). For the CAR indicator of HPA-axis stress reactivity, AUC_I, we applied different analytical strategies. In study 1, the MBSR group showed a significant decrease on AUC_I ($d = 0.64$, $p < .05$) among the university students. In Study 3, we blindly identified participants with physiological symptoms of burnout (blunted or negative baseline AUC_I) for separate analyses, since we considered AUC_I-increases (rather than further decreases or no change) as the desired outcome change for these participants. Indeed, we did find significant AUC_I increases for such OC participants, indicating a healthy re-establishment of HPA-axis reactivity to awakening. The MBI participants in the present two RCTs did not decrease more than the either inactive (CICO), active (NMSR), or TAU control groups on AUC_I. Oppositely, both MBSR and OC decreased the magnitude of cortisol secretion significantly more than an inactive (Study 1) or TAU (Study 3) control group. CAR changes during long-term

[21] A post hoc comparison of OC vs. the Danish population sample mean from the SF-36-MCS manual (Bjørner et al., 1997) based on the methods by Rosnow & Rosenthal (1996) reveals a between-group difference of $d = .93$, 95% CI[0.13, 1.86].

stress are complex and not yet understood (Danhof-Pont et al., 2011), precluding solid conclusions from the present studies. Nonetheless, studies of MBIs and cortisol changes have produced mixed findings, perhaps due to methodological flaws (Matousek et al., 2010). The methods applied here may be advantageous in studies with participants with initial physiological signs of burnout (blunted or negative CAR), since oppositely directed effects on an outcome (AUC_I) among participants in a stress reduction intervention may level out any overall effects. Such analytic strategies must be predefined and conducted by researchers blinded to participants' group status.

6.4.2 Effects of professional contact hours and meditation compliance

Study 3 indicated that the number of professional contact hours was not a factor for OC treatment effects, since most outcome changes or endpoints (T_3-values) were nearly identical for OC-G and OC-I (Supplementary panel 1 in Appendix III). This is important for health political reasons, since OC-G is a much cheaper intervention than OC-I. We predicted it, since studies on mental health promotion paradigms show that intervention format is not a crucial factor for treatment effects (Brown et al., 1998; Main et al., 2005). Similarly, a review on MBIs for healthy samples at work places did not show a moderating role of intervention group size (Virgili, 2013). Finally, a meta-analyses across previous reviews of the comparative efficacy of individual and group psychotherapy concluded that these formats were equally effective (McRoberts, Burlingame, & Hoag, 1998). More systematic research is needed on the importance of different formats *within* the same programs, as recommended by the European Psychiatric Association in their guidelines for developing evidence-based mental health promotion strategies in public health sectors (Kalra et al., 2012).

We found no consistent relationships between MBI compliance and treatment effects. In Study 1, detailed MBSR compliance data and outcome change scores were unrelated. In Study 3, outcome change scores were generally not associated with OC session attendance rates, except for changes in the threshold of visual perception (t_0), where higher attendance was indicative of larger improvements. Although this supports a session compliance effect on t_0, we did not demonstrate this in Study 1, and overall, Study 3 did not support a significant effect of increased OC attendance.

In spite of the inconsistent findings, the topic is important. It touches upon a heartfelt core assumption in many types of MBIs, namely that the number of weekly meditation practices makes a difference per se. As mentioned in Chapter 1, reviews of MM-based studies of compliance have not supported this notion (Carmody & Baer, 2009; Sedlmeier et al., 2012; Toneatto & Nguyen, 2007; Vettese et al., 2009; Virgili, 2013). More recent studies of MM for stress management (de Vibe et al., 2013) and studies of other MBIs corroborate this. For example, larger pre-post increases in weekly minutes of RR-meditation during the *Cardiac Rehabilitation Program* predicted larger increases in wellbeing scores, but were unrelated to changes in anxiety and hostility scores across 845 cardiac outpatients participating in the program (Chang, Casey, Dusek, & Benson, 2010). But before drawing any fast conclusions, related research fields should be considered.

Experimental meditation studies are similarly inconsistent. On the one hand, several studies of experienced meditators have indicated that increased meditation experience is associated with increased attentional stability (Brefczynski-Lewis et al., 2007), larger reductions of breathing rates during a meditation session (Lazar et al., 2005), faster visual processing and improved selective attention (Braboszcz et al., 2013), increased connectivity within attentional networks (Hasenkamp & Barsalou, 2012), and increased cortical thickness in medial frontal and somatosensory cortices (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010). Similarly, studies of short-term MBIs for meditation novices have reported that increased compliance with the meditative practices of such programs were related to increased neural activity in a region (right anterior insula) involved in the ability to pay intention to internal, bodily states during attention tasks (Farb, Segal, & Anderson, 2012) and with improved performance on a go-no-go task and increased recruitment of frontal executive neural regions (e.g., dorsolateral and medial frontal cortices) during an emotional Stroop task (Allen et al., 2012). Such studies provide empirical support to the idea that higher amounts of weekly meditation increase the effects of MBIs per se.

However, many studies have failed to find any such associations. For example, three neuroimaging studies of experienced meditators of different traditions and matched controls (Kang et al., 2013; Luders et al., 2009; Vestergaard-Poulsen et al., 2009) found that life time years of meditation experience in the meditators were not related to the thickness or neural density of any cortical or subcortical regions in the brain. However, in between-group comparisons, the meditators showed increased cortical thickness in ventromedial frontal regions related to executive attention and emotional control (Kang et al., 2013, Luders et al., 2009), increased hippocampal volume, which is indicative of improved top-down control of the FF response (Luders et al., 2009), and increased neural density in a brain stem region also related to control of the FF response (dorsal nucleus of the vagus nerve) (Vestergaard-Poulsen et al., 2009). Similarly, a study of fractional anisotropy (an indicator of whitematter integrity of fiber tracts) in the brain's major fiber tracts in 27 experienced meditators found no associations between meditation experience and fractional anisotropy in any fiber tracts, although meditators showed stronger connectivity in medial frontal areas than matched controls in between-group comparisons (Luders, Clark, Narr, & Toga, 2011).

Life time years of meditation practice were also not related to the performance on a Stroop task similar to the one applied in Study 1 (Chaan & Woollacut, 2007) or to attentional and working memory task scores in a study of 33 meditators and matched controls (Lykins, Baer, & Gottlob, 2012). As a final example, the amount of MM during an 8-week MBI was not related to changes in amygdala reactivity to either positive or negative images (Desbordes et al., 2012).

The picture is also complex in studies of meditation experience and self-reported mindfulness, e.g., the on the Five Factor Mindfulness Questionnaire (Baer et al., 2006) and the MAAS (Brown & Ryan, 2003). Both of these scales are constructed with the explicit purpose of being sensitive to effects of meditative (especially MM) training. For the FFMQ, studies by Ruth Baer and colleagues have shown higher scores in experienced meditators compared with controls (Baer et al., 2008; Lykins & Baer, 2009; Lykins et al., 2012) [22]. However, the FFMQ facet *Observe* seems to be negatively related with distress in meditators, but positively related to distress in non-meditators, indicating a complex relationship between self-reported self-observance, psychological distress, and meditation experience (Baer et al., 2006, Baer et al., 2008; Lykins et al., 2012)[23]. In addition, other researchers have reported that only a few FFMQ facets were related to meditation experience (Thompson & Waltz, 2007) or that no relationships between FFMQ and meditation experience were robust (Barnhofer, Duggan, & Griffith, 2011; Falkenström, 2010; Lilja et al., 2011). On the MAAS, zen meditators (Brown & Ryan, 2003), Buddhist monks (Christopher, Christopher & Charoensuk, 2009) and hatha yoga practitioners (Brisbon & Lowery, 2011) reported higher mindfulness scores than non-meditating control groups. Oppositely, MAAS scores were not related to (very limited degrees of) meditation experience in university students (Baer et al., 2006; MacKillop & Anderson, 2007), in a cross-cultural survey of Thai and US students (Christopher, Gilbert, Neary, Pearce, & Charoensuk, 2009), or to meditation experience within a sample of Dutch, experienced meditators (Schoormans & Nyklíček, 2011).

These research fields are relevant to the discussion of the importance of compliance with the daily meditative practices in MBIs. Clearly, several fields of meditation research do not support a consistent relationship between the number of minutes or times spent mediating per week,

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[22] Some participants (*n* not reported) in Lykins et al. (2012) also participated in Lykins and Baer (2009).
[23] It has been suggested that the function of self-observation (as measured by Observe scores) changes with meditation experience because the attitude behind the self-observation may become less critical or more self-compassionate with increased meditation (Shapiro et al., 2006; Vago & Silbersweig, 2012). However, increased self-compassion was not supported as a mediator of MBI effects by a review (Gu et al., 2015).

per month, or during the life time and the outcomes under scrutiny – e.g., brain structure or neural blood flow during cognitive tasks, therapeutic changes, attention tests, or self-reported mindfulness. A straightforward conclusion is that other factors are at play. This would explain why the seemingly MBSR-specific effect on the d2 Test in Study 1, as well as the vast majority of all treatment effects in Study 1 and Study 3, were unrelated to the number of (attempted) meditations. The influence of non-specific factors, such as social support, regular contact with a caring, professional instructor, and expectancy effects for therapeutic changes has been recognized as important in clinical studies for decades. A large meta-analysis published in *Psychological Bulletin* compared several schools of psychological therapy and concluded that the investigated types of psychological interventions were equally effective (Wamphold et al., 1997). Although this is controversial, at least there is not strong evidence that specific therapeutic techniques result in different therapeutic effect sizes overall.

To be perfectly frank concerning meditation compliance in MBIs: First, there is no empirical basis for many MBIs' emphasis on daily compliance with meditative practices. Second, the non-specific elements of many types of therapeutic interventions seem important, as presently supported by the similar stress reduction effects of MBSR and NMSR in Study 1. This should not discourage further studies in MBIs. Rather, it seems most likely that any effects of meditative practices do not work in isolation in short-term MBIs. The effects, and the principles they rest upon (e.g., self-awareness, self-compassion, patience, prioritizing conscious choices) may very well also be crucially dependent upon "non-specific" factors (e.g., the relevant knowledge, compassion and patience of the instructor). Such interactions in interventional factors for positive changes remain to be investigated for MBIs. However, in acknowledgement of these unanswered questions, the OC paradigm does not overly emphasize compliance with the weekly meditation assignments (Jensen, 2013). Rather, the OC program emphasizes that the purpose of participating is to investigate the personal relevance of the two overall strategies (*Open Attention* and *Calm Processing*) through meditation and other techniques (Jensen, 2013) and to discover the personally optimal amount of meditation, not to complete the maximally possible amount. This compliance strategy seems to differ slightly than the strategy in MBSR (Kabat-Zinn, 1994) and RR (Benson & Proctor, 2010), for example, where more emphasis is placed on completing daily meditations. The OC strategy of placing less emphasis on daily meditation and more on discovering one's personal needs was supported by the first review on factors for dropout and negative consequences of MBIs, in which the authors stated: "Finally, during the program we emphasize that participants know best what they need and when a particular type of practice (e.g., yoga) will or will not suit their current situation"

(Dobkin et al., 2012, p. 48). However, Dobkin and colleagues underlined that too few studies had been conducted to provide an empirically based answer.

This discussion of compliance (strategies) naturally also leads to questioning the idea of conceptualizing and measuring compliance within MBIs in terms of detailed accounts of MBSR meditation practices (as in Study 1), or the simpler OC session attendance rates (as in Study 3). The field of compliance research has become more and more multifactorial and difficult to integrate (Blackwell, 2002; DiMatteo & DiNicola, 2002). One factor for treatment effects, for example, may concern emotional and instrumental dimensions of the perceived "working alliance" (Horvath & Greenberg, 1989) with the therapist or instructor. In mainstream (non-MBI) research, the perceived working alliance has predicted effects of psychotherapeutic interventions in several studies (Constantino et al., 2010; Lingiardi, Colli, Gentile, & Tanzilli, 2011; Webb et al., 2011). To my knowledge, this interventional aspect has not been studied with respect to MBIs.

Essentially, more research into compliance and the many different specific and non-specific elements of MBIs, and on possible interactions between them, is needed. Daily meditation practice during an MBI may be important for some people, under certain circumstances, but for others, even a few weekly meditations may be enough to increase e.g., a clearer awareness of their situation and thus intensify the therapeutic process, which may then be facilitated by other means, as suggested by an early review on the relevance of meditation to psychotherapy (Kutz et al., 1985).

6.4.3 Meditation and attentional functions

Attention is theoretically and practically central to MBIs (Chapter 1). In this section, I discuss the present findings concerning attentional functions and their potential relations with MBIs and health.

6.4.3.1 Meditation and attentional stability

An interesting and growing area of meditation research concerns the stability or variability of attentional functions over time (Allen et al., 2013; Lutz et al., 2009). Aspects of attentional stability and instability were investigated in all the present studies.

In Study 1, we examined three outcomes based on the RT Coefficient of Variation (CV), because RT variability seems to be less sensitive to attentional effort and practice effects and more ecologically valid than raw RTs (Flehmig et al., 2007; Steinborn et al., 2008). Changes in DART CV scores did not differ between the four groups. However, RT stability (CV) *decreased* for INCO, while MBSR showed significantly *more* stable RTs than did NOCO at T_2 (Appendix I). This suggested that MBSR improved the CV, and that the increased post-treatment task effort in INCO did not confound the DART CV. The potential impenetrability of the CV to attentional effort was further supported in STAN: On neutral trials in STAN, INCO showed significant and large pre–post effects in analyses of raw RTs, which a post hoc test indicated as a significantly larger improvement than in the combined stress reduction groups. However, on the CV for the same trials, INCO did not improve. Thus, the CV scores again seemed resistant to effects of attentional effort. The NMSR group showed a similar pre-post effect on the DART CV as the MSBR group. Relatedly, pre-post changes on the MAAS scores, reflecting the perceived everyday instability of attention, were very similar for NMSR and MBSR, $\omega^2 = .02$. MAAS-changes did not correlate with DART CV changes (data not shown). These findings show that on two independent measures of attentional variability and instability, respectively, the MBSR group did not improve more than the NMSR group. Concluding, non-specific stress reduction may affect (these measures of) attentional stability to the same degree as MBSR.

Therefore, it could be reasoned that both MBIs and non-meditation-based programs may decrease stress and improve attentional present-centeredness. As mentioned, long-term stress is in itself harmful for attentional functions perhaps due to neurotoxic effects on the prefrontal cortex (Arnsten, 2009). Theories of mechanisms of change in MBI consistently argue that increased mindfulness is the mediator of decreased stress or psychological symptoms (for a review, see Gu et al., 2015). In support of this hypothesis, a meta-analysis of 12 studies of mediators of change in MBSR and MBCT found consistent evidence for a significant and moderate mediating effect of increased mindfulness[24] on beneficial changes in health-related outcomes (Gu et al., 2015). However, these 12 mediation studies did not at all document significantly larger mindfulness mediation effects in MBIs compared to active control groups. In other words, although self-reported mindfulness (e.g., decreases in inattentiveness) may represent a significant mediator of change in MBIs, it has not been shown that it is an MBI-specific mediator. Indeed, many other activities than MBIs, such as exercise or improved sleep quality (Kahn et al., 2013), may increase one's attentiveness to the daily life (Brown & Cordon, 2007; Shapiro & Giber, 1984).

Summarizing Study 1, MBSR did not lead to any unique effects on PSS, DART, STAN, the Stroop task, CAR-variables, or on the MAAS. It is then unfortunate that studies without active control groups constitute the major part of research in meditation and attentional stability

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[24] An aspect of attentional functions was present in all mediation studies' measures of mindfulness, although most mediation studies used facetted mindfulness scales, such as the FFMQ (Gu et al., 2015).

(e.g., Jha, Krompinger, & Baime, 2007; Moore & Malinowsky, 2009; Valentine & Sweet, 1999). Similarly, research on MBIs for youth or children have shown promising attentional stability effects, but generally applied inactive control groups (Baijal, Jha, Kiyonaga, Singh, & Srinivasan, 2011; Napoli, Krech, & Holley, 2005; Rani & Rao, 1996). A few studies showed superior attentional effects of RR meditation compared to muscle relaxation (Semple et al., 2010) or, as mentioned, of MM on an emotional Stroop task compared to an active control group (Allen et al., 2012). It was potentially important that the financial incentive improved only RTs and not the CV, since it is relevant to discover measures resistant to effects of attentional effort (Sarter et al., 2006). More active control group studies are needed on attentional stability and MBIs.

6.4.3.2 MBIs and attentional selectivity

Another theoretically central aspect of meditation and attention concerns the executive control of the attentional focus. In the d2 Test of Attention (Brickenkamp, 2002), the post-treatment error distribution (ED) for the MBSR group differed significantly from that in all other groups. In other groups, error rates increased significantly during the middle section of the d2 Test, indicating a tiring effect. The ED in the d2 Test has long been proposed as an important measure of sustained selective attention (Spreen & Straus, 1998). The error increment in the middle test section was present in all groups at baseline, where it was even especially pronounced in the MBSR group. Thus, we interpret the differential ED in MBSR at T_2 as an MBSR-induced attenuation of the tiring effect. This interpretation is in accordance with the attention-resource model that attributes vigilance decrements to the exhaustion of mental resources (Warm, Parasuraman, & Matthews, 2008). These results support attentional improvements after MBSR independent of both stress reduction and the perceived task incentive, although the finding was a between-group comparison. Superior d2 error performance was also found in experienced meditators compared with novices (Moore & Malinowski, 2009). However, as mentioned, the d2 ED effect was unrelated to MM-compliance, and was thus presumably due to several aspects of the MBSR program. In addition, *attentional selectivity* is a broad term, and MBI-research on selectivity of different types is needed. For example, we found no effects of MBSR on visual perceptual selectivity, the TVA α parameter.

6.4.3.3 Meditation, MBIs, and perceptual thresholds

In Study 1, the threshold of conscious visual perception, t_0, improved significantly in the MBSR group and not in any other group. The MBSR group showed a significantly larger improvement than in the non-incentive controls, but not compared to the incentive controls or NMSR. The degree of improvement in the perceptual threshold was significantly (Bonferroni-corrected) associated with the increase in self-reported mindfulness (MAAS scores) within the MBSR group. This relationship was further strengthened by a post hoc correlation indicating that higher MAAS scores were related to lower perceptual thresholds across groups at baseline, $r = -.40$, $p = .005$. In Study 3, the OC group improved t_0 significantly more than TAU controls, also to a near-significant degree ($p = .054$) when controlling for baseline t_0. Larger t_0-improvements were associated with higher OC session attendance rates. Study 3 thus corroborated and expanded our perceptual findings from Study 1 in a more stressed and demographically broader sample. In addition, we have recently solidified these findings in a third study showing significant t_0-improvements after an 8-week MBI, in a squadron of elite soldiers (Meland, Jensen, & Vangkilde, *in preparation*).

Perceptual improvements may be important for MBI research. Developing hypotheses state that improved conscious awareness of perceptual signals represents a core mechanism of change in MBIs since it promotes insight into changes in personal states and increased awareness of the environment, reduces rumination by focusing on the present moment, and strengthens conscious, rather than automatic, processing (Bedford, 2012; Bushell, 2009; Shapiro et al., 2006). Similarly, Benson and colleagues (Kutz et al., 1985) argued that MM and RR meditation practices (as well as zen and several types of yoga) may contribute to therapeutic progress because of a stronger, inner awareness and increased information flow from preconscious to conscious levels of processing. Similarly, an early theory argued that TM promoted beneficial changes partly because inner and outer perceptual information bypassed conceptually driven information processing to a stronger degree (Lindsay & Norman, 1977). Finally, a historical parallel is found in indo-Tibetan Buddhist traditions, where an ultimate goal of meditation is termed *direct perception*, referring to the ability to instantaneously (“directly”) *perceive* the deepest or purest, unmodified nature of both the phenomenological and objective world (Bushell, 2009). In summary, these accounts and theories propose that a more undistorted bottom-up perception within several sensory modalities may represent a mechanism of change behind the effects of MBIs or continued meditative training.

Our TVA results support this notion since the theoretical TVA-model (Bundesen, 1990) and its neural interpretation (Bundesen, Habekost, & Kyllingsbæk, 2005) state that t_0 improvements may reflect an ability to rely more on preset visual attentional weights, rather than engaging in ongoing, conscious recalibration hereof. OC and MBSR may therefore have improved the perceptual threshold partly because participants became less prone to modulate visual attention in a top-down controlled fashion. This fits with the purpose of the MBSR and OC programs, which are both focused on promoting relaxed and receptive awareness of sensory information without modifying the experience or the sensory input, i.e., on promoting a bottom-up-driven perception.

In further support of perceptual improvements after MBIs, the threshold for conscious visual registration measured by critical flicker fusion (CFF) tests[25] was also improved by MM (Brown et al., 1984), and by yoga (Braboszcz et al., 2013; Raghuraj & Telles, 2002; Telles et al., 1995, 2007; Vani et al., 1997). A mismatch negativity (MMN)[26] study also supported improved attentional preprocessing (significantly increased MMN amplitudes) in meditators after concentrative meditation compared to a condition of relaxed breathing, and the meditators' MMN amplitudes during concentrative meditation were also significantly larger than MMN amplitudes in an inactive (relaxation) control group (Srinivasan & Baijal, 2007). Experienced meditators also improved their threshold for visual spatial discrimination during a MM retreat (MacLean et al., 2010). Short-term TM seemed to render visual discrimination less dependent upon pre-existing cognitive schemata (Dilbeck, 1982). Finally, MBSR participants also improved their sensorimotor and proprioceptive thresholds, as seen from a significantly improved ability to detect smaller manipulations in computerized indications of their ongoing bodily movements, which was not found in an inactive control group (Naranjo & Schmidt, 2012).

For these reasons, and in parallel to the physiological relaxation response (RR), which has been observed across many types of meditation (Park et al., 2013), a common psychological "relaxation response" produced by MM, TM, and RR-based meditation (and perhaps other types of meditation or psychotherapy) may involve an increased signal-to-noise ratio, which is pivotal for near-threshold perception, or an increased permeability from unconscious to conscious levels of processing, all in all lowering the stimulation needed for conscious registration of changes or stimulation within several sensory modalities. However, this remains a speculation, and much more research is needed on common perceptual effects across different types of meditation or MBIs.

6.4.3.4 Attentional effort and the intention to be present

The conscious intention to purposefully sustain attentiveness towards the present moment is another central aspect to several models or explanations of MM (Kabat-Zinn, 1994; Shapiro et al., 2006). In

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[25] CFF tests measure the frequency at which a flickering light is perceived to be steady. Thus, CFF performance may reflect the frequency with which the optic tract discharges signals (Vani et al., 1997).

[26] MMN paradigms measure electroencephalographic indications (decreased amplitude) of change detection by presenting a few mismatching (deviating) stimuli among a series of matching stimuli. Increased MMN amplitude presumably reflects increased preattentive processing of changes and improved change detection.

these models, increased top-down intentionality is an integral part of mindfulness. This of course complicates the interpretation of Study 1, aiming to separate effects of increased top-down driven attentional effort in INCO from "specific" (MM-based) effects of MBSR. Our findings showed that the financial task incentive was especially important to outcomes based on raw RTs. For example, INCO improved to a significantly larger degree than MBSR on attentional set shifting indexed by gray-digit RTs in DART, indicating a substantial effect of attentional effort on forced choice performance within a vigilance test. This finding is in contradiction to specific predictions on effects of MM (Bishop et al., 2004). However, attentional shifts are probably mediated by context-dependent networks (Rushworth, Krams, & Passingham, 2001) and attentional set shifting is not a uniform phenomenon that allows simple inferences from highly abstract tests, such as DART, to complex mental set shifts from e.g., negative judgments of oneself to self-related acceptance (for reviews see Kiesel et al., 2010; Monsell, 2003). Thus, these DART-findings should be interpreted primarily as a methodological critique against the use of abstract RT-based measures as indications of MBI-based improvements of attentional set shifting (e.g., Jha et al., 2007; Tang et al., 2007). Attentional shifting clearly seems central to meditative training, where participants again and again practice the ability to shift attention away from a distraction (e.g., a thought about a task at work) and back to the focus during the meditation (e.g., the breath). Thus, while Study 1 did indicate that MBSR did not improve mental set shifting, a more cautious explanation of the results is that the abstract DART task did not capture any potential set shifting effects of MBSR.

Another corner stone of MBSR (and other MBIs) is continued training in the ability to pay attention to the present moment. For the same reason, it was provocative that the incentive controls, INCO, improved their mean RTs on neutrally cued trials in STAN to a significantly higher degree than MBSR and NMSR combined. The ability to sustain attention over time has been argued by a previous MM study (Jha et al., 2007) to be validly measured by raw RTs in a spatial cueing paradigm, the so-called Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). Specifically, Jha et al. (2007) found lower RTs in meditators than in controls on the no-cue trials and this result was taken as an indication of improved attentional orienting, reflecting the basic attentional readiness to react. However, our data supported that the MBSR participants in the study by Jha et al. (2007) may simply have tried harder to comply with the ANT task during the post-treatment test session, since we found remarkable improvements on neutral trials for INCO, also reflecting the basic readiness to react in the absence of information. Further, a study of Chinese students receiving five days of a MM-based program (Tang et al., 2007) did not improve more on the orienting aspect of the ANT than a RR meditation group (Tang et al., 2007), indicating that the RT-based measure of attentional orienting in ANT (or STAN, which is based on the ANT) does not specifically capture effects of mindfulness meditation. An MBI for school children did also not improve the orienting aspect of the ANT, while it did improve other ANT-outcomes more than a wait-list control group (Baijal et al., 2011). As for DART, the STAN findings most of all direct a methodological critique towards previous studies claiming that simple RT-based improvements of vigilance support meditation-*specific* effects on sustained attention. More knowledge is needed on vigilance abilities, types of meditation, and different types of attentional effort. A recent comparison of TVA-based versus ANT-based tests indicated a stronger reliability of TVA-based methods for evaluating attention (Habekost, Petersen, & Vangkilde, 2014), supporting the potential resistance of TVA-based tests to attentional effort, as indicated by the small TVA-based changes in INCO.

The Stroop results in Study 1 also showed the importance of attentional effort. MBSR and INCO *both* demonstrated significantly fewer color naming errors on the incongruent block than did the non-incentive controls at the post-treatment test session and pre–post effect sizes were similar within INCO and MBSR (Supplementary Table I in Appendix I). Two previous meditation studies controlled for self-reported task effort and still found superior selective attention improvements on an emotional Stroop task after MM (Allen et al., 2012) and a Stroop color-word task after just three sessions of Zen meditation (Wenk-Sormaz, 2005) compared to active control groups. Experienced mindfulness meditators also showed superior Stroop color-word performance than a control group (Moore & Malinowski, 2009). But importantly, none of these studies actively manipulated control participants' task incentive. This may be important, since previous research has demonstrated significant effects on Stroop paradigms through financial or educational incentives, suggesting that attentional effort is a prominent factor in Stroop (Chajut & Algom, 2003; Huguet, Dumas, & Monteil, 2004; Huguet, Galvaing, Monteil, & Dumas, 1999; MacKinnon, Geiselman, & Woodward, 1985). In addition, several studies of MBIs or MM found inconsistent or no effects of meditation or MBIs on Stroop paradigms (Alexander, Langer, Newman, Chandler, & Davies, 1989; Anderson, Lau, Segal, & Bishop, 2007; Chan & Woollacott, 2007; Kozasa et al., 2012).

It is important to consider alternative explanations for the critical results in Study 1. Several pieces of evidence supported that the findings were not due to a therapeutically ineffective MBSR intervention. First, intervention compliance was satisfactory (see Appendix I). Second, the MBSR instructor was an authorized specialist in clinical psychotherapy and a highly experienced meditation trainer directing a mindfulness meditation center in Copenhagen[27]. Third, the MBSR intervention effectively decreased physiological stress markers (AUC_G and AUC_I) and improved self-reported stress and attention. The decrease on PSS (d = .61) and the increase on the MAAS (d = 1.27) were larger than self-report effects of MBIs for healthy samples in general (Sedlmeier et al., 2012). Thus, the absence of unique attentional effects from MBSR on RT-based outcomes did not seem to be due to low compliance, a lack of experience on behalf of the instructor, or due to an therapeutically inefficient intervention. Rather, MBSR did simply not improve RT-based measures to a significantly higher degree than psychomotoric stress reduction or a financial task incentive. This again is an important critique of previous studies, which have been mostly based on RTs.

6.4.4 Self-reported inattentiveness, meditation, and health

Study 2 represented the first validation study of a Danish translation of the MAAS. In this regard, it was important that scores on the Danish translation of the MAAS confirmed to our psychometric expectations. CFA corroborated a unifactorial structure of the MAAS across and within genders with model fit estimates (RMSEA, CFI) similar to those of the original validation (Brown & Ryan, 2003), as well as satisfactory TLI. Factor structure, test-retest reliability and incremental validity results were not affected by gender. The convergent validity results uniformly aligned with our predictions: The MAAS scores correlated positively with scores on measures of mindfulness (FFMQ), self-directedness (TCI-SD), emotional intelligence (TMMS), and physical health (SF-36-PCS) – and negatively with scores on measures of avoidant personality (TCI-HA), experiential avoidance (AAQ-II), symptoms of depression (MDI), and perceived stress (PSS).

The psychometric validation of the Danish translation of the MAAS is of course important for Danish mindfulness and attention researchers, but also for the international research field. Although the construct measured by MAAS scores has been supported as unifactorial by studies of Spanish (Johnson, Wiebe, & Morera, 2014; Soler et al., 2012), Italian (Veneziani & Voci, 2015), Chinese (Black, Sussman, Johnson, & Milam, 2012; Deng et al., 2012), and Thai samples (Christopher, Gilbert et al., 2009), the Iranian version of the MAAS had to be reduced from 15 to seven items to achieve a unifactorial structure (Ghorbani, Watson, & Weathington, 2009), and a US study only confirmed a unifactorial model in women (MacKillop & Anderson, 2007). The present Study 2 thus reaffirmed the validity of a unidimensional interpretation of MAAS scores, i.e., that

[27] Tine Norup, the MBCR instructor in Study 1, also directed The Center for Wisdom and Compassion.

that it is valid to speak of *general* inattentiveness when referring to MAAS scores, rather than MAAS subscores of context-specific inattentiveness. This is also relevant for MBIs, where it is assumed that training attentiveness of the breath will improve attention (decrease inattentiveness) across many contexts and modalities of perception (Bushell, 2009; Horan, 2009).

As another important research question for Study 2, the MAAS scores were highly reliable across the yearly seasons, even according to the ICC estimate of individual absolute scores. MAAS scores were also significantly more reliable than scores on a measure of psychological distress, the BSI-53-GSI. This novel finding supports that a general proclivity to be inattentive towards the present moment constitutes a more foundational psychological phenomenon than symptoms of psychological distress, which seem to fluctuate more over long periods of time. Strengthening the generalizability of this finding, we replicated the long-term test-retest reliability estimates of the MAAS scores within genders and strata of age, education, income, and an internationally standardized indicator of occupational socioeconomic status (SES), the ISCO-88. These test-retest findings support that the long-term stability of the MAAS scores is not dependent upon demographic or socioeconomic factors. The validated occupational SES-scoring method of Study 2 addresses a gap in cross-sectional mindfulness-health research, since by far the majority of previous studies have only investigated unvalidated occupational parameters (e.g., mental health worker or not, [Baer et al., 2008; Lykins & Baer, 2009]; nurses versus non-nurses, [McCracken & Yang, 2008]; working inside or outside the home, [MacDonald & Hastings, 2010]; jobs with tenure versus jobs without tenure, [Avey, Wernsing, & Luthans, 2008]; middle managers versus top managers, [Trousselard et al., 2010]) or self-reported socioeconomic class (Masuda, Anderson, & Sheehan, 2010). These studies yielded mixed findings on the relevance of occupation for MAAS scores. More research on validated measures of SES and mindfulness or inattentiveness is needed.

A third finding of importance from Study 2 was that our SEM analyses indicated that the MAAS scores continued to predict scores on well-established scales of psychological distress and mental health, respectively, in the adult community sample after controlling these associations for demographic variables, income, occupational SES, two personality factors, recent severe life events, social desirability, and BMI. This implicates that the degree of inattentiveness may explain unique variance in mental health variables. Longitudinal support for this was produced in an SEM analysis revealing that the MAAS scores obtained during spring continued to predict psychological distress scores (BSI-18-GSI) six months later after controlling for the same set of potential confounders. Although causality cannot be established by cross-sectional studies, these findings suggest that the degree of inattentiveness towards the present moment plays an independent role for mental health, since these primary associations were not explained by related, relevant factors.

Finally, we demonstrated satisfactory or good short-term retest reliability for the MAAS scores produced by healthy university students over a two-week interval. This is relevant for e.g., experimental meditation research, which is often carried out with students over short time spans or for studies applying several pre- and/or post-intervention self-report assessments to increase statistical power and ecological validity (Vickers, 2003), such as Study 3 (Appendix III).

6.4.5 Strengths and limitations to the three studies

The major strength of Study 1 was the randomized design comparing MBSR to two active and one inactive control group, which had not been applied before and yielded important findings. Another strength of Study 1 and Study 3 was the use of self-reported, physiological, as well as behavioral outcomes. Study 1 had several limitations. One concerned the use of a relatively small sample of mainly female, healthy university students with a narrow age range, limiting the generalizability to other sample types. A limitation of the findings indicating potential MBSR-specific effects lies in the large number of attentional outcomes investigated. In this regard, Study 1 can be considered an exploratory MBI-attention study, where a lot of outcomes were tested to investigate if MBSR seemed to yield any specific attentional effects. However, with a large number of tests, the risk of false positive findings increases. In this regard, the between-groups d2 effect sizes were small and the *p*-values did not survive correction for multiple tests. Thus, more studies on attention and MBIs are needed, and I do encourage further studies on the d2 Test and TVA-based tests and MBIs.

The major strengths of Study 2 included the randomly invited adult community sample, the long-term test-retest interval of six months, and the thorough control for potential confounders. A limitation lay in the cross-sectional design, precluding causal conclusions. In addition, although Study 2 was well-powered to detect effects of income (Supplementary figure 1 in Appendix II), studies of more representative samples, adolescents, experienced meditators, and patient groups are needed to add further knowledge on the effect estimates' generalizability. Some scales used for the convergent validity tests (TMMS, FFMQ, and AAQ-II) have not been validated in Danish. However, our translations were carried out by professional translators and meditation researchers, the professional back-translations were approved by the original scales' authors, these scales' scores all proved internally consistent, and all convergent validity results were in line with our predictions. Our short-term test-retest reliability sample involved only students of which 87% were women. However, scores on the MAAS were unrelated to gender in the students (ϱs < .01), and the long-term test-retest reliability of the MAAS scores was not gender-related. Brief 5-item versions of the MAAS have been found to be psychometrically superior to the full 15-item version (Höfling, Moosbrugger, Schermelleh-Engel, & Heidenreich, 2011; Van Dam et al., 2010), but Study 2 only investigated the full MAAS.

A main strength to Study 3 was the comparison of two intervention formats, OC-G and OC-I, to a TAU control group. This addressed a lack of knowledge on the influence of MBI intervention formats and social group support. A significant practical strength of Study 3 was also the recruitment of stressed participants through local GPs, which helped to evaluate the need for such a program in the local public health sector and to gain valuable know-how on the implementation of an MBI in a public health care setting. Among limitations, the cortisol findings were limited by a low sample size (both Study 1 and Study 3 collected cortisol for $n = 48$), a single sampling day, and the relatively large variability in the CAR data. While CAR is a widely used stress-physiological measure, it is highly sensitive to variations in daily stress levels and acute stressors. Future studies might benefit from investigating hair cortisol, which can reveal cortisol levels across longer periods of time and also seems a promising measure of mental health and risk for mental diseases in population surveys (Wosu, Valdimarsdóttir, Shields, Williams, & Williams, 2013). Limitations of Study 3 also include the need for studying longer time periods, such as a year. A longer study period would enable more complex health impact assessments (HIA) methods including both subjective and objective societal health parameters, such as measures of the occurrence of stress-related depression or days of stress-induced absence from work (Kraemer & Gulis, 2014)[28]. An active control group would also have improved the ability to detect OC-specific effects. However, an unrestricted TAU design allowed for a comparison of OC with the current, unsystematic treatments offered for healthy adults dealing with prolonged stress.

Across the studies, a methodological strength lay in using identical measures in several studies, i.e., the MAAS and the PSS in all studies, the SF-36-MCS and MDI in Study 2 and Study 3, and the TVA-based and CAR outcomes in Study 1 and Study 3 (Table 2). As reiterated throughout, research is needed on different (versions of) MBIs and potentially specific and non-specific effects of these. Coherent methods across studies of different MBIs may aid in discovering common and specific mechanisms of change and, in time, constructing evidence-based theories.

[28] For a discussion on subjective as well as objective HIA parameters, see the thematic issue on HIA in Health Promotion International (e.g., Eckerman, 2013; Kemppainen, Tossavainen, & Turunen, 2013).

7.0 Perspectives and recommendations

Meditation is recognized as a potentially important element in treatments for a range of illnesses, and most prominently for stress reduction. Hospitals and other health institutions in many countries are applying MBIs, and the perspectives seem large, based on the overall positive effects. Future research should focus on clarifying the mechanisms of change in MBIs, and to develop evidence-based interventions and theories, and to conduct well-controlled research. The present studies may contribute with a few potentially valuable methodological perspectives.

Study 1 underlined the importance of active control groups. It also warranted further studies of potentially MBI-specific effects on sustained selective attention and the threshold for visual perception. I strongly encourage further cognitive studies including experimentally motivated control groups, since so few meditation studies have investigated this potential confounder. More theoretical consideration should here be given to the distinction between e.g., financially increased intentionality and the (perhaps less tiring) intention in sustaining attention as trained in meditation.

Relatedly, different formats of the same MBI paradigms should be studied further. While meta-analyses have investigated e.g., MBI group size or program length across studies (see Chapter 1), more randomized within-study examinations of MBI formats using identical procedures, outcomes, and instructors are needed. Similarly, studies are needed on ways of optimizing recruitment, screening, dropout and compliance strategies, and compliance measures.

Based on Study 2, further studies into the long-term test-retest reliability of self-reported attentional functions, as well the specificity of their associations with mental health parameters in the general population are warranted. Questionnaire data may be cross-validated by comparisons to behavioral (e.g., online) attention tests, and the relevance of self-reported attention or mindfulness to objective health parameters and economical health-sectorial outcomes (e.g., the use of medication, hospitalization, and other public health care services) should be studied. Longitudinal population studies are also important to better test causal theories.

An important perspective for future meditation studies in general is to develop a more contextual understanding of the importance of mindfulness or attentiveness for health. For example, we showed in Study 2 that higher income and higher SES-ranking occupations were significantly associated with higher MAAS scores. We expected this association due to the consistently observed, increased and prolonged stress exposure in lower SES groups and since lower SES is generally indicative of lower education, two factors which are both associated with decreased attentional functions. Alongside many other mindfulness researchers (see Appendix II), I therefore recommend more thorough research on background factors and potential confounders to develop a more contextual perspective on relations between MBIs, attention, and health. Should attentional functions continue to be supported as relevant and independent predictors for e.g., mental health or stress scores in the general population, this would provide further support to public implementation of effective programs shown (in active control group studies!) to decrease stress and specifically improve attention (MBIs, perhaps). Using different study designs may promote valuable insights.

All in all, meditation research has had a rough childhood; but I would like to end on a positive note. Meditative techniques have been practiced for millennia and by millions. First-hand accounts have overall described experiences of increased wellbeing, personal insight and balance, and again, the evidence for beneficial effects of MBIs for stress reduction are quite consistent. But what should happen in the youth and adulthood of meditation research? I would hope for a closer integration of qualitative and quantitative perspectives. Meditation is about systematic attempts at developing your own consciousness, a subjectively perceived world of impressions, and one of the greatest mysteries. Academic third-person research, including the present studies, is still in its infancy in understanding the deeper perspectives of meditation, the potentially life-transforming developments and deeply moving experiences that it may also involve. Methodological integration in studies of meditation and MBIs may be a necessary next step to extend the map for possible scientific understandings of meditative strategies and their effects, from being calm in the face of fear or during a physiological stress response, to receiving a deep and ineffable feeling of peace by attending to your breath, and other conscious ways of developing ourselves socially and ethically through meditation. However, while we are growing up as meditation researchers, two of the core principles from the present MBIs may be appropriate as seeds of inspiration: to train a clear open-minded attentiveness towards the complexity behind a phenomenon of interest, and to cultivate patience, to remain calm while allowing the unfolding of frustrations and wishes for faster progress.

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Appendix I

Study 1

Journal of Experimental Psychology: General

Appendix I

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Mindfulness Training Affects Attention—Or Is It Attentional Effort?

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Improvements in attentional performance are at the core of proposed mechanisms for stress reduction in mindfulness meditation practices. However, this claim can be questioned because no previous studies have actively manipulated test effort in control groups and controlled for effects of stress reduction per se. In a blinded design, 48 young, healthy meditation novices were randomly assigned to a mindfulness-based stress reduction (MBSR), nonmindfulness stress reduction (NMSR), or inactive control group. At posttest, inactive controls were randomly split into nonincentive and incentive controls, the latter receiving a financial reward to improve attentional performance. Pre- and postintervention, 5 validated attention paradigms were employed along with self-report scales on mindfulness and perceived stress and saliva cortisol samples to measure physiological stress. Attentional effects of MBSR, NMSR, and the financial incentive were comparable or significantly larger in the incentive group on all reaction-time-based measures. However, selective attention in the MBSR group improved significantly more than in any other group. Similarly, only the MBSR intervention improved the threshold for conscious perception and visual working memory capacity. Furthermore, stress-reducing effects of MBSR were supported because those in the MBSR group showed significantly less perceived and physiological stress while increasing their mindfulness levels significantly. We argue that MBSR may contribute uniquely to attentional improvements but that further research focusing on non-reaction-time-based measures and outcomes less confounded by test effort is needed. Critically, our data demonstrate that previously observed improvements of attention after MBSR may be seriously confounded by test effort and nonmindfulness stress reduction.

Keywords: meditation, MBSR, stress, cortisol, relaxation

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Mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1994) is a meditation-based treatment program applied to diverse clinical conditions with positive results (Baer, 2003; Grossman, Niemann, Schmidt, & Walach, 2004). Two reviews of MBSR as a tool for stress reduction reported promising results, but hardly any of the reviewed trials were blind and appropriately randomized, and control groups were often inadequate (Chiesa & Serretti, 2009; Irving, Dobkin, & Park, 2009). In addition, the factors contributing to change as a result of MBSR are poorly understood, and the need for rigorous research on this issue is widely recognized (Baer et al., 2006; K. W. Brown, Ryan, & Creswell, 2007; Chiesa & Serretti, 2009; Dimidjian & Linehan, 2003; Hayes, Luoma, Bond, Masuda, & Lillis, 2006; Irving et al., 2009; S. L. Shapiro, Carlson, Astin, & Freedman, 2006).

It has been proposed that the mechanisms responsible for positive change following MBSR involve attentional improvements, the cultivation of a nonjudgmental attitude, and an intention to be present in the now (Baer, 2003; S. L. Shapiro et al., 2006). This is in line with the most common definitions of mindfulness. Jon Kabat-Zinn, the founder of MBSR, defines *mindfulness* as "paying attention on purpose, in the present moment, and nonjudgmentally" (Kabat-Zinn, 2003, p. 145). Furthermore, attentional training and improvement are core elements in traditional meditation practices, and meditation types are often defined according to their attentional characteristics (Andresen, 2000; Lutz, Slagter, Dunne, & Davidson, 2008).

There is tentative support for meditation-related improvements in attention, but methodological flaws have been plentiful. A recent large review concluded: "The primary psychological domain mediating and affected by meditative practice is attention . . . but relatively few empirical evaluations of meditation and attention have been conducted" (Cahn & Polich, 2006, p. 200). Studies of experienced meditators or intensive meditation retreats provide compelling evidence: Tibetan monks showed extraordinary abilities to sustain perceptual focus on one visual field (Carter et al., 2005), and participants on long-term retreats showed improved performance on the attentional blink task (Slagter, 2007; Slagter, Lutz, Greischar, Nieuwenhuis, & Davidson, 2009), a dichotic listening task (Lutz et al., 2009), and a visual discrimination task

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(MacLean et al., 2010). Functional brain imaging has also shown increased stability in the amygdala response to a negative distractor during a sustained attention task in experienced meditators compared with incentive controls, and the stability in amygdala was furthermore positively associated with hours of meditation practice (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). Likewise, structural brain studies have found experience-related thickening or the absence of age-related thinning of areas involved in interoceptive awareness and attention, such as the insula, putamen, and prefrontal cortex (Hölzel et al., 2008; Lazar et al., 2005). This has been replicated and further corroborated by a corresponding absence of age-related decreases in sustained attention (Pagnoni & Cekic, 2007). Experience-related findings within the nonnovice groups support the notion of a causal relationship between meditational training and neurocognitive attentional improvements. However, these findings cannot be directly transferred to mechanisms of change in MBSR for meditation novices. Studies of experts are mostly cross-sectional, and meditator samples are small and not representative of the persons for whom meditation training is part of a therapeutic intervention, not a lifestyle. Likewise, intensive retreats in remote mountain settings are not directly comparable to MBSR.

The Importance of Attentional Effort

To our knowledge, no previous studies of MBSR have actively manipulated test motivation in the control groups, even though issues related to motivation have been noted repeatedly (D. H. Shapiro & Walsh, 1984). Intervention participants may experience performance pressure during posttesting due to demand characteristics (the perceived expectations of the experimenter) or be more motivated because of culturally endorsed expectations of meditation effects. The potential impact of such expectations is firmly supported in mainstream cognitive neuroscience. Closely related to motivation stands the concept of "attentional effort," which can be defined as "a function of the task's cognitive incentive [which] primarily [represents] the subjects' motivation to perform" (Sarter, Gehring, & Kozak, 2006, p. 147). Research shows that the cognitive incentive of a task can have a wide range of neuronal effects. For example, increased effort modulated activity in regions and circuits involved in processing attended target stimuli (Serences et al., 2005), synchronized neuronal firing (Fries, Reynolds, Rorie, & Desimone, 2001; Moran & Desimone, 1985), and modified neuronal firing rate (Fries et al., 2001; Treue & Maunsell, 1996). Increased effort also improved performance on a choice reaction time (RT) task (Pashler, 1998, p. 384), a sustained attention task (Tomporowski & Tinsley, 1996), and the Stroop color–word task (Chajut & Algom, 2003), an acknowledged test of inhibition and selective attention.

Critically, similar results have been reported in the meditation literature without controlling for (i.e., assessing or manipulating) attentional effort. Synchronized neuronal firing is a common finding in electroencephalographic (EEG) studies of meditation (Cahn & Polich, 2006), and improved sustained or selective attention (e.g., on the Stroop task) has been reported with no or only brief assessments of attentional effort (Bögels, Hoogstad, van Dun, de Schutter, & Restifo, 2008; Wenk-Sormaz, 2005). One study that is frequently cited as support for the beneficial attentional effects of meditation found improvements in sustained attention after short-term meditation, but the authors noted that "many controls" complained about "how boring" the task was (Valentine & Sweet, 1999, p. 66) and considered this a possible explanation for their findings. Another frequently cited study found improved attentional orienting after MBSR, indexed by faster RTs in a spatial cuing paradigm (Jha, Krompinger, & Baime, 2007), but this study did not consider attentional effort. However, Fan & Posner (2004), cocreators of the applied paradigm, acknowledged: "It is also possible that *increased effort* may facilitate more efficient use of the peripheral cue, [which] could indicate improved orienting" (p. S212, italics added). Accordingly, the MBSR participants in Jha et al. (2007) may have simply "tried harder" during the second test session. Semple (2010) reported enhanced vigilance after MBSR but also did not consider attentional effort during the postintervention test. In a cross-sectional study using functional neuroimaging, Farb et al. (2007) found increased deactivation in midline cortical areas in MBSR patients compared with wait-list controls when asked to sustain moment-to-moment awareness. The authors suggested that MBSR had improved this ability by strengthening midline cortical suppression. However, studies have shown that task effort alone can suppress activity in regions representing nontarget features (O'Connor, Fukui, Pinsk, & Kastner, 2002; Shulman et al., 1997). Farb et al. assessed the perceived ease or ability to sustain focus on the present moment but not the motivation to do so, or general task effort. The importance of controlling for test effort in attentional research was further accentuated by an imaging study comparing meditators with two groups of novices, one of which was offered a monetary reward. This modest cognitive incentive resulted in significantly higher blood flow in almost every attention-related region of interest in the incentive controls compared with the nonincentive controls (Brefczynski-Lewis et al., 2007).

An important part of the present study was to investigate whether response speed variability would be more resistant than raw RTs to effects of attentional effort, and thus recommendable for future studies. We chose the coefficient of variation (CV) of the raw RTs (defined as the *SD* of RT/mean RT) as our measure of response speed variability. Cognitive meditation studies often focus on response speed and accuracy, whereas mainstream cognitive researchers have discussed the advantages of assessing response speed variability for a century (Vanbreukelen et al., 1995). In a large study of healthy adults using several attentional tests, only the CV-based outcomes proved to be "virtually unaffected by practice effects" (Flehmig, Steinborn, Langner, Anja, & Westhoff, 2007, p. 141). The CVs on a range of attentional tests were better predictors of school performance in children than were mean RT and *SD*s (Steinborn, Flehmig, Westhoff, & Langner, 2008) and were proposed as an indicator of overall vigilance performance (Dockree et al., 2006). Variability measures are also more useful indicators of attentional function in cognitive impairment (Flehmig et al., 2007). Thus, the CV was also hypothesized to be more ecologically valid than simple RTs.

Another Achilles' heel in MBSR research has been designing control interventions that can effectively disentangle the mechanisms of change. Ideally, the control intervention should "filter out" prespecified factors and thus promote an understanding of the "active ingredient" in MBSR (Chiesa & Serretti, 2009, p. 598). However, non-MBSR activities may enhance mindfulness (Hayes & Shenk, 2004), and stress reduction itself generally improves attention (Chajut & Algom, 2003). Thus, it is important to clearly define the elements of MBSR being tested.

The Present Study

In light of the issues just described, we tested effects of MBSR on attention in meditation novices in a blinded, randomized trial. We compared four groups: (1) MBSR, (2) an active control group receiving a nonmindfulness stress reduction (NMSR) course, (3) an inactive group receiving an incentive, and (4) a nonmanipulated inactive group. Pre- and postintervention, participants completed five validated tests of attention, as well as questionnaires on mindfulness and perceived stress, and we assessed saliva cortisol levels in response to awakening. To our knowledge, no previous study of attentional effects of MBSR has used a similar design.

Leading researchers have predicted improved sustained attention, selective attention, and attentional set shifts after mindfulness training "which can be measured using standard vigilance tests" (Bishop et al., 2004, p. 232). In accordance with this operational definition of mindfulness and the preliminary, experimental MBSR literature, we hypothesized that MBSR would improve vigilance. We included two vigilance paradigms: one based on sustained *dual attention,* including a set-shifting task, and one based on sustained *selective attention*. To test selective attention, we also included a Stroop paradigm, as proposed by Bishop et al. (2004). Because returning attention to the present moment is a cardinal part of MBSR (Kabat-Zinn, 1990) and most meditational practices (Lutz et al., 2008), we also considered it relevant to include a *temporal attention* paradigm to assess this skill. Finally, we considered it important both theoretically and empirically to include a test of *visual attention*. On the basis of phenomenological reports, historical texts, and a few empirical studies, we hypothesized that MBSR would result in unique decreases in the perceptual threshold. We also expected that performance on a perceptual task that is not based on RTs would be less likely to be confounded by attentional effort (see the Instruments and Outcomes section for a detailed account of the choice of tests and more specific predictions).

We provide consistent evidence across several tasks that previously reported attentional improvements after MBSR (especially results based on RTs or task speed) may be seriously confounded by attentional effort as well as general stress reduction. Thus, these previous results may be caused by factors such as increased performance pressure or nonspecific stress reduction rather than by mindfulness training per se. Although this is our main conclusion, we also found that only MBSR led to improvements in the perceptual threshold and a measure of sustained, selective attention. These are the first findings on attentional improvements after MBSR that cannot be ascribed to NMSR or attentional effort. Primarily, however, we argue for methodological refinements of study design and choice of attentional measures in order to improve the validity of future investigations of the mechanisms of change in MBSR.

Method

Participants and Procedures

The Danish Ethics Committee approved the applied protocols (#21161 and KF 01 2006-20). Participants were recruited through oral presentations and posters at the Department of Psychology, University of Copenhagen, and all provided informed consent before the study. Controls were paid \$250, and incentive controls an additional \$50. To ensure honest completion of the practice diaries, intervention participants were paid \$850, disregarding their compliance.

Participants and compliance. Figure 1 illustrates the participant flow. After 2 weeks, inclusion was closed and screening for age, health, and experience with meditation and yoga resulted in 60 eligible persons. All eligible men (n = 18) were included, and the inclusion of 30 women was randomized. The remaining 12 women were put on a wait list, and three were randomly selected for baseline testing. Three groups (each n = 16)—balanced for age, sex, marital status, education, and perceived stress—completed ECTS[1] points during the semester, and all five subscales on the NEO Personality Inventory—Revised (Costa & McCrae, 1992) were created and randomly assigned to one of the following groups: collapsed inactive controls (CICO), NMSR, or MBSR. One MBSR participant was hospitalized after 8 days, so a random participant was included from the baseline-tested wait list. After 22 days, one person from NMSR left the study due to illness, but no replacement was included this late in the study.

In total, 49 participants were included, and 47 (66% women) 20–36 years of age completed the study. The majority (94%) were university students (mean education = 15 years) taking exams corresponding to a full semester (29 ± 6 ECTS). All were physically and psychologically healthy as evaluated on the Symptom Checklist-90—Revised (Derogatis, 1977) and a screening questionnaire (70 items) used at the Copenhagen University Hospital. All reported to be meditation and yoga novices on a brief questionnaire and when interviewed.

CICO was randomly split before the posttest by one of the authors (Steen G. Hasselbalch). *Incentive controls* (INCO; n = 8) were offered a financial bonus of \$50 if they could "improve" (not defined to them) compared with baseline. One researcher (Christian G. Jensen) carried out all tests blinded to participants' group status within 3 weeks prior to and 2 weeks after the interventions.

Compliance was monitored through diaries in which daily home (formal and informal) practices and course attendance were noted. Compliance was considered satisfactory. MBSR participants attended 7.6 ± 0.8 courses (NMSR: 7.0 ± 0.8), including the retreat, and practiced 35 ± 7 times formally (NMSR: 30 ± 9) and 32 ± 12 times informally (NMSR: 31 ± 14).

Intervention programs.

MBSR. The detailed methodology of MBSR has been described elsewhere (Kabat-Zinn, 1990, 1994). A standard MBSR program was implemented by a licensed psychologist and experienced mindfulness instructor. The program was designed as an 8-week course with one weekly meeting for 2.5 hr to develop mindfulness skills and talk about stress and coping. "Formal" home assignments (45 min/day) following CDs with guided meditation practices—as well as "informal" (15 min/day) assignments to be carried out during other, daily activities—were given every week to support training outside the courses. An intensive retreat (7 hr) was held during the sixth week. The three most central exercises in MBSR are the body scan, the sitting meditation, and hatha yoga postures. During the body scan, participants are lying

[1] European Credit Transfer and Accumulation System.

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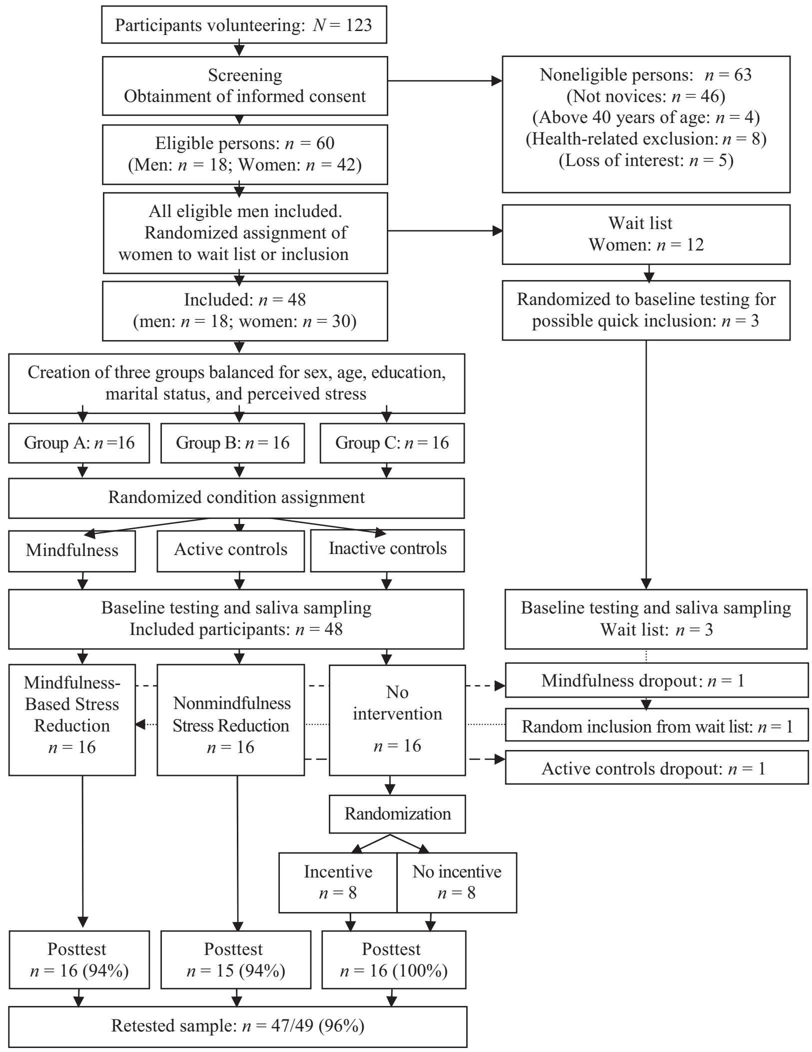

Figure 1. Participant flow throughout the study.

down with eyes closed, carefully observing areas of the body, just noticing how they feel moment by moment with a nonjudgmental attitude. Instructions are open and generally without suggestions (e.g., “Notice how your legs are in this moment—whether they are heavy or light. Just notice how they are, and let it be okay”). Likewise, breath exercises and hatha yoga train mindfulness in part through continued, nonjudgmental noticing of bodily sensations. In sitting meditation, participants are encouraged to observe and be curious about their thoughts as they wander—but crucially not to judge them as “good” or “bad.” Thus, an essential goal is a renewed relation to the total life experience, incorporating a nonjudgmental attitude toward all things, beings, thoughts, and emotions. Awareness of the transiency of all things is aimed for to improve the central ability to “let go” of, for example, painful thoughts and emotions. This presumably reduces tendencies to ruminate and eases the nonjudgmental returning of awareness to the present moment, a cardinal skill developed specifically in MBSR.

NMSR. We decided to focus our investigation on two central MBSR elements: meditation and training in a nonjudgmental attitude. Accordingly, the NMSR control intervention was designed to resemble MBSR but did not include (a) meditation practices or (b) training in a nonjudgmental attitude. The NMSR course was implemented by an authorized psychomotrician. The course took place in the same physical room as the MBSR course and was structurally similar to it, including one weekly meeting for 2.5 hr, equal amounts of formal (also following a CD) and informal home assignments, and an identical practice diary. This was meant to “filter out” nonspecific effects of stress reduction, contact with an instructor, and social support. Guided relaxations, during which participants were lying down with their eyes closed, were carried out, but instructions were deliberately based on suggestions, such as “Feel your legs resting against the floor. Now imagine how the muscles in your calves are relaxing. Feel how the lower legs are becoming heavier as they are getting more and more relaxed.” This is contrary to MBSR, in which the guided instructions are far more open and generally nonsuggestive (see previous paragraph). Therefore, NMSR did not train the nonjudgmental attitude through accepting whatever bodily sensations were experienced or through psychoeducation on

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the presumed value of this attitude. Each course also included yoga, grounding exercises, and 20 min of circulatory training. A central strategy was to increase participants' body consciousness, helping them to become aware of ways to relax during stress.

Instruments and Outcomes

Five attentional tasks were presented in randomized order. Computerized tasks were presented in E-Prime (Version 1.2; Psychology Software Tools, Pittsburgh, PA) using stationary IBM computers (1.3 GHz, 1GB RAM) with 20-in. CRT screens (refresh rate 100 Hz) seen at a distance of approximately 60 cm. Rooms were semidarkened and situated in a designated, experimental area. A test session lasted 2 hr including a 10-min break between each task.

Dual attention to response task (DART; Dockree et al., 2006). DART was developed from an established vigilance test, the Sustained Attention to Response Task (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), by including a continuous performance task to increase the sensitivity in healthy adults. Both tests have been found to correlate with self-reported everyday attentional failures. In an operational definition of mindfulness, leading researchers predicted improved vigilance and attentional set shifts after mindfulness training. DART provides measures of both set shifts and vigilance. Thus, we predicted that MBSR would improve overall DART performance and set-shifting RTs.

Accordingly, there were two DART outcomes. The first was *RT CV for white digits* (white digits *SD*/white digits mean RT), proposed as an indicator of overall DART performance (Dockree et al., 2006). To test the validity of this proposal, we examined bivariate correlations between the white-digit CV and commission errors, premature presses, and reaction omissions, respectively. The second was *RTs on gray digits*, a measure of attentional switching (Dockree et al., 2006). To further test the resistance of CV-based outcomes to attentional effort, we also analyzed the gray-digit RTs after transforming them into a *gray-digit CV*.

In the version applied, white and gray digits from 1 through 9 were presented sequentially in 28 cycles, including three practice cycles. Participants were instructed to monitor the digit color, pressing *1* after white digits and *2* after gray digits but to always withhold the response after the digit *3*. Digits were presented for 150 ms above a fixation cross on a light gray background. Of the 225 test digits, 10 were gray. The interstimulus interval was either 1,000 ms or 1,500 ms, yielding a duration of 1,400 ms from digit onset to digit onset. Participants pressed *1* with their favored index finger (right in all cases) and *2* with the middle finger of the same hand. The task lasted 6 min.

Spatial and temporal attention network (STAN; Coull & Nobre (1998). The STAN task expands on the widely used spatial orienting tasks (see e.g., Posner, Snyder, & Davidson, 1980), incorporating research on temporal orienting (Correa, Lupiáñez, Madrid, & Tudela, 2006). It has been validated for use in healthy adults (see Coull, 2009). Temporal orienting relies on an established (see e.g., Posner & Petersen, 1990) left-lateralized frontoparietal network and is recruited "particularly [when] directing attention toward a particular moment in time" (Coull & Nobre, 1998, p. 7434). Because returning attention to the present moment is a cardinal part of MBSR training (Kabat-Zinn, 1990), STAN was considered a theoretically relevant test. We chose two primary, RT-based outcomes. The first was *RTs after invalidly cued, short temporal trials*. In these trials, the temporal cue indicated a long (1,500 ms) cue–target interval (CTI), but in fact the target appeared after a short (750 ms) CTI. Thus, these RTs indicated how quickly a participant was able to return attention to the present moment and react at an unexpected point in time. Our second, primary outcome was *RTs after uninformative cues* (neutral cues), measuring the ability to stay alert in the absence of external temporal information and again orient attention to the moment when the target suddenly appeared. To further examine the resistance of CV-based outcomes to attentional effort, we also transformed and analyzed our second outcome to a *neutral trials CV*. The functionality of the task was corroborated by examining, across groups, the disadvantage of invalid cues compared with neutral cues, and the advantage of valid cues compared with neutral cues and invalid cues, respectively.

Each trial displayed a central cue (100 ms) and two peripheral boxes, inside one of which a target (× or +) appeared for 50 ms (see Figure 2). Participants were instructed to focus on the fixation cross, covertly detect the targets, and react as fast as possible by pressing a button with their favored index finger (right in all cases). Targets were preceded by either spatial cues predicting target location (left or right); temporal cues predicting the CTI (750/1,500 ms; also referred to as "short" or "long" trials); or neutral, uninformative cues. Spatial and temporal cues were either valid (80% of trials, indicating the correct location or CTI) or invalid (indicating the opposite location or CTI). Participants were informed that cues were "likely" to be valid. One practice block of each condition (spatial, temporal, or neutral) preceded the experimental task consisting of nine blocks (of 40 trials each): three temporal, three spatial, and three neutral, in that order. The total task duration was 12 min 45 s. The data were filtered using cutoff points at 100 ms and 750 ms. No outliers were removed. We analyzed only the 750-ms temporal trials, because the 1,500-ms temporal trials were confounded by mounting expectations (Coull, 2009; Coull & Nobre, 1998; Nobre, 2001) and motor preparation (Coull, Frith, Büchel, & Nobre, 2000).

Stroop color–word task (Stroop, 1935). This task is widely used as a reliable test of selective attention and of cognitive flexibility and control (MacLeod, 1991, 2005). These factors are presumably affected by mindfulness training, leading Bishop et al. (2004) to specifically propose Stroop as a relevant paradigm in an operational definition. Benefits on the Stroop test after short-term (Wenk-Sormaz, 2005) and long-term (Moore & Malinowski, 2009) meditation have been found, but other studies have found no effects of short-term mindfulness training (Alexander, Langner, Newman, Chandler, & Davies, 1989; Anderson, Lau, Segal, & Bishop, 2007). In addition, attentional effort has consistently been demonstrated as a prominent factor in Stroop (Chajut & Algom, 2003; Huguet, Dumas, & Monteil, 2004; Huguet, Galvaing, Monteil, & Dumas, 1999; MacKinnon, Geiselman, & Woodward, 1985). On the basis of this literature, we hypothesized that attentional effort would be an important factor in Stroop. Thus, both theoretically and empirically the Stroop test was important to investigate.

We presented two blocks of 100 color words (*red, blue, yellow,* or *green*) printed in red, blue, yellow, or green ink (font: Times New Roman; height: 0.4 cm) and arranged in a 10 × 10 word matrix on two separate pieces of paper with a small space in between. The first block presented "congruent" color words (e.g.,

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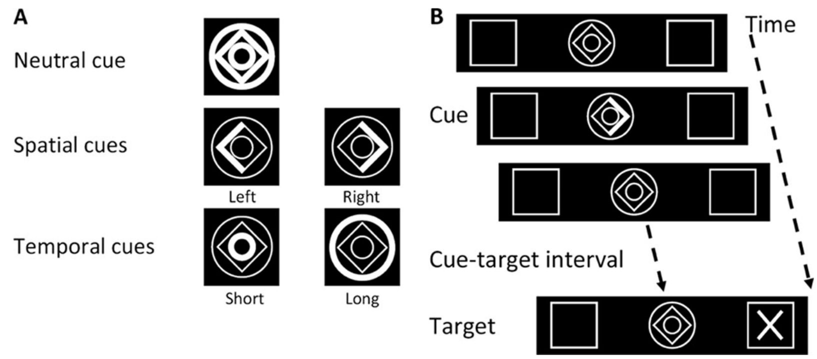

Figure 2. A: Cue types used in the spatial and temporal attention network task to direct attention to a particular location or stimulus-onset time. The neutral cue does not provide spatial or temporal information. Spatial cues direct attention to the left or right. Temporal cues direct attention to a short or long cue–target interval (CTI). B: A valid spatial trial, directing the participant's attention to the right location, with no information about the CTI. Adapted from "Where and When to Pay Attention: The Neural Systems for Directing Attention to Spatial Locations and to Time Intervals as Revealed by Both PET and fMRI," by J. T. Coull and A. C. Nobre, 1998, *Journal of Neuroscience, 18,* p. 7427. Copyright 1998 by the Society for Neuroscience.

red in red ink), whereas the second block presented "incongruent" words (e.g., *red* in green ink). Instructions were to state the ink color as fast as possible while avoiding mistakes. Naming errors were allowed to be corrected. Block completion time was measured in seconds with a handheld stopwatch and naming errors noted on a response sheet. Because effects on response speed are hard to discover in healthy adults on Stroop due to floor effects (MacLeod, 2005), and because MBSR was primarily hypothesized to change the inhibition process (Bishop et al., 2004), our outcome for group comparisons was the *incongruent block error rate*. Block RTs (in s) and the Stroop interference effect (the difference between incongruent and congruent block RTs) were examined across and within groups in secondary analyses to confirm the task functionality (see supplemental materials, Table I).

The d2 Test of Attention (Brickenkamp, 2002; Brickenkamp & Zillmer, 1998). The d2 Test of Attention is a paper-and-pencil cancelation task measuring sustained and selective attention. The test was chosen because these abilities were again predicted to be positively affected by mindfulness training (Bishop et al., 2004), and d2 performance was superior in experienced meditators compared with controls (Moore & Malinowski, 2009). The psychometric properties of the test have been well supported (Bates & Lemay, 2004).

The d2 sheet contains 14 lines of letters, and the task is to cross out *d*s with two dashes, which are interspaced with distractors. The time limit for each line is 20 s. Again, because MBSR has been predicted to improve selective attention by leading researchers (Bishop et al., 2004), for our group comparisons we chose three outcomes hypothesized to be the most sensitive in this young, healthy sample. They each measured one of the following error performances: (1) the *total error rate* (E; commissions and omissions); (2) the *error percentage* (E%, calculated as E/TN $\times$ 100, where TN represents the total number of processed items); and, following the d2 manual, (3) the *error distribution* (ED), defined as the error sums for three test sections (lines 1–5, lines 5–10, and lines 11–14). Pre–post results for TN and also TN adjusted for errors (TN $-$ E) are provided in Table I of the supplemental materials. The *concentration performance* measure (Bates & Lemay, 2004) was irrelevant due to too few incorrectly canceled items.

The CombiTVA paradigm. The theory of visual attention (TVA; Bundesen, 1990) is a computational theory that accounts for behavioural and neurophysiological attentional effects and provides an ideal framework for investigating and quantifying attentional performance. In contrast to most computerized attention tests using RTs, TVA-based testing employs unspeeded, accuracy-based measures of basic visual perception and attention unconfounded by motor components. We considered the CombiTVA paradigm, which combines both whole and partial reports, an important test to include both theoretically and empirically. First, phenomenological reports and historical texts indicate that meditative training changes and improves especially attention and visual perception (D. P. Brown, 1977). Early studies also found perceptual alterations with more meditative experience (D. P. Brown & Engler, 1980), improved the perceptual threshold and discriminatory ability for visual flashes after an intensive mindfulness retreat (D. Brown, Forte, & Dysart, 1984), and improved visual perception after just 2 weeks of transcendental meditation training (Dilbeck, 1982). In a recent review of this field, Bushell (2009) argued that Buddhist meditation practices should facilitate near-threshold perception in the visual domain, and a study of experienced meditators showed improved ability to detect target stimuli presented in rapid succession (attentional blink task) after an intensive retreat (Slagter, 2007, Slagter et al., 2009). Thus, we were particularly interested in the possibility of separating effects on the visual threshold for conscious perception and the speed of information processing (see later). Finally, we also expected this accuracy-based measure to be less sensitive to attentional effort, given that task does not require speeded motor responses involving cortical motor areas. We hypothesized that MBSR would result in unique improvements of the perceptual threshold, because this was assumed to be affected primarily by meditation, which was not included in NMSR.

TVA-based testing has previously been shown to be a highly sensitive tool for quantifying separate functional components of

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visual attention in healthy participants (see e.g., Finke et al., 2005). The *CombiTVA* paradigm (see Vangkilde, Bundesen, & Coull, 2011) employed is a combination of two classical attention paradigms (whole and partial report; see Sperling, 1960, and Shibuya & Bundesen, 1988). The test comprised one practice block of 24 trials and nine test blocks of 36 trials and took 40 min to complete. Trials were initiated by a red fixation cross in the middle of a black screen, succeeded by a 100-ms blank screen before the stimulus display with six possible locations was presented on an imaginary circle (r = 7.5 degrees of visual angle) centered on the fixation cross. After a variable stimulus duration, the display was masked by a 500-ms mask display made from red and blue letter fragments. Then the screen turned black, and the participant could type in the letter(s) that he or she had seen. In whole report trials, either two or six red target letters were presented, whereas partial report trials contained two red target letters and four blue distractor letters. Displays with six target letters were shown for each of six stimulus durations (10, 20, 50, 80, 140, or 200 ms), whereas all other displays were shown for 80 ms. All trial types were intermixed, and the letters were chosen randomly without replacement from a set of 20 letters (ABDEFGHJKLMNOPRSTVXZ) in the font Ariel broad with a point size of 68. Participants were to make an unspeeded report of all red letters they were "fairly certain" of having seen (e.g., to use all available information but refrain from pure guessing).

The number of correctly reported letters in each trial constituted the main dependent variable. The performance of the participants was computationally modeled using a maximum likelihood fitting procedure (for details see Kyllingsbæk, 2006, and Dyrholm, Kyllingsbæk, Espeseth, & Bundesen, 2011) to derive estimates of four attentional parameters. First is t_0, the threshold of conscious perception, defined as the longest ineffective exposure duration measured in milliseconds below which the participant has not consciously perceived, and therefore cannot report, any letters. Because this value is estimated from performance, the perceptual threshold need not be exactly at any of the presented stimulus exposure durations. Second is K, the maximum capacity of visual working memory measured in number of letters. Third is C, the speed of visual processing measured in letters processed per second. Fourth is alpha, the top-down controlled selectivity, defined as the ratio between the attentional weight of a target and the attentional weight of a distractor. The alpha value is estimated by comparing performance in the partial report trials with performance in the two-target whole report trials. A participant with perfect selection should be unaffected by distractors and thus report the same number of targets regardless of the number of distractors. Efficient attentional selection is indicated by α values close to 0, whereas α values close to 1 indicate no prioritizing of targets compared with distractors.

Physiological Stress, Self-Report, and Compliance

Saliva cortisol sampling. Physiological stress was characterized by cortisol secretion in response to awakening, a valid indicator of the hypothalamic–pituitary–adrenal (HPA) axis activity (Pruessner et al., 1997). Noninvasive, minimally stressing cotton swab sampling following written instructions was performed at home after a practice sampling prior to the sampling day. Five samples were taken: Sample 1 upon awakening, and Samples 2–5 every 15 min for the subsequent hour. Participants registered the exact time of awakening and of each sampling and stored the samples in glass tubes below 5 degrees Celsius. Within 48 hr, samples were received and stored at −80 degrees Celsius. The entire batch was analyzed in one step using electrochemiluminescens immunoassay on Cobas equipment (Roche, Mannheim, Germany). Using principal component analyses, Fekedulegn et al. (2007) demonstrated that saliva cortisol outcomes fall in two categories relating primarily to either the magnitude of the secretion or the pattern of the secretion over time. Following Fekedulegn et al., we calculated *area under the curve with respect to ground* (AUC_G), representing the total magnitude of cortisol secretion, and *area under the curve with respect to increase from awakening* (AUC_I). Higher AUC_I values denote a more reactive or less stable HPA system. Both outcomes were supported as valid, always showing significant correlations with two or three of their highest loading factors (Fekedulegn et al., 2007, Table 5).

Self-reported mindfulness and stress. The Mindfulness Attention and Awareness Scale (MAAS; K. W. Brown & Ryan, 2003) is often used in MBSR research and has been demonstrated to yield a reliable measure of mindfulness level. As a single-factor measure, the MAAS does not capture facets of mindfulness but was chosen as a phenomenological counterpart to the behavioral tests because it focuses on everyday experiences of attentional functions. Perceived stress was evaluated with Cohen's Perceived Stress Scale (PSS; Cohen & Williamson, 1988), one of the more widely used scales for indexing perceived stress during the past 14 days. Cronbach's α for MAAS and PSS in the present study was always .85–.90. Both scales were completed in Danish. The PSS was a back-translated version approved by Cohen (see Olsen, Mortensen, & Bech, 2004). The MAAS was a professionally translated version that has now been slightly edited, back-translated, and approved by K. W. Brown. Questionnaires on health and history of illnesses, lifestyle, psychiatric symptoms, and personality were also completed, but results are not reported here.

The influence of MBSR compliance. As an exploration, we tested correlations between attentional change scores (Time 2 [T2] score – T1 score) and each of four compliance variables (number of courses attended, number of formal home practices, number of informal home practices, and total activity, which equaled the sum of the first three variables), as well as correlations between compliance variables and change scores for cortisol secretion and self-report.

Data Analyses

On attentional tests, group differences at baseline (T1) and posttreatment (T2) were tested in three to four nonorthogonal comparisons. First, MBSR was compared with *nonincentive controls* (NOCO) and INCO, respectively. If this did not yield significant group differences, the inactive controls were collapsed into one group (CICO), and MBSR was compared with this inactive control group representing an intermediate level of increased attentional effort. Finally, MBSR was compared with NMSR. Although orthogonal comparisons are preferable, they are no longer considered as crucial as once was the case (Howell, 2007). Furthermore, considering the lack of previous studies using a similarly rigorous design, the possibility of detecting new systematic group effects was prioritized. On self-report scales and cortisol levels, MBSR was compared with CICO (the inactive controls were always collapsed, because the financial incentive was unrelated to these data) and NMSR. "Corrected" p values were Bonferroni-

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corrected for the total number of tests carried out on the outcome (excluding explicitly termed “post hoc” tests). Conducting Bonferroni corrections for the total number of tests in settings where dependent variables are related (as many attentional outcomes are) is often considered too conservative a strategy (see e.g., Nakagawa, 2004). Time × Group interactions for single outcomes were evaluated in mixed model analyses of variance (ANOVAs) treating time (pre/post) as the within-subject variable and group as the between-subjects variable. On exploratory grounds, we tested bivariate correlations between change scores (T2 – T1) on MAAS and change scores on attentional parameters to probe whether increases in mindfulness were associated with attentional improvements. The use of change scores limits the influence of absolute T1 or T2 scores. Mediation analyses were deemed inappropriate due to the low sample size. Effect sizes relating to associations between variables were estimated with Pearson’s r or R^2. Cohen’s d was used for the between-group differences and pre–post effects and was adjusted for dependence among means (Morris & Deshon, 2002, formula 8). Effect sizes for Time × Group interactions were estimated with omega squared. Dropouts ($n = 2$) were excluded, but no other data were excluded from attentional tests or self-report scales. Different outlier criteria (e.g., >2.58 *SD*s, $p < .01$) changed these results only by a small and nonsignificant degree. We received 45 saliva sets pre and post. A few scores were not calculable due to incorrect sampling. The total data set from one MBSR participant was excluded, all cortisol values always being >3.0 *SD*s from the grand mean. Thus, 162 of 188 potential scores (86%; 47 × 2 times × 2 scores) were included. Statistical analyses were carried out in SPSS (Version 18.0), and effect sizes were calculated in Microsoft Excel 2007.

Results

Tasks

DART. The CV was supported as a valid indicator of DART performance. A higher CV (lower stability) was related to more omission errors and more premature presses at both time points (rs = .38 – .60, ps < .04 [corrected]). A lower stability was not related to more commission errors at T1 ($r = .22$, $p > .1$), but this expected finding was present at T2 ($r = .38$, $p = .03$ [corrected]). Baseline correlations between white-digit RTs and the corresponding CV ($\rho = -.20$, $p > .17$) and between gray-digit RTs and the gray-digit CV ($\rho = .17$, $p > .27$) were nonsignificant. This supported the relative independence of the CV from RTs. MBSR did not differ from any other group at baseline on the DART outcomes (ps ≥ .12). Posttreatment, MBSR showed slower RTs on gray digits compared with those for INCO ($p < .05$, $d = 0.87$). Other RT analyses showed no group differences at T2 (ps > .15). Concerning RT stability, MBSR demonstrated more stable RTs on white digits (a lower CV) than did NOCO at T2, $t(22) = 2.10$, $p < .05$, $d = 0.95$. As INCO descriptively decreased their RT stability from pre–post ($d = -0.26$), while MBSR descriptively improved it ($d = 0.19$), it was supported that the higher stability in MBSR compared with NOCO at T2 was not due to increased attentional effort. NMSR, however, improved with a descriptively higher effect size than that for MBSR ($d = 0.68$; see supplemental materials, Table I). A post hoc t test revealed that NMSR was also more stable than NOCO at T2 ($p < .02$ [corrected], $d = 1.56$). Importantly, these results indicated that general stress reduction, rather than mindfulness training specifically, affected the CV.

In the pre–post analyses for gray-digit RTs, the Time × Group interaction was highly significant between MBSR and INCO, $F(1, 22) = 15.37$, $p < .01$ (corrected), $\omega^2 = .30$. This was driven by a remarkable improvement in INCO on this measure of attentional switching ($p = .02$ [corrected], $d = 1.44$), as well as a nonsignificant slowing in MBSR (see Figure 3, Panel A). T1 scores predicted T2 scores ($R^2 = .37$, $p < .001$), but the aforementioned Time × Group interaction was still significant in an analysis of covariance (ANCOVA) using T1 scores as a covariate ($p = .002$, $\omega^2 = .24$). An explorative mixed-model ANCOVA comparing all four groups supported that changes in gray-digit RTs differed between the groups, $F(3, 41) = 4.77$, $p = .006$, $\omega^2 = .14$. These important results indicated that the RT-based measure of attentional switching (gray-digit RT) was seriously confounded by attentional effort. Equally important, therefore, the gray-digit CV proved more resistant to effects of task effort (see supplemental

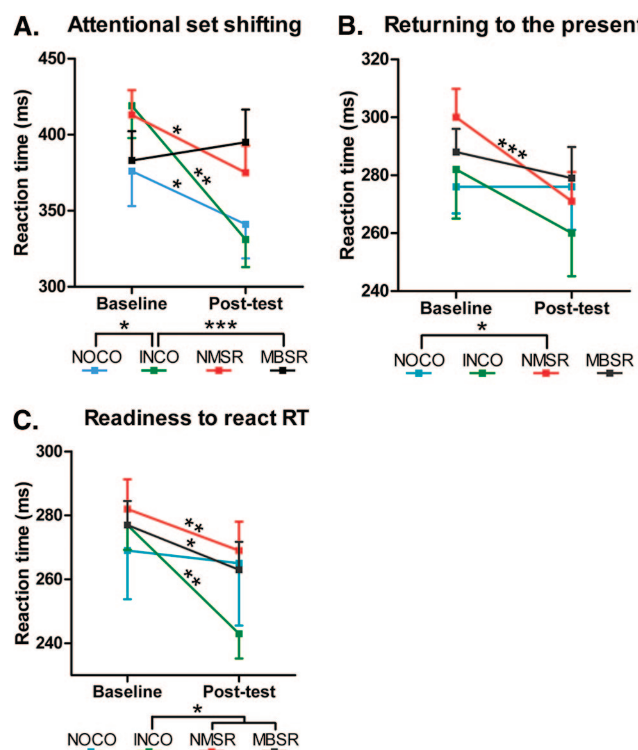

Figure 3. Attentional outcomes confounded by attentional effort. Time × Group interactions are indicated below each panel. A: Gray-digit trials in the dual attention to response task (DART), measuring the speed of task-switching processes. Incentive controls (INCO) improved significantly more than did mindfulness-based stress reduction (MBSR) participants. B: Invalidly cued, short temporal trials in the spatial and temporal attention network (STAN) task, measuring the ability to reorient attention to the present moment. Nonmindfulness stress reduction (NMSR) participants (but not MBSR participants) improved significantly, and significantly more than did nonincentive controls (NOCO). C: Mean reaction time (RT) across neutral trials using noninformative cues in STAN. INCO improved significantly more than did the intervention groups combined. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. p values are uncorrected for multiple comparisons. Error bars indicate one standard error of the mean.

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materials, Figure S1). The data for the gray-digit CV was negatively skewed and therefore log-transformed, yielding normally distributed data. No pre–post group differences were significant ($ps > .12$), and MBSR did not at all differ from INCO or NMSR ($ps > .55$). Likewise, no groups improved on the gray-digit CV ($ps \geq .08$; the nonsignificant results were not due to the log-transformation, as seen from explorative analyses of the untransformed CV data). Other Time × Group interactions in DART yielded $ps > .1$. (In the supplemental materials, Table I displays descriptive results and within-group pre–post effects for DART, the Stroop color–word task, the CombiTVA test, and the d2 test, and Table III displays all significant Time × Group interactions.)

STAN. Overall, the STAN paradigm functioned as expected. Valid cues speeded up RTs compared with neutral cues and invalid cues, respectively, whereas invalid cues slowed RTs compared with neutral cues ($ps \leq .003$). As found in DART, the CV of RTs on neutral trials was supported as independent of the raw RTs, because these outcomes were not at all related ($\rho = .02$, $p > .9$). Group differences at T1 as well as T2 were nonsignificant ($ps > .26$). Likewise, pre–post changes in MBSR were not significantly different from those in any other group ($ps \geq .15$). Furthermore, when we examined the within-group changes on the central condition measuring the ability to reorient attention to the present moment (temporally invalidly cued trials), we found that MBSR did not improve ($p > .3$, $d = 0.29$), whereas NMSR did ($p < .01$ [corrected], $d = 1.09$). A post hoc test even showed that NMSR improved significantly more than did NOCO, $F(1.21) = 5.28$, $p = .03$, $\omega^2 = .13$. INCO did not improve significantly and showed a lower pre–post effect size ($p > .13$, $d = 0.61$). Once again, these results demonstrate the importance of active control interventions in attentional short-term meditation studies.

On the noninformative (neutrally cued) trials measuring the ability to stay vigilant in the absence of information, changes in MBSR were not different from those in any other group ($ps > .06$). In fact, the only pre–post group difference approaching significance was found when comparing MBSR with INCO, and this test indicated that the financial incentive nearly resulted in significantly larger improvements than in the MBSR intervention (ANCOVA adjusting for baseline), $F(1, 21) = 3.91$, $p = .061$, $\omega^2 = .07$. A post hoc ANCOVA comparing INCO with the collapsed stress reduction groups showed that the incentive did improve neutral RTs significantly more than did stress reduction in general, $F(1, 39) = 6.41$, $p = .016$, $\omega^2 = .05$. Within groups, MBSR did improve ($p = .04$, $d = 0.57$) descriptively more than did NOCO ($p > .6$, $d = 0.21$), but NMSR ($p < .01$, $d = 0.91$) and especially INCO ($p < .01$, $d = 1.56$) improved to an even larger effect than did MBSR. These large effect sizes on the neutral trials again emphasize the importance of incentive and active control groups in RT-based tasks measuring the ability to remain vigilant and react to sudden target stimuli.

The CV results measuring the stability of RTs on neutral trials were quite different from the simple RT-based results. First, no groups improved their CV ($ps \geq .15$). Second, pre–post group differences were not approaching significance ($ps > .24$). These results again supported the resistance of the CV to attentional effort and practice effects (see supplemental materials, Figure S2), as we also found for the gray-digit CV in DART. This important methodological point should be of interest to all fields of attentional research.

Stroop color–word task. The interference effect was robust, because incongruent blocks slowed completion times at both test sessions ($ps < .0001$, $ds > 4.0$). MBSR did not differ from any group at baseline ($ps \geq .37$). Posttreatment, MBSR made fewer errors on incongruent blocks than did NOCO ($p = .04$, $d = 1.00$). However, a post hoc test showed that INCO now also committed fewer errors than did NOCO ($p < .04$, $d = 1.15$; baseline $p = .25$). Pre–post changes did not differ between the groups ($ps > .7$). Within groups, INCO showed the largest pre–post response speed effect size on both the congruent block ($p < .05$, $d = 0.92$) and the incongruent block ($p < .05$, $d = 1.21$; see supplemental materials, Table I). In summary, our Stroop results indicated that Stroop performance was confounded by attentional effort on both the incongruent error rate and the task speed. MBSR did not produce unique effects on this measure of selective attention.

The d2 Test of Attention. Groups did not differ on d2 outcomes at T1 ($ps \geq .37$). At T2, the error distribution, ED, in MBSR differed from that in CICO ($p = .02$ [corrected], $\omega^2 = .11$), NMSR ($p = .052$ [Greenhouse-Geisser-, then Bonferroni-corrected], $\omega^2 = .11$), NOCO ($p < .03$ [corrected], $\omega^2 = .13$), and INCO ($p = .050$, $\omega^2 = .08$), respectively. A post hoc, overall comparison supported ED differences between the four groups, $F(6, 84) = 2.30$, $p = .052$ (Greenhouse-Geisser corrected), $\omega^2 = .08$. These Group × Section interactions were clearly interpretable (see Figure 4, Panel A). Whereas NOCO, INCO, and NMSR increased the error rate from the first to the second section ($ps \leq .02$) and decreased from the second to the third ($ps \leq .05$), MBSR did not change between any sections ($ps \geq .32$). Importantly, the increase in errors during the middle section was present in all groups at T1 ($ps \leq .04$), and it was even especially pronounced in MBSR ($p < .01$). The middle increase in ED is dependent on the number of lines per test section (4, 6, and 4, respectively), so in order to better interpret the ED findings, we also examined the errors per line (EL) within-group for each section. Whereas all other groups descriptively increased their EL during the middle section ($ps = .07$–$.10$), suggesting a tiring effect, MBSR descriptively decreased ($p = .07$). Other group contrasts at T2 yielded $ps > .1$. Pre–post changes in the ED differed significantly between MBSR and NOCO ($p = .050$), MBSR and CICO ($p = .051$), MBSR and NMSR ($p < .01$ [corrected]) but not between MBSR and INCO ($p > .3$). Other changes did not differ significantly between groups ($ps \geq .1$). However, only MBSR improved significantly on the total error rate, E ($p = .01$ [corrected], $d = 0.93$). Tests of E changes within other groups yielded $ps > .3$. NMSR improved the error percentage, E% ($p = .04$, $d = 0.62$), but only MBSR improved after Bonferroni-correction ($p < .01$ [corrected], $d = 1.14$). In summary, MBSR showed improvements on all measures of error performance in the d2 test, suggesting that meditation training and training in a nonjudgmental attitude improved selective attention to a degree that was not achieved by stress reduction or attentional effort alone.

The CombiTVA paradigm. Parameters C and K have often been found to be positively correlated in normal samples (see e.g., Finke et al., 2005), reflecting faster processing in participants with larger visual working memory capacities. This was replicated at T1 and T2 ($rs = .70$–$.77$, $ps < .001$). All other parameters were unrelated ($ps \geq .08$). Groups did not differ on any parameters at T1 or T2 (all $ps > .12$; (see descriptives in supplemental material, Table I).

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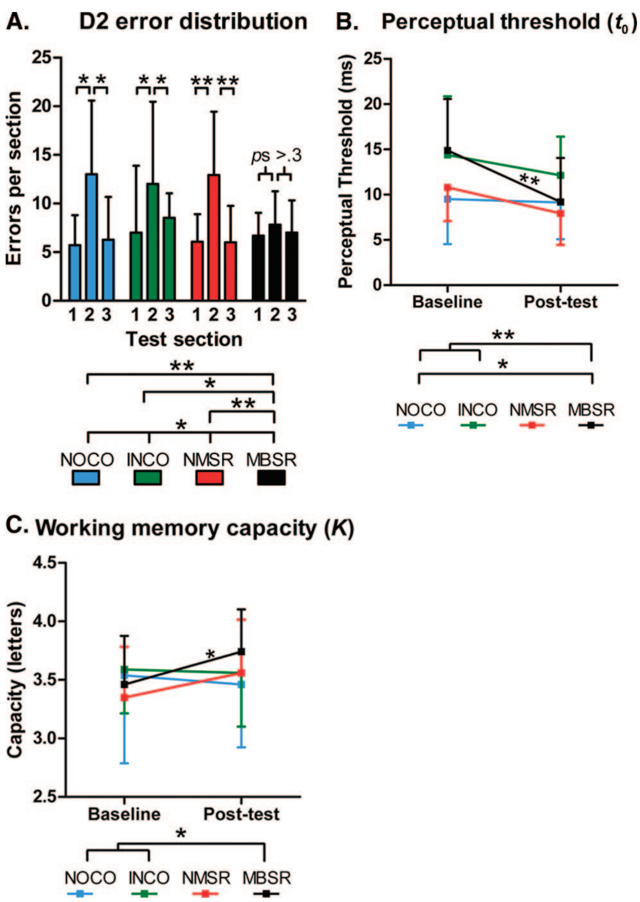

Figure 4. Attentional measures affected especially by mindfulness-based stress reduction (MBSR). Section × Group interactions (see Panel A) or Time × Group interactions (Panels B and C) are indicated below the figures. A: Sectionwise distribution of errors in the d2 Test of Attention. MBSR participants did not show a significant increase in errors during the middle test section. B: Pre–post changes in the perceptual threshold (t_0) in the theory of visual attention-based task (CombiTVA). Only MBSR participants improved significantly, and this represented a significantly larger improvement than in the inactive controls. C: Pre–post changes in visual working memory capacity (*K*) in the CombiTVA task. MBSR improved significantly more than did collapsed inactive controls (CICO). Nonmindfulness stress reduction NMSR), but not attentional effort, was a confounding factor. Error bars indicate one standard error of the mean. NOCO = nonincentive controls; INCO = incentive controls.

Pre–post, however, MBSR showed a marked improvement in the threshold of conscious perception, $t_{0,}$ which was effectively unchanged in NOCO, yielding a significant Time × Group interaction, $F(1, 22) = 7.31$, $p < .05$ (corrected), $\omega^2 = .16$ (see Figure 4, Panel B). This was also significant compared with CICO, in which half of the participants were motivated, $F(1, 30) = 6.85$, $p = .014$ (Bonferroni-corrected $p = .056$), but not compared with INCO or NMSR ($ps > .15$). T1 scores were predictive of T2 scores ($R^2 = .69$, $p < .001$). Thus, T1 score was used as a covariate in two ANCOVAs. The Time × Group interaction in MBSR versus NOCO remained significant ($p < .04$, $\omega^2 = .04$), though with unequal variances (Levene's $p = .012$). However, the Time × Group interaction in MBSR versus CICO also remained significant ($p < .02$), variances were equal ($p = .09$), and the effect size was slightly increased ($\omega^2 = .05$). This refuted the idea that the larger improvements in MBSR compared with inactive controls could be explained by baseline differences, and the increased effect size when including the incentive controls supported that attentional effort was not confounding these results. Within groups, only MBSR improved significantly on t_0 ($p = .02$ [corrected]), whereas other groups' pre–post tests yielded $ps > .1$. This MBSR effect size was descriptively twice as large as in any other group (see supplemental materials, Table I). Of potential importance, within MBSR, MAAS changes also correlated with t_0 changes ($r = -.67$, $p = .02$ [corrected]), indicating that increases in mindfulness were associated with improvements of the threshold. This finding was further supported in a post hoc baseline test showing that MAAS was negatively associated with t_0 ($\rho = -.40$, $p = .005$), indicating that higher levels of mindfulness were related to a lower perceptual threshold across participants. MBSR increased their visual working memory capacity, *K*, significantly more than did CICO, $F(1, 30) = 4.74$, $p < .04$, $\omega^2 = .10$. T1 scores predicted T2 scores ($R^2 = .66$, $p < .0001$), but the group effect was still significant when using T1 scores as a covariate, $F(1, 29) = 5.11$, $p = .03$, $\omega^2 = .05$, and only MBSR demonstrated significant improvement on *K* ($p < .03$, $d = 0.64$). The exploratory analyses of correlations between changes in *K* and mindfulness level showed that *K* score was not associated with MAAS score across groups at any time ($ps > .4$). However, for MBSR only, MAAS change scores correlated with *K* change scores ($r = .68$, $p = .02$ [corrected]), indicating that increases in mindfulness were associated with improved working memory capacity. For processing speed, *C*, and attentional selectivity, α, pre–post changes did not differ between groups ($ps \geq .2$). INCO showed the largest descriptive improvement on the measure of attentional selectivity (see supplemental material, Table I).

Physiological Stress and Self-Report

The groups did not initially differ on any cortisol measures ($ps > .2$). At T2, MBSR showed a tendency toward a lower AUC_G than did CICO ($p = .068$, $d = 0.76$). Other T2 contrasts were nonsignificant ($ps > .4$). For AUC_G ($R^2 = .32$.) and AUC_I ($R^2 = .19$), baseline levels predicted T2 levels ($ps < .03$). Time × Group interactions adjusted for baseline revealed that MBSR decreased more than did CICO, $F(1, 23) = 7.50$, $p = .02$ (corrected), $\omega^2 = .14$, but not NMSR ($p > .5$). On AUC_I, MBSR tended toward a larger decrease than did CICO in an uncorrected ANOVA, $F(1, 24) = 3.76$, $p = .064$, $\omega^2 = .09$, but not when using baseline as a covariate ($p > .16$). MBSR did not decrease more than did NMSR ($p > .4$). Within groups, MBSR decreased near-significantly on AUC_G, $t(12) = 2.13$, $p = .054$, $d = 0.68$. Descriptively, NMSR decreased ($d = 0.27$), whereas CICO increased ($d = -0.54$, $ps > .1$; see Table 1). Only MBSR decreased significantly on AUC_I, $t(12) = 2.23$, $p < .05$, $d = 0.64$. NMSR decreased descriptively ($d = 0.59$, $p = .09$). CICO showed no change ($p = .5$). These results supported that MBSR reduced both the magnitude of cortisol secretion and the HPA axis reactivity.

Self-report measures. Higher levels of mindfulness were associated with lower levels of perceived stress (PSS) at baseline ($r = .40$, $p < .01$). Groups did not differ on PSS initially ($p > .7$), but MBSR displayed lower baseline MAAS levels than did NMSR

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Table 1
Descriptives for Cortisol Secretion Measures and Self-Report Scales

Outcome and time	Inactive controls			Nonmindfulness course			Mindfulness course		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Cortisol secretion (nmol/L per hr)									
AUC_G									
Time 1	577	276	14	634	204	13	543	303	14
Time 2	745	451	14	555	258	11	416	189*	15
AUC_I									
Time 1	618	329	14	170	137	13	173	306	14
Time 2	680	211	14	186	83	11	119	228*	15
Self-report scales									
MAAS									
Time 1	4.24	0.54	15	4.24	0.45	15	3.57	0.78	16
Time 2	4.33	0.65	13	4.46	0.54	15	4.30	0.74***	16
PSS									
Time 1	13.2	6.4	15	12.1	6.0	15	13.8	6.2	16
Time 2	13.7	5.6	13	13.2	6.1	15	10.8	3.4*	16

Note. AUC_G = area under the curve with respect to ground; AUC_I = area under the curve with respect to increase from awakening; MAAS = Mindfulness Attention Awareness Scale; PSS = Cohen's Perceived Stress Scale.
* $p < .05$. *** $p < .001$. Within-group pre–post change is significant at the .05 level/.001 level (uncorrected for multiple tests).

and CICO (*p*s $<$ .05 [corrected]) due to unknown factors and despite the careful balancing on many factors. Posttreatment, groups did not differ on PSS (*p*s $>$ .15) or on mindfulness levels (*p*s $>$ .4). Pre–post, MAAS and PSS change scores (T2 score – T1 score) were negatively related (r = –38, p = .01), indicating that increases in mindfulness were associated with decreases in stress. Only MBSR increased significantly on MAAS, $F(1, 15) = 25.53$, $p < .001$ (corrected), $d = 1.27$. NMSR increased descriptively ($p = .09$, $d = 0.58$). Because baseline mindfulness level predicted the posttreatment level ($R^2 = .43$, $p < .001$), and due to the initial group differences, T1 scores were used as a covariate. The two ANCOVAs indicated that after correction for baseline levels, MBSR still displayed a larger increase in mindfulness compared with CICO ($p = .015$, $\omega^2 = .09$) but not with NMSR ($p > .15$, $\omega^2 = .02$).

PSS decreased significantly in MBSR ($p = .04$, $d = 0.61$), whereas it increased marginally in CICO and NMSR. Baseline PSS scores were significantly related to T2 scores ($p = .002$, $R^2 = .20$). ANCOVAs with baseline scores as a covariate indicated that MBSR decreased significantly more than did CICO ($p < .03$, $\omega^2 = .11$) but not more than did NMSR ($p > .07$, $\omega^2 = .06$).

Compliance with the MBSR intervention. Compliance was not related to attentional change scores, changes in self-report, or changes in cortisol secretion (*p*s $>$ .05), and no clear patterns were evident.

Discussion

This study examined whether mindfulness-based stress reduction (MBSR) would result in larger beneficial attentional effects than would a nonmindfulness stress-reduction (NMSR) course and increased task incentive invoked by a financial reward offered during the postintervention test session. First, in support of the generalizability of our findings to other MBSR programs with healthy novices, is it important to note that the attentional results are based on an MBSR intervention that was effective in reducing stress, according to both self-report and physiological measures. Thus, the overall absence of unique attentional effects from MBSR (discussed later) was not due to an inefficient intervention.

MBSR led to increased mindfulness, and to a significantly greater degree than the inactive group. As intended, NMSR did not affect mindfulness, suggesting that mindfulness meditation and training in a nonjudgmental attitude are in fact important elements of MBSR. Perceived stress (PSS) decreased significantly for those in the MBSR group—and more so compared with the inactive controls—but decreases in PSS did not differ between the MBSR group and the active controls, which was also the intended effect. The decrease following MBSR was comparable ($d = 0.61$) to effects generally found on well-being scales after mindfulness courses ($d = 0.50$; Grossman et al., 2004). Finally, mindfulness was negatively associated with PSS, and the greater the increase in mindfulness from pre- to posttest, the greater the perceived decrease in stress. Physiologically, the MBSR group showed significantly decreased cortisol secretion and significantly lower secretion than did the inactive controls at T2. From pre- to posttest, cortisol secretions were reduced significantly more in the MBSR group than in the inactive controls, whereas MBSR did not differ from NMSR in any cortisol analyses. There are some limitations to the cortisol results, including small sample size, the relatively large variability in the data, and the single sampling day. Still, these results are supportive of a beneficial effect of MBSR on cortisol secretion, consistent with previous findings (Matousek, Dobkin, & Pruessner, 2010).

Attentional Measures Confounded by Attentional Effort

Incentive controls (INCO) improved remarkably on the measure of attentional set shifting indexed by gray-digit RTs in DART and

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to a significantly larger degree than did the MBSR participants. This reveals a potentially substantial effect of attentional effort on forced choice performance within a vigilance test. The MBSR group did not even improve descriptively, which is inconsistent with the proposed beneficial role of mindfulness in processes of attentional set shifting (Bishop et al., 2004). This is in accordance with a previous study finding improvements on working memory and vigilance but not switching (Chambers, Lo, & Allen, 2008). Attentional set shifting, however, is not a uniform phenomenon that allows simple inferences from highly abstract tests to discussions of complex abilities, such as shifts from negative judgments to cognitive–emotional acceptance (for reviews see Kiesel et al., 2010; Monsell, 2003). To the contrary, measures of attentional shifts may be mediated by context-dependent networks (Rushworth, Krams, & Passingham, 2001). *Attentional* switching, as defined by Posner and Petersen (1990), may also be mediated by different networks than *intentional* set shifts (Rushworth, Paus, & Sipila, 2001), and the financial incentive presumably affected the intentional aspect of participants' performance specifically. The DART measure of switching abilities might also have been confounded by factors such as working memory load, whereas alternating runs paradigms using a fixed number of trials in each task condition may provide a purer measure of switching costs (Kiesel et al., 2010).

In STAN, the incentive controls improved, especially on neutrally cued trials, and to a significantly greater degree than did the stress reduction groups combined. In neutral trials, the cue is uninformative, and thus, the target can appear at both locations after both intervals, requiring a sustained readiness to react. The mindful ability to sustain a vigilant state has been argued (Jha et al., 2007) to be validly indexed by RTs in a spatial cuing paradigm, the attention network task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). Jha et al. (2007) found lower RTs in meditators than in controls on the no-cue trials, which was taken as an indication of improved attentional "orienting." As noted in the introduction, however, the MBSR participants in the study by Jha et al. may simply have tried harder during the second test session. This interpretation was supported by our data, because we found remarkable improvements on noninformatively cued (neutrally cued) trials for the incentive group. Therefore, the improvements found in Jha et al. might have been caused by factors other than MBSR. Another study found no effects on the ANT after a brief mindfulness course (Tang et al., 2007). More research is clearly needed to draw any conclusions about the effects of MBSR and test effort on such trial types.

The ability to remain vigilant and return to the present moment is quintessential to many meditative practices (Lutz et al., 2008). This ability, as well as other temporal attention functions, may also be important in real-life situations, for example when estimating the temporal moment at which moving objects will collide (Coull, Vidal, Goulon, Nazarian, & Craig, 2008) and when perceiving fast speech (Correa et al., 2006). The temporal trials in STAN have been found to be specifically associated with increased activation in left-lateralized ventral prefrontal areas assumed to be involved in top-down control of attention (Coull et al., 2000; Coull & Nobre, 1998; Nobre, 2001). Thus, cognitive stress research should continue to evaluate temporal attention using STAN or similar paradigms, but our results clearly argue for a rigorous consideration of the potential confounding effects of attentional effort on RTs. Likewise, general stress reduction should be considered as a potential factor leading to improved temporal attention, because the NMSR group improved markedly on temporal invalid trials in STAN and to a significantly greater degree than did NOCO. This potential confound in RT measures was less pronounced for RT stability, as argued later.

The Stroop results further corroborated the importance of attentional effort in MBSR studies. Both the MBSR and incentive groups demonstrated significantly fewer naming errors on the incongruent block than did the nonincentive group at T2, with similar effect sizes between the groups. Likewise, when considering pre–post effect sizes, the INCO group demonstrated descriptively larger improvements on completion times for both congruent and incongruent blocks than did any other group. Moore and Malinowski (2009) found superior selectivity on the Stroop task for experienced meditators compared with novices, and Stroop performance improved after just three meditation sessions for novices (Wenk-Sormaz, 2005). In contrast, another MBSR study using a Stroop task found no effects (Anderson et al., 2007), and mindfulness training did not lead to improved Stroop performance in a study that included elderly participants (Alexander et al., 1989). Wenk-Sormaz (2005) assessed effort (task compliance) briefly on a Likert scale but did not manipulate test effort directly. Importantly, in mainstream Stroop research, contextual factors such as social competition and rewards have consistently been found to improve Stroop performance (Huguet et al., 2004, 1999; MacKinnon et al., 1985). Thus, attentional effort may be a serious confounding factor in studies using the Stroop task to assess effects of short-term meditation on selective attention.

In addition, the selectivity parameter derived from the CombiTVA test, α, improved in NMSR but not in MBSR, whereas INCO once more demonstrated larger descriptive improvements than did MBSR. Thus, this selectivity measure seemed more susceptible to improvements from the NMSR course and a cognitive (financial) incentive than to MBSR (see supplemental materials, Table I). In accordance with the Stroop results, these findings support the idea that stress reduction—as well as the perceived task incentive during the test session—can affect top-down attentional selectivity.

In summary, our results on attentional effects of NMSR and attentional effort challenge the validity of many previous studies claiming attentional benefits after short-term meditation or MBSR without considering (either by assessing or by manipulating) these two factors. The main weakness of the present study is the limited sample size and the number of attentional measures and statistical tests. However, our results consistently showed serious confounding effects of attentional effort on RT-based measures. We therefore recommend a future emphasis on finding attentional measures that are less susceptible to these influences.

Attentional Measures Less Confounded by Attentional Effort

Three central measures of RT stability in DART and STAN were based on the RT coefficient of variation, CV, because RT stability was expected to be less sensitive to attentional effort and practice effects and more ecologically valid (cf. Flehmig et al., 2007; Steinborn et al., 2008). First, supporting the independence of CV from simple RTs, the three applied CV measures did not

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correlate with the corresponding RTs, though faster RTs can be moderately associated with less variance in some tests (Flehmig et al., 2007). We also found support for the possibility that CV for white-digit RTs in DART is a valid indicator of overall DART performance (Dockree et al., 2006), showing significant, negative relationships with the rate of omission errors, premature presses, and commission errors. This supports the proposal by Dockree et al. (2006) that CV is a measure of overall performance on the vigilance task. Changes in DART CV scores were not significantly different between groups, but MBSR showed significantly more stable RTs than did NOCO at T2, suggesting that MBSR improved CV. Stability decreased for the INCO group between pre- and posttest, refuting the idea that attentional effort is a confound for CV in DART. However, the higher stability at T2 in the MBSR compared with the NOCO group might have been a random effect of allocating the least stable persons to NOCO (see descriptives in the supplemental material, Table I), and the effect size for the change in the NMSR group was larger than for the MSBR group. Thus, MBSR did not lead to any unique effects on the CV in DART. Still, we consider it methodologically important that increased motivation improved only RTs and not CV. The impenetrability of CV to attentional effort was replicated in STAN. On the neutral trials, which require a sustained readiness to react, the INCO group showed significant and large pre–post effects on simple RTs, which amounted to a significantly larger improvement than the stress reduction groups combined. However, on CV for the neutral trials, INCO did not improve, and all between-groups pre–post comparisons were not significant.

In STAN, we were particularly interested in the invalidly cued, temporal trials as a measure of the ability to return attention to the present moment (which is required in short, invalid temporal trials when a long CTI is cued), because this is a pivotal component of MBSR (Kabat-Zinn, 1994). However, the within-group results indicated that RTs decreased significantly for only the NMSR group, whereas the MBSR group did not improve. This can be seen as an example of how an activity not directly aimed at training mindfulness may nonetheless increase aspects of mindfulness (Hayes & Shenk, 2004), complicating research strategies as well as the conceptual definition of a "nonmindfulness" intervention. The NMSR group did not increase on the MAAS, but returning attention to the present moment is only one facet of mindfulness, whereas MAAS taps the overall construct. The incentive controls did not show as large an improvement as did the NMSR group for the invalidly cued temporal trials. More studies are needed to determine the important factors for temporal attention performance.

Attentional Measures Uniquely Affected by MBSR

In the d2 Test of Attention (Brickenkamp, 2002), the posttreatment ED for the MBSR group differed significantly from that in all other groups. Whereas all other groups, including INCO, increased error rates significantly during the middle section of the task, the MBSR group actually approached a significant decrease ($p = .07$), although the error increment in the middle section was present in all groups at baseline. We interpret this as an MBSR-induced attenuation of the tiring effect. This interpretation is in accordance with the attention-resource model that attributes vigilance decrements to the exhaustion of mental resources (Warm, Parasuraman, & Matthews, 2008). These results support attentional improvements after MBSR independent of both stress reduction and the perceived task incentive, which to our knowledge has never been shown before. The pre–post changes in ED within the MBSR group also differed significantly from NOCO, NMSR, and CICO (in which half of the participants were financially motivated to try harder). Pre–post changes for the MBSR group did not differ significantly from those for INCO, but INCO still showed a descriptive increase in errors during the middle test section at T2. The impression of unique effects of MBSR on error performance in the d2 test was further supported by the fact that the MBSR group was the only group to demonstrate highly significant (Bonferroni-corrected $ps \leq .01$) and large improvements in E and E% (see supplemental materials, Table I). All groups scanned significantly more items at T2 (see supplemental materials, Table I), but only the MBSR group committed significantly fewer errors, thus lowering E% markedly. The majority of errors were omission errors, supporting the idea that MBSR specifically improved the ability to sustain a selective focus in the presence of distractors, rather than the ability to inhibit error commission. Our d2 results therefore corroborate findings of superior d2 error performance in experienced meditators compared with novices (Moore & Malinowski, 2009). A causal role of long-term meditation is also possible, because the between-groups effect sizes calculated from Moore and Malinowski's (2009) sample size and t values (formulas in Rosnow & Rosenthal, 1996; Rosnow, Rosenthal, & Rubin, 2000) were larger (total score: $d = 1.64$; errors: $d = 1.29$) than any posttreatment group differences in the present study. As opposed to the left-lateralized temporal orienting network supposedly employed in STAN, it has been proposed that sustaining attention in unarousing contexts may primarily involve right frontoparietal regions (Posner & DiGirolamo, 2000; Posner & Petersen, 1990). Thus, the d2 results are consistent with suggestions (Cahn & Polich, 2006; Newberg & Iversen, 2003) that meditation requiring sustained attention enhances this right-lateralized network.

Concerning the limitations of the d2 results, continuous performance tasks such as DART are also thought to challenge this network (Dockree et al., 2006), so the DART results are somewhat contradictory to the d2 results. However, DART and the d2 test differ in many respects, for example in their administration form (computer/paper), attentional demands (there are no set shifting or dual attention tasks in d2), and stimulus type (numbers/letters). Most important, d2 primarily measures selective attention, whereas DART measures sustained, dual attention. The between-groups d2 effect sizes, however, were small, and the p values did not survive Bonferroni-correction. Importantly, our results did not seem to be confounded by general stress reduction or attentional effort, but replications are encouraged.

Using an experimental paradigm based on TVA (Bundesen, 1990), we also quantified changes in four basic visual attentional functions: the threshold of conscious perception, visual working memory capacity, processing speed, and top-down controlled selectivity. Several interesting results were found. Only the MBSR group demonstrated large and significant improvement in visual threshold. This indicates a decrease in the amount of time required for encoding visual information into conscious, short-term memory (i.e., an ability to identify material presented for shorter durations). Intriguingly, the degree of improvement in the perceptual threshold was significantly (Bonferroni-corrected) associated with the

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increase in self-reported mindfulness within the MBSR group. This relationship was further strengthened by an association between higher levels of mindfulness and lower perceptual thresholds across groups at baseline ($r = -.40$, $p = .005$).

Bushell (2009) argued that the Buddhist meditative goal of developing superior perceptual and attentional capacities to "achieve penetrating insight into the nature of phenomena" (p. 348) should facilitate near-threshold perception in the visual domain. Bushell's claim is primarily based on psychophysical studies of human light detection capabilities, but our finding supports his claim by showing that the conscious threshold of vision can be modulated in novices after MBSR. Semple (2010) used signal detection methods to evaluate performance in a sustained attention task and found that an MBSR group showed higher stimulus discriminability than did both active and passive control groups. MacLean et al. (2010) found that an intensive meditation retreat increased discriminability after 6–7 weeks, which was sustained at follow-up. Increased discriminability or sensitivity in signal detection reflects an increase in the signal-to-noise ratio, which is pivotal for near-threshold perception. Thus, heightened sensitivity could also explain the decrease in the perceptual threshold found here. Furthermore, in the TVA-based test a fixation cross was always presented 500 ms before the stimulus display. If the participants are able to use the appearance of the cross as a temporal warning cue, this could potentially help them focus their attention at the exact moment in time when the stimulus displays are presented. The results from STAN did not support improved temporal orienting of this type in the MBSR group, but unpublished data from the Center for Visual Cognition (where the TVA test was developed) suggest that valid temporal cues can actually lower the perceptual threshold. The improvement in MBSR was significant compared with NOCO and CICO, although between-groups effect sizes were small (see supplemental materials, Table III). Also, changes in MBSR did not differ significantly from changes in NMSR and INCO. Still, the pre–post effect in MBSR was numerically twice as large as in INCO and NMSR (see supplemental materials, Table I). This descriptive difference suggests that MBSR in novices can result in unique attentional modulations not caused by mere test effort or general stress reduction. Though this positive finding is in need of replication, it is in line with studies showing beneficial effects of short-term meditative training on other measures of visual perceptual threshold or visual discrimination (D. Brown et al., 1984; Dilbeck, 1976; Vani, Nagaranthna, Nagendra, & Telles, 1997). An intensive meditation retreat also improved experienced meditators' detection of both the first and second of two target visual stimuli presented in close temporal proximity on an attentional blink task, which may reflect faster visual processing (Slagter, 2007; Slagter et al., 2009). Greater psychological sensitivity to colors was demonstrated in a projective test (Rorschach) as a function of meditation experience (D. P. Brown & Engler, 1980). A recent review of the few existing empirical studies, phenomenological reports, and historical texts (Bushell, 2009) also predicted improvements in visual perceptual threshold and visual attention in general after Buddhist meditation practices.

Only the MBSR-participants showed a positive, significant increase in working memory capacity, and this also constituted a significantly larger improvement than in the inactive controls. Paying the control participants to perform better did not improve memory capacity, supporting the interpretation that heightened attentional effort did not cause the observed changes in the MBSR group. Furthermore, MBSR improvements in capacity were significantly associated with improved mindfulness, as indexed by the MAAS, again suggesting that training mindfulness in MBSR may actively promote an increase in working memory capacity. However, level of mindfulness was never associated with the capacity measure across groups. In addition, there is a lack of comparable studies testing the effects of MBSR on working memory capacity. Rather, studies have tended to include tests that require working memory but that do not yield a direct capacity measure. Jha, Stanley, Kiyonaga, Wong, and Gelfand (2010) showed that in military cohorts, mindfulness training prevented a decrease on an indirect measure of working memory capacity, which is regularly observed during a highly stressful predeployment interval. They proposed that mindfulness-related improvements in working memory capacity could mediate some of the positive effects observed after mindfulness-based interventions and that these practices could protect against functional impairments resulting from high-stress situations. Two studies employing the Digit Symbol Substitution subtest from the Wechsler Adult Intelligence Scale battery that requires intensive (visual) working memory involvement found a significant, but small, effect (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010) or no effect (Semple, 2010) of MBSR. However, in an *n*-back task used as an additional effect measure, Zeidan et al. (2010) found that the working memory–related component was positively affected by MBSR, whereas processing speed was unaffected. Interestingly, this pattern is similar to the dissociation between the benefits of MBSR on visual working memory, but not visual processing speed, found in our study. Many investigations have shown that people with larger working memory spans have greater attentional control (Kane, 2005; Kane & Engle, 2002), so the improvement observed only within the MBSR group could be seen as supportive of unique improvements in top-down attentional control from MBSR. However, capacity improved descriptively for the NMSR group (whereas INCO descriptively decreased), so NMSR was a potential confounder. In addition, in the TVA-based test the capacity parameter is usually not associated with the measure of attentional selectivity, which we also replicated here. Again, further studies are needed to determine the specific MBSR-related effects on attentional control and working memory capacity.

We failed to find any relationships between MBSR compliance and changes in cognitive outcomes, self-report, or cortisol secretion. This could be seen as limitation of the results, but compliance findings are often negative in MBSR research. A review concluded that the correlations between program contact hours and outcome effect sizes were not significant for both clinical and nonclinical samples (Carmody & Baer, 2009), and cognitive effects of mindfulness training have been reported after just 3 days (Tang et al., 2007), 1 hr (Wenk-Sormaz, 2005), and even 15 min (Arch & Craske, 2006) of training. Obviously, these results call for more thorough investigations of compliance.

In summary, our results are the first to provide empirical support for the hypothesis that MBSR can uniquely improve attentional subsystems, such as the ability to sustain a selective attentional focus (error performance in the d2 test) and functional components of visual attention, including the threshold of visual perception and visual working memory capacity (CombiTVA paradigm). How-

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ever, the d2 results were only marginally significant, and the CombiTVA paradigm did not show significantly larger effects of MBSR than did NMSR. Thus, taken together we feel that the most important demonstration here was that simply increasing test effort during the second test session, as well as NMSR, can have even larger effects than does MBSR on several attentional skills considered central to MBSR, such as temporal orienting, a sustained readiness to react (STAN test), and attentional set shifting (DART test). Thus, the main, and critical, conclusion that can be drawn from this study is that many previous investigations of MBSR or short-term meditation-specific attentional improvements should be regarded with caution because they do not control for attentional effort or nonspecific stress reduction. We found that attentional effort in particular affected raw RTs. In contrast, measures of RT stability and perceptual, attentional performance unconfounded by motoric processes (perceptual threshold, visual working memory capacity) were more resistant to effects of test effort. We encourage other researchers to apply a similar design with active and incentive control groups in larger studies, possibly also including more distressed individuals, for whom MBSR may lead to a greater improvement in attentional functions than for a young, healthy sample.

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Supplementary Table I. Descriptives and pre-post effect sizes (*d*s) from the DART, the Stroop Color-Word task, the D2 test, and the TVA-test (main results in bold).

Test paradigm Outcome	Test time	No incentive (n = 8) *M*	*SD*	*d*	Incentive (n = 8) *M*	*SD*	*d*	Non-mindfulness course (n = 15) *M*	*SD*	*d*	Mindfulness course (n = 16) *M*	*SD*	*d*
Dual Attention to Response Task													
White digit RT (ms)	1	172	(44)		252	(78)		227	(57)		208	(65)	
	2	139	(38)	1.42**	174	(38)	1.30**	194	(44)	.97**	170	(50)	.81**
Commission Error RT (ms)	1	214	(102)		253	(84)		300	(156)		253	(100)	
	2	206	(79)	.18	196	(83)	.49	233	(142)	.42	218	(95)	.33
Grey digit RT (ms)	1	376	(65)		419	(60)		413	(63)		383	(77)	
	2	341	(63)	.61*	331	(51)	**1.44****	375	(69)	.59*	395	(86)	-.21
Coefficient of Variation (see text)	1	0.53	(.09)		0.42	(.12)		0.49	(.09)		0.48	(.13)	
	2	0.56	(.07)	-.26	0.45	(.14)	-.26	0.45	(.05)	.86	0.46	(.12)	.21
Stroop Color-Word Task													
Congruent Block time (s)	1	48	(10)		52	(8)		57	(11)		51	(6)	
	2	46	(8)	.40	46	(8)	.92*	52	(6)	.51	48	(5)	.62*
Incongruent block time (s)	1	93	(19)		87	(10)		100	(15)		97	(13)	
	2	88	(18)	.77	82	(8)	**1.21***	95	(12)	.47	90	(12)	**1.18*****
Incongruent block error rate	1	3.8	(3.0)		2.3	(1.8)		2.7	(2.7)		2.8	(2.5)	
	2	3.6	(1.7)	.06	1.9	(1.6)	.17	2.3	(1.8)	.13	2.1	(1.5)	.21
D2 test of attention													
Total score, *TN*	1	552	(44)		525	(52)		505	(49)		538	(63)	
	2	588	(45)	1.34**	563	(57)	1.92***	558	(45)	1.78***	574	(62)	1.45***
Total score – errors, *TN-E*	1	524	(58)		500	(43)		480	(52)		517	(61)	
	2	562	(60)	2.09**	543	(54)	2.10***	536	(43)	2.12***	559	(59)	1.81***
Spread, *S*	1	13	(3)		14	(2)		13	(4)		12	(3)	
	2	10	(4)	1.15*	10	(4)	.84 (*)	11	(4)	.54 (*)	10	(5)	.66*
Total error rate, *E*	1	28	(21)		26	(28)		25	(22)		21	(14)	
	2	26	(21)	.20	21	(17)	.63	22	(22)	.28	15	(22)	**.93****
Error percentage, *E%*	1	5.3	(4.2)		4.7	(4.9)		4.9	(4.4)		3.9	(2.5)	
	2	4.7	(3.7)	.38	3.6	(2.8)	.69	3.9	(3.9)	.62*	2.5	(1.9)	**1.14*****
Theory of Visual Attention Test													
Perceptual Threshold, t_0 (ms)	1	10	(6)		14	(8)		11	(7)		15	(11)	
	2	9	(5)	.42	12	(5)	.27	8	(6)	.45	9	(9)	**1.14****
Processing Speed, *C* (letters / s)	1	35	(12)		38	(10)		36	(12)		39	(13)	
	2	40	(14)	.86*	40	(10)	.37	40	(14)	.70*	41	(11)	.35
Capacity of Visual STM, *K* (letters)	1	3.54	(.90)		3.59	(.45)		3.35	(.78)		3.46	(.78)	
	2	3.46	(.64)	-.16	3.56	(.55)	-.21	3.56	(.82)	.42	3.74	(.68)	**.64***
Attentional selectivity, α (see text)	1	0.53	(.15)		0.61	(.26)		0.64	(.31)		0.69	(.29)	
	2	0.48	(.33)	.29	0.48	(.18)	.93	0.52	(.27)	.47	0.61	(.32)	.30

* / ** / ***. Pre-post change significant at the 0.05 level / 0.01 level / 0.001 level (2-tailed, uncorrected for multiple tests).

Supplementary Table II. Mean reaction times (ms) per trial type in the Spatial & Temporal Attention Network task (STAN).

Cue Type	Field / CTI	Session	No incentive[a]		Incentive[a]		Non-mindfulness course[b]		Mindfulness course[c]	
Temporal cues			*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Temporal invalid	750	1	276	(26)	282	(49)	300	(38)	288	(32)
Temporal invalid	750	2	274	(41)	262	(44)	274	(44)	271	(39)
Temporal valid	750	1	259	(22)	257	(14)	275	(35)	281	(37)
Temporal valid	750	2	252	(32)	239	(30)	256	(30)	260	(33)
Neutral cues										
Neutral	750	1	285	(45)	286	(29)	293	(33)	291	(32)
Neutral	750	2	275	(51)	251	(24)	282	(39)	273	(33)
Neutral mean	–	1	269	(43)	277	(22)	282	(36)	277	(30)
Neutral mean	–	2	265	(55)	243	(22)	269	(35)	263	(35)
Neutral	Left	1	268	(44)	283	(25)	287	(34)	279	(31)
Neutral	Left	2	266	(58)	248	(25)	270	(37)	263	(32)
Neutral	Right	1	271	(45)	279	(26)	277	(39)	276	(32)
Neutral	Right	2	264	(52)	238	(20)	266	(39)	263	(39)
Spatial cues										
Spatial valid	Left	1	266	(49)	273	(21)	280	(40)	269	(35)
Spatial valid	Left	2	240	(28)	235	(40)	262	(32)	252	(34)
Spatial valid	Right	1	254	(47)	267	(27)	271	(41)	262	(29)
Spatial valid	Right	2	247	(43)	240	(26)	259	(32)	249	(31)
Spatial invalid	Left	1	296	(49)	284	(55)	315	(54)	299	(36)
Spatial invalid	Left	2	284	(32)	272	(39)	301	(51)	274	(31)
Spatial invalid	Right	1	302	(53)	289	(57)	308	(60)	295	(41)
Spatial invalid	Right	2	286	(55)	270	(44)	296	(36)	282	(36)

[a]$n = 8$. [b]$n = 15$. [c]$n = 16$.

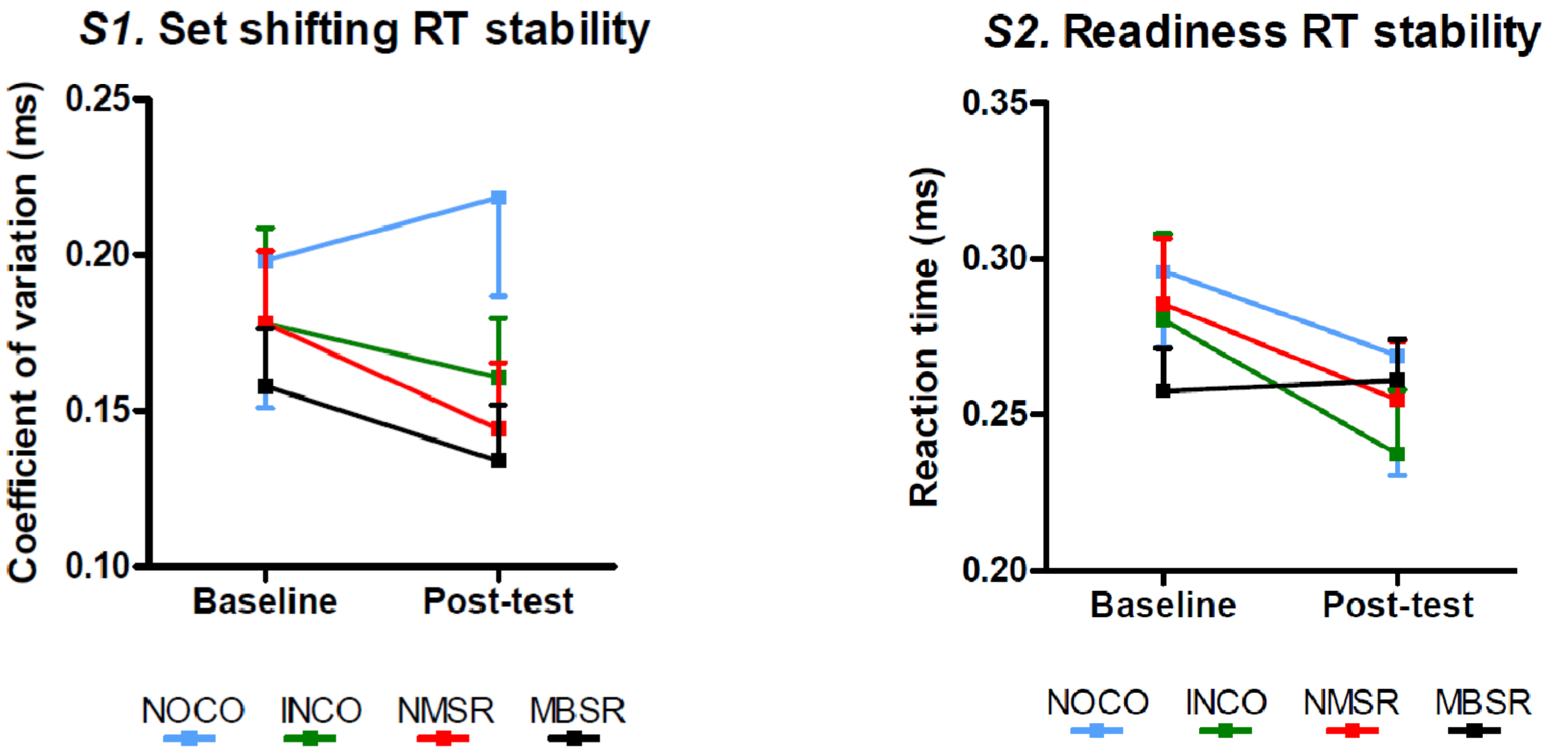
Note. CTI = Cue-Target Interval (ms; see Figure 2).

Supplementary Table III. Significant Time × Group interactions.

Paradigm	Test	Comparison	F	df	p	ω^2	Interpretation
Dual Attention to Response Task (DART)							
Grey digit RT	ANCOVA	MBSR *vs*. NOCO *vs*. INCO *vs*. NMSR	4.77	46	.006	.14	Group changes differed overall
Grey digit RT	ANCOVA	MBSR *vs*. INCO	12.70	24	.002	.24	INCO improved more than MBSR.
Spatial and Temporal Attention Network task (STAN)							
Neutral trials RT	ANCOVA	MBSR *vs*. (NMSR + MBSR)	5.94	39	.016	.05	INCO improved more than the stress reduction groups combined.
Temporal invalid trials	ANOVA	NMSR *vs*. NOCO	5.28	23	.032	.13	NMSR improved more than NOCO
D2-test of attention							
Error distribution[a]	ANOVA	MBSR *vs*. NOCO *vs*. INCO *vs*. NMSR	2.73	92	.028	-	Group changes differed overall
Error distribution[a]	ANOVA	MBSR *vs*. NOCO	3.21	46	.050	-	MBSR improved Section 2 more than NOCO.
Error distribution[a]	ANOVA	MBSR *vs*. CICO	3.13	62	.051	-	MBSR improved Section 2 more than CICO.
Error distribution[a]	ANOVA	MBSR *vs*. NMSR	7.03	62	.004	-	MBSR improved Section 2 more than NMSR.
Theory of Visual Attention test (TVA)							
Perceptual threshold	ANCOVA	MBSR *vs*. NOCO	4.95	24	.037	.04	MBSR improved more than NOCO.
Perceptual threshold	ANCOVA	MBSR *vs*. CICO	6.21	32	.019	.04	MBSR improved more than CICO.
Working memory capacity	ANCOVA	MBSR *vs*. CICO	5.11	32	.032	.05	MBSR improved more than CICO.
Cortisol secretion							
AUC – Ground	ANCOVA	MBSR *vs*. CICO	7.50	26	.012	.14	MBSR decreased more than CICO.
Mindfulness Attention and Awareness Scale (MAAS)							
Overall mindfulness	ANCOVA	MBSR *vs*. CICO	6.81	29	.015	.09	MBSR increased more than CICO.
Cohen's Perceived Stress Scale (PSS)							
Overall stress score	ANCOVA	MBSR *vs*. CICO	5.64	29	.025	.11	MBSR decreased more than CICO.

[a]. Time × Group × Section interaction. No effect size is provided due to the complexity of interpreting such an effect (see "Data Analyses").
Note. p-values are two-tailed and uncorrected for multiple comparisons (see text for Bonferroni-corrected p-values).

Supplementary Figures



Supplementary Figures. *S1*. Pre-post group changes on the grey digit *CV* in DART. No groups improved significantly, and no Time × Group interactions were significant. *S2*. Pre-post group changes on the *CV* for neutrally cued trials in STAN. No groups improved significantly, and no Time × Group interactions were significant. Error bars represent one standard error of the mean.

Appendix II

Study 2

General Inattentiveness is a Long-term Reliable Trait Independently Predictive of Psychological Health: Danish Validation Studies of Mindful Attention Awareness Scale

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Abstract

The Mindful Attention Awareness Scale (MAAS) measures the perceived degree of inattentiveness in different contexts and is often used as a reversed indicator of mindfulness. MAAS is hypothesized to reflect a psychological trait or disposition when used outside attentional training contexts, but the long-term test-retest reliability of MAAS scores is virtually untested. In addition, it remains unknown whether the MAAS predicts psychological health after controlling for standardized socioeconomic status classifications. First, the MAAS translated to Danish was validated psychometrically within a randomly invited healthy adult community sample (N=490). Factor analysis confirmed that the MAAS scores quantified a unifactorial construct of excellent composite reliability and consistent convergent validity. Structural equation modeling revealed that the MAAS contributed independently to predicting psychological distress and mental health, respectively, after controlling for age, gender, income, socioeconomic occupational class, stressful life events, and social desirability, β=0.32-.42, ps<.001. Second, the MAAS inattentiveness scores showed satisfactory short-term test-retest reliability in 100 retested healthy university students. Finally, the MAAS sample mean scores as well as individuals' scores demonstrated satisfactory test-retest reliability across a six months interval in the adult community (retested N=407), intraclass correlations ≥ .74. Importantly, the MAAS scores displayed significantly stronger long-term test-retest reliability than scores measuring psychological distress, z=2.78, p=.005. Test-retest reliability estimates did not differ within demographic and socioeconomic strata. In conclusion, scores on the Danish MAAS were psychometrically validated in healthy adults. The MAAS' inattentiveness scores reflected a unidimensional construct, a long-term reliable disposition, and a factor of independent significance for predicting psychological health.

Keywords: mindfulness; personality; scale validation; Brief Symptom Inventory; SF-36; mind-wandering; default mode network; emotional intelligence; avoidance; self-directedness.

A growing body of research is now aiming to clarify how attentional present-centeredness, a central facet of “mindfulness” (Baer et al., 2006), or conversely, how inattentiveness or “mind-wandering” (Killingsworth & Gilbert, 2010; Smallwood, 2013), may relate to psychological health parameters in the population. This novel research often implicitly or explicitly proposes that the psychological property of attentiveness versus inattentiveness is more fundamental and causally influential than symptomatic states such as psychological distress or wellbeing, respectively. This hypothesis is long-standing. Meditative traditions have argued for millennia that clarity, depth, and stability of conscious attention are more foundational for health than the fluctuating contents of conscious experience (Bedford, 2012; Bushell, 2009; Grabovach et al., 2011; Sedlmeier et al., 2012). Theories of personality have proposed that tendencies towards being mentally focused versus defocused represent psychological traits affecting health and resiliency (Eysenck, 1995; Mendelsohn, 1976).

Reviews of the efficacy of mindfulness-based interventions (MBI) have overall provided supporting evidence for the use of MBI for adults experiencing anxiety and depression (Hofmann et al., 2010; Khoury et al., 2013; but see Toneatto and Nguyen; 2007), stress and well-being (Goyal et al., 2014; Khoury et al., 2013; Sedlmeijer et al., 2012), and for prevention of relapse in recurrent major depressive disorder (Piet & Hougaard 2011). While the mechanisms of change in MBI are still unclear, several theoretical accounts have argued that the cultivation of attentional stability is one of the key mediators of change (e.g., Cahn & Polich, 2006; Hölzel et al., 2011; Lutz et al., 2008; Shapiro et al., 2006). This assumption is supported by many studies showing improvements on simple, non-arousing tests of sustained attention after different types of meditation (e.g., Semple, 2010; Valentine & Sweet, 1999), as well on sustained selective attention in contexts of competing stimuli or distractors (e.g., Jensen et al., 2012; Lutz et al., 2009; Moore & Malinowsky, 2010) – and superior sustained attention abilities have been supported in cross-sectional neuroimaging studies comparing experienced meditators to demographically and ethnically matched non-meditating controls (e.g., Brefzinsky-Lewis et al., 2007; Tang et al., 2007; Pagnoni & Cekic, 2007). Similarly, concerning MBI for children and adolescents, MBI and other meditation-based treatments have showed promising effects although effect sizes were typically smaller than those obtained with adults (Black et al., 2009), and although more controlled research is needed (Burke, 2010). The most recent systematic review and meta-analysis of MBI and youth concluded that MBI showed promising effects and speculated that attentional improvements were "the internal psychological mechanism that transmits the effects of mindfulness interventions" (Zoogman et al., 2014, *p*. 10). Although speculative, this assumption is supported by preliminary evidence of attentional improvements in children after MBI (Flook et al., 2010; Napoli et al., 2005) and improvements of attentional (including attentional stability or 'alertness') in adolescents after MBI (Baijal et al., 2011), and improvements of sustained attention in children trained in Transcendental Meditation (Rani & Rao, 1996).

Based on the emphasis on developing a stronger attentiveness to the present moment in the Buddhist mindfulness tradition , one of the most used mindfulness scales of today, namely the presently investigated Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), aims to quantify the degree of attentional instability, or, more specifically, the perceived frequency of everyday 'attentional lapses' or remembered instances of 'mind-wandering'. The MAAS was originally termed a "trait scale" by the developers, who hypothesized that inattentiveness is an independently measurable, psychological trait or disposition of importance for psychological health in the general population (Brown & Ryan, 2003, *p*.838). Brief state versions of the MAAS have also been developed (e.g., Black et al., 2012a; Weinstein et al., 2009), and scores on the MAAS are also sensitive to attentional training such as mindfulness meditation (e.g., Jensen et al., 2012). But importantly, when the MAAS is used outside MBI or attentional training, it is hypothesized to reflect a trait or a relatively stable psychological disposition.

Trait researchers in other areas have examined the long-term test-retest reliability of measures reflecting e.g., the proclivity to be more or less purposefully inattentive (avoidant) towards novelty, perceived threats, and punishment (Cloninger et al., 1994) or the degree of clarity in one's attentiveness towards emotions (Salovey et al., 1995), respectively. However, the underlying assumption of the MAAS and in much of the current mind-wandering research is broader, since it essentially predicts that the degree of inattentiveness to ongoing experience *in general* should reflect a more foundational psychological disposition, and thus a more reliable disposition over time, than fluctuating symptomatic states. This assumption echoes ancient meditative philosophies but has to our knowledge not received thorough empirical evaluation. The MAAS is ideal for this purpose, since it inquires about *general* tendencies to be inattentive, e.g., towards ongoing activities, emotions, bodily sensations, thoughts, and other persons.

Test-retest reliability concerns the variability in repeated assessments separated in time (Bland & Altman, 1986; Guttman, 1945) and is crucial for scales intended to measure a stable disposition or trait (McCrae et al., 2011). The MAAS scores have shown satisfactory test-retest reliability in US students after four weeks (N=60, r=.81; Brown & Ryan, 2003) and 10 weeks (N=82, r=.73; (Barnes et al., 2007), and in a Spanish university community after two weeks (N=32, r=.82; Soler et al., 2012). In contrast, the MAAS scores showed poor test-retest reliability after three weeks in Chinese students (N=70, r=.54; Deng et al., 2012). This range of samples sizes in test-retest studies is typical of the mindfulness literature, and this is unfortunate. With N=60 (the mean N of the four studies), an average correlation of r=.70 (the N-weighted mean r) has a 95% confidence interval from r=.55—.81 (Hays, 1973), spanning very different interpretations of the test-retest reliability. A large MAAS study of Chinese adolescents (retested N>3,000, mean age = 16.2 years, standard deviation = 0.7 years), showed increasingly low test-retest reliability from three months (r=.52), over 10 months (r=.41), and to 13 months (r=.35) of abbreviated versions of the MAAS adapted for adolescents (Black et al., 2012a). A decline in test-retest correlation coefficients is expectable for any psychological measure over time (Watson, 2004) and latent growth modeling analyses of the large Chinese adolescent sample supported the stability of the MAAS scores over 13 months (Black et al., 2012b). In Western samples, scores on the MAAS produced by adolescents showed adequate short-term test-retest reliability in the original validation, intraclass correlation =.79 (Brown et al., 2011). More MAAS studies on adolescents are needed. In sum, although the MAAS is widely used in population surveys of mindfulness and health, the long-term test-retest reliability of MAAS scores for adults has not been tested in large samples. Even the short-term reliability needs further investigation in larger samples, since the small samples investigated previously render it impossible to evaluate the test-retest reliability (or the magnitude of measurement error) with a satisfactory degree of precision (Watson, 2004). The present study therefore investigated the long-term test-retest reliability of the MAAS scores over a six months interval and in a randomly invited community sample. This addresses a gap in the test-retest literature on the MAAS, which has primarily investigated small, less representative samples over short time intervals.

Interpretations of the MAAS

The validity of interpreting the MAAS mean as an indicator of mindfulness is consistently supported via theoretically appropriate correlations with other measures. Scores on the MAAS (when reversed so that higher scores reflect a more present-centered or mindful attention) have consistently been positively related to other indicators of mindfulness (Baer et al., 2006; Brown et al., 2013; Brown et al., 2009; Frewen et al., 2008; Soler et al., 2012), negatively related to psychological avoidance scores (Christopher et al., 2009b; Masuda et al., 2012; McCracken et al., 2007; Mitmansgruber et al., 2009; Palmer & Rodger, 2009; Schütze et al., 2010; Weinstein et al., 2009), and positively related to acceptance scores (Brown & Ryan, 2003; Christopher et al., 2009a; McCracken & Zhao-O'Brien, 2010; Soler et al., 2012). The MAAS is also sensitive to meditation-based training since intervention groups' mean scores on the MAAS have shown significant increases after MBI (Chambers et al., 2008; Dobkin, 2008; Jain et al., 2007; Jensen et al., 2012; Kilpatrick et al., 2011). Further, MAAS-changes have been significantly related to improvements in psychological health after MBI (Carlson & Brown, 2005; Jensen et al., 2012; Michalak et al., 2008; Shapiro et al., 2011). Finally, MAAS mindfulness has shown meaningful, positive correlations with brain activity in attentional regions (Creswell et al., 2007) and negative correlations with electrophysiological markers of cognitive repression (Brown et al., 2013). The MAAS overlaps with, but is not explained by, other executive functions such as working memory and self-control (e.g., Black et al., 2011), self-efficacy (Black et al., 2012a), and self-esteem (Brown & Ryan, 2003; Thompson & Waltz, 2007). However, when interpreted as a measure of mindfulness, the MAAS score has been criticized for lacking construct validity since it is based on reversed items (i.e., all MAAS items measure inattentiveness, rather than mindfulness) and since MAAS items do not evaluate e.g., attitudinal or ethical aspects of mindfulness, such as acceptance, empathy, or non-judgment (Grossman, 2011; Hayes & Feldman, 2004; Prazak et al., 2012), although 'mindfulness' has not been successfully defined (Bergomi et al., 2013; Grossman, 2011). The developers of the MAAS chose to focus on inattentive experiences since they argued that inattentive states are much more common in the population than 'mindful' or fully attentive states. As a result, the everyday degree of inattentiveness should be more accurately reported. Initial, unpublished studies of convergent and incremental validity were also in keeping with a reversed scale and showed no advantages of including other aspects of mindfulness (Brown & Ryan, 2004).

All things considered, the MAAS may not represent a theoretically encompassing measure of mindfulness. However, it is a strong candidate to evaluate general inattentiveness to the present moment, or as a reversed indicator of mindful attention. The mindfulness aspect of attention is important for meditation research and of widespread current interest, also within fields of everyday attentional failures, such as task-irrelevant thoughts (Allen et al., 2013). We prefer to interpret the MAAS score as a measure of "general inattentiveness", since this terminology is directly in line with the actual phrasing of all 15 items measuring inattentiveness in different situations.

Do scores on the MAAS predict health beyond socioeconomic status?

Another overlooked area in MAAS research concerns the importance of socioeconomic status (SES). SES is a complex and dynamic construct, which cannot be objectively defined because it depends on e.g., sociocultural power structures and values. However, SES can be functionally defined as the "social and economic factors that influence what positions individuals or groups hold within the structure of a society" (Galobardes et al., 2004, *p*.4). There is overwhelming evidence for a strong impact of SES on psychological health and distress (Adler et al., 1994; Adler & Rehkopf, 2008; Matthews & Gallo, 2011; McEwen, 2012). International reviews have demonstrated a 1.5-2.0-fold higher risk of psychological illnesses in lower SES groups (Fryers et al., 2003; Lorant et al., 2007; Lorant et al., 2003). The mechanisms behind this historically consistent 'social gradient in health' are multidirectional and not yet explained (Matthews & Gallo, 2011), but theoretical models agree that two important factors lie in the increased stressor exposure in lower SES groups, which in turn may lead to an increased stress vulnerability (Adler & Newman, 2002; Diderichsen et al., 2001; McEwen, 2012). The most applied SES indicators are education, occupation, and income (Chen et al., 2013; Matthews & Gallo, 2011; Stephens et al., 2012).

Findings concerning these SES indicators (e.g., education, income and occupational variables) and the MAAS are mixed. The MAAS did not predict perceived stress or health after controlling for education in Asian workers (McCracken & Yang, 2008). Oppositely, lower inattentiveness (higher mindfulness) on the MAAS still mediated cognitive resources into increased mental health after controlling for education, an occupational variable (tenure *vs*. no tenure) and other factors in US workers (Avey et al., 2008). Canadian students' scores on the MAAS were related to completed years of university studies (r=.14; Howell et al., 2008), but this was not found for US students, r=.01 (O'Loughlin & Zuckerman, 2008). Two studies of pain patients did not find any association between scores on the MAAS and education (McCracken et al., 2007; McCracken & Keogh, 2009), while one study demonstrated decreased inattentiveness with higher education, r=.20 (McCracken & Thompson, 2009), although this study found four factors in the commonly unifactorial MAAS. Occupation type (nurses *vs*. non-nurses) did not influence scores on the MAAS in an Asian study (McCracken & Yang, 2008). However, unemployed pain patients reported significantly higher inattentiveness (lower MAAS scores) than employed patients, r=.19 (McCracken & Velleman, 2010). With respect to income, one thorough study showed that higher income and higher increases in income were consistently related to a lower degree of general inattentiveness (rs=.12-.31), but importantly, lower MAAS inattentiveness scores still signified higher wellbeing after controlling for income variables (Brown et al., 2009). Students' scores on the MAAS predicted distress scores after controlling for 'self-reported socioeconomic class' (Masuda et al., 2009). These findings are difficult to interpret due to the differential and unvalidated SES indicators applied. Thus, MAAS studies testing the influences of internationally developed and nationally normed SES classification systems are needed.

Evidence is therefore lacking as to whether scores on the MAAS predict measures of psychological distress and health, respectively, after controlling for SES. This ignorance is important. It concerns whether present moment attentiveness constitutes more of a symptom than a cause. Undisputedly, low SES increases exposure to many 'stressors' (i.e., biopsychosocial factors that require adaptation to avoid negative consequences; McEwen, 2012), such as poor nutrition, increased verbal abuse, violence, job insecurity, decreased access to health care, and death (Matthews & Gallo, 2011). At the same time, it is well-established that long periods of increased psychosocial stress are harmful for many attentional functions (Chajut & Algom, 2003), physiologically perhaps via neurotoxic effects on prefrontal (Arnsten, 2009) and hippocampal regions from prolonged hypercortisolism (De Kloet et al., 2005). For these two reasons, it seems likely that low SES causally promotes both increased psychological distress as well as impaired attentional functions. Consequently, negative associations between scores on the MAAS and psychological health parameters unadjusted for SES may be inflated by their common dependence upon SES. Unfortunately, most surveys on the MAAS and health indicators do not report anything on the potential influence of even basic demographic and SES covariates such as age, gender, education, income, or occupation (e.g., Christopher & Gilbert, 2010; Coffey & Hartman, 2008; Cordon & Finney, 2008; Heppner et al., 2008; Peters et al., 2011; Waters et al., 2009).

Factorial studies of the MAAS

The original factor analytic studies of scores on the MAAS suggested an underlying strongly unidimensional construct (Brown & Ryan, 2003). This was reaffirmed in several Spanish translations (Johnson et al., 2013; Soler et al., 2012), an Italian version (Veneziani et al., 2014), a Chinese sample (Black et al., 2012; Deng et al., 2012), and a Thai sample (Christopher et al., 2009b). However, the Iranian MAAS had to be reduced from 15 to seven items to achieve a unidimensional structure (Ghorbani et al., 2009), and a US study only confirmed a unifactorial model in women (MacKillop & Anderson, 2007). The MAAS scores' internal consistency

(Cronbach's alpha [α], Cronbach, 1951) is generally good (α >.80; Brown & Ryan, 2003; Carlson & Brown, 2005; Hansen et al., 2009; Masuda et al., 2009; McCracken & Velleman, 2010; Siever & Weinstein, 2009). However, α does not measure scale unidimensionality (Biemer et al., 2007; Cortina, 1993). Rather, α testing *assumes* unidimensionality (the tau equivalent model; Graham, 2006) and a violation of this renders α unreliable, underlining the need for further factor studies. Finally, the MAAS has not been validated in Danish.

The present study

In Part 1 of the present study, our primary objectives were to (a) validate the Danish version of the MAAS psychometrically with respect to the factorial structure, the composite internal reliability, the internal consistency, and the convergent validity. Further, Part 1 aimed (b) to test whether scores on the MAAS predicted psychological distress and psychological health, respectively, after controlling thoroughly for demographics, SES, and other potential confounders. In Part 2, we aimed (c) to test the short-term test-retest reliability of the MAAS scores. Finally, Part 3 was designed (d) to examine the long-term test-retest reliability of the MAAS scores and whether the MAAS estimates of general inattentiveness were significantly more reliable across a six-month interval than scores on a well-established scale of psychological distress. The present study adds new knowledge to the fields of mindfulness and mind-wandering research especially due to the thorough incremental validity tests in Part 1 and the thorough long-term test-retest reliability tests in Part 3.

Part 1. Community Survey

Part 1 aimed to (a) validate the Danish version of the MAAS psychometrically with respect to the factorial structure, the composite internal reliability, the internal consistency, and the convergent validity, as well as (b) to test whether scores on the MAAS predicted psychological distress and psychological health, respectively, after controlling thoroughly for demographics, SES, and other potential confounders.

Method

Procedure and Participants

The Ethics Committee for the Capital Region of Denmark approved the protocol for Part 1 and Part 3 of the present study (ID H-2-2010-111). Statistics Denmark randomly invited a sample of 3025 persons balanced for gender, year of birth, and zip code within the City of Copenhagen. Three consecutive letters were sent (102 addresses proved outdated), inviting citizens fluent in Danish and not currently diagnosed or treated for psychiatric illness to participate during the month of May 2012 in the 'Copenhagen Health Survey' at the Copenhagen University Hospital. A total of 572 citizens (19.6%) completed a 70-item screening questionnaire on our website. Among these, we excluded n=22 due to problematic alcohol use (Alcohol Use Disorders Identification Test score>20) or recreational drug use (>24 times per year). For simplicity, we also excluded persons who did not complete all questionnaires (n=60), which did not change results significantly. The final sample thus comprised 490 healthy participants. Table 1 summarizes descriptive characteristics. Highly educated (professional educations >4 years) and high-income citizens were overrepresented while citizens with shorter educations or low income were underrepresented compared to the national population at the time (Statistics Denmark, 2011a, b). However, concerning income, this yielded a more evenly distributed percentage of participants within different income strata, increasing statistical power to detect confounding effects of income (Supplementary Figure 1). Participants received a compensation of 300 DKK and signed informed consent. The survey involved genotyping and other questionnaires [anonymized reference], but was designed primarily to study the MAAS and the Five Factor Mindfulness Questionnaire (Baer et al., 2006).

Assessment of Relevant Covariates

Participants reported age, sex, education, personal and household income the previous year, occupational status (employed/not employed/time since employment), occupational variables (job title, job description, number of employees, self-employed or not), ethnicity, marital status, housing conditions (alone, with partner, with family), perceived culture of belonging (Danish/other), citizenship (Danish/other), tobacco and alcohol use, and Body-Mass Index (BMI). Two researchers independently scored occupation from 1—5 (anonymized: researcher 1, 2) following the Danish version of the International Standard Classification of Occupations-88 (ISCO-88; Statistics Denmark, 1996). The inter-rater reliability of ISCO-88 scores was excellent, Spearman's ϱ=.90. All final ISCO-88 classifications were agreed upon. We also examined Stressful Life Events (SLE; (Kendler et al., 1995)) within the last year (SLE Recent) and the lifetime (Total SLE), respectively, and Marlowe-Crowne Social Desirability (MCSD), indexing the proclivity to respond to questionnaires in socially desirable ways (Crowne & Marlowe, 1960), which has been associated with the self-reported general inattentiveness scores on the MAAS (Brown & Ryan, 2003).

Self-report Variables

Primary self-report variables.

Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) quantified the perceived, everyday degree of inattentiveness to the present moment via 15 items rated from 1 (almost always) to 6 (almost never). Higher MAAS averages indicated stronger attentional present-centeredness. Sample items are: Item 1: "*I could be experiencing some emotion and not be conscious of it until some time later*"; Item 5: "*I tend not to notice feelings of physical tension or discomfort until they really grab my attention*; Item 10: "*I do jobs or tasks automatically, without being aware of what I'm doing*". The MAAS was translated into Danish by three mindfulness researchers, an educated translator, and a British psychology professor residing in Denmark. It was professionally back-translated by an independent company and sent to Kirk Brown, who recommended a few adjustments and approved the final version after an additional translation and back-translation.

Psychological distress was measured with *Brief Symptom Inventory-53 (BSI-53)*, assessing a broad range of psychological symptoms through 53 items (Derogatis & Melisaratos, 1983; Olsen et al., 2004, 2006). Items were rated on a 5-point Likert scale from 0 (none) to 4 (extreme), based on the recollection of the last week (e.g., to what degree have you been affected by "*Trouble falling asleep*" or "*Fear of leaving your home alone*"). We applied only the Global Severity Index (GSI), which indexes the global severity of mental distress as a mean of all items. The GSI is well validated and was highly, internally consistent in the present study, α=.96. Mental health was measured with the 36-item *Short-Form Health Survey-36* in the standard 4-week recall version (SF-36; Ware & Sherbourne, 1992; Ware et al., 1993). SF-36 has been validated for Danish use (Bjorner et al., 1998a; Bjorner et al., 1998b), and yields eight dimension scores: 1) Physical functioning, 2) Role limitations due to physical problems, 3) Bodily pain, 4) General health, 5) Emotional functioning, 6) Vitality, 7) Role limitations due to emotional problems, and 8) Mental health. Each dimension is scored from 0 (poor health) to 100 (best possible). We focused on the Mental Component Summary score (SF-36-MCS), calculated by weighting all dimension scores according to the Danish manual (Bjørner et al., 1997). The internal consistency of SF-36-MCS was satisfactory (α involved recalibration of 10 items as specified in the Danish manual), α=.76.

Secondary self-report variables.

For the convergent validity tests we predicted negative associations between the MAAS means and psychological distress and avoidance scores, respectively. Psychological distress was measured with a Danish validated version of the *Perceived Stress Scale* (PSS; Cohen et al., 1983), estimating perceived stress during the last two weeks (Andreou et al., 2011; Reis et al., 2010) (present α=.87); and with the Danish validated *Major Depression Inventory* (MDI; Bech et al., 2001) evaluating the frequency of the ten ICD-10 depressive symptoms during the past two weeks (present α=.82). Avoidance was characterized with *Acceptance and Action Questionnaire-II* (AAQ-II, Bond et al., 2011) measuring psychological inflexibility and avoidance (present α=.82); and with the Danish validated version of the personality scale Temperament and Character Inventory Harm Avoidance (TCI-HA; Cloninger et al., 1994), reflecting the proclivity to avoid novelty, non-reward and punishment (present α=.75). Conversely, we predicted positive associations between the MAAS scores and scores on self-report scales measuring a broader conceptualization of mindfulness, emotional intelligence, self-regulation abilities, and physical health, respectively. Specifically, mindfulness was quantified by the total score of *Five Facet Mindfulness Questionnaire* (FFMQ, Baer et al., 2006). *Trait Meta-Mood Scale* (TMMS; Salovey et al., 1995) assessed emotional intelligence through three subscales (emotional clarity, attentiveness, and regulation ability, all present αs≥.75), summarized in TMMS Total, present α=.89. *TCI Self-Directedness* (TCI-SD) measured executive self-regulation and abilities for adapting successfully to changes, present α=.81. *SF-36 Physical Component Summary* (SF-36-PCS) indexed overall physical health, present α=.74. FFMQ, TMMS, and AAQ-II were translated and professionally back-translated several times in collaboration with the scale developers (FFMQ: Ruth Baer; TMMS: Peter Salovey; AAQ-II: Frank Bond).

Data Analyses

The unifactorial model fit of the MAAS scores was examined with confirmatory factor analysis (CFA). We treated data categorically and applied the weighted least square means and variance adjusted (WLSMV) estimator, as recommended with the present sample size (Brown, 2006). We evaluated model fits with four metrics: the chi square test (χ^2), the Steiger-Lind root mean square error of approximation (RMSEA; <0.08=acceptable fit, <0.05=good fit), the Bentler Comparative Fit Index (CFI), and the Tucker-Lewis fit Index (TFI) (for CFI and TFI >0.90 indicated acceptable fits, while values >0.95 indicated good fits; (Schreiber et al., 2006)). Since χ^2 is highly sensitive to sample size, we considered CFI, TLI, and RMSEA as primary. We pre-selected a model-generating approach allowing for item cross-loadings as evaluated by modification indices and only if cross-loadings were meaningful with respect to item content.

The internal consistency of the MAAS scores was evaluated with the composite reliability (CR), Cronbach's alpha (α), and corrected item-total correlations. Cronbach's α is the most reported internal consistency measure but, as mentioned, assumes that all items contribute equally to the scale. The CR, on the other hand, takes item-scale complexity into account since it estimates the internal reliability as the composite of the items while adjusting for the standardized loadings and the measurement errors of each item. For both α and CR, values >0.70 were considered satisfactory.

The incremental validity of the MAAS scores was tested in two structural equation models (SEM) with psychological distress (BSI-53-GSI) and mental health (SF-36-MCS) scores as outcomes, respectively. We screened for demographic, socioeconomic, and life style covariates in marginal correlations using bootstrapping (10,000 samplings) and $p<.05$ as a variable inclusion criterion (using $p<.01$ and fewer samplings yielded similar results) and adjusted the two SEM analyses accordingly. We report effect sizes with beta and β (standardized beta). Convergent validity was examined in eight Bonferroni-corrected correlations. CFA and SEM models were computed in MPlus (*vs*. 7); other analyses in SPSS (*vs*. 20). Excluding potential outliers (scores >3 *SD* from means, always <2.5%) did not affect results substantially or significantly, so all data were included.

Results

Factor Structure

The unifactorial model of the MAAS scores with one first-order latent factor yielded good CFI and TLI, and borderline acceptable RMSEA (Table 2). However, modification indices and item contents both suggested a meaningful cross-loading between item 7 ("*It seems I am 'running on automatic,' without much awareness of what I'm doing"*) and item 8 ("*I rush through activities without being really attentive to them*"). Allowing for this cross-loading rendered RMSEA acceptable (Table 2). The unifactorial structure was confirmed for both men (χ^2[89]=139, RMSEA=0.057 [90%CI=0.037, 0.075], CFI=0.983; TLI=0.981) and women (χ^2[89]=259, RMSEA=0.078 [90%CI=0.067, 0.089], CFI=0.971; TLI=0.966). The unifactorial structure of scores on the Danish translation of the MAAS was thus supported.

Internal Reliability and Consistency

The internal composite reliability of the MAAS inattentiveness scores was excellent, *CR*=0.91. The internal consistency of the MAAS scores was good, α=.88. Exploratory analyses revealed that the item-adjusted mean item-total correlation was satisfactory, *r*=.56 (all items correlated with the item-adjusted total MAAS scores [*r*s>.40], except from item 6, *r*=.27). These results indicated good internal reliably and consistency.

Convergent Validity

Table 3 displays convergent validity results (as well as zero-order correlations between the MAAS scores and the main outcomes, for comparisons with other studies). All predictions were supported. The MAAS means were negatively associated with scores on self-report scales measuring perceived stress, depressive symptoms, avoidant personality, and experiential avoidance; and positively related with scores on instruments measuring mindfulness, emotional intelligence, self-directedness, and physical health, respectively.

Incremental Validity: Structural Equation Modeling

The MAAS scores showed an approximately normal, slightly leptokurtic distribution (Shapiro-Wilk $p=.024$) with no signs of floor or ceiling effects. The ranked correlation bootstrapping tests revealed that average inattentiveness scores on the MAAS were associated with age ($\varrho=.16$, p<.001), Recent SLE, $\varrho=-.19$, $p<.001$, and to a lower degree with gender ($\varrho=-.10$, $p=.03$). Increased age, fewer stressful life events within the past year, and male gender were related to less inattentiveness (indicating higher mindfulness). As expected, associations with income ($\varrho=.19$, $p<.001$) and occupational SES (ISCO-88; $\varrho=.12$, $p=.010$) both indicated that lower SES was related to more pronounced inattentiveness. Social desirability scores (MCSD) were also related to scores on the MAAS ($\varrho=.25$, $p<.001$), meaningfully indicating that stronger tendencies to report socially desirable answers were associated with reports of less inattentiveness. The MAAS scores were unrelated to education ($\varrho=.01$), ethnicity ($\varrho=.06$), alcohol consumption ($\varrho=-.03$), tobacco use ($\varrho=-.07$), as well as perceived culture, employment status, and BMI, $\varrho s\leq.02$. Concerning the outcomes, women showed higher scores on the BSI-53-GSI ($\varrho=.14$, $p=.001$) but not on the SF-36-MCS ($\varrho=-.06$, $p>.15$); and BMI was related to SF-36-MCS scores, $\varrho=.10$, $p<.04$. We therefore adjusted our SEM analysis testing scores on the MAAS as a predictor for psychological distress (BSI-53-GSI) for age, gender, income, ISCO-88, Recent SLE, and MCSD. The SF-36-MSC model was adjusted similarly, and also for BMI. Figures 1 and 2 show SEM results. Scores on the MAAS predicted significant variance in BSI-53-GSI, beta=-.16 (95%CI[-.19, -.143], β=-.42, p<.001. The MAAS scores also predicted significant variance in SF-36-MCS, beta=4.89 (95%CI[3.94, 5.84]) β=0.32, p<.001. Both SEM results were replicated separately for men and women. Higher inattentiveness was thus supported as an independent predictor of higher psychological distress as well as lower psychological health. Although personality was not the focus of the present study, we conducted two exploratory SEM tests also controlling for TCI-HA and TCI-SD scores, since personality is overlooked as a control covariate in mindfulness studies (Weinstein et al., 2009). In these analyses, scores on the MAAS continued to independently predict BSI-53-GSI (β=-.27) and SF-36-MCS (β=.21), *ps*<.001.

Part 2. Short-Term Test-retest reliability

In Part 2, we aimed to test the short-term test-retest reliability of the MAAS inattentiveness scores.

Method

The short-term test-retest reliability of the MAAS scores was examined using a two-week interval. This was relevant for studies collecting data over short time spans, such as experience sampling on a weekly basis, studies of effects of briefer meditation retreats, or intervention studies using several baseline or post-treatment assessments to increase ecological validity and statistical power (Vickers, 2003).

Participants and Procedures

The Institute of Psychology, University of Copenhagen, approved Part 2 of the study. After oral invitations at the university, 127 students participated. It was always emphasized that participation was voluntary. We excluded students with self-reported psychiatric (n=2) diagnoses or incomplete responses (n=6). Thus, 119 provided baseline (T_1) data, and N=100 also retest (T_2) data (84.0% retest rate). The retested sample comprised 87.0% women and 96.0% undergraduates. The mean age was 22.3 years, (SD=3.8, range=19—43). Most were employed (64.3%) in addition to their studies. Men and women did not differ on age, education or employment, ps>.5. At T_1 and T_2, all completed questionnaires in-class on demographics, health, employment, the MAAS and a 4-item Perceived Stress Scale (PSS-4; Cohen & Williamson, 1988).

Data Analyses

We examined Cronbach's α for scores on the MAAS and PSS-4 at T_1 and T_2. The test-retest reliability of the MAAS scores was evaluated primarily with the intraclass correlation coefficient (ICC) using two two-way random models for group means and individual scores, respectively. Absolute test-retest reliability is more important than correlational test-retest reliability when investigating a hypothesized trait, but for comparison with other studies, we also conducted a zero-order Spearman's ϱ test-retest correlation bootstrapped with 10,000 samplings (ICC and ϱ $\geq$.70=satisfactory, >.80=good, and >.90=excellent).

Results

MAAS general inattentiveness scores were never related to age, gender, or employment, ϱs>.07, ps>.6. The MAAS scores' internal consistency was good at T_1 (α=.83) and T_2, α=.90. The absolute test-retest reliability was good for the MAAS group mean (ICC=.88, 95%CI[.82, .92]) and satisfactory for individual participants' scores on the MAAS, ICC=.78, 95%CI[.69, .85]. The secondary test-retest correlation was satisfactory, ϱ=.77, 95%CI[64, .88]. Higher scores on the MAAS was related to lower PSS-4 at T_1 (r=-.44) and T_2 (r=-.56), ps<.0001. Thus, the short-term test-retest reliability of the MAAS scores' estimate of general inattentiveness was supported.

Part 3. Long-Term Test-retest reliability

Part 3 was designed to examine the long-term test-retest reliability of the MAAS scores and whether the MAAS estimates of general inattentiveness were significantly more reliable across a six-month interval than scores on a well-established measure of psychological distress.

Method

Participants and Procedures

The Ethics Committee for the Capital Region of Denmark approved the protocol for Part 1 and Part 3 of the present study (ID H-2-2010-111). Thus, Part 3 was a follow-up on Part 1. In November 2012, six months after the first community survey, we re-invited participants for a retest round, which N=407/490 (83.1%) completed. The retest sample was similar to the baseline sample on gender distribution (65.6% women), age (M=36.8 years, SD=9.8, range=18—53), education (74% had a professional education >4 years), personal income (M=3.44, SD=1.94), ISCO-88 (M=3.74, SD=1.62), ethnicity (94.8% Caucasians), and baseline (May 2012) scores on the MAAS, ps>.19.

Participants completed the MAAS, the FFMQ, and the Brief Symptom Inventory-18 (BSI-18, Derogatis, 2001). BSI-18 is a further development of BSI-53 incorporating 18 items. We focused on the General Severity Index (BSI-18-GSI), which is directly comparable to the BSI-53-

GSI, and the two are strongly correlated (r>.90; Derogatis, 2000). The BSI-18-GSI was internally consistent, α=.89.

Data Analyses

As for the short-term test-retest reliability, we evaluated the MAAS scores' absolute long-term test-retest reliability with the ICC in two two-way random absolute agreement models for means and individual participants' MAAS scores, respectively, as well as a secondary test-retest correlation (ϱ) bootstrapped with 10,000 permutations. Furthermore, we cross-validated test-retest reliability estimates within genders and median-split groups of age, professional education (≤4 years, >4 years), income (50% highest, 50% lowest), and ISCO-88 (≤4, >4). Most importantly, to investigate if the degree of general inattentiveness was a more reliable trait than psychological distress, we calculated BSI-18-GSI for the T_1 (May) data (results were similar when using the full BSI-53-GSI as T_1 data) and examined whether bootstrapped retest correlations for scores on the MAAS and the BSI-18-GSI scores, respectively, differed significantly according to Steiger's z-test (Steiger, 1980) using peer-reviewed SPSS syntax for this purpose (Weaver & Wuensch, 2013).

Results

The MAAS scores showed good-excellent internal consistency, α=.90. The long-term absolute test-retest reliability of the MAAS means was good (ICC=.85 (95% CI [.82,.88]) and satisfactory even for individual participants' scores, ICC=.74, 95% CI[.69, .78]. The secondary bootstrapped test-retest correlation also indicated satisfactory reliability, ϱ=.74, 95% CI[.68, .79]. Test-retest reliability estimates were similar within each gender and within median-split groups of age, education, income, and ISCO-88, all $ICCs$≥.81, all ϱs≥.70. Scores on the MAAS were negatively related to BSI-18-GSI scores at T_1 (May) (ϱ=-.48) and at T_2 (November), ϱ=-.49. Most importantly, the long-term test-retest reliability coefficient for the MAAS scores was significantly stronger than the test-retest correlation for the BSI-18-GSI scores (ϱ=.63), z=2.78, p=.005 (ϱ difference=.10, 95%CI=[.03, .18]). These findings are in keeping with the theoretical proposals that inattentiveness constitutes a more fundamental and reliable trait than symptoms of distress, which may fluctuate more over time. Since the present study was among the first long-term studies of the MAAS, we also conducted two exploratory SEM analyses of the long-term relevance of the MAAS inattentiveness scores for psychological distress, examining whether the MAAS estimates during May predicted BSI-18-GSI scores during November. The first model controlled for the identified covariates of age, gender, ISCO-88, SLE, income, and MCSD. This analysis supported that higher general inattentiveness predicted higher psychological distress even at long term, beta=-.20, 95%CI [-.15, -.27], β=-.34, p<.001. The second model also controlled for TCI-HA and TCI-SD scores. It supported that the MAAS scores still significantly predicted distress, although with a reduced effect size, beta=-.11, 95%CI [-.05, -.17], β=-.18, p<.01.

Discussion

The present study provided some of the first empirical evidence to a long-standing assumption in meditation research, namely that the degree of (in)attentiveness to the present moment experience – here measured by the MAAS score – is a reliable human disposition over long time intervals. We found consistent support for this assumption in several respects. First, the MAAS scores showed good test-retest reliability across a six months interval in a large, randomly invited, adult community sample, ICC=.85; ϱ=.74. Thus, the MAAS scores were as stable over time as scores on the 30 subfacets of the NEO-PI-R personality scale (rs=.76-.83 over a five- to ten-year period, McCrae et al., 2011). These findings corroborate the original proposal that the MAAS is a “trait scale” (Brown & Ryan, 2003, *p*.838), i.e., that the MAAS score reflects a human disposition which is stable over time when measured outside attention training contexts.

Second, the test-retest reliability of the MAAS scores was significantly stronger than for a well-established measure of symptoms of psychological distress, the BSI-53-GSI, as evidenced by Steiger’s z-test, $z = 2.78$, $p = .005$.

Third, when examining the generalizability of our findings, we replicated the long-term test-retest reliability estimates of the MAAS scores within both genders and all strata of age, education, income, and an internationally standardized (and nationally normed in Denmark) indicator of occupational socioeconomic status (SES), the ISCO-88. The highly consistent test-retest findings support that the long-term stability of the MAAS scores is not dependent upon demographic or socioeconomic factors. The present validated occupational SES-scoring method addresses a gap in cross-sectional mindfulness-health research, since by far the majority of previous studies have only investigated unvalidated occupational variables (e.g., mental health worker or not, Baer et al., 2008; Lykins & Baer, 2009; nurses versus non-nurses, McCracken & Yang, 2008; working inside or outside the home, MacDonald et al., 2010; jobs with tenure versus jobs without tenure, Avey et al., 2008; middle managers versus top managers, Trousselard et al., 2010; or self-reported socioeconomic class Masuda et al., 2009), which have yielded mixed findings as described in the introduction. More thorough research on validated measures of SES and mindfulness is needed.

As a fourth argument supporting the assumption that attentional instability is a long-term reliable psychological trait, we found that even single participants’ absolute MAAS scores were reliable across the seasons (test-retest model for single scores, ICC = .74), supporting that the MAAS average reflects a stable psychological disposition, also on an individual level. This adds knowledge to previous test-retest studies of the MAAS investigating only the stability of the MAAS group mean (e.g., Barnes et al., 2007; Brown & Ryan, 2003; Deng et al., 2012; Soler et al., 2010). Finally, our findings are supported by two psychometrically thorough studies of briefer versions of the MAAS for Chinese adolescents, which also supported the test-retest reliability of the MAAS scores produced by adolescents over time intervals from 3—13 months (Black et al., 2012a, 2012b). The lower test-retest coefficients (*r*s=.35—.52) obtained by Black et al. compared to the present estimates may be explained by the use of briefer MAAS versions as well as by the difference in sample ages, since younger age groups generally show lower test-retest reliability estimates as demonstrated by a meta-analysis of the test-retest reliability of scores on different trait scales within different age groups (Roberts and DelVeccio, 2000).

In a broader perspective, the present findings are in keeping with theories within the meditation literature (Bedford, 2012; Bushell, 2009; Grabovac et al., 2011; Shapiro et al., 2006), the personality literature (Eysenck, 1995; Mendelsohn, 1976), and empirical studies on 'mind-wandering' (Antisevic et al., 2012; Killingsworth & Gilbert, 2010) arguing that the degree of (in)attentiveness in noticing ongoing experience is not simply a function of symptomatic states, but may represent a more foundational and thus more reliable psychological property over time, which may independently predict or influence more fluctuating states of the mind, such as the degree of psychological distress.

A growing body of neuroscientific and clinical literature also suggests a causal influence of inattentiveness on mental health, cognition, and mental disease (for a review: Antisevic et al., 2012). Relatedly, we here demonstrated that scores on the MAAS independently predicted both symptoms of distress and psychological health, respectively. Even though we could not examine causality in the present studies, our findings do suggest a causal role for the degree of general inattentiveness (on the MAAS). First, our SEM analyses revealed that higher MAAS scores continued to predict lower psychological distress (BSI-53-GSI), as well as stronger mental health

(SF-36-MCS), after controlling for age, gender, income, ISCO-88, stressful life events, social desirability, BMI (only used as a control covariate in the SF-36-MCS model), two personality factors (TCI-HA and TCI-SD), and all interactions between these factors, *p*s<.001. Second, a causal role for inattentiveness on psychological distress was supported in our similarly controlled longitudinal SEM model showing that the MAAS scores reported at baseline, during the month of May, continued to predict psychological distress six months later, during November.

Relations between attentional functions and emotion regulation inspire an increasing number of studies in clinical and cognitive neuroscience (Okon-Singer et al., 2015; Viviani, 2013) and research on affective cognition (Elliot, 2011). Generally, improved attentional functions (e.g., attentional stability, working memory capacity, and attentional control) are related to improved emotion regulation. In the present community sample, more stable attention scores on the MAAS predicted less psychological distress and higher levels of psychological health, respectively, and was also related to higher emotional intelligence on the TMMS, ϱ=.43, *p*<.0001. Interestingly, a recent, systematic review and meta-analysis found consistent evidence across 16 studies for a significant and moderate mediating effect of increased self-reported mindfulness scores on beneficial changes in treatment outcomes such as stress, depression and anxiety (Gu et al., 2015). Longitudinal mediation analyses rest on the assumption that the self-reported mindfulness scores are stable over time outside meditative training, so the present study supports the validity of longitudinal mediation analyses based on MAAS scores. Extending this type of research, our findings open up the possibility of using the MAAS for clinical research with longer interventions than the usual 6-12 weeks in MBI. Also related to the MAAS and emotion regulation, Brown et al. (2012) showed that scores on the MAAS predicted lower electrophysiological neural responses (Late Positive Potential, LPP) to pictures of both positive and negative emotional valence. The authors suggested that higher attentiveness (i.e., lower inattentiveness as measured by the MAAS) may temper the subsequent emotional impact on executive control networks, perhaps improving the ability to cope with emotional stressors. Support for this proposition comes from the neuroscientific literature on attention and emotion regulation showing that attending more closely to emotional stimuli often decreases the neural response in amygdala (Viviani, 2013). Relatedly, experienced meditators also showed lower LPP after negative (but not positive) emotional pictures than demographically matched controls (Sobolewski et al., 2011), and meditators usually report higher MAAS scores than controls (Brisbon & Lowery, 2011; Brown & Ryan, 2003; Christopher et al., 2009a), although this is not always found (e.g., Schoormans & Nyklíček, 2011). On the other hand, several neuroimaging studies have supported that meditation may decrease mind-wandering (Brewer et al., 2011; Brewer & Garrison, 2014) and improve sustained attention (Tang et al., 2007) and the robustness of blood flow in sustained attention networks after auditive, emotionally stressing distractors (Brefczynski-Lewis et al., 2007). The present study is relevant to this field of research because the MAAS is probably the most used mindfulness scale today, and because increased knowledge on associations between demographics, SES, and psychological markers of mindfulness represents a necessary next step in developing empirically founded contextual theories and perspectives on the generalizability of findings obtained with the smaller and more restricted samples typical of neuroimaging. Mindfulness and meditation research has historically suffered from many methodological flaws concerning confounding factors (Andresen, 2000; Ospina et al., 2007). So, to reiterate other mindfulness researchers, further thorough investigations are needed on mindfulness scores and income (Brown et al., 2009), occupation (Avey et al., 2008; Baer et al., 2008; MacDonald & Hastings, 2010), and education (Baer et al., 2008; McCracken & Yang, 2008; Palmer & Rodger, 2009). Virtually all studies of mediating factors for the beneficial effects of mindfulness training focus on intra-psychological variables (e.g., attention, rumination, or self-compassion; Gu et al., 2015). Theories of mindfulness often neglect social factors in focusing on perceptual or cognitive processes (Bedford, 2012; Bishop, 2002; Bushell, 2009; Grabovac et al., 2011; Kabat-Zinn, 1990; Shapiro et al., 2006), although one study argued for social foundations for mindfulness (Shaver et al., 2007).

Theoretical and methodological attentiveness to background factors in mindfulness and attention research seems a promising area for future research. For example, a large systematic review of mindfulness training for healthy samples recently concluded that "The largest effects of meditation were obtained for variables that referred to positive changes in relationships" and thus suggested a potential association between mindfulness and social functioning, underlining the need for more research on mindfulness and social factors (Sedlmeijer et al., 2012, *p*. 1155). We presently showed that higher income and higher SES-ranking occupations (ISCO-88) were both indicative of higher MAAS scores. We expected this association due to the consistently observed, increased and prolonged stress exposure in lower SES groups and since lower SES is generally indicative of lower education, two factors which are both associated with decreased attentional functions. All in all, we recommend a more contextual perspective on attention and psychological health. In line with this, the developers of the MAAS (Brown & Ryan, 2003) stated: "It is likely…that the developmental trajectory of the mindful disposition is significantly influenced by the forces of socialization and culture" (Brown et al., 2007, *p*. 229). Again, the present studies support that inattentiveness to the present moment *does* independently predict psychological health parameters beyond demographics and SES. Thus, we encourage further studies in this field. Controlling for background variables will presumably not reduce the effects of the MAAS scores to insignificance, since the effect estimates from our SEM analyses were similar to less thoroughly controlled cross-sectional research on the MAAS scores and similar outcomes on the SF-36 (Cho et al., 2009; McCracken & Velleman, 2010; McCracken & Yang, 2008) and to studies of scores on the MAAS and on the GSI (Carmody et al., 2008; Dundas et al., 2013). Notwithstanding, this is important to investigate.

Specific facets of mindfulness measurement tools may differ in their importance for psychological health. For example, only two facets of the Five-Facet Mindfulness Questionnaire (FFMQ) still predicted psychological distress after controlling for age, education and job type (Cash & Whittingham, 2010). One of the FFMQ facets that *did* independently predict distress was 'Act with Awareness', which is based on MAAS items, in line with the present results. Therefore, the attentional (as opposed to attitudinal and intentional; Shapiro et al., 2006) aspect of mindfulness may especially predict health beyond SES, but more research is necessary to determine how different facets of mindfulness relate to demographics, SES, and human health.

The Danish translation of the MAAS proved psychometrically sound. Confirmatory factor analyses corroborated a unifactorial structure of the MAAS scores across and within genders with model fit estimates (RMSEA, CFI) similar to those of the original validation (Brown & Ryan, 2003), as well as satisfactory TLI. A post hoc exploratory factor analysis (EFA) also supported that the MAAS scores reflected a one-dimensional construct (data not shown). The good internal consistency of scores on the Danish translation of the MAAS was reaffirmed as highly consistent at four separate assessments, αs=.83—.90.

Concerning demographic factors, women reported slightly higher inattentiveness (lower MAAS scores) than men, but factor structure, test-retest reliability and incremental validity results were not affected by gender. The majority of cross-sectional MAAS studies found no gender differences (de Bruin et al., 2011; Carlson & Brown, 2005; Deng et al., 2012; Howell et al., 2008; Jermann et al., 2009; Niemiec et al., 2010), though with a few exceptions (Barnes et al., 2007; Black et al., 2012a). Scores on the MAAS were uncorrelated with education, ethnicity, perceived culture, employment status, and life style variables such as BMI, alcohol, and tobacco use. These observations are important for smaller studies with low statistical power to detect confounding.

Convergent validity tests uniformly confirmed our predictions: Scores on the MAAS correlated positively with scores on another mindfulness scale (FFMQ), self-directedness (TCI-SD), emotional intelligence (TMMS), and, to a weaker degree, physical health (SF-36-PCS). Conversely, the MAAS scores showed robust, negative associations with scores on self-report instruments measuring avoidant personality (TCI-HA), experiential avoidance (AAQ-II), symptoms of depression (MDI), and perceived stress (PSS), respectively (Table 3). MAAS scores did not correlate with scores on the FFMQ facet 'Observe'. However, it is commonly found that Observe is not related to the overall FFMQ scores or to other mindfulness scores in non-meditating samples (Baer et al., 2008). Therefore, this result does not weaken the convergent validity findings for the Danish MAAS. Rather, it supports that FFMQ Observe is not a valid indicator of mindfulness in non-meditating samples. We are currently also conducting the psychometric validation of the Danish FFMQ, which will present further details on this issue, e.g., with respect to the factor structure of different mindfulness scores on the FFMQ.

Limitations of the present surveys include the cross-sectional design, precluding causal conclusions. The community sample also had higher mean educational level and income than the average population. Although the study was well-powered to detect effects of income (Supplementary Figure 1), studies of more representative samples, adolescents, experienced meditators, and patient groups are needed to increase the effect estimates' generalizability. However, the satisfactory long-term test-retest reliability estimates (ICC and ϱ) were replicated within demographic and socioeconomic strata, strengthening the generalizability of this central result within healthy adults. Some scales used for the convergent validity tests (TMMS, FFMQ, and AAQ-II) have not been validated in Danish. However, translations were thorough, the professional back-translations were approved by the original scales' authors, these scores all proved internally consistent, and all convergent validity results were in line with our predictions. Our short-term test-retest reliability sample involved only students and 87% were women. However, scores on the MAAS were not related to gender in the students (ϱs$<.01$), and the long-term test-retest reliability of the MAAS means was not gender-related. Brief 5-item versions of the MAAS have been found to be psychometrically superior to the full 15-item version (Höfling et al., 2011; Van Dam et al., 2010), but the present study only investigated the full MAAS. Finally, the absence of a clinical group and an expert meditator group limits the generalizability beyond healthy, non-meditating samples.

In conclusion, we provided novel, empirical support to popular, but poorly investigated proposals that the general degree of inattentiveness to the present moment constitutes a psychological trait or natural, human disposition. Scores on the MAAS were consistently supported as reflecting a unifactorial, internally reliable construct. Inattentiveness scores on the MAAS predicted unique variance in both psychological distress and mental health, respectively, after thorough assessment and control for potential confounders. The MAAS scores showed satisfactory test-retest reliability across a six months interval, even for individual, absolute scores. Finally, the MAAS inattentiveness scores displayed significantly stronger long-term test-retest reliability than scores on a validated measure of psychological distress. May the following therefore *not* go unnoticed: our degree of general inattentiveness seems a measurable, unidimensional construct, a reliable trait over long periods of time, and a fundamental factor of independent significance for psychological health.

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Table 1. Descriptive data for the community sample

	Total (*N*=490)		Men (*n*=173)		Women (*n*=317)		*d*
Sociodemographic variables	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	
Age (years)	35.44	(9.89)	35.69	(9.52)	35.29	(10.10)	0.04
Personal income (index 1—7)[a]	3.32	(1.94)	4.01	(2.18)	2.95	(1.68)	0.57*
ISCO-88 (index 1—5)	3.60	(1.66)	3.73	(1.68)	3.53	(1.65)	0.12
	n	*(%)*	*n*	*(%)*	*n*	*(%)*	
Currently employed[e]	425	(86.7)	151	(87.28)	274	(86.44)	0.01
Professional education	*n*	*(%)*	*n*	*(%)*	*n*	*(%)*	
No professional education[b]	13	(2.7)	4	(2.31)	9	(2.84)	
Low (1—3 years)[c]	75	(15.3)	27	(15.61)	48	(15.14)	0.02
Middle (3—4 years)[d]	47	(9.6)	16	(9.25)	31	(9.78)	
High (>4 years)[e]	355	(72.4)	126	(72.83)	229	(72.24)	
Cultural variables	*n*	*(%)*	*n*	*(%)*	*n*	*(%)*	
Caucasian origin	459	(93.7)	168	(97.11)	291	(91.80)	0.24*
Perceived culture=Danish	458	(93.4)	167	(96.53)	291	(91.80)	0.16
Self-report covariates	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Stressful life events – past year	3.87	(3.63)	3.55	(3.42)	4.03	(3.73)	0.13
Stressful life events – lifetime	5.77	(4.53)	5.25	(4.37)	6.05	(4.59)	0.18*
Social Desirability (MCSD)	41.64	(5.50)	42.26	(5.62)	41.31	(5.41)	0.17
Primary Self-report Variables	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	
MAAS	4.28	(0.68)	4.37	(0.64)	4.23	(0.70)	0.21*[f]
BSI-53-GSI	0.37	(0.39)	0.30	(0.31)	0.41	(0.43)	0.28*
SF-36-MCS	70.47	(15.41)	72.00	(13.70)	69.04	(16.23)	0.19
Convergent validity Self-report scales	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	
FFMQ-Total	140.13	(16.53)	140.64	(15.33)	139.86	(17.17)	0.05
Trait-Meta-Mood Scale	116.99	(14.66)	115.59	(14.12)	117.76	(14.91)	0.15
TCI-Self-directedness	33.72	(6.36)	33.94	(6.37)	33.59	(6.36)	0.06
SF-36-PCS	87.78	(12.20)	89.08	(9.51)	87.06	(13.47)	0.17
TCI-Harm Avoidance	12.52	(6.31)	10.54	(5.88)	13.60	(6.28)	0.50*
AAQ-II	53.77	(8.13)	55.31	(7.45)	52.94	(8.36)	0.30*
Perceived Stress Scale	12.45	(6.04)	11.43	(5.46)	13.00	(6.28)	0.26*
Major Depression Inventory	7.04	(5.51)	6.67	(4.63)	7.25	(6.04)	0.10

Notes.* .p<.05(two-tailed, uncorrected).[a]. Self-reported personal income the previous year was indexed from 1-7 according to national distributions of personal income (Statistics Denmark, 2011a; see Supplementary Figure 1). [b]. Regional norm=24.6%; all participants completed public school. [c].Regional norm=27.8% [d].Regional norm=20.2% [e].Regional norm=22.3% (Statistics Denmark, 2011b). [f]. An exploratory test revealed that MAAS was not related to gender after controlling for MCSD, p=.10. AAQ-II=Acceptance and Action Quesionnaire-II. BSI-53-GSI=Brief Symptom Inventory-53-General Severity Index. FFMQ = Five Factor Mindfulness Questionnaire. ISCO-88=International Standard Classification of Occupations-88. MAAS=Mindful Attention Awareness Scale. MCSD=Marlowe-Crowne Social Desirability. SF-36-MCS=Short Form Health Survey-36-Mental Component Summary. SF-36-PCS= Short Form Health Survey-36-Physical Component Summary. TCI=Temperament and Character Inventory.

Table 2. Unifactorial model fit indexes of the Danish Mindful Attention Awareness Scale

	Chi Square (df)	RMSEA	(90% CI)	CFI	TLI
CFA model without modifications	433 (90)	0.088	(0.080-0.097)	0.959	0.952
CFA model with modifications[a]	332 (89)	0.075	(0.066-0.083)	0.971	0.966
SEM model on BSI-53-GSI	392 (193)	0.046	(0.039-0.052)	0.978	0.976
SEM model on SF-36-MH	419 (208)	0.045	(0.039-0.052)	0.977	0.974

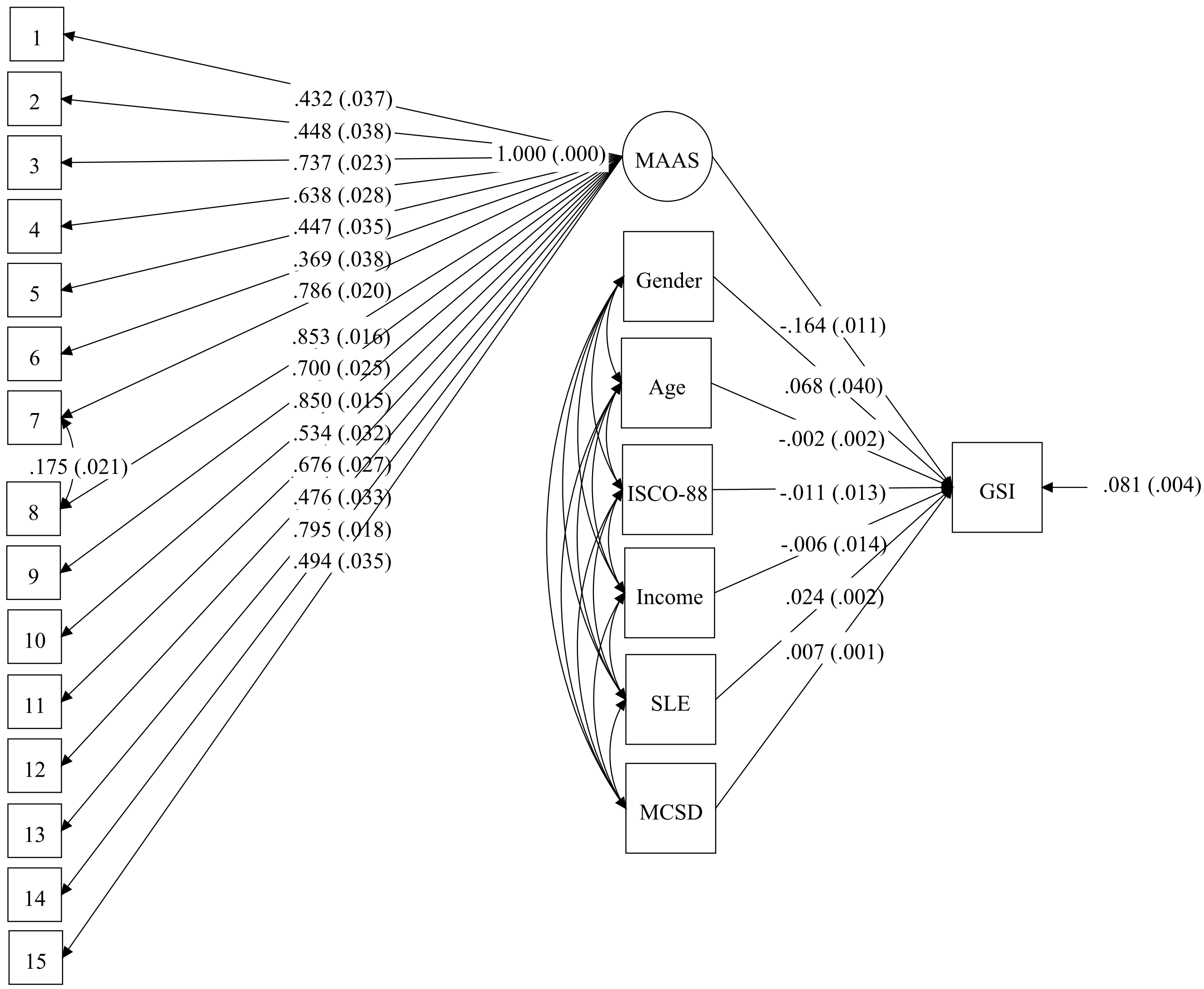
Notes. CFI=Bentler Comparative Fit Index. TLI= Tucker-Lewis Fit Index. [a].This model allowed for a cross-loading between items 7 and 8.

Table 3. Convergent validity results for the Danish version of the Mindful Attention Awareness Scale

	Spearman's Rho	(95% CI)	(99% CI)
Predicted positive associations with MAAS			
Five Facet Mindfulness Questionnaire - Total	.52 *	.45, .58	.43, .60
Five Facet Mindfulness Questionnaire – Total excluding Observe	.59 *	.52, .65	.50, .67
Five Facet Mindfulness Questionnaire – Describe	.38 *	.30, .47	.28, .49
Five Facet Mindfulness Questionnaire – Act with awareness	.69 *	.64, .75	.62, .76
Five Facet Mindfulness Questionnaire – Nonjudging	.39 *	.31, .47	.29, .49
Five Facet Mindfulness Questionnaire – Nonreactivity	.21 *	.11, .29	.08, .32
Five Facet Mindfulness Questionnaire – Observe	.01	-.08, .10	-.11, .13
Trait Meta-Mood Scale – Total	.43 *	.35, .50	.33, .52
Trait Meta-Mood Scale – Clarity of feelings	.50 *	.43, .56	.40, .58
Trait Meta-Mood Scale – Emotional repair	.29 *	.20, .37	.18, .39
Trait Meta-Mood Scale – Attention to feelings	.17 *	.08, .25	.06, .28
Temperament and Character Inventory – Self-Directedness	.46 *	.39, .53	.36, .55
Short Form Health Survey-36 – Mental components			
Mental Health	.41 *	.33, .48	.30, .50
Emotional function	.34 *	.26, .42	.23, .44
Social role function	.30 *	.22, .38	.19, .40
Vitality and energy	.41 *	.33, .48	.30, .50
Short Form Health Survey-36 – Physical components			
Body pain (high score=low pain)	.15 *	.06, .24	.04, .26
Physical function	.17 *	.08, .25	.06, .28
Physical role function	.27 *	.19, .35	.16, .37
General Health	.28 *	.20, .36	.17, .38
Predicted negative associations with MAAS			
Brief Symptom Inventory-53 – General Severity Index	-.52 *	-.46, -.58	-.43, -.60
Major Depression Inventory	-.40 *	-.33, -.48	-.30, -.50
Perceived Stress Scale	-.53 *	-.47, -.59	-.45, -.61
Acceptance and Action Questionnaire-II	-.47 *	-.39, -.53	-.37, -.55
Temperament and Character Inventory – Harm Avoidance	-.36 *	-.28, -.43	-.26, -.46

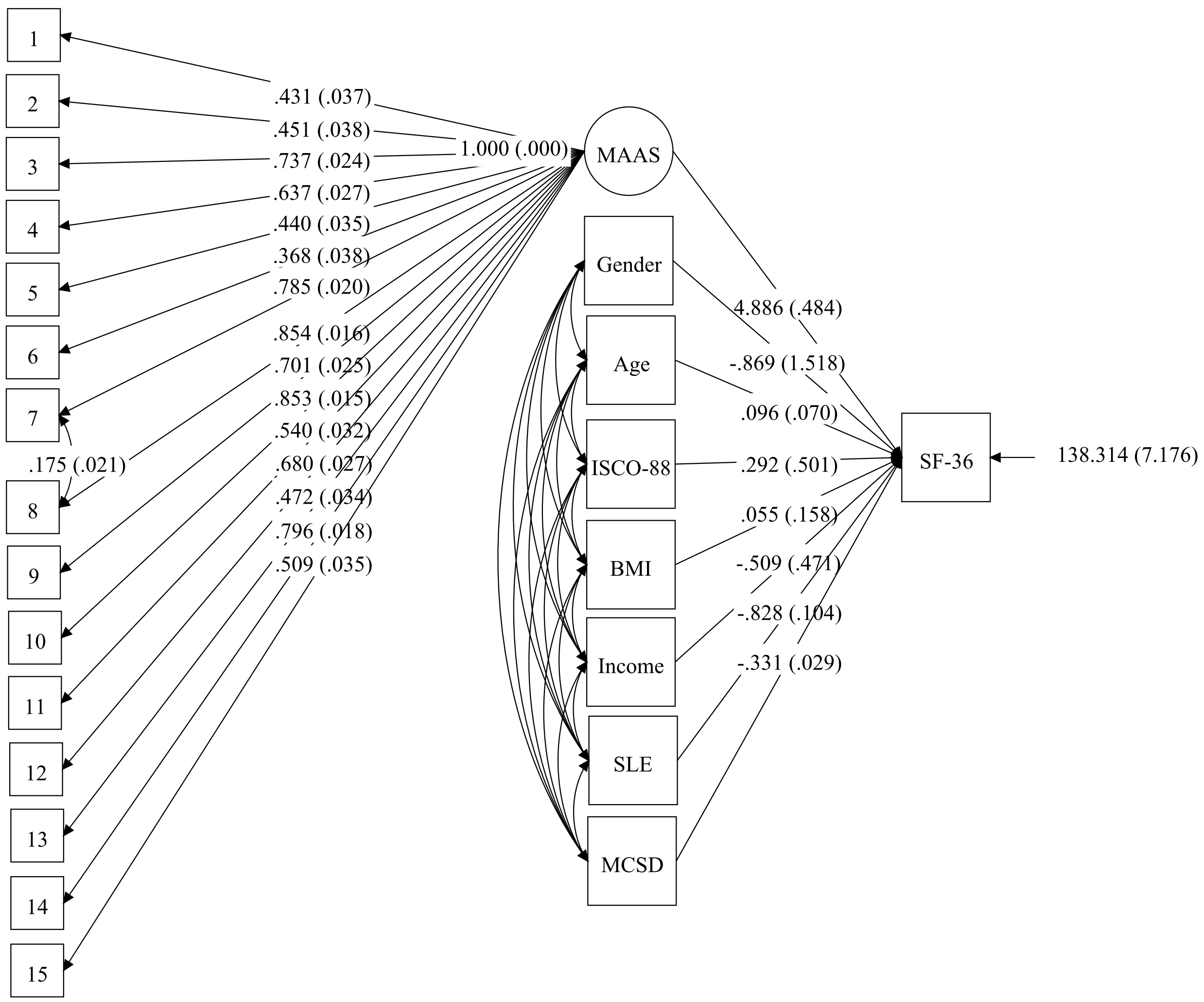
*.$p \leq .01$ (two-tailed, Bonferroni-corrected). MAAS=Mindful Attention Awareness Scale. N=490.

Figure 1. Structural equation modeling of general inattentiveness (MAAS) as a predictor of psychological distress



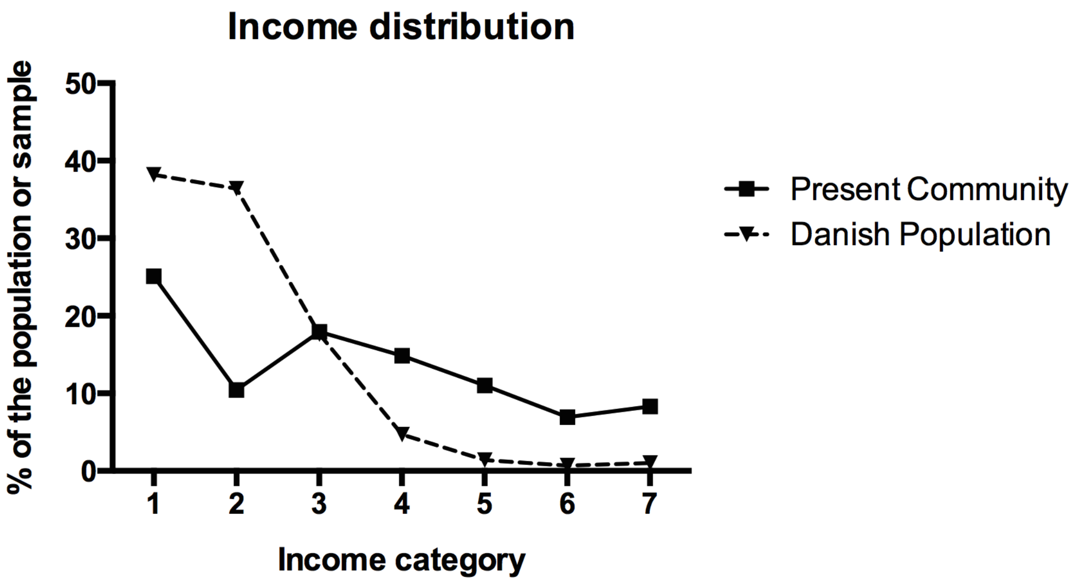
Notes. GSI=Brief Symptom Inventory-53-General Severity Index. ISCO-88=International Standard Classification of Occupations-88, Income=self-reported income during the previous year; MAAS=Mindful Attention Awareness Scale; MCSD=Marlowe-Crowne Social Desirability; SLE= stressful life events. A cross-loading between item 7 and item 8 was allowed for in the model (see text). The final model revealed that the MAAS predicted significant variance in BSI-53-GSI after controlling for the six potential confounders, beta=-.16 (95%CI[-.19, -.14], β=-.42, p<.001.

Figure 2. Structural equation modeling of general inattentiveness (MAAS) as a predictor of mental health



Notes. GSI=Brief Symptom Inventory-53-General Severity Index. ISCO-88=International Standard Classification of Occupations-88, Income=self-reported income during the previous year; MAAS=Mindful Attention Awareness Scale; MCSD=Marlowe-Crowne Social Desirability; SLE= stressful life events. A cross-loading between item 7 and item 8 was allowed for in the model (see text). The final model revealed that the MAAS predicted significant variance in SF-36-MCS after controlling for the six potential confounders, beta=4.89 (95%CI[3.94, 5.84]) β=0.32, p<.001.

Supplementary figure 1. Income distributions in the Danish population and the presently studied community sample



Notes. Income categories reflects yearly personal income defined as: 1: <150.000 DKK; 2 ≥ 150.000 and < 250.000 DKK; 3: ≥ 250.000 and < 350.000 DKK; 4: ≥ 350.000 and < 450.000 DKK; 5: ≥ 450.000 and < 550.000 DKK; 6: ≥ 550.000 and < 650.000 DKK; 7: ≥ 750.000 DKK.

Reference for national income distributions: Statistics Denmark 2011a, retrieved May 27, 2014 from: http://www.dst.dk/pukora/epub/Nyt/2011/NR223_1.pdf

Appendix III

Study 3

Appendix III

Open and Calm – A randomized controlled trial evaluating a public stress reduction program in Denmark

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Keywords

Relaxation Response; RR-MHP; 3RP; cortisol; 5-HTTLPR; attention; wellbeing; meditation; mindfulness; serotonin

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Abstract

Objective. Prolonged psychological stress is a risk factor for illness and constitutes an increasing public health challenge creating a need to develop public interventions specifically targeting stress and promoting mental health. The present randomized controlled trial evaluated health effects of a novel program: Relaxation-Response-based Mental Health Promotion (RR-MHP). **Methods.** The multimodal, meditation-based course was publicly entitled "Open and Calm" (OC) since it consistently trained relaxed and receptive ("Open") attention, and consciously non-intervening ("Calm") witnessing, in two standardized formats (individual or group) over nine weeks. Seventy-two participants who complained to their general practitioner about reduced daily functioning due to prolonged stress or who responded to an online health survey on stress were randomly assigned to OC formats or treatment as usual, involving e.g., unstandardized consultations with their general practitioner. Outcomes included perceived stress, depressive symptoms, quality of life, sleep disturbances, mental health, saliva cortisol, and visual perception. Control variables comprised a genetic stress-resiliency factor (serotonergic transporter genotype; 5-HTTLPR), demographics, personality, self-reported inattentiveness, and course format. **Results.** Intent-to-treat analyses showed significantly larger improvements in OC than in controls on all outcomes. Treatment effects on self-reported outcomes were sustained after 3 months and were not moderated by age, gender, education, or course format. The dropout rate was only 6%. **Conclusions.** The standardized OC program reduced stress and improved mental health for a period of 3 months. Further testing of the OC program for public mental health promotion and reduction of stress-related illnesses is therefore warranted. A larger implementation is in progress.

Trial registration: ClinicalTrials.gov.: NCT02140307. Registered May 14 2014.

***Keywords**: Stress reduction; mental health promotion; meditation; cortisol; attention*

Appendix III

Public health sectors in modernized countries are burdened by growing reports of prolonged, psychosocial stress. Otherwise healthy individuals experience that the demands of the environment (most often their occupation) exceed their available resources to a degree that disrupts their daily functioning by way of e.g., concentration problems, irritability, anxiousness, depressive symptoms, fatigue, or bodily pain. About a fourth of North Americans regularly experience high levels of stress (Anderson et al., 2012). In Denmark, such estimates increased from 6% in 1987, to 9% in 2005, and 15% in 2012 (Christensen, 2012; Jakobsen et al., 2013). Prolonged stress is associated with impairments of the cardiovascular, immune, metabolic and nervous systems (McEwen, 2012). For example, long-term psychosocial stress is related to significant increases in neurological inflammatory processes (Lucassen et al., 2014), and with increased risk for depression (Hill et al., 2012). Recent research also connects stress to sleep disturbances (Porkka-Heiskanen et al., 2013).

For these reasons, health agencies have underlined a public need for evidence-based programs specifically targeting psychosocial stress and promoting stress resiliency (World Health Organization, 2005). This was also governmentally reinforced in Denmark (Borg et al., 2010). Unfortunately, only about 5% of Danish health research concerns public health (Gulis et al., 2010).

Therefore, we developed a program designed for stressed, but otherwise healthy adults to reduce stress and promote mental health and resiliency. Reviews have documented that meditation-based multimodal programs reliably reduce stress in healthy samples (Chiesa & Serretti, 2009; Goyal et al., 2014; Sedlmeier et al., 2012). However, meditative programs are generally modeled on complex philosophical-religious systems and not academic theories (Sedlmeier et al., 2012). As an exception, the so-called Relaxation Response (RR) research tradition lead by Herbert Benson and colleagues has through four decades provided empirical evidence supporting that a few core methodological commonalities are evident across many contemplative traditions', and that regular practicing of these techniques is sufficient for eliciting physiological stress reduction and for improving overall health (Park et al., 2013). In targeting a broad demographic group, and since we aimed to develop a theoretically driven and methodologically consistent and well-defined program, we selected RR-based meditation. For the same reasons, we structured the course content according to the well-established body-psycho-social understanding of stress (e.g., McEwen, 2012). Finally, a novel, cognitive framework model termed "Open and Calm" (OC) was used every week to integrate the meditative, bodily, cognitive, and social practices.

Our primary hypotheses were that OC would reduce self-reported perceived stress as well as physiological stress as measured by cortisol secretion upon awakening (Fekedulegn et al., 2007). Based on longitudinal studies suggesting that a blunted HPA-axis response to stimulation (awakening) develops with prolonged distress over time (Booij et al., 2012) and on several studies associating burnout with blunted HPA-axis reactivity (Juster et al., 2011; Marchand et al., 2014; Moya-Albiol et al., 2010; Pruessner et al., 1999), we specifically hypothesized that intervention participants with blunted baseline cortisol secretion curves upon awakening would exhibit a reestablishment of HPA-axis reactivity. Oppositely, stressed intervention participants with non-blunted cortisol reactivity were predicted to decrease their cortisol awakening response relative to controls. However, HPA-axis dysregulation in relation to prolonged stress and burnout is complex and not fully understood (Danhof-Pont et al., 2011). Our secondary hypotheses stated that OC would improve self-reported mental health, quality of life, symptoms of depression, and sleep disturbances, as well as visual attention, as argued by theories of mechanisms of change in meditation (Bedford, 2012; Bushell, 2009). It was also theoretically important to investigate several potential treatment effect moderators: First, carriers of S and LG alleles in the serotonin transporter-linked polymorphic region (5-HTTLPR) of the SCL6A4 gene (Canli & Lesch, 2007) show increased risk for depression after severe stress in most population studies (Karg et al., 2011), as well as increased cortisol response to stressors (Chen et al., 2009; Mueller et al., 2010). Second, the personality trait "harm avoidance", reflecting a proclivity to repress stressful stimuli, may decrease stress resiliency, while increased "self-directedness", reflecting overall top-down self-regulation abilities, may promote stress resiliency (Stoyanov & Cloninger, 2012). Third, variables such as age, gender, and education are recommendable covariates in public health promotion to evaluate the demographic applicability of the intervention (Kalra et al., 2012).

Method

Participants

Participants were stressed, but otherwise healthy, Danish adults (65% women) aged 18—59 years (Mean = 42.2, Standard Deviation = 8.9, interquartile range: 36-48). Participants seldom reported to have no professional education, and relatively often to have longer professional educations, compared with the Copenhagen adult population at the time (Statistics Denmark, 2014) (% of sample / % of population: no professional education: 8.3/33.1; apprenticeship: 23.6/21.9; 1-3 years: 13.9/4.7; bachelor degree or 3-4 years: 23.6/21.9; > 4 years: 30.6/18.5). All were Caucasian. The majority (92%) never meditated regularly (> 2 times / week for > 1 month) before. Supplementary table 1 provides more detailed sample characteristics, e.g., on the "Control Variables" described below. The inclusion criteria were the age 18-59 years, fluency in Danish, and subjective report of reduced daily functioning due to prolonged stress. This was evaluated in a 1-hr personal inclusion interview (Figure 1). The main exclusion criteria were current treatment for any illness; >1 diagnosed or treated ICD-10 mood disorder (F30-39), stress-related (F40-43) or somatoform (F45) disorder within three years; any other ICD-10 diagnoses for adults; Hamilton Depression Rating Scale score >20 at the inclusion interview (these criteria ensured that participants experienced stress-related problems, but were not suffering from psychiatric disorders); recreational drug use >24 times per year or > 50 times in the lifetime; Body-Mass-Index (BMI) >30.0 (due to exploratory psycho-physiological measurements), and medication use affecting the brain or cortisol.

Procedures

The present Clinical Registered Trial (Clinicaltrials.gov ID: NCT02140307), approved by the Danish Ethics Committee (H-3-2012-092), recruited volunteers through 20 General Practitioners (GP) and an online medical recruitment company. Figure 1 shows participant flow and retest rates. Participants provided informed consent. Stratifying for age and gender, the last author (XX), who had no participant contact, block-randomized three consecutively enrolled cohorts of n=24 to intervention in individual format, group-format, or treatment as usual (TAU), involving e.g., extra GP visits, or stress leave. Groups were randomized with a ratio of 1:1:1 using www.random.org. An *a priori* power calculation in G-power (Faul et al., 2007) revealed a required N=54 (power=.95, three groups, three measurements [pre, post, follow-up], expected effect f = 0.25, sphericity correction = 1). Expecting 15-30% dropout (Ospina et al., 2007), N=72 were recruited.

Danish, validated self-report instruments were completed online at home. Double-blinded baseline data (T_1, Jan.-Mar., 2013) were obtained before randomization (Figure 1). To increase validity, scales were completed both at 4 weeks and 2 weeks pre-intervention and 2 weeks and 4 weeks post-intervention (Apr.-Jun, 2013). T_1 and T_2 scores reflect the average of each pair of completions, as recommended (Vickers, 2003). Cortisol (for financial reasons only collected for the first n=48) and attention were tested within 2 weeks before and after the intervention period by researchers blinded to participant status at T_2. Follow-up 3 months after the intervention (T_3, Oct.-Dec., 2013) included self-report. Participants were not contacted during the follow-up period itself.

The intervention

The "Open and Calm" (OC) program was based on the Relaxation Response (RR) tradition (Park et al., 2013), which has for decades empirically supported that many meditative techniques elicit the same physiological, parasympathetic RR, involving e.g., lowered heart rate, blood pressure, and respiration rate. RR theory proposes that the core methods across meditative techniques necessary for eliciting the RR are: (a) the continuous returning of attention to a meaningful focus, i.e., focused attention training, and (b) the non-reactive or contemplative witnessing of ongoing experience. The OC meditation focused on these aspects and termed them “Open” (relaxed and receptive attentiveness) and “Calm” (non-intervening witnessing). The course structure was modeled on the well-established overall understanding that bodily (biological), psychological, and social factors interact in stress, stress resiliency, and health, focusing each week on working with either the body, the mind, or social relationships, in a cyclic fashion. Meditation was trained every week; bodily, cognitive, and social practices followed the weekly themes. Importantly, all practices focused on training the OC states (e.g., Open attention toward the breath, an emotion, or another person) and were theoretically integrated by a core OC cognitive framework model. The standardized 9-week OC program was offered in two formats: The group format (OC-G) involved weekly 2.5-hr group sessions (*n*=8 per group) and two optional 1.5-hr personal sessions. The individual format (OC-I) involved personal, weekly 1.5-hr sessions. Formats used identical materials, e.g., a 120-page course book (anonymized, 2013), online materials, 1—2 daily meditations of 10—20 min following audio files, and frequent “mini-meditations” of 1-2 min.

Measures

Control Variables

Demographics and life style. Factors investigated as covariates included age, gender, education, occupational status, meditation experience, alcohol consumption, tobacco use, and BMI.

Genotype. Saliva was collected in DNA Genotek tubes (Ottawa, Canada) and frozen at –80 degrees Celsius until analyzed. Polymerase chain reaction (PCR) was used to amplify the 5-HTTLPR and two oligonucleotide primers (Wendland et al., 2006) to generate allele-specific fragments: short (S) allele 469 bp and long (L) allele 512 bp. PCR was performed in a GeneAmp

PCR System 9700 (Applied Biosystems MspI). The genotype covariate quantified the efficiency of 5-HT reuptake: 0=SS/SLG, *n*=14; 1=SLA/LGLA, *n*=41; 2=LALA, *n*=15; missing: *n*=2.

Personality. From Temperament and Character Inventory (TCI) (Cloninger et al., 1994) the personality trait *Harm Avoidance* (TCI-HA) evaluated the proclivity to avoid novelty, non-reward and punishment. The trait *Self-Directedness* (TCI-SD) measured executive, self-regulation and adaption. TCI-HA and TCI-SD were recommended as screening tools in public health studies of stress (Stoyanov & Cloninger, 2012). Both factors were internally consistent, Cronbach's αs≥.84.

Stressful life events. Stressful Life Events (SLE; Kendler et al., 1995) was used to investigate SLE within the past year and the lifetime (e.g., assault, job loss, serious illness, loss of a confidant).

Attentional instability. Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003) evaluated attentional instability at baseline via 15 items and was internally consistent, α=.88.

Test motivation. At each cognitive test, participants rated how motivated they were to comply with the task on a 7-point Likert-scale from 0 (not at all motivated) to 6 (very motivated).

Course attendance. The total number of attended OC sessions quantified compliance. Detailed meditation logging has not shown consistent relationships with meditation-based effects (Carmody & Baer, 2009; Virgili, 2013) and was not prioritized due to the participant burden.

Outcome Variables

Perceived stress. Cohen's Perceived Stress Scale (PSS; Cohen & Williamson, 1988) comprise 10 items of stress-related experiences rated from 0 (never) to 4 (very often) for their frequency during the past two weeks, providing an overall score. The PSS was always internally consistent, αs≥.82.

Mental health. Short-Form Health Survey-36 (SF-36; Ware et al., 1993) measures eight health dimensions: 1) physical function, 2) physical role limitations, 3) bodily pain, 4) general health, 5) emotional function, 6) vitality, 7) emotional role limitations, and 8) mental health. Each dimension is scored from 0 (poor) to 100 (best possible). The Mental Component Summary score (SF-36-MCS) was based on weighting of all dimensions (Bjørner et al., 1997). At all times, α was ≥.71.

Depressive symptoms. Major Depression Inventory (MDI; Bech et al., 2001) involve ratings of the frequency of the ten ICD-10 depressive symptoms during the past two weeks (0=not at all, 5=all of the time). The total MDI was investigated and was always internally consistent, αs>.83.

Quality of Life. The 5-items Quality of Life (QOL) developed by WHO assesses quality of life through positive affect and vitality. The Danish QOL has high validity and QOL scores <50 is a risk marker for depression (Folker & Folker, 2008). QOL was internally consistent, all present αs>.81.

Sleep disturbances. Pittsburgh Sleep Quality Index (PSQI; (Buysse et al., 1989) indexes sleep disturbances during the past month via 19 items. On the examined PSQI Global, scores >5 indicate increased risk for depression. Consistency was mostly satisfactory, αs: T_1=.61; T_2=.77; T_3=.69.

Physiological stress. The cortisol awakening response (CAR) reflects hypothalamic–pituitary–adrenal (HPA) axis activity (Fekedulegn et al., 2007). After written and verbal instructions and training, participants performed home-samplings of saliva in Salivette tubes (Sarstedt, Neubringen, Germany). Sample 1 was taken immediately upon awakening, and samples 2–5 every 15 min for the subsequent hour. Participants registered the time of awakening and of each sampling. Within 48 hrs samples were centrifuged and stored at –80 degrees Celsius. The entire batch was analyzed in one step using electrochemiluminescent immunoassay (Cobas equipment, Roche, Germany). Our outcomes were the *Area Under the Curve with respect to ground* (AUC_G), representing the total magnitude of cortisol secretion; and the *Area Under the Curve with respect to increase from awakening levels* (AUC_I), reflecting the HPA axis' cortisol response to awakening (Fekedulegn et al., 2007). Participants with symptoms of burnout at T_1 (blunted CAR [AUC_I] curves) were analyzed separately. Blunted T_1 CAR curves were identified by inspection of individual curves by two researchers (anonymized, anonymized) blinded to participant group status.

Appendix III

Visual attention. The computational Theory of Visual Attention (TVA; Bundesen, 1990) framework quantifies functions of visual attention using accuracy-based testing. The TVA-based test used here (ad modum Vangkilde et al., 2011) comprised two practice blocks and three test blocks of 30 trials presenting six red letters on a computer screen. The letter display durations were varied systematically (20 – 200 ms), and terminated by pattern masks (500 ms) before participants made an unspeeded report of letters they were "fairly certain" of having seen. In cognitive test rooms, participants were instructed to refrain from pure guessing and to aim for an accuracy of 80—90%. They were informed about their accuracy after each block. Three parameters of attention were extracted by mathematical modeling (Dyrholm et al., 2011): The storage capacity of visual short-term memory (*K*; 5 degrees of freedom [df]), the speed of visual processing (*C*; 1 df), and the threshold for conscious visual perception (t_0; 1 df). Since meditation may specifically improve visual perceptual thresholds (Jensen et al., 2012; MacLean et al., 2010), t_0 was our visual attention outcome, while *K* and *C* analyses were exploratory.

Statistical Analyses

Intent-To-Treat (ITT) models were applied, replacing missing T_2 or T_3 scores with T_1 or T_2 scores, respectively. Treatment effect analyses adjusted for covariates (see 'Control Variables') related to (p<.05) outcome changes within groups (different criteria for selecting covariates did not change any results significantly). All *p*-values were Bonferroni-Holm-corrected within outcome types (self-report/cortisol/attention). OC format was not expected to affect intervention effects (Brown et al., 1998; Main et al., 2005; Virgili, 2013) but this was investigated in an initial OC-I *vs*. OC-G comparison. If formats did not differ (p<.05), the collapsed OC was compared to controls. If formats did differ, each format was to be compared to TAU in turn. Group differences in outcome changes were investigated in two-way repeated measures ANCOVAs using Time (T_1/T_2/T_3) and Group (e.g., OC/controls) as independent variables. A multivariate analysis of variance

(MANOVA) examined whether gender, age (median split), or education (3 *df*) affected long-term (T_1—T_3) changes across self-report scales in OC. Effects were expressed with Cohen's *d* (group differences and pre-post within group effects ad modum Morris & Deshon, 2002; formula 8), Pearsons *r* or Spearman's *rho* (ϱ) (variable associations), or partial eta-squared, η_p^2, (Time×Group effects). Excluding scores >3.0 *SD* from group means (<2% in all analyses) yielded similar results. One score was excluded, being a T_2 t_0-value (0.7%; replaced with the T_1 t_0-value) of inadequate data quality. MDI and PSQI data were skewed and $\log^{10}$-transformed, yielding normal distributions. Internal consistency of questionnaires was assessed with Cronbach's alpha, α. We pre-defined AUC_G and PSS as primary outcomes. AUC_I, SF-36-MCS, MDI, QOL, PSQI, and t_0 were secondary outcomes. Analyses were carried out in SPSS (IBM, vs. 20.0) and Microsoft Excel 2011.

Results

Course Attendance

OC had a 94% (*n*=45/48) completion rate. In total, group participants attended more sessions (mean[M]=8.3, *SD*=2.7) than individual format participants (M=6.7, *SD*=2.0) (*p*=.020), but required less (M=3.9 hrs, *SD*=1.7) professional contact hours per participant (M=10.0 hrs, *SD*=3.0), a ratio of 2.56. Session attendance rates were unrelated to outcome changes unless otherwise is stated.

Self-report

Intervention format did not affect self-report changes, *p*s>.1 (uncorrected; Supplementary Panel 1). The total intervention group improved significantly more on all scales than TAU controls, *p*s<.01 (Table 2; Panel 1). Effects were sustained or significantly improved on all scales during follow-up and OC differed significantly from controls on all scales at T_3, *p*s<.02. OC increased above the quality of life risk marker for depression; controls did not (Panel 1, d). OC decreased slightly below the sleep disturbances risk marker for depression; controls did not (Panel 1, e). The MANCOVA showed no effect of age, gender, or education across self-report effects for OC, $p>.2$.

[Insert Table 1 and Panel 1 about here, please]

Physiological Stress

Groups did not differ on any cortisol outcomes at baseline, *p*s>.09 (uncorrected; Supplementary table 2). For participants with a non-blunted T_1 CAR, the intervention group decreased significantly more than controls on the magnitude of cortisol secretion (AUC_G), $p<.05$, $\eta^2=.21$. Since OC showed non-significantly higher baseline cortisol (AUC_G) levels, we conducted a *post hoc* ANCOVA also controlling for baseline AUC_G. This test reaffirmed that the treatment group decreased significantly more than controls, $F(1,28)=4.35$, $p<.05$, $\eta^2=.17$. Within groups, only OC decreased significantly, $p=.018$, $d=-0.59$ (Panel 1, f; Supplementary table 2). Group changes for AUC_I did not differ, but only OC decreased significantly, $p=.018$, $d=-0.76$ (Supplementary panel 2, a). Blunted baseline CAR was identified for $n=18$ in OC, and $n=2$ in TAU. Group comparisons were therefore not meaningful for these AUC_I analyses. As we hypothesized, CAR-blunted OC participants showed a significantly increased AUC_I, $p=.015$, $d=0.88$ (Supplementary panel 2, b). This effect suggested a healthy reestablishment of HPA-axis reactivity to stimulation (here: awakening).

Visual Attention

Intervention format did not affect changes in the perceptual threshold, t_0, $p>.6$ (Supplementary Panel 1, f). The total intervention group improved significantly more than controls on t_0 ($p<.05$, $\eta^2=.056$) due to significant improvement in OC and no change in controls (Supplementary panel 2, d; Supplementary table 2). A *post hoc* ANCOVA controlling for t_0 at baseline still supported a significant Time × Group interaction ($p=.054$) with a virtually unchanged effect size, $\eta^2=.054$.

Additionally, higher OC attendance rates were indicative of larger t_0 improvement, ϱ = -.33, p=.023. The exploratory analyses of visual short-term memory capacity, K, and processing speed, C, showed no significant treatment effects, ps>.2 (uncorrected).

Discussion

Experiences of prolonged psychosocial stress is currently not targeted by evidence-based programs in most public health sectors (Kalra et al., 2012). The present RCT supported that the multimodal, meditation-based program "Open and Calm" (OC) developed specifically for this purpose decreased participants' perceived stress, depressive symptoms, and sleep disturbances, and increased their self-reported mental health and quality of life (positive affect and vitality) significantly more than the Danish health sector's unsystematic treatment as usual (TAU; e.g., increased visits with the general practitioner) for otherwise healthy adults complaining about reduced daily functioning due to prolonged stress. Treatment effects were consistently sustained at 3 months follow-up and OC participants reported significantly better mental health than TAU controls at follow-up on all self-report scales (Table 1). According to well-established cut-offs, OC reduced the risk for depression due to poor quality of life (QOL; Folker & Folker, 2008) and sleep disturbances (PSQI; Buysse et al., 1989). OC participants reported follow-up levels corresponding to Danish norms for perceived stress (Stigsdotter et al., 2010), mental health (Bjørner et al., 1997), and symptoms of depression (Olsen et al., 2004) (Panel 1). Control participants showed heightened risk for depression and suboptimal mental health scores throughout the six months study period.

Comparing with other stress reduction programs, OC improved the included self-report parameters with similar or larger effect sizes (mean self-report T_1-T_3 d =1.10; mean self-report T_1-T_2 d=0.70; Table 1) than for courses based on mindfulness, transcendental meditation, or other types of meditation for healthy samples according to meta-analytic reviews (Chiesa &

Serretti, 2009: *d*=0.74; Grossman et al., 2004: *d*=0.50; Sedlmeier et al., 2012: *d*s = 0.54-0.56). Similarly, the effect from baseline to 3-month follow-up of OC on Cohen's perceived stress scale (PSS; *d*=1.30) was larger than a baseline-3-months follow-up analysis on PSS of public stress reduction workshops based on cognitive and/or behavioral therapy (Main et al., 2005, mean *d*=0.91). Thus, OC seems quite effective compared with other stress reduction programs.

Physiological stress, in terms of cortisol secretion and HPA-axis dynamics, was also significantly improved by the intervention, but not in controls. For participants with an initially present (non-blunted) CAR, the magnitude of cortisol secretion (AUC_G) decreased significantly, and significantly more than in controls, also after controlling for baseline levels. Decreasing circulating levels of cortisol may be important in restoring health and preventing negative consequences of prolonged stress, e.g., because it may prevent neural atrophy in frontal and hippocampal regions, improving top-down regulation of limbic systems, promoting stress resiliency (Charney, 2004). The stimulated HPA-axis output (AUC_I) also decreased significantly in OC participants with non-blunted baseline CAR (Supplementary panel 2, a). This change may relate to improved stress resiliency, since HPA-axis reactivity has been associated with several risk factors for depression, including 5-HTTLPR genotype (Chen et al., 2009). However, although no CAR changes were observed in the controls, AUC_I changes did not differ between OC and TAU. Thus, the main cortisol effect of OC was a reduction in the magnitude of cortisol secretion. In addition, as we hypothesized, AUC_I increased significantly for OC participants with a blunted baseline CAR. This suggests that HPA-axis dynamics, i.e., HPA axis reactivity to stimulation (awakening), was re-established (Supplementary panel 2, b). Cortisol studies of meditation and stress reduction have produced mixed findings and lacked methodological rigor (Matousek et al., 2010), rendering the present analytic strategy potentially applicable to future studies of prolonged stress. HPA-axis reactivity (AUC_I) potentially generalizes from responses to simple cues to e.g., psychosocial stress

(Chen et al., 2009). However, cortisol is complexly related with prolonged stress and further studies of HPA-axis dynamics, prolonged stress, and burnout are needed (Danhof-Pont et al., 2011).

Visual perception

The threshold of conscious visual perception, t_0, improved significantly more in OC than in controls, also when adjusting for baseline. Further, larger t_0-improvements were associated with increased OC compliance. This corroborates the previously reported finding that the TVA t_0 parameter was specifically improved by meditation and not by physical stress reduction (Jensen et al., 2012). Interestingly, the TVA-model (Bundesen, 1990; Bundesen et al., 2005) states that t_0 improvements may reflect stronger reliance on bottom-up-driven perception, rather than conscious recalibration of attentional weights. OC may therefore have improved the perceptual threshold because participants became less prone to consciously modulate visual attention. This aligns with the OC training in *relaxed* and *receptive* ("Open") awareness of sensory information and a *non-intervening* ("Calm") conscious witnessing. As mentioned, these are essential elements for many meditative traditions. Correspondingly, the visual perceptual threshold was also improved by yoga (Braboszcz et al., 2013; Vani et al., 1997) and mindfulness meditation (Jensen et al., 2012; MacLean et al., 2010). Mindfulness has also improved the threshold for conscious registration of proprioceptive stimuli (Naranjo & Schmidt, 2012) and the perceptual threshold in an auditory temporal discrimination task (Droit-Volet et al., 2015). As argued by recent theories, meditation may facilitate insight into personal states and promote objective perception in general through increased perceptual sensitivity within several sensory modalities, i.e., through a lowering of the stimulation needed for conscious registration (Bedford, 2012; Bushell, 2009). Our findings support these proposals, but clearly more research on bottom-up perceptual effects of meditation is needed.

Experiences from the practical implementation

The ‘Open and Calm’ program was well received with a 94% completion rate and high satisfaction among participants. GPs found it easy to use a simple, online referral system and maintaining the full screening at the program distributor (Copenhagen University Hospital) ensured similar inclusion procedures throughout. However, among 20 referring GPs, ten GPs referred only one—two patients each. GPs and psychiatrists are generally not accustomed to referring stressed, but otherwise healthy individuals to treatment (Min et al., 2013). To achieve sustainability, we reiterate recommendations (Kalra et al., 2012) that mental health program distributors employ health workers specifically for sustaining recruitment through local health facilities.

Intervention format (individual/groups of *n*=8) did not moderate treatment effects (Supplementary panel 1). This is important, since individual courses required 2.6 times more professional contact hours per participant. Workshops for even larger groups also reduced stress (Brown et al., 2000; Main et al., 2005) and anxiety (Brown et al., 1998). A stepped care model (Davison, 2000) may be recommendable, where larger group programs are offered as a first-line treatment, while smaller or individual courses are offered when deemed necessary. Importantly, more systematic research is needed on public health intervention formats (Kalra et al., 2012).

The dropout rate of only 6% (*n*=3/48) seems important, since dropout in meditation-based stress reduction programs typically ranges 15-30% (Ospina et al., 2007). Based on participant feedback, the two most appreciated elements of the OC program was the cognitive framework model, the meditative practices, and the programme structure, repeating bodily, mental, and social themes. Participants seemed to find the program easy to integrate into personal contexts. This, however, should be clarified by qualitative studies. We speculate that the choice of conducting evening sessions lowered the dropout rate especially for employed OC group participants, enabling them to maintain a normal working week. Similarly, individual participants could flexibly book course sessions in expanded working hours (8am-6pm).

Limitations of the present RCT include the need for studying longer time periods, such as a year. A longer study period would enable more direct health impact assessments (Kraemer & Gulis, 2014), such as measures of the occurrence of stress-related depression or days of stress-induced absence from work. An active control group would have improved the ability to detect OC-specific effects. However, an unrestricted TAU design allowed a comparison of OC with the current, unsystematic treatments offered for healthy adults dealing with prolonged stress.

Conclusion

This RCT revealed that the OC program designed specifically for public stress reduction and mental health promotion improved self-reported stress, depressive symptoms, sleep disturbances, mental health, and quality of life, a physiological stress marker (the magnitude of cortisol secretion), and the threshold for visual perception significantly more than treatment as usual for Danish, stressed adults. The program participant completion rate was 94%. All self-report effects were sustained or further improved at 3 months follow-up. Multivariate analyses showed no general effect moderation by age, gender, or education. In sum, the OC program was consistently supported as effective. Further testing of potential advantages, including long-term more direct health sectorial benefits, of the OC program is therefore warranted. Due to the positive results, a larger implementation of the OC program is in progress in the health promotion sector in the municipality of Copenhagen.

Competing interests

The OC program is now implemented on a larger scale in the municipality of Copenhagen, which benefits the first author (CGJ), who is now funded as a director of this implementation.

Authors' Contributions

CGJ conceived of the study, was the main developer behind the intervention and principal in conducting the statistical analyses and writing the manuscript. JL participated in designing the online intervention elements, and conducted 40% of the tests sessions, and participated in the statistical analyses of the visual test and the writing of the manuscript. AP and SAV participated in programming, analyzing, and interpreting the visual test, and in writing the manuscript. SPR conducted 60% of the test sessions and participated in coordination of participants, and in writing the manuscript. VGF headed the collection, analyses, and interpretation of cortisol data and participated in writing the manuscript. DA headed the collection, analyses, and determination of genotypical variations. GMK and SGH participated in designing the study, analyzing all types of data, and writing the manuscript, and SGH performed the randomizations. JD participated in developing the intervention, planning and supervising the study, and in writing the manuscript.

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Appendix III

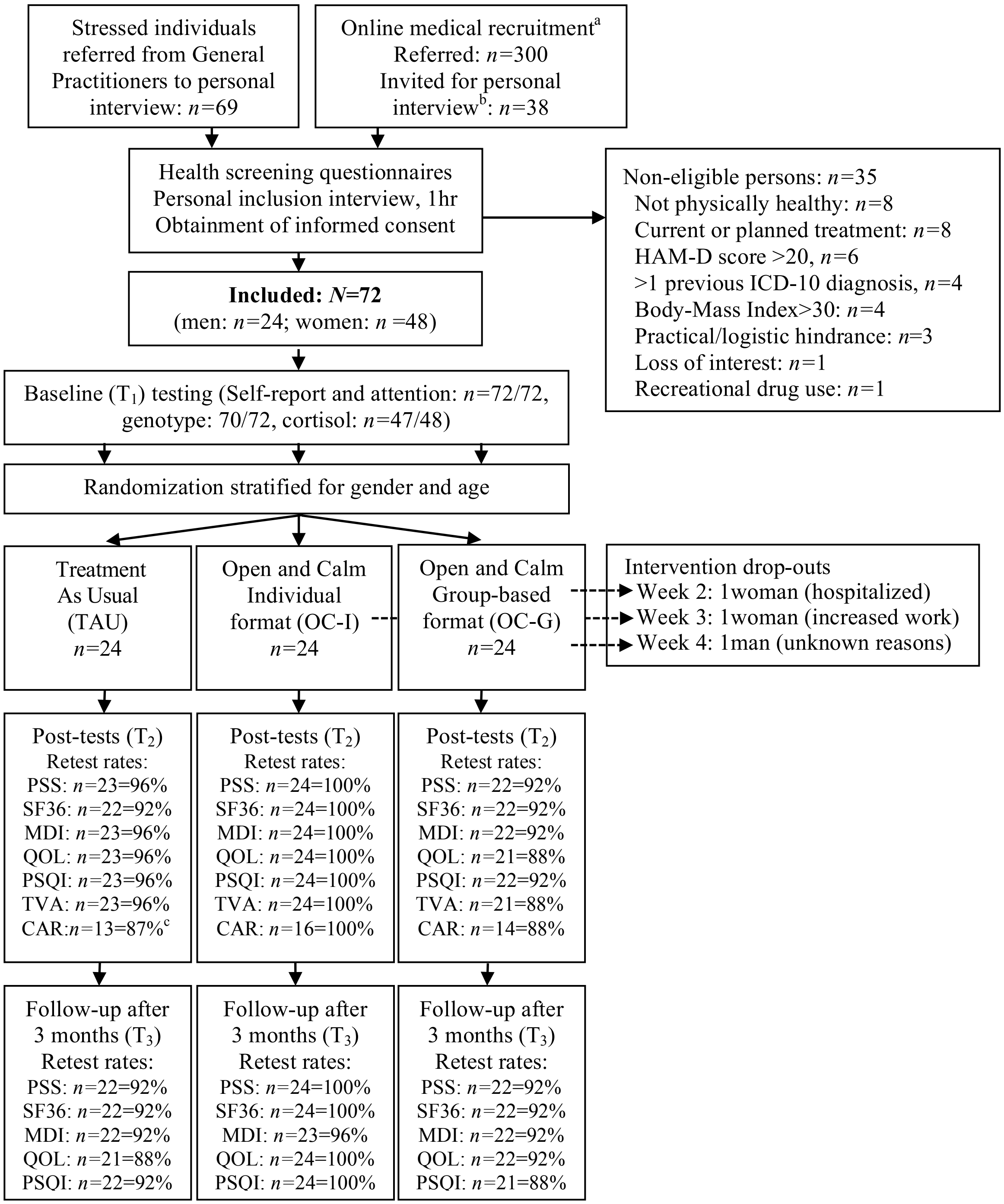
Table 1. Treatment effects on self-report outcomes

Outcome	Open and Calm (OC)			Treatment as Usual (TAU)			OC *vs*. TAU		OC *vs*. TAU change[a]		
	M	*(SD)*	*d (within)*	*M*	*(SD)*	*d (within)*	*d (between)*	*p*	*F*	η_p^2 *(between)*	*p*
Perceived Stress (PSS)											
Pre-treatment (T_1)	18.75	(6.48)		18.22	(4.01)		0.09	.718			
Post-treatment[b] (T_2)	12.88	(7.31)	0.92***	17.33	(3.51)	0.22	0.71**	.012	12.18	.15***	.001
Follow-up[c] (T_3)	11.64	(6.26)	0.24	16.77	(3.83)	0.25	0.93***	.001			
Pre-treatment-Follow-up			1.30***			0.39*					
Mental Health (SF-36-MCS)											
Pre-treatment (T_1)	47.24	(26.05)		55.06	(17.26)		0.20	.299			
Post-treatment[b] (T_2)	51.22	(25.17)	0.21	52.95	(19.26)	-0.18	0.08	.971	5.78	.08**	.008
Follow-up[c] (T_3)	67.09	(17.57)	0.89***	57.73	(16.38)	0.30	0.55*	.012			
Pre-treatment-Follow-up			0.99***			0.15					
Depression (MDI)											
Pre-treatment (T_1)	16.98	(8.67)		15.75	(7.10)		0.15	.551			
Post-treatment[b] (T_2)	10.04	(8.65)	0.91***	13.27	(5.97)	0.36	-0.42*	.044	8.05	.11**	.002
Follow-up[c] (T_3)	8.04	(6.01)	0.51	12.42	(6.02)	0.22	-0.74**	.006			
Pre-treatment-Follow-up			1.44***			0.60*					
Quality of Life (WHO-5)											
Pre-treatment (T_1)	46.88	(17.32)		48.67	(15.72)		-0.11	.671			
Post-treatment[b] (T_2)	62.04	(19.84)	1.01***	53.92	(14.54)	0.31	0.45	.080	4.90	.07**	.009
Follow-up[c] (T_3)	65.75	(16.44)	0.23	55.67	(15.19)	0.10	0.64**	.014			
Pre-treatment-Follow-up			1.06***			0.39					
Sleep Quality (PSQI)											
Pre-treatment (T_1)	6.97	(2.49)		6.67	(2.81)		0.12	.531			
Post-treatment[b] (T_2)	5.43	(3.63)	0.47***	5.92	(2.73)	0.25	-0.15	.254	7.14	.09**	.003
Follow-up[c] (T_3)	4.96	(2.93)	0.22	6.63	(3.16)	-0.22	-.56*	.017			
Pre-treatment-Follow-up			0.73***			0.01					

Notes. * $p<.05$. ** $p<.01$. *** $p<.001$. All *p*-values are two-tailed and based on intent-to-treat-analyses; p-values for OC *vs*. TAU changes are also adjusted for relevant biopsychosocial variables (see "Control variables" in main text) and Bonferroni-Holm corrected. [a]. Effect sizes indicate pre-treatment—post-treatment—follow-up Time×Group effects.[b]. Within-group effect sizes indicate pre-treatment—post-treatment effects.[c]. Within-group effect sizes indicate post-treatment—follow-up effects. MDI=Major Depression Inventory. PSQI=Pittsburgh Sleep Quality Index. PSS=Cohen's Perceived Stress Scale. SF-36-MCS=Short Form Health Survey-36-Mental Component Summary.

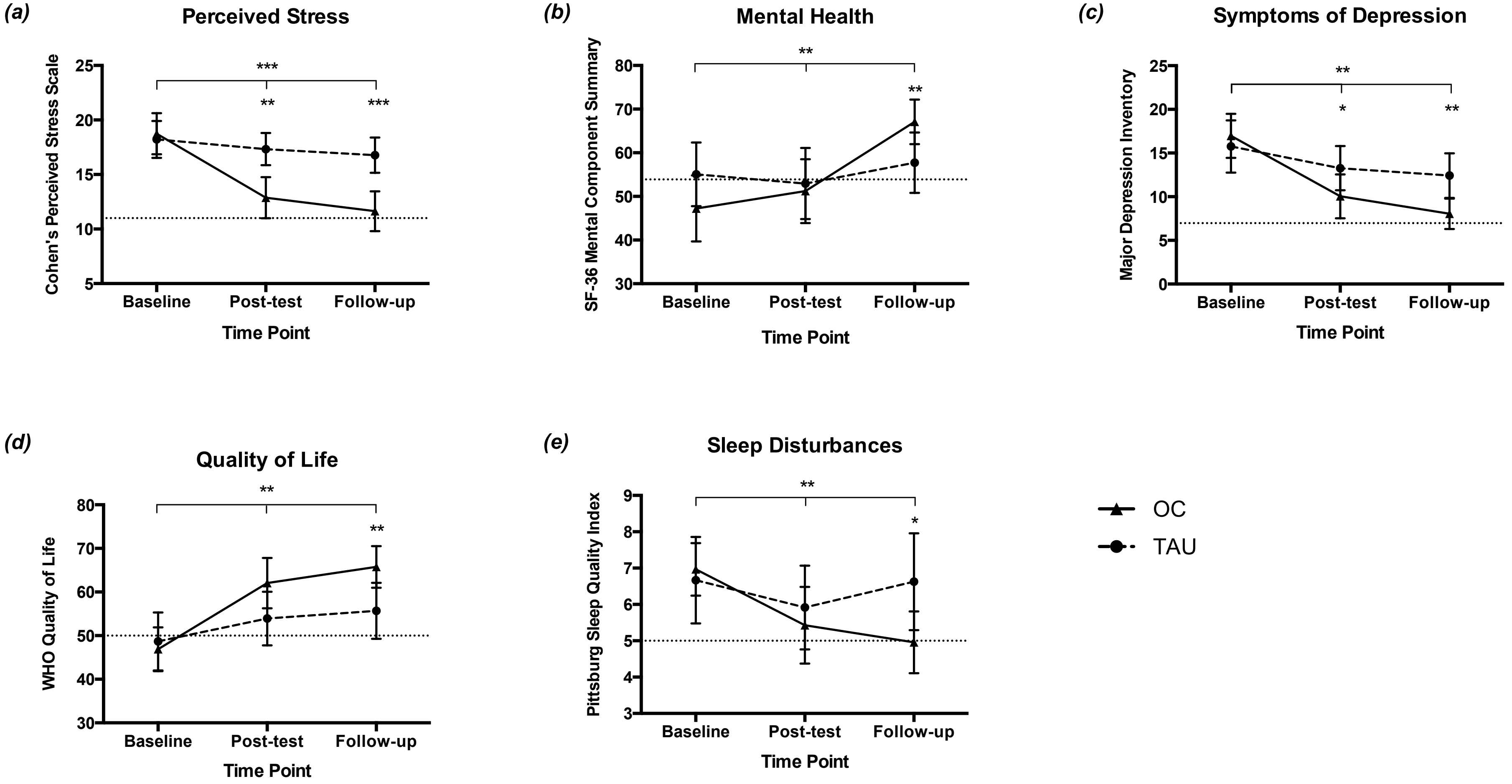
Appendix III

Figure 1. Participant flow in the Open and Calm Randomized Controlled Trial



Notes. HAM-D=Hamilton Depression Rating Scale 17 items. PSS=Perceived Stress Scale. SF36=Short-Form Health Survey Mental Health Component Summary Score. MDI=Major Depression Inventory. QOL=Quality of Life. PSQI=Pittsburgh Sleep Quality Index. TVA=Theory of Visual Attention test. CAR=Cortisol Awakening Response test.[a]. Online invitations were issued by the professional recruitment company within public health, Medicollect. [b].Interviews were conducted by the first author (XX), a clinical neuropsychologist and experienced meditator.[c].The retest ratio is 87% (*n*=13/15) since only 15 cortisol sets from TAU participants were received before randomization.

Panel 1. Group comparisons on self-report outcomes



Notes. *.*p*<.05.**.*p*<.01.***.*p*<.001. *p*-values are two-tailed, corrected for multiple tests (Bonferroni-Holm), and based on intent-to-treat-analyses (Open and Calm [OC] *N*=48. Treatment As Usual [TAU] *N*=24) after adjustment for relevant biological, socioeconomic, and psychological trait variables. Asterisks (*) above horizontal lines represent *p*-values of Time*Group effects, while asterisks or *p*-values above error bars represent p-values of between-group comparisons (Table 2). Error bars represent 95% CI of the mean. ***(a).*** The dotted line represent the mean among a national region-stratified random sample of >21,000 Danish adults (Stigsdotter et al., 2010). ***(b)*** The dotted line represents the age-adjusted Danish norm for the SF36-Mental Health Component (Bjørner et al., 1997) ***(c).*** The dotted line represents the Danish norm (Olsen et al., 2004). ***(d)*** Scores below the dotted line represent a risk marker for depression (Folker & Folker, 2008). As seen, the 95%CI still contains this cut-off for TAU, but not for OC. ***(e)*** Scores above the dotted line represent a risk marker for depression (Buysse et al., 1989). TAU remains at increased risk at all time points. Specifically, 67% of OC and 63% of TAU were at increased risk at baseline. At follow-up, this was still found for 63% of TAU, but only 35% of OC.

Supplementary table 1. Sample characteristics

Measures	TAU		OC-I		OC-G		Comparison
Demographics and health variables	*%*	*(n)*	*%*	*(n)*	*%*	*(n)*	*p*
Gender (women)	58.33	(14)	70.77	(17)	66.67	(16)	>.6
Employment (employed)	91.70	(22)	79.20	(19)	91.70	(22)	>.3
Smokers (% daily smokers)	12.50	(3)	0	(0)	4.17	(1)	>.1
Meditation Experience (% yes[a])	8.33	(2)	12.50	(3)	4.17	(1)	>.5
	Mean	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*p*
Age (years)	42.58	(7.19)	42.46	(9.21)	41.67	(10.38)	>.9
Professional education	3.71	(1.27)	3.21	(1.38)	3.42	(1.44)	>.4
Body-Mass-Index	24.96	(2.82)	25.53	(3.20)	23.88	(2.72)	>.1
Alcohol consumption (units/week)	4.87	(4.11)	3.02	(2.01)	4.21	(3.46)	>.5
Psychological background variables	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*p*
Stressful life events (past year)	4.21	(2.95)	*4.96*	(2.89)	4.21	(3.58)	>.6
Stressful life events (lifetime)	2.29	(1.52)	*2.75*	(1.7)	2.54	(1.44)	>.4
TCI Self-Directedness (TCI-SD)	26.33	(8.80)	29.38	(7.48)	30.92	(7.91)	>.1
TCI Harm Avoidance (TCI-HA)	19.63	(11.25)	20.25	(9.99)	23.04	(11.8)	>.4
Attentional instability (MAAS)	3.77	(0.55)	3.62	(0.77)	3.90	0.68	>.1

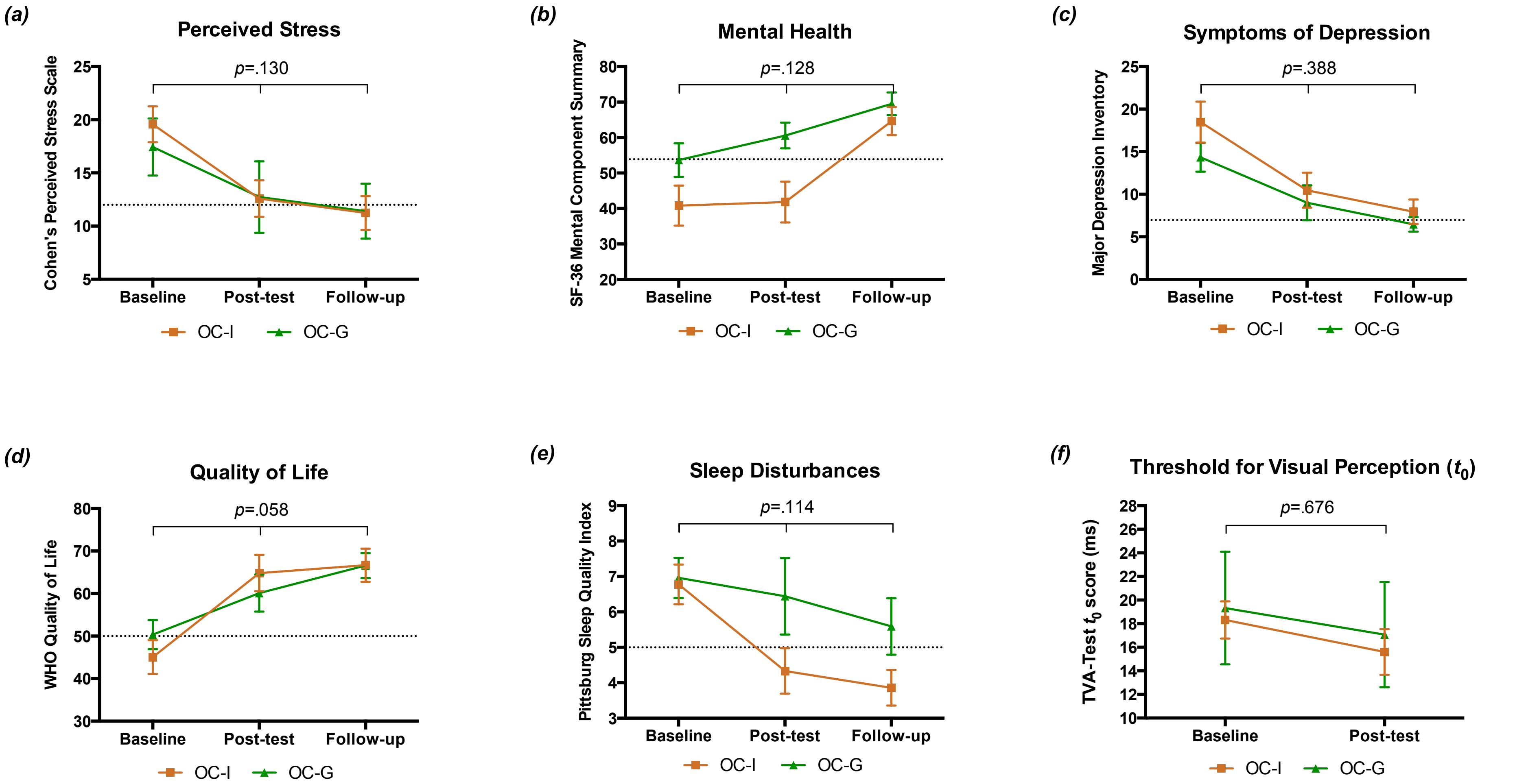
Notes. *p*-values are two-tailed, uncorrected for multiple tests. OC-I = Open and Calm – Individual format. OC-G = Open and Calm – Group format. TAU = Treatment As Usual. Professional education is scored from 1—5: 1= no professional education, 2 = 1-2 years, 3 = 2-3 years, 4 = 3-4years, 5 = >4 years. TCI = Temperament and Character Inventory. MAAS = Mindfulness Attention Awareness Scale. [a]. Meditation experience was defined as having meditated > 2 times per week for > one month.

Supplementary table 2. Treatment effects on cortisol and visual attention

Outcome	Open and Calm (OC)			Treatment As Usual (TAU)			OC *vs*. TAU		OC *vs*. TAU change[a]		
	M	*(SD)*	*d (within)*	*M*	*(SD)*	*d (within)*	*d (between)*	*p*	*F*	η_p^2 *(between)*	*p*
Cortisol awakening response											
Normal baseline CAR											
AUC-Ground (T_1)	1489.40	(312.94)		1277.30	(333.05)		.68	.094	5.76	.21*	.050
AUC-Ground (T_2)[b]	1339.65	(299.73)	-0.59*	1251.23	(449.28)	-.12	.25	.541			
AUC-Increase (T_1)	436.62	(315.46)		329.26	(261.31)		.38	.359	0.60	.03	.450
AUC-Increase (T_2)	269.10	(237.67)	-0.76*	175.64	(192.25)	-.50	.44	.287			
Blunted baseline CAR											
AUC-Ground (T_1)	1078.02	284.22		1426.71	(615.59)	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]
AUC-Ground (T_2)[b]	1094.08	272.35	0.08	697.23	(416.05)	-[c]	-[c]	-[c]			
AUC-Increase (T_1)	-112.22	291.29		-396.09	(336.46)	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]
AUC-Increase (T_2)[b]	81.60	276.40	0.88*	103.11	(369.51)	-[c]	-[c]	-[c]			
Visual attention											
Perceptual threshold, t_0 (T_1)	18.82	(9.14)	-0.35*	16.40	(6.39)	0.15			4.07	.06*	.048
Perceptual threshold, t_0 (T_2)[b]	16.34	(9.75)		17.12	(9.81)						
STM capacity, *K* (T_1)	2.67	(0.57)	0.12	2.78	(0.67)	0.06			0.29	.00	.592
STM capacity, *K* (T_2)[b]	2.74	(0.65)		2.82	(0.74)						
Processing speed, *C* (T_1)	50.60	(17.16)	0.07	50.57	(16.24)	0.29			0.89	.01	.348
Processing speed, *C* (T_2)[b]	51.85	(17.82)		55.53	(16.53)						

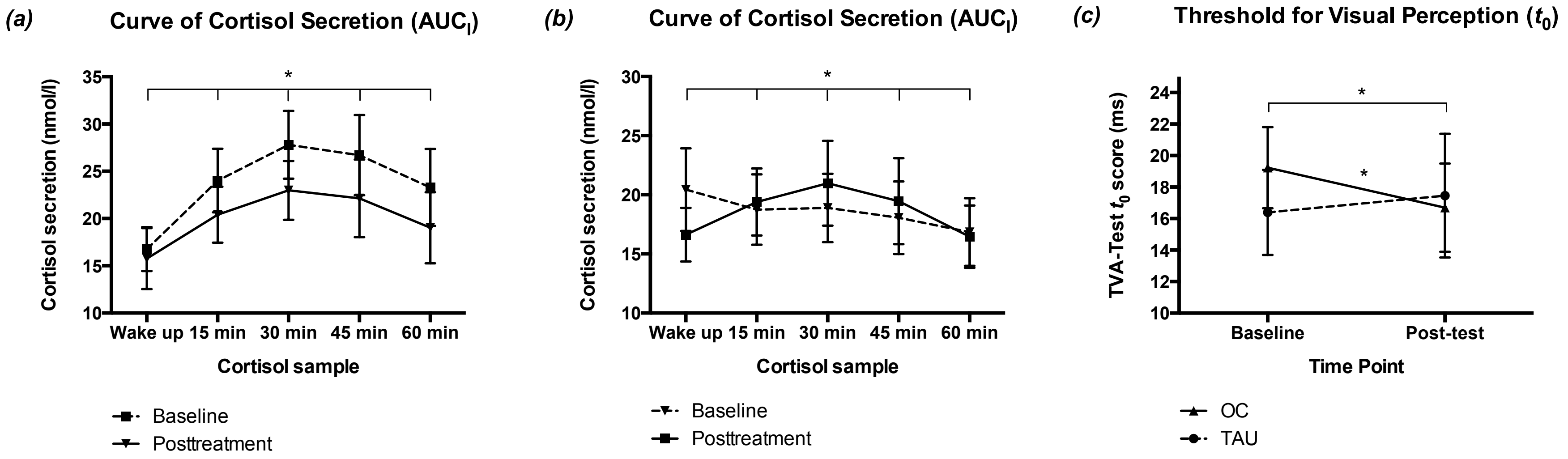
Notes. *.p<.05.**.p<.01.***.p<.001. All p-values are two-tailed and based on intent-to-treat-analyses (non-blunted OC n=15; TAU n=13; blunted OC n=18; blunted TAU n=2). [a]. p-values for OC *vs*. TAU changes are Bonferroni-Holm corrected and effect sizes indicate pre-treatment—post-treatment—follow-up Time×Group effects.[b]. Within-group effect sizes indicate pre-treatment—post-treatment effects adjusted for dependence among means (Morris & Deshon, 2002, formula 8).[c].Test not conducted since TAU n=2.

Supplementary panel 1. Comparisons of interventional formats on self-report and visual perception



Notes. *.p<.05.**.p<.01.***.p<.001. p-values are two-tailed, corrected for multiple tests (Bonferroni-Holm), and based on intent-to-treat-analyses (Open and Calm [OC] N=48. Treatment As Usual [TAU] N=24) after adjustment for relevant biological, socioeconomic, and psychological trait variables. Asterisks (*) above horizontal lines represent p-values of Time*Group effects, while asterisks or p-values above error bars represent p-values of between-group comparisons (Table 2). Error bars represent 95% CI of the mean. ***(a).*** The dotted line represent the mean among a national region-stratified random sample of >21.000 Danish adults (Stigsdotter et al., 2010). ***(b)*** The dotted line represents the age-adjusted Danish norm for the SF36-Mental Health Component (Bjørner et al., 1997) ***(c).*** The dotted line represents the Danish norm (Olsen et al., 2004). ***(d)*** Scores below the dotted line represent a risk marker for depression (Folker & Folker, 2008). ***(e)*** Scores above the dotted line represent a risk marker for depression (Buysse et al., 1989). As seen, OC-I shows descriptively (but not significantly) larger improvement on sleep disturbances than OC-G. ***(f)*** Changes in the threshold for visual perception, t_0.

Supplementary panel 2. Changes in the slope of cortisol secretion and the threshold for conscious visual perception



Notes.*.p<.05. p-values are two-tailed and based on intent-to-treat-analyses after adjustment for covariates (see "Control variables"). Error bars represent 95% CI of the mean. ***(a)*** AUC_I decreased significantly for OC participants with a present (non-blunted) cortisol awakening response (CAR), n=15. ***(b)*** AUC_I increased significantly for OC participants with blindly identified blunted baseline CAR, n=18. ***(c)*** OC decreased significantly more than TAU on the threshold for conscious visual perception, t_0, also after control for baseline t_0 score, p=.054 (see text).